

A Systematic Review of Value Co-Creation Models for Engineering Asset Management Collaborative Ecosystems

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Abstract

This study examines the importance of integrating collaborative ecosystem theory into the broadband transdisciplinary approach of Engineering Asset Management (EAM). The authors seek to contribute to moving beyond traditional organization-centric EAM approaches toward systemic, multi-actor value co-creation models. This systematic review aims to investigate existing work on value co-creation across different areas and assess whether these works can be transposed to EAM. To achieve this, a structured, systematic literature review was conducted in accordance with PRISMA guidelines, using Scopus and Web of Science as information sources. The search combined the keywords “collaborative,” “ecosystem,” “value co-creation,” and “model,” resulting in 72 peer-reviewed articles. Bibliometric analysis was performed using *EndNote* (version 2025.2), *Excel* (version 16.110.2), and *VOSviewer* (version JAVA 1.0), complemented by thematic analysis structured around the three research questions. The results reveal a significant increase in publications after 2021, the predominance of ecosystem and value co-creation concepts, and the existence of fragmented conceptual, governance, and analytical models. The findings confirm a persistent gap that needs to be addressed to properly integrate collaborative ecosystems and enable value co-creation in EAM, providing a structured foundation for developing an integrated ecosystem-based asset management framework in this space. By conducting a structured, systematic literature review and synthesizing conceptual, governance, and analytical models, this research consolidates fragmented knowledge and proposes an integrative perspective that positions value co-creation, multi stakeholder governance, and digital enablement as central mechanisms for enhancing ecosystem performance and sustainability in asset-intensive environments.

Keywords: collaboration; ecosystem; value; co-creation model; asset management



Received: 21 May 2026

Revised: 25 June 2026

Accepted: 27 June 2026

Published: 9 July 2026

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1. Introduction

1.1. Historical Development of Engineering Asset Management (EAM)

Engineering Asset Management is increasingly embedded in complex socio-technical systems characterized by high interdependence among organizations, regulators, technology providers, and users. In a foundational work, Amadi-Echendu et al. (2007) presents the definition and history of EAM (asset management applied to engineering assets) [1]. The expression was initially used in the scientific literature of the late 1960s and early 1970s,

with relation to the business, financial, and insurance sectors [2–6], and to items providing value to their owners (such as investment portfolios). But it also had its own roots and preponderant developments in different areas of engineering. The first scientific studies in these areas, namely, on terotechnology and the management of engineered physical assets, emerged in the 1970s [7–10] as an extension and broadening of the scope of engineering studies focusing on the maintenance of industrial facilities [11]. Until the 1990s, the focus was predominantly technical and fragmented, with an emphasis on asset maintenance and on using information and communication technologies to manage asset data and support decision-making. In the 1990s, the argument emerged that asset management required an interdisciplinary approach that combined engineering, business, and commerce. Experience with the application of this new approach in the industry gained momentum, and several associative movements, regular conferences, commercial initiatives, and technical guides helped consolidate the discipline of physical asset management [12]. The two versions of the Publicly Available Specification PAS 55 [13,14] were important milestones in systematizing the approach to physical asset management and in accelerating subsequent standardization efforts. Terotechnology combined economic and engineering management and was the forerunner of the business thinking implicit in PAS 55. The 2008 release of PAS 55 emphasized the importance of risk management in asset management.

In 2014, the ISO 55000 series of international standards helped diffuse asset management worldwide and in the broadest sense of the term, i.e., covering both physical and non-physical assets in a transdisciplinary fashion. These standards brought this important business function into the realm of ISO management system standards, linking it conceptually with other well-known management system standards covering quality, safety, and the environment, etc. [15,16]. This conceptual link was facilitated by the publication of a common framework for ISO management system standards High Level Structure (HLS) [17,18]. Transdisciplinary co-creation goes beyond simply disseminating information, fostering trust and social learning, and accelerating the use of knowledge by making scientific research a social and collaborative process, not just a linear transfer of information. This happens because transdisciplinary research not only observes change but also involves researchers and social partners in the transformation process, ensuring that solutions are applicable to real-world contexts [19,20]. After the publication of the first ISO 55000 series of standards in 2014, several major publications in the field were revised in view of aligning with the principles and terminology established in those standards [21,22].

In 2024, the core set of the ISO 55000 series of standards was revised. This update impacted EAM, with its stronger focus on sustainable outcomes and value realization. The new set of ISO 55000 series is applicable to a wide range of stakeholders, covering government, academia, industry, the built environment, and society. The 2024 ISO 55000 series facilitates the engagement of the five stakeholder categories of the quintuple helix model and can thus be seen as a catalyst for an ecosystem [23,24] for the management space [25,26]. The quintuple helix model provides a fundamental basis for the emergence of innovation ecosystems, defining the main stakeholders who generate and disseminate knowledge and innovation [27,28]. Quintuple helix innovation ecosystems comprise continuous interactions, knowledge exchanges, and co-evolutionary processes that create the conditions for the formation of interconnected networks of actors. It is through these dynamic and recursive interactions that ecosystems emerge as structured yet adaptive configurations of relationships aimed at value creation [17]. Value is co-created through the integration of resources among multiple actors, reinforcing the idea that ecosystems arise from collaborative processes embedded within these helices [18]. Therefore, the quintuple helix naturally leads to an ecosystem configuration. This transition reflects a natural shift to a dynamic, interaction-based model, where multisectoral collaboration, co-evolution, and

value co-creation become central mechanisms for the development and sustainability of the ecosystem. The quintuple helix model offers a framework for understanding the connection between knowledge and innovation in fostering sustainable development [29], addressing the socio-ecological transition of society, the economy, and democracy. By integrating knowledge, innovation, and environmental concerns and fostering cross-sector knowledge exchange, the model supports innovative, sustainable, and inclusive solutions [30], giving rise to the ecosystem.

The concept of assets has evolved significantly over time, reflecting changes in economic systems, technological development, and management practices. Traditionally, assets were primarily understood in physical terms, particularly in industrial and engineering contexts, where the focus was on tangible resources such as infrastructure and equipment [31]. However, earlier economic thought already distinguished between different forms of capital, including land, labor, and produced capital, as discussed in classical economics since the 18th century [32]. In the late 20th century, the recognition of natural assets gained prominence, particularly with the emergence of ecological economics and the concept of ecosystem services [33], highlighting the role of environmental resources such as land, water, and biodiversity. Concurrently, manufactured or constructed assets, defined as human-made physical resources, became central to asset-intensive industries and are commonly classified as durable (e.g., infrastructure and machinery) or non-durable (e.g., consumables), depending on their lifecycle characteristics [31,34]. From the 1990s onwards, there was a growing recognition of non-physical assets, particularly intangible and knowledge-based resources, driven by the rise of the knowledge economy and digital transformation [35,36]. These include virtual assets, such as data, digital platforms, and information systems, as well as conceptual assets, such as intellectual property, organizational capabilities, and brand value. The formalization of these perspectives in standards such as [37] reflects a shift toward a holistic understanding of assets as entities that generate value, whether tangible or intangible, financial or non-financial [17,37]. This evolution underscores the need to manage diverse asset types in an integrated manner, particularly within complex and collaborative ecosystems where value is co-created across multiple stakeholders [17,34].

Figure 1 proposes a chronological diagram of the evolution of engineering asset management as presented above, from interdisciplinarity to transdisciplinarity towards a fully active ecosystem.

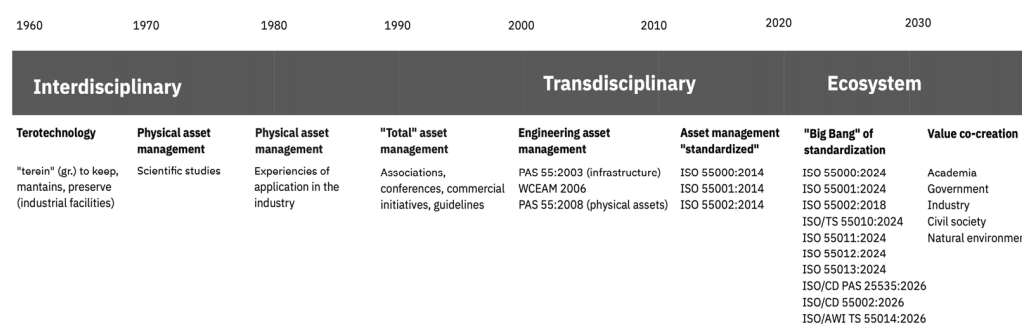


Figure 1. Evolution of the EAM concept (adapted from Almeida, 2024; Amadi-Echendu, 2007; Vieira, 2025; Wijnia, 2016) [1,25,38,39].

1.2. Innovation Ecosystems

The concept of an ecosystem originates from environmental science, where interactions among components shape the behavior and evolution of the system. Translating these ecological dynamics into socio-economic contexts requires integrating theories from anthropological ecology, such as co-evolution, environmental determinism, and political

ecology, which help explain how actors interact and co-create value within innovation environments [24]. The term innovation ecosystem was introduced by Adner (2006) to describe collaborative arrangements in which organizations combine offerings to deliver customer solutions [17]. In such ecosystems, networks of actors such as organizations, research institutions, financial entities, and regulators interact to create innovation and create value through shared goals, relationships, knowledge, and technologies [40–43]. These ecosystems integrate both tangible and intangible resources and require scientific and technological tools to support coordination and performance [24,44]. Innovation ecosystems are therefore understood as complex, dynamic, and multi-stakeholder structures that evolve from clusters to networks and ultimately to helix-based innovation models [23,41]. Within these environments, diverse stakeholders (including government, academia, industry, civil society, and the built environment) interact in multi-level knowledge networks that facilitate value exchange, collaboration, and resource sharing [45,46]. However, their development is challenging due to differing interests and knowledge bases, requiring governance mechanisms capable of fostering shared visions, trust, and coordinated co-evolution [47]. Compared with innovation ecosystems or networks, ecosystems emphasize broader socio-economic interactions and collaborative value creation, contributing to societal development, sustainability goals, and improved quality of life [42,48].

1.3. Overcoming Towards an EAM Collaborative Ecosystem

After the introduction of the ISO 55000 standards on asset management in 2014, one of the main challenges of the asset management community was to overcome the poor alignment between the financial and non-financial (engineering) perspectives in asset-intensive organizations [49]. There was a recognized need for a joint approach to both financial and non-financial functions and a shift from a focus on a backward-looking perspective (such as in financial accounting and regulatory reporting activities) to an overall outlook that supports decision-making for the future, which was filled in with the new updates in 2024 with the new version of the ISO 55000 series [37,50–52].

Asset management has traditionally focused on the optimization, reliability, and lifecycle performance of physical and infrastructure assets, with strong roots in engineering, maintenance, and operations management [31]. In contrast, innovation management has evolved mainly within the domains of strategic management, technology management, and entrepreneurship, emphasizing the creation of new knowledge, technologies, and market opportunities [53]. As a result, these sectors have largely progressed in parallel research streams, addressing different organizational challenges. However, the increasing complexity of socio-technical systems, digital transformation, and sustainability pressures are progressively blurring these boundaries. In asset-intensive sectors, the long-term realization of value from assets increasingly depends on continuous innovation, data-driven decision-making, and collaborative stakeholder engagement. This emerging context highlights the need to bridge asset management and innovation management perspectives to enable integrated approaches that support value co-creation within engineering asset management ecosystems.

Traditional organization-centric and hierarchical governance approaches are proving insufficient to address the growing challenges of digital transformation, lifecycle complexity, sustainability pressures, and systemic risk exposure [54,55]. As asset-intensive sectors become more innovation-oriented, digitally enabled, and interconnected, value creation shifts from isolated organizational performance toward ecosystem-level outcomes mediated by platforms, collaborative networks, and institutional arrangements. An example of the value destroyed is the cascading failures.

The 2025 Iberian Peninsula blackout, which disrupted telecommunications, railways, roads, and water supplies across Portugal and Spain, illustrates how interdependently created or destroyed value reaches an ecosystemic scale, reinforcing the urgent need for a collaborative, co-creation-based ecosystem in EAM.

EAM have unique features setting them apart from typical collaborative ecosystems, including very long asset lifecycles that create intergenerational obligations [18]; interdependent infrastructures causing failure propagation across boundaries [56]; strict regulatory constraints and standardization environment (e.g., the ISO 55000 series) [14]; multi-stakeholder complexity with varied goals and incentives [5,25]; and ongoing budget constraints necessitating resource-aware decisions [18]. These traits make EAM a challenging domain that demands specific framework requirements, which must be critically assessed when reviewing models.

The core principle of asset management is value realization from assets [21,22,34,57]. The concept of value is described in both ISO 56000 and ISO 55000 [34,58], which show that it is central to both asset management and innovation management, although it has traditionally been interpreted from different disciplinary perspectives. In the asset management field, value is understood as the outcome generated by assets in fulfilling organizational objectives, balancing performance, risk, and cost throughout the asset lifecycle [31]. This perspective is reflected in the ISO 55000 framework, where asset management is defined as the coordinated activity of an organization to realize value from assets, including both tangible and intangible assets, across financial and non-financial dimensions [34]. Conversely, in the innovation management domain, value is associated with the successful implementation of new or significantly improved products, services, processes, or business models that generate benefits for organizations, users, and society [53]. This understanding is embedded in the ISO 56000 family, which defines innovation as a new or changed entity that realizes or redistributes value [58].

The Global Forum on Maintenance and Asset Management (GFMAM) and the Institute of Asset Management (IAM) published a revised version of their flagship asset management manuals, aligned with the terminology of the latest version of the asset management standards [57,59]. These are foundational documents for many organizations and businesses implementing the EAM approach, including those external to GFMAM or the IAM. The IAM Anatomy provides guidance on the breadth of asset management covering 39 topics in ten major areas, namely [59], (1) strategy and planning, (2) decision making, (3) lifecycle delivery, (4) information management, (5) organization and people, and (6) risk management, (7) values and outcomes, (8) review and continual improvement, (9) leadership and governance, and (10) purpose and context. The GFMAM Landscape is divided into seven groups of topics, namely [56], (1) Context and stakeholders, (2) governance, (3) asset management planning, (4) leadership and people, (5) data and information, (6) delivery, and (7) value realization.

There are some experimentation platforms testing collaborative ecosystems in engineering asset management within the Pan-Iberian space [26]. These experimentation platforms seek to interconnect actors across asset-intensive sectors and the quintuple innovation helix to foster multistakeholder collaboration. The sectors covered by this experimental platform are (i) AECO; (ii) agriculture; (iii) banking and financial market infrastructure; (iv) defense; (v) digital infrastructure; (vi) drinking water; (vii) energy; (viii) health; (ix) higher education and research; (x) industrial processing; (xi) logistics; (xii) public administration; (xiii) real estate; (xiv) space; (xv) transport; (xvi) wastewater; and (xvii) waste.

The article is divided into different sections. In Section 2, the method for conducting the systematic literature review is presented. In Section 3, the results of the systematic

literature review are presented, starting with a general analysis of the articles, including the years of publication, the main journals published, the sectors identified with the corresponding authors, and the terms identified using *VOSviewer*. In Section 4, the conclusions of the work highlight its importance and scientific contributions. One of the main conclusions is that accelerating collaborative ecosystems in asset management is increasingly necessary in complex environments. The results suggest that effective acceleration depends on well-defined roles within ecosystems, structured information governance, balanced involvement of multiple stakeholders, and a dynamic configuration of value networks.

The main contribution of this article is the systematic mapping and critical analysis of existing models related to collaborative ecosystems, specifically as they potentially apply to the context of engineering asset management. Based on a structured literature review, the article identifies, classifies, and examines these models, proposing an original tripartite taxonomy (conceptual, operational, and analytical models) as an organizing framework. Positioned as a theoretical basis, this taxonomy supports the future empirical development of a collaborative ecosystem framework for engineering asset management. The objectives are (i) to map the models identified in the research; (ii) to analyze and classify them by assumptions, focus, and limitations; (iii) to propose a taxonomy that organizes the models coherently; and (iv) to establish theoretical foundations for future empirical research.

2. Materials and Methods

This research employed a structured, systematic literature review to ensure transparency, rigor, and replicability in identifying, selecting, and analyzing scientific publications on collaborative ecosystems, value co-creation, and modeling approaches applicable to EAM. The review process followed a systematic approach inspired by the guidelines [60], combining bibliometric screening with thematic content analysis. We selected two databases (Scopus and Web of Science) due to their academic credibility and comprehensive coverage. The research method is based on a fourth-step approach combining a preliminary search with the PRISMA method, as presented in Table 1 and detailed in the following sections.

The second stage is based on a set of 8 surveys in order to include the largest number of words related to the subject under study, as presented in Table 1 and detailed in the following sections.

Table 1. Structure of the search string used in the Scopus and Web of Science Search API.

Research	Domain	Operators and Keywords Used
Preliminary (first step)	Article elements	TITLE/KEY
	Systematic review	TITLE-ABS-KEY (Systematic Review) AND TITLE-ABS-KEY (value co-creation) OR TITLE-ABS-KEY (value creation)) AND (LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (EXACTKEYWORD, "Systematic Review") OR LIMIT-TO (EXACTKEYWORD, "Review") OR LIMIT-TO (EXACTKEYWORD, "Systematic Literature Review"))
	Operator	AND
	Limitations of scope	LIMIT-TO (LANGUAGE, "English")

Table 1. Cont.

Research	Domain	Operators and Keywords Used
Second step	Article elements	TITLE/KEY
	Systematic review	TITLE-ABS-KEY (Service ecosystem) AND TITLE-ABS-KEY (asset management) AND TITLE-ABS-KEY (engineering asset management))
		TITLE-ABS-KEY (Innovation ecosystem) AND TITLE-ABS-KEY (asset management) AND TITLE-ABS-KEY (engineering asset management))
		TITLE-ABS-KEY (Platform ecosystem) AND TITLE-ABS-KEY (asset management) AND TITLE-ABS-KEY (engineering asset management))
		TITLE-ABS-KEY (Collaborative ecosystem) AND TITLE-ABS-KEY (asset management) AND TITLE-ABS-KEY (engineering asset management))
		TITLE-ABS-KEY (Interorganizational collaboration) AND TITLE-ABS-KEY (asset management) AND TITLE-ABS-KEY (engineering asset management))
		TITLE-ABS-KEY (Infrastructure resilience) AND TITLE-ABS-KEY (asset management) AND TITLE-ABS-KEY (engineering asset management))
		TITLE-ABS-KEY (Asset-intensive system) AND TITLE-ABS-KEY (asset management) AND TITLE-ABS-KEY (engineering asset management))
		TITLE-ABS-KEY (Critical infrastructure) AND TITLE-ABS-KEY (asset management) AND TITLE-ABS-KEY (engineering asset management))
	Operator	AND
	Limitations of scope	LIMIT-TO (LANGUAGE, “English”) AND
Third step	Article elements	TITLE/KEY
	Systematic review	TITLE-ABS-KEY (value co-creation) AND TITLE-ABS-KEY (model) AND TITLE-ABS-KEY (collaborative) AND TITLE-ABS-KEY (engineering assets)
	Operator	AND
	Limitations of scope	LIMIT-TO (LANGUAGE, “English”)
Fourth step	Article elements	TITLE/KEY
	Systematic review	TITLE-ABS-KEY (value co-creation) AND TITLE-ABS-KEY (model) AND TITLE-ABS-KEY (collaborative) AND TITLE-ABS-KEY (ecosystem)
	Operator	AND
	Limitations of scope	LIMIT-TO (LANGUAGE, “English”)

2.1. Preliminary Research

A preliminary research was conducted using the following keywords in the Scopus database: (i) “Systematic Review” AND (ii) “value co-creation”; OR (iii) “value creation”. This non-systematic review yielded a total of 1702 articles. The Scopus search engine was used to narrow down the results with the keywords “review”, resulting in 577 articles. To be even more focused, as we wanted to determine the number of systematic reviews

on value co-creation or value creation, we selected the keywords (i) “Systematic Review”, AND (ii) “Review”, AND (iii) “Systematic Literature Review”, resulting in a total of 287 articles (Table 1).

These figures reveal that there is a high scientific interest in value creation and co-creation and that the number of structured systematic reviews in this field is significant and covers a broad range of sectors and disciplines. We divided the articles into different sectors to try to understand which ones would be the most relevant. We were able to locate 14 sectors: (i) AECO; (ii) agriculture; (iii) banking and financial market infrastructure; (iv) defense; (v) digital infrastructure; (vi) health; (vii) higher education and research; (viii) industrial processing; (ix) logistics; (x) public administration; (xi) transport; (xii) tourism, (xiii) wastewater; and (xiv) waste.

In order of prevalence, we have health (39.2%), digital infrastructure (17.8%), higher education and research (8.1%), industrial processing (7.8%), logistics (7.5%), banking and financial market infrastructure (7.2%), agriculture (3.9%), public administration (3.3%), tourism (2.1%), AECO (1.5%), waste (0.6%), defense (0.3%), transport (0.3%), and waste water (0.3%).

The sectors in this analysis relate to asset management and show their dispersion across various areas. By creating a collaborative ecosystem in engineering asset management, these sectors can be interconnected and co-create value. This analysis highlights a focus on people’s health and well-being, with health as the most relevant sector, emphasizing a people-centric ecosystem that is fundamental to accelerating the collaborative ecosystem.

The reviews do not focus specifically on the context of engineering asset management or on accelerating collaborative ecosystems. In fact, if we search for the keyword “Asset management,” we obtain 0 results. Thus, the need for and importance of this article become evident, as it seeks to consolidate existing knowledge, integrate diverse theoretical perspectives, and propose a structured model of value co-creation for collaborative asset management ecosystems, thereby helping to fill a relevant scientific and practical gap.

To address this gap, this article aims to answer the following research questions: (i) Why do we need a value co-creation model for engineering asset management? (ii) What are the best models and frameworks to conceptualize/describe value co-creation in an engineering asset management collaborative ecosystem? (iii) How can engineering asset management collaborative ecosystems be activated/accelerated to maximize value co-creation? Additionally, the study seeks to identify the most appropriate terminology for conceptualizing collaborative ecosystems in this context.

The ecosystem perspective has gained significant prominence across the management and innovation literature. The digital business ecosystem conceptualizes economic communities of interdependent actors that co-evolve through cooperation and competition [54], whereas the service ecosystem research emphasizes resource integration and value co-creation among multiple stakeholders [61]. Digital business ecosystems further extend this logic by highlighting the role of platforms, data infrastructures, and governance mechanisms in orchestrating distributed collaboration [56]. Moreover, emerging sustainability-oriented models integrate governance, strategy, risk, and technology within multi-level ESG co-creation structures [62].

Despite this growing body of research, existing studies remain fragmented across sectors and application domains. Many contributions explicitly integrate ecosystem health, digital, business, construction, etc., into a unified framework. As shown in the preliminary analysis, there are several terms related to engineering asset management that are not interconnected or associated with engineering asset management. It is essential that this connection be established within a collaborative ecosystem to enable value co-creation.

At the core of this fragmentation lies an insufficient conceptualization of value creation itself. Contemporary ecosystem research, grounded in Service-Dominant Logic and service ecosystems, frames value not as a linear output generated by a single organism but as a co-created, systemic, and emergent outcome resulting from the integration of resources among multiple actors [61,63]. In asset-intensive contexts, value extends beyond economic returns to encompass lifecycle performance, requisite resilience, sustainability, and the mitigation of shared risks across interconnected stakeholders. Resilience can be defined through two frameworks. Neukam et al. (2025) introduce requisite resilience, emphasizing actors, capabilities, and responses to match external complexity. It is a calibrated capacity needing active design and maintenance [64]. Woods (2015) adds four forms: (1) rebound, recover from disruptions; (2) robustness, absorb disturbances; (3) graceful extensibility, expand capacity beyond boundaries; and (4) sustained adaptability, regulate and renew capacity over time within complex systems [65]. However, the mechanisms through which value networks are structured, governed, and accelerated in engineering asset management remain underdeveloped. In particular, the acceleration of collaborative ecosystems in this domain remains underexplored.

2.2. Second Step

Once we completed the preliminary investigation, we moved on to the second step of the research, which was conducted using a set of searches with different words related to the study to see if there were already studies conducted with the same objective. With this research, we aimed to cover as many words as possible related to the creation of collaborative ecosystems in asset management. In Table 2, we present a summary of the articles and the results in the 14 articles considered for analysis in this section.

Table 2. Summary of the articles in the second step.

Words	Scopus			Web of Science		
	First Results	Results: LIMIT-TO (LANGUAGE, "English")	Downloads	First Results	Results: LIMIT-TO (LANGUAGE, "English")	Downloads
"Service ecosystem" AND "asset management" AND "engineering asset management"	76	24	22	14	80	19
"Innovation ecosystem" AND "asset management" AND "engineering asset management"	39	10	8	55	33	9
"Platform ecosystem" AND "asset management" AND "engineering asset management"	42	8	6	52	32	10

Table 2. Cont.

Words	Scopus			Web of Science		
	First Results	Results: LIMIT-TO (LANGUAGE, "English")	Downloads	First Results	Results: LIMIT-TO (LANGUAGE, "English")	Downloads
"Collaborative ecosystem" AND "asset management" AND "engineering asset management"	17	14	10	18	14	2
"Interorganizational collaboration" AND "asset management" AND "engineering asset management"	2	1	0	4	4	1
"Infrastructure resilience" AND "asset management" AND "engineering asset management"	144	56	48	299	213	90
"Asset-intensive system" AND "asset management" AND "engineering asset management"	18	102	76	630	409	101
"Critical infrastructure" AND "asset management" AND "engineering asset management"	351	102	76	630	409	101
Total	689	222	173	1234	809	238
Sum of items downloads			411			
Sum after eliminating duplicates			316			
Total considered after reading the abstracts			14			

Of 411 articles, after reading and analyzing the abstracts to determine relevance to the study, only 14 were considered. The following analysis examines each article based on its relevance to the central theme of this research: co-creation models for collaborative ecosystems applied to Asset Management (AM). None of the analyzed articles addressed value co-creation, a key element in collaborative ecosystems. However, Table 3 presents the definitions of the models identified in the article analysis. Nonetheless, the models presented in the table will not be considered as they do not align with the study's theme.

Table 3. Model definitions of the second step.

Model Name	Definition	Reference
IBM Collaborative Lifecycle Management (CLM)	Characterized as an “open-commercial” ecosystem, a modality that lies between the fully proprietary model and the open-source model, maintaining transparent communication channels while preserving intellectual property rights.	[66]
No name	It represents the ecosystem supporting high-reliability engineering assets as a dynamic and reconfigurable network of actors, resources, and activities, contextualized by three interdependent factors—reliability assurance, knowledge ecosystem, and business model—that shape the interactions and trust mechanisms among the multiple stakeholders.	[67]
No name	It explains how leaders of multi-sided digital platform ecosystems create and capture value through three interdependent dynamic capabilities—innovation, scanning/sensing, and integration—with integrative capabilities being the central mechanism for orchestrating complementary actors, reducing transaction costs, and reinforcing positive network effects that determine the platform leader’s sustainable competitive advantage.	[68]
Data Marketplace	A platform for the commercial exchange of data assets between suppliers and consumers, operated by an organization or consortium that defines the rules for orchestration, pricing, and licensing.	[69]
Data Spaces	Federated and decentralized ecosystems that enable interoperable and sovereign data sharing between organizations from different sectors, following common usage standards and policies defined by the IDSA (IDS-RAM) reference model.	[69]
Federated Learning	A collaborative approach to distributed AI model training where data remains localized on each participating node and only model weights are shared with a central or decentralized server.	[69]
BonsAPPs/AI Engineering Pipeline	A multi-stakeholder AI engineering platform that structures collaboration between innovators, data scientists, developers, and integrators through a marketplace of reusable AI artifacts, from research to hardware deployment.	[69]
Collaborative Digital Twin Ecosystem (CDTE)	An ecosystem that connects multiple independent digital twins and supporting systems (ERP, legacy systems, AI) to support informed decision-making in complex multi-stakeholder environments.	[70]
Collaborative Digital Twin Architecture (CDTA)	Technical architecture that enables the formation of CDTEs through trust management mechanisms, asset governance based on NFTs, dynamic policy enforcement via smart contracts, and distributed storage.	[70]

2.3. Third and Fourth Steps Using the PRISMA Methodology

After having completed the preliminary investigation and second step, we moved on to the third phase of the research, following the PRISMA methodology [59]. For this methodology, we used a combination of the following keywords: (i) “value co-creation” AND (ii) “model”, AND (iii) “collaborative”, AND (iv) “ecosystem”, AND (v) “engineering asset” (Table 1).

As in the case of our preliminary research presented above, we obtained no results, prompting us to broaden the search and remove the keyword “engineering asset.” This is further confirmation of a gap in the field of asset management in general, and in EAM in particular, regarding the study of value co-creation models and collaborative ecosystems.

In the third step of the main research, a combination of the following keywords was cumulatively used: (i) “value co-creation” AND (ii) “model”, AND (iii) “collaborative”, AND (iv) “ecosystem” (Table 1).

These keywords were selected to reflect the study’s core conceptual dimensions: collaborative interaction, ecosystem perspective, value creation, and model-based structuring. The keywords were deliberately selected to reflect the conceptual foundation of this research. As shown in the preliminary research, this has already been carried out across various sectors related to the EAM. Therefore, it is important to carry out this work at EAM to create a collaborative ecosystem and enable value co-creation. The term “collaborative” underscores the central role of multi stakeholder interaction in engineering asset management. An ecosystem is the holistic, adaptive, and interdependent structure in which these interactions occur and jointly create value [54]. Value co-creation emphasizes that value emerges from collective engagement and shared processes rather than from isolated organizational actions [54,71,72]. Figure 2 shows the conceptual framework that articulates the scientific intent of the investigation and a structured perspective that can be replicated.

Table 4 presents the methods used in accordance with the PRISMA guidelines [60]. Figure 3 shows the PRISMA diagram for visualization, the literature search, and the selection process. The checklist of PRISMA is presented in the Supplementary Materials.

Table 4. Methods used in accordance with the PRISMA guidelines.

Topic	Method
Eligibility criteria	All articles included in this study meet three eligibility criteria: (i) publications in English; (ii) articles published or at the final stage of publication to ensure that all candidate records have been peer-reviewed; (iii) no restrictions were placed on the year of publication, journal title, number of citations, or other characteristics. The choice of publications in English is because it is the official scientific language and the most widely used. All articles excluded in this study meet two eligibility criteria: (i) publications in languages other than English; (ii) articles that have not yet been published.
Information sources	Science Direct and Web of Science between November and December 2025.
Search strategy	Two criteria were applied: (i) the articles must be in English, (ii) all duplicate articles must be removed.
Selection process	All articles that met the eligibility criteria were included. All articles were independently reviewed by the lead author of the study.
Data collection process and synthesis methods	The articles were analyzed in general terms with respect to the number published per year, the journals in which they appeared, the authors, and the terms used. To this end, we extracted information from <i>EndNote</i> , where all articles are stored for analysis, and used <i>Excel</i> to analyze publication year, journal, and author. The terms presented in the articles were analyzed using <i>VOSviewer (version JAVA 1.0)</i> software. To replicate the methodology used in <i>VOSviewer</i> software, we detail the procedures performed: (i) we imported the list of articles from <i>Endnote</i> into <i>VOSviewer</i> , (ii) we selected “Title and abstracts fields” and then “full counting,” (iii) we removed the list and standardized the synonymous terms, (iv) we repeated the steps from (i) but included the list of synonymous terms to be considered in the new analysis, and (v) we only included terms that appeared more than 3 times.
Data items	All articles that met the eligibility criteria were included.
Study risk of bias assessment	This literature review identifies sources of bias risk. The review process was conducted by a single person, which poses a risk to the study’s overall quality because there is no redundancy for resolving conflicts. A formal risk of bias assessment was not conducted due to the exploratory nature of the review.
Effect measures	As the review was qualitative in nature, no statistical effect measures were applied.
Reporting bias assessment	Repost bias assessment was not formally assessed.
Certainty assessment	Certainty assessment was not formally assessed.

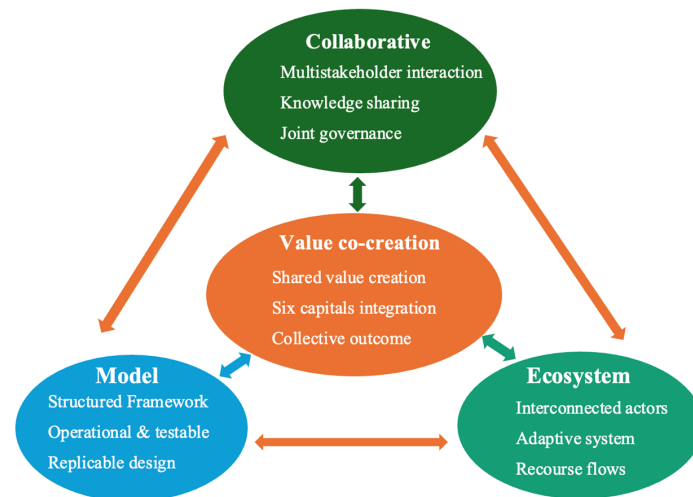


Figure 2. Conceptual framework for collaborative ecosystem value co-creation model. The arrows represent the connections between the keywords.

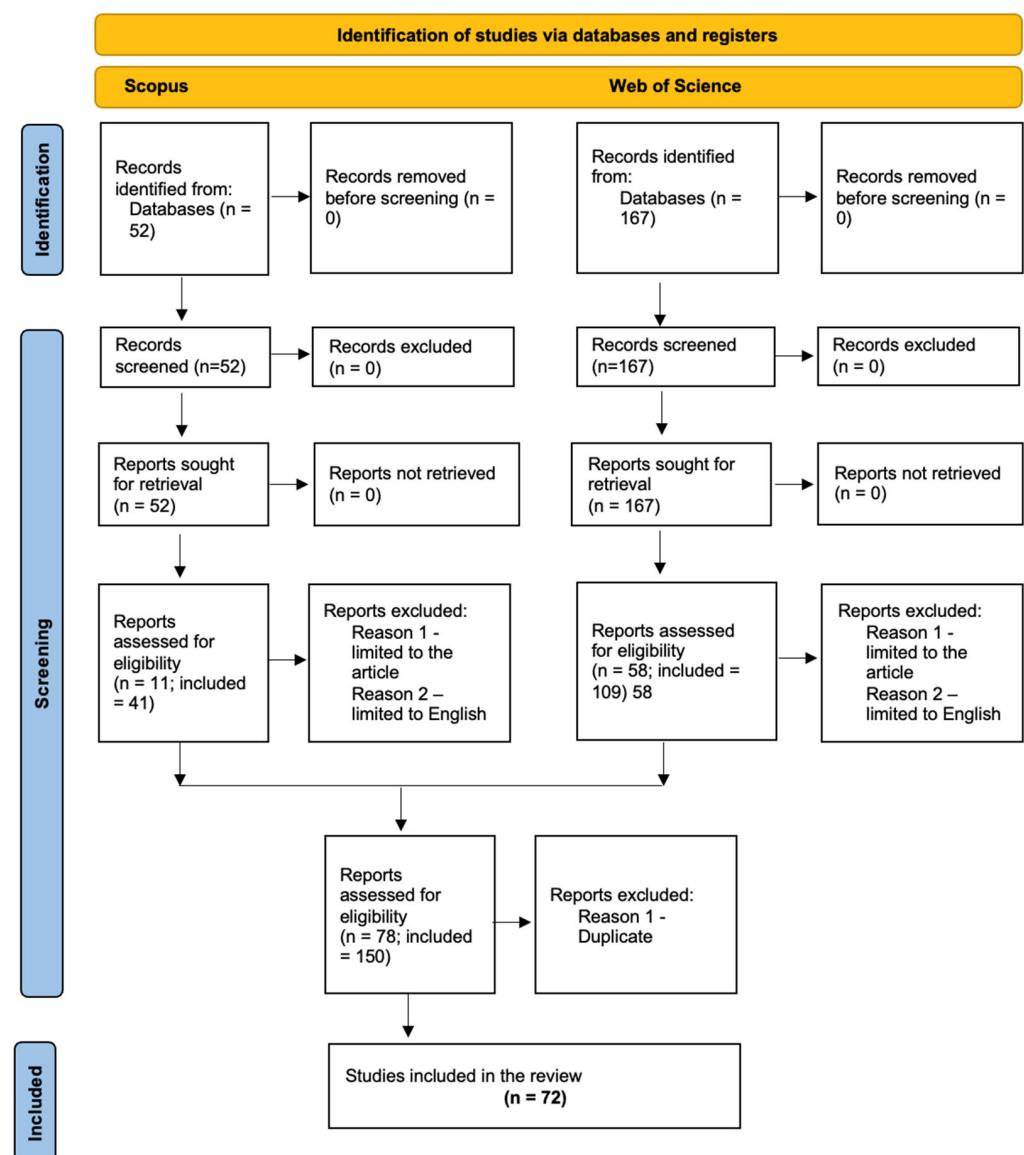


Figure 3. PRISMA flow diagram illustrating the literature search and selection process. Bold: total studies included in the review.

3. Results

This section is divided into two parts: (i) a bibliometric analysis of the results, and (ii) a general analysis and discussion of the findings. The bibliometric analysis is further divided into two: (i) analysis of the articles by year of publication, journal, and authors; and (ii) terms used within the scope of research on collaborative ecosystems. The general analysis and discussion of the results aim to address the research questions.

3.1. Bibliometric Analysis of Results

Analysis of the Articles by Year of Publication, Journal, and Authors

The first article dates to 2011. Between 2012 and 2015, there were no articles in our results. Publications resumed in 2016 with two publications; in 2017, they decreased again to one; in 2018, there were four; and in 2019 six. In 2020, they decreased to one publication, which might be explained by COVID-19. In 2021, four publications were identified. Since then, the number has increased, with 2024 and 2025 being the years with the highest numbers, 10 and 29, respectively. In Figure 4, we present all the percentages and the number of publications identified in our results.

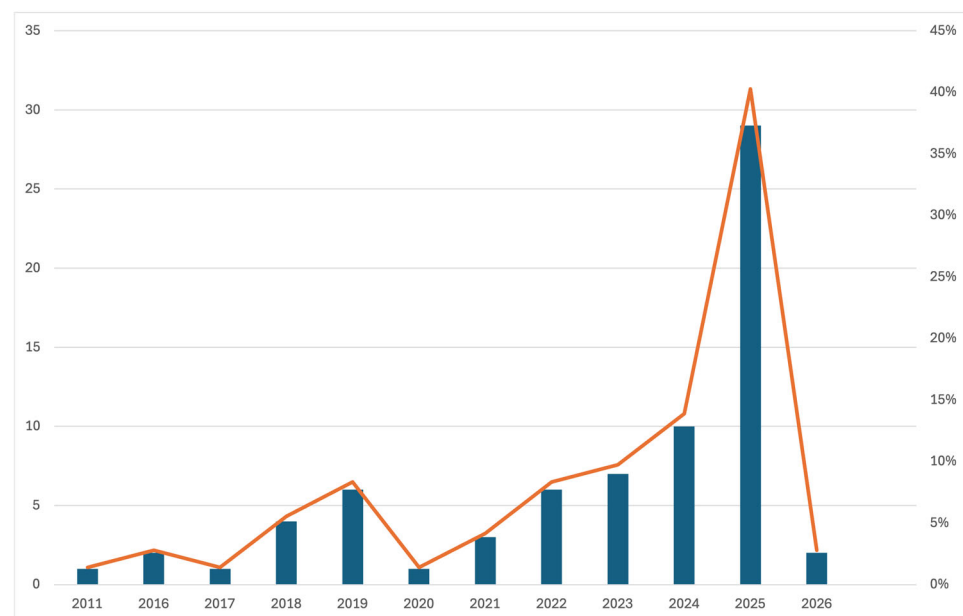


Figure 4. Percentages and the number of publications identified.

The 72 articles were published across 62 journals. In the top five, we find Sustainability, Journal of Cleaner Production, Ecosystem Services, Journal of Business Research, and Marketing Intelligence and Planning, with 6, 3, 2, 2, and 2 publications, respectively. The remaining Journals each had only one publication. That indicates substantial heterogeneity among journals. In Table 5, we present the top five journals.

Table 5. Top five journals.

Journal	Number of Publications	Percentages of Publications
Sustainability	6	8%
Journal of Cleaner Production	3	4%
Ecosystem Services	2	3%
Journal of Business Research	2	3%
Marketing Intelligence and Planning	2	3%

Analyzing the authors and co-authors of the 72 articles, we identified 281 authors, some of whom appeared multiple times, yielding 258 distinct authors. None of the authors analyzed had more than two articles. Of the 258 authors, 25 were responsible for two articles. Analyzing the authors and co-authors of the 72 articles, we identified 281 authors, some of whom appeared multiple times, yielding 258 distinct authors. None of the authors analyzed had more than two articles. Of the 258 authors, 25 were responsible for two articles. We divided the articles by sectors and analyzed only the main authors. The 72 articles resulted in 11 sectors, some of which appear in more than one sector. The top three sectors with the highest percentage were Digital infrastructure (44%), Banking and financial market infrastructure (13%), and Logistics (10%). The analyzed articles show that the sectors seek and research the creation of a collaborative ecosystem. All sectors are strongly connected to asset management engineering, underscoring the importance of the work and the need to foster a collaborative ecosystem in the field. Table 6 shows the sectors, and the corresponding percentages.

Table 6. Sectors and percentages.

Sectors	Percentage
Digital infrastructure	43%
Banking and financial market infrastructure	10%
Logistics	10%
Agriculture	6%
Health	6%
Higher education and research	6%
Public administration	6%
Tourism	3%
Industrial processing	4%
Energy	1%
Water	1%

3.2. Analysis Based on the Terminology Used in the Articles

Using *VOSviewer*, we extracted term lists from the titles and abstracts of the analyzed articles. In the first list, we identified 528 terms (title and abstract fields, ignoring structure abstract labels, and ignoring copyright statements); some were synonyms. We created a list for the program to consider synonyms and select the full count, yielding 410 terms. Of the 410 requested terms, those repeated more than three times were identified, totaling 24 terms.

Table 7 presents the results by frequency of occurrence, along with their relevance scores. The relevance score is an attribute that measures the importance or specificity of terms in a visualization map and is generally used to highlight the most representative terms. In Table 7, the number of occurrences does not correspond to the relevance score. The term “value co-creation” leads the relevance score with 0.0761 but ranks second in occurrence. The *VOSviewer* network visualization of keyword co-occurrence is shown in Figure 5. In Figure 6, we can see the relationship between them. The relevance score is visualized by the line color, and the words with the highest occurrence are highlighted.

The yellow cluster (collaboration, economy, and value co-creation) represents the central conceptual core of the research. The blue cluster (development, digital, ecosystem, person, and technology) represents the digital enablement layer, associating ecosystem development with technological transformation. The red cluster (insight, IoT, paper, smart technology, sustainable development, and sustainable smart ecotourism) reflects sectoral applications of smart technologies geared towards sustainability, illustrating how these

concepts are already being applied in specific domains (such as tourism). Finally, the green cluster (conservation area, knowledge, management, manager, model, research, and shrub advancement) represents knowledge-based management models applied to environmental management/conservation contexts.

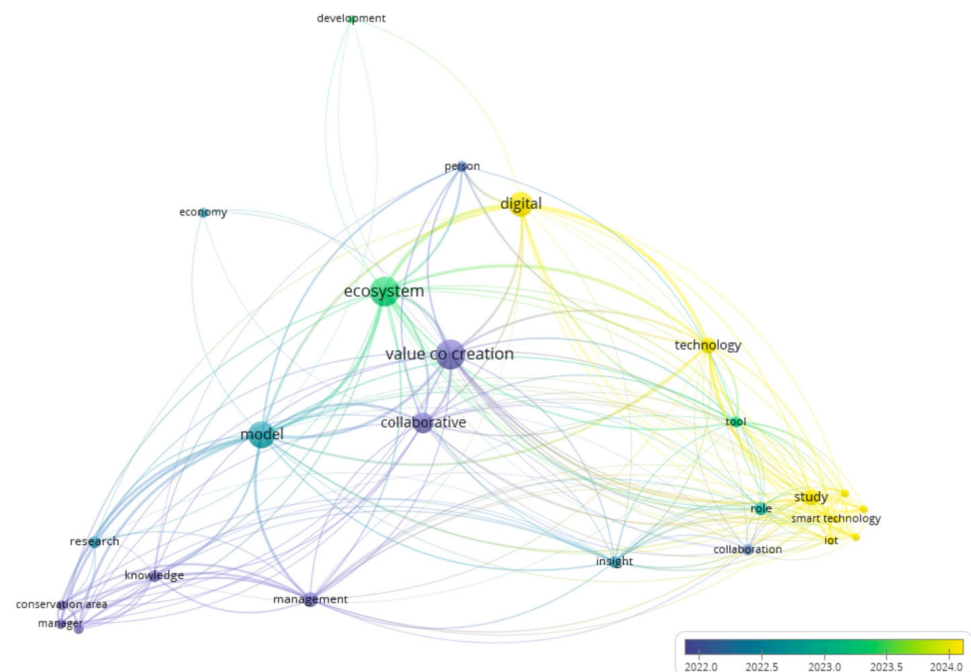


Figure 5. VOSviewer network visualization of keyword co-occurrence.

Table 7. Top 24 terms.

Term	Occurrences	Relevance Score
ecosystem	38	0.2414
value co creation	38	0.0761
model	28	0.3686
collaborative	25	0.0284
digital	25	0.5894
study	11	1.1361
technology	11	0.5388
management	9	0.8693
role	7	0.7115
insight	6	0.2764
knowledge	6	1.465
research	6	1.2762
person	5	0.6117
tool	5	0.5399
conservation area	4	2.1088
economy	4	0.5111
manager	4	2.1088
shrub encroachment	4	2.1088
development	3	1.1497
IoT	3	1.4302
smart technology	3	1.4302
sustainable development	3	1.4967
sustainable smart ecotourism	3	1.4302
systematic review	3	1.4967

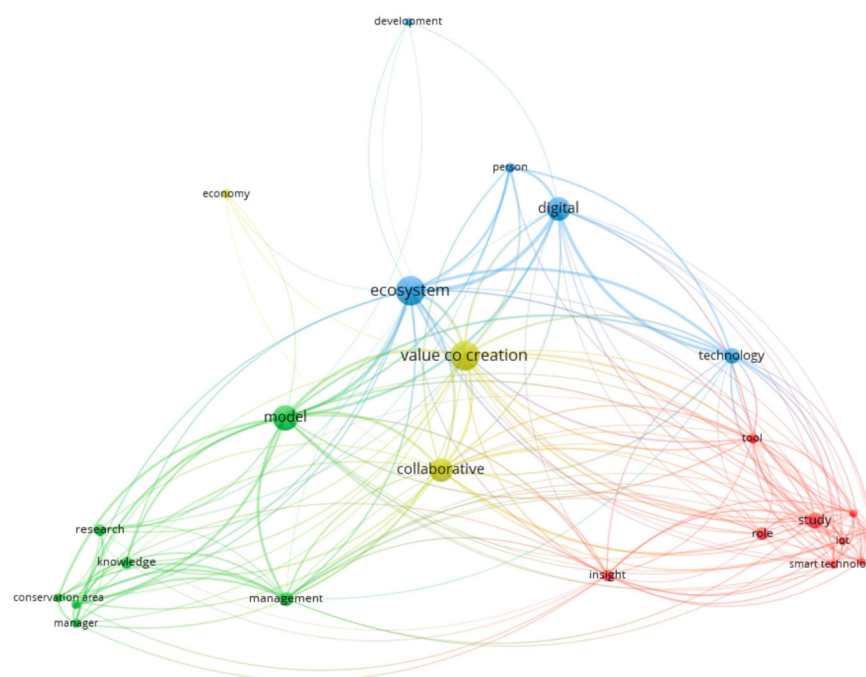


Figure 6. VOSviewer network visualization of clusters.

Taken together, these four clusters show that the literature on collaborative ecosystems and value co-creation (yellow cluster) is already linked to a digital enablement axis (blue cluster) and concrete sectoral applications in other resource-intensive domains (red and green clusters). However, as demonstrated in the previous analysis (zero results for ‘asset management’), none of these clusters includes engineering asset management as an application domain, reinforcing precisely the gap that this article seeks to fill.

In our analysis, we identified four clusters, i.e., four groups of terms with strong interconnections. These four clusters are represented by different colors in Figure 6. The first cluster comprises the terms “insight”, “IoT”, “role”, “smart technology”, “study”, “sustainable development”, and “sustainable smart ecotourism” in red. The second cluster comprises the terms “conservation area”, “knowledge”, “management”, “manager”, “model”, “research”, and “shrub encroachment” in green. The third cluster comprises the terms “development”, “digital”, “ecosystem”, “person”, and “technology” in blue. And finally, the fourth cluster comprises the terms “collaborative”, “economy”, and “value co-creation” in yellow.

3.3. Examination of Results

This section examines the results of the research in light of the three main research questions proposed in this article: (i) Why do we need a value co-creation model for engineering asset management? (ii) What are the best models and frameworks to conceptualize/describe value co-creation in an engineering asset management collaborative ecosystem? (iii) How can engineering asset management collaborative ecosystems be activated/accelerated to maximize value co-creation?

The examination seeks to identify and explore the underlying conceptual constructs and the appropriate terminology for value co-creation models for EAM collaborative ecosystems.

The V-model proposed by [73] bridges research design and its practical processes, organizing intentions and results into three levels of complexity. This model is universal and pragmatic, serving as a visual language to integrate practice and research. The V-Model helps reduce technical uncertainty, mainly by connecting the semi-structured level (objectives) to the structured level (technical details). The V-Model reduces uncertainty by

requiring each tactical objective to be broken down into structured, measurable activities, ensuring that technical development is not based on assumptions but on a rigorous, testable design [73]. Figure 7 shows the adapted V-model for our research work. With this article, we aim to address the following three points.

Why do we need a value co-creation model for engineering asset management?

In the preliminary research, the sectors found are all related to engineering asset management. The second research clearly shows a gap in the literature when they are not related to engineering asset management, with zero articles found when searching for the keyword “asset management.” In the third research, removing the keyword “asset management” yielded results, and after analyzing the sectors, it was possible to show that they are related to engineering asset management (Table 3). The terms relate to engineering asset management (EAM), but there is no systematic approach to EAM, making them multi-sectors when they are sub-sectors of EAM. It becomes urgent to connect these sectors through a collaborative ecosystem to bridge the gap.

The literature reviewed demonstrates that asset-intensive systems are increasingly embedded in complex, multi-actor environments characterized by digital interdependence, sustainability pressures, lifecycle integration, and shared risk exposure. Business ecosystem theory highlights that performance emerges from co-evolving, interdependent actors rather than isolated firms, while Service-Dominant Logic (SDL) and service ecosystem perspectives conceptualize value as co-created through resource integration across institutional arrangements [74,75]. However, these conceptual advances have not been systematically translated into the specific governance, lifecycle, and performance structures required in EAM contexts.

Empirical and analytical studies further reinforce this need. Game-theoretical analyses show that decentralized, non-cooperative configurations frequently converge to optimal Nash non-cooperative game, whereas coordinated, integrated decision-making models achieve Pareto optimality outcomes and higher collective performance [76]. This suggests that without structured mechanisms to align incentives, distribute value, and coordinate multi stakeholder roles, ecosystem performance in asset management remains constrained.

Moreover, sustainability-oriented ecosystem research emphasizes that value in contemporary systems is multidimensional—economic, environmental, and social—and must be governed through structured platform mechanisms, information governance, and clearly defined ecosystem roles [54,55]. Yet, existing studies remain fragmented and rarely integrate governance design, digital enablement, sustainability, and asset lifecycle management into a unified architecture.

Therefore, a dedicated value co-creation model for an engineering asset management collaborative ecosystem is necessary to (i) conceptualize value; (ii) structure value networks and multi stakeholder roles; and (iii) accelerate ecosystem performance under sustainability constraints.

Such a model would not only consolidate fragmented theoretical streams but also provide a practical governance and coordination framework that enhances requisite resilience, innovation, and long-term sustainable value generation in asset-intensive systems.

What are the best models and frameworks to conceptualize/describe value co-creation in an engineering asset management collaborative ecosystem?

The literature presents a broad range of conceptual models and analytical frameworks to support collaboration within multi-actor ecosystems. Foundational work on digital business ecosystems defines them as economic communities of interacting organizations and individuals that co-evolve through cooperation and competition [54]. With the rise of digital technologies, these ecosystems increasingly develop around digital platforms that mediate interactions, coordinate transactions, and enable the creation of shared value [54,55].

From a governance and structural perspective, ecosystem performance has been associated with key characteristics such as modularity, customization, multilateralism, and coordination, as well as with clearly defined actor roles, including keystones, dominators, hub landlords, and niche players. The design of ecosystem architecture—centralized, decentralized, or distributed—also significantly affects robustness, fault tolerance, scalability, and risk exposure [54].

Service-oriented frameworks further enrich this perspective by conceptualizing ecosystems as configurations of actors that integrate resources through reciprocal service exchange. The Service-Dominant Logic (SDL) and service ecosystem literature emphasize value co-creation, interdependence, and institutional arrangements as core mechanisms shaping ecosystem outcomes [74,75]. Analytical tools such as fuzzy-set Qualitative Comparative Analysis (fsQCA) have been applied to identify multiple causal configurations leading to high ecosystem performance, acknowledging equifinality and contextual diversity [77].

More recently, sustainability-oriented models—including synergistic sustainability and ESG co-creation frameworks—propose multi-level structures integrating governance, strategy, risk, technology, human capital, and products to align economic, environmental, and social objectives through collaborative mechanisms [62]. Together, these models and frameworks provide a diverse but fragmented foundation for accelerating collaborative ecosystems, highlighting the need for integrative approaches tailored to asset-intensive contexts.

We divide the presented models into three different types: Conceptual Models, Operational Models, and Analytical Models. These models do not compete with one another; rather, they are complementary and operate at different layers of the phenomenon under study. The relationship among the three categories is not only one of complementarity but also of sequential dependence. Conceptual models establish the assumptions without which operational models have no foundation; operational models, in turn, create the institutional conditions without which analytical models have no measurable object. It is not possible to test causal configurations of collaboration if roles, shared resources, and governance rules are not defined. The Conceptual Models provide the ontological and epistemological framework of the research. These models explain what an ecosystem is, who the actors are, how value is conceptualized, and the principles that govern interactions (e.g., service ecosystem, service-dominant logic, value co-creation frameworks, business ecosystems). They operate at a high level of abstraction and are essential for establishing a common language, defining conceptual boundaries, and justifying the thesis's theoretical choices. Without these models, empirical analysis would lack conceptual coherence and theoretical rigor. The Operational Models translate these theoretical principles into actionable mechanisms, explaining how ecosystems function in practice and how they can be coordinated, regulated, and sustained over time. They include platform governance models, roles within the ecosystem (orchestrator, keystone, and complementors), ecosystem life cycles, access-over-ownership logic, and information governance models (e.g., selective disclosure). These models operate at the meso level of the system and are crucial for linking theory to practice, enabling analysis of organizational design, interorganizational coordination, risk mitigation, and the creation of shared value in real-world contexts. The Analytical Models provide the formal tools necessary to test, compare, and validate the behaviors described by the conceptual and operational models. Models such as differential, Nash non-cooperative game, Stackelberg, and Pareto, as well as the fsQCA method, enable the analysis of strategic dynamics, interdependencies, complex causality, and cooperation trajectories over time. These models operate at a rigorous analytical level, ensuring that propositions are not only conceptually plausible but also empirically and logically supported.

In Table 8, we present a summary of the models identified in the articles studied, classified into three types (conceptual/theoretical models, operational and governance models, and analytical and mathematical models), along with their definitions.

Table 8. Model definitions of the third and fourth steps.

Model Type	Model Name	Definition	Reference
Conceptual models	Business ecosystem	An economic community of interdependent organizations (companies, institutions, and individuals) that co-evolve through collaborative and competitive interactions to create collective value. The performance of each actor depends on the health of the ecosystem, requiring coordination, role specialization, and continuous adaptation.	[78]
	Digital Business ecosystem (DBE)	Distributed socio-technical network where economic actors and digital technologies (platforms, data, software, and infrastructure) collaboratively co-create value. The DBE allows organizational and industrial boundaries to be overcome, supporting flexible, interoperable, and innovation-oriented business models, distributed governance, and digital scalability.	[54,55,79]
	Service-Dominant Logic (SDL)	A theoretical perspective that redefines value as something co-created through the integration of resources among multiple actors, rather than being embedded in products. Services, knowledge, and interactions are the basis for value creation, positioning customers, partners, and users as active participants in service ecosystems.	[80,81]
	Service Ecosystem	A dynamic, self-adjusting system of multiple actors that integrate resources through exchanges of services, coordinated by shared institutional arrangements, where value emerges from interactions rather than from isolated entities.	[79]
	Balanced centrality	An approach that considers all actors in the ecosystem (platforms, organizations, partners, customers) as equally relevant, promoting a balance between individual interests and the overall performance of the ecosystem.	[77]
	Business service lifecycle	Models that describe the evolution of ecosystems through phases (emergence, development, maturity, and transformation), highlighting the need for continuous adaptation and dynamic capabilities to ensure requisite resilience.	[54]

Table 8. *Cont.*

Model Type	Model Name	Definition	Reference
Operational models	Five actor Service Ecosystem Model	Conceptual model that expands the triadic logic to five interdependent actors (platform, supplier, customer, complementary partners, and institutional actors), demonstrating that value co-creation emerges from systemic interactions coordinated by governance mechanisms and institutional frameworks.	[61]
	Governance model	A set of rules, incentives, and coordination mechanisms that enable multiple actors in a digital ecosystem to be aligned, controlled, and integrated, distinguishing it from hierarchical or purely market-based models.	[54,82]
	Ecosystem roles (orchestrator, keystone, complementary, hub)	Distinct strategic roles that structure the ecosystem: the orchestrator coordinates, the keystone ensures stability, the complementors create specialized solutions, and the hub integrates and connects the actors.	[78,83,84]
	Access-over-ownership logic	Economic logic that favors temporary access to assets over ownership, increasing efficiency, flexibility, and sustainability in the use of physical and digital resources.	[78,85]
	Participatory system Mapping (PSM)	Collaborative methodology that involves stakeholders in modeling complex systems, identifying interdependencies, feedback, and leverage points to support integrated decisions.	[84]
	ESG co-creation model	A model that conceptualizes sustainability as a co-creative and systemic process, integrating governance, strategy, risk, technology, human capital, and products/services to generate economic, social, and environmental value.	[62]
Analytical models	Nash vs. Stackelberg vs. Pareto-optimal collaboration	Types of strategic coordination: Nash (non-cooperative), Stackelberg (leadership with incentives), and Pareto-optimal (total cooperation), the latter being the one that maximizes the overall value of the ecosystem.	[76]
	fsQCA causal configuration	A configurational analytical method that identifies combinations of necessary and sufficient conditions for certain outcomes, capturing complex causality, equifinality, and asymmetries in collaborative ecosystems.	[77]

How can engineering asset management collaborative ecosystems be activated/accelerated to maximize value co-creation?

In collaborative ecosystem research, value is increasingly conceptualized as a systemic and relational construct rather than an organization-level output. Value co-creation is

defined as a process in which multiple actors integrate heterogeneous resources and capabilities to generate mutual benefits, shifting the analytical focus from individual organizations to interdependent value systems [78,86,87].

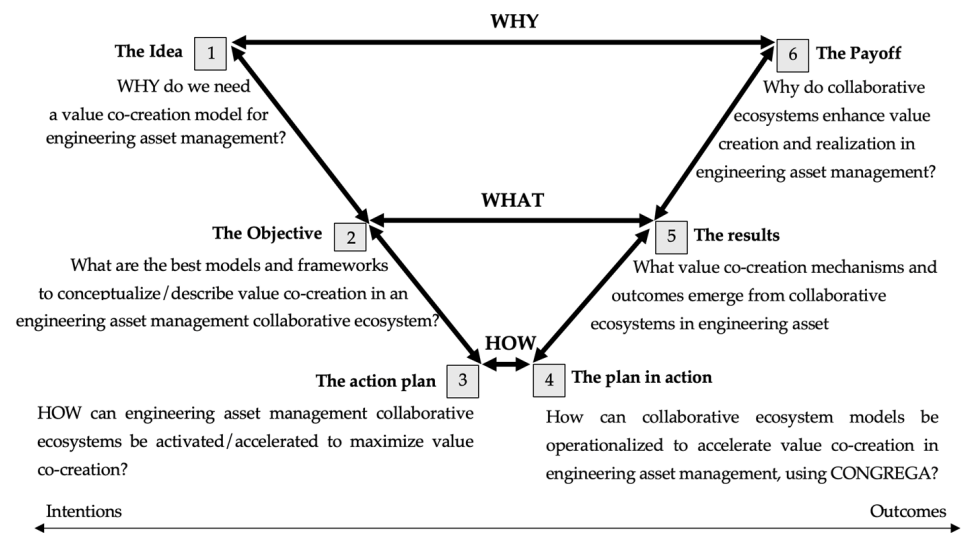


Figure 7. The V-model for our research. Stages one to three refine intentions; stages four to six expand outcomes.

Value creation in such contexts occurs through value networks rather than linear value chains. Collaborative Networked Organizations (CNOs), Virtual Customer Communities (VCCs), and platform-based ecosystems exemplify how distributed actors co-create value through digital interactions, shared knowledge, and coordinated innovation processes [87,88]. These networks are inherently interdependent, meaning that the performance of individual actors is tightly coupled with the health and stability of the ecosystem [54].

A recurring theme in the literature is the transition from ownership-based models to access-based logics, in which value is derived from the efficient and sustainable use of shared assets rather than from asset possession [78,85]. Digital platforms, governance mechanisms, and selective information-sharing models play a critical role in enabling trust, mitigating ecosystem risks, and balancing collective value creation with individual value capture [81]. These insights provide a robust conceptual basis for understanding value and value networks within collaborative engineering asset management ecosystems. Table 9 shows terms and definitions for the collaborative ecosystem model found in our research.

Table 9. Terms and definitions for the collaborative ecosystem model.

Term	Definition	Reference
Actor Engagement	The interaction and integration of resources among multiple actors.	[89]
Balanced Centricity	All stakeholders have the right to satisfy their needs and desires simultaneously, increasing the well-being of each individual actor and the network.	[77,90]
Barriers to Collaboration	Obstacles such as preconceived assumptions about the motivations of other partners, entrenched disciplinary thinking, and the use of confusing terminology that hindered communication between scientists and the business sector.	[91]

Table 9. Cont.

Term	Definition	Reference
Boundary Spanner	Refers to the role of the university in connecting ecosystems and actors that would otherwise be isolated.	[92]
Boundary Work	Management of boundaries between different institutions and types of knowledge to facilitate information exchange.	[91]
Business Ecosystems	Networks of interconnected and interdependent actors who collaborate (and compete) for the efficient delivery of a product or service.	[83]
Business Model Canvas	A visual tool for conceptualizing organizational strategies.	[93]
Business Model Innovation (BMI)	Defines how an ecosystem creates and captures value, going beyond product or process innovation to serve as the engine of change itself.	[94,95]
Circular Economy	A model that replaces linear value chains with closed-loop systems focused on reuse, recycling, and resource efficiency.	[93,94]
Co-Creation of Knowledge	A collaborative process in which different actors produce new and shared knowledge about a common problem.	[84]
Co-Creation of Services	Collaborative strategy involving the active participation of partners in the design, execution, and learning of service processes.	[96]
Co-Evolution	The capacity of the ecosystem and its partners to collectively transform in response to threats or opportunities.	[55]
Collaborative Business Model	Describes the configuration and logic of how organizations in a network collaborate and exchange resources to support co-creation and capture value.	[82,97]
Collaborative Networks	A group of partners who collaborate multilaterally to achieve individual and collective goals.	[55,82]
Communities of Practice	Groups of people who share a domain of interest and engage in joint learning and problem-solving activities.	[92]
Core Enterprise	Leading partner in the ecosystem with the ability to select, control, and guide innovation partners.	[98]
Digital Business Ecosystem	The collaborative environment where value co-creation and digital platform management take place.	[99]
Digital Entrepreneurship	An essential driver in modern innovation systems and ecosystem models, facilitating the transition to platform-based models.	[99]
Digital Platform Ecosystem	Collaborative network with actors who integrate resources around a platform for value creation.	[56]
Digitalization	Incorporation of technologies such as IoT (Internet of Things), AI (Artificial Intelligence), and Virtual Reality in BMs.	[93]
Service Dominant Logic	Theoretical framework that views actors not only as producers or consumers, but as collaborative systems that participate in value creation through the integration of resources and service offerings.	[56,80]
Ecosystem	Where partners interact and create complementarities.	[93]
Ecosystem Glue	The invisible and dynamic alignment between partners that sustains collaboration over time, going beyond a simple shared vision.	[95]

Table 9. Cont.

Term	Definition	Reference
Ecosystem Management	Building a network that ensures value flow and system stability in the face of external influences.	[56]
Ecosystem-as-Affiliation	An approach focused on partner networks connected to a leading company or platform.	[95]
Ecosystem-as-Structure	A perspective that focuses on the value proposition of the ecosystem and the alignment of activities.	[95]
Energy Flow	Refers to the circulation of value within the ecosystem; this can be economic value, intellectual value, or emotional value.	[100]
Entrepreneurial Ecosystem	The environment composed of interconnected actors who support entrepreneurship.	[80,93]
Industry 4.0	Characterized by a model of cooperation, openness, and sharing, where innovation transcends the boundaries of a single entity.	[94,98]
Industry 5.0	Industrial paradigm focused on human centrality, sustainability, and requisite resilience, evolving from the efficiency of Industry 4.0.	[101]
Innovation Community	Composed of innovation partners who maintain stable development relationships around common value creation goals.	[102]
Innovation-Oriented Platforms	Ecosystems that orchestrate collaborative innovation among partners.	[103]
Institutional Arrangements	Interrelated sets of partners that form a coherent assembly to facilitate the co-creation of value.	[85,104]
Interorganizational Entity	Discursive representations of established relationships, such as partnerships, alliances, and networks.	[97]
Keystone Actor	Companies that lead the ecosystem, provide the platforms, set common goals, and coordinate the network of actors.	[83]
Knowledge Co-Production	Refers to the collaborative process of engaging partners to share and generate knowledge that integrates different value systems and norms.	[91]
Knowledge Ecosystem	A system-level approach that includes sociopolitical dimensions, public health networks, and databases for the co-creation of knowledge.	[105]
Knowledge-Concept-Proposal	A design-based approach that involves partners in the development of knowledge, innovative concepts, and concrete proposals.	[95]
Leverage Points	Variables in a system where a small change can produce significant changes throughout the system.	[84,106]
Living Lab	Defined as user-centered open innovation ecosystems.	[104,107]
Network Activation	Use of networks for sharing resources and technical knowledge.	[108]
Network Level	Information that is visible and accessible to all stakeholders in the collaborative network.	[82]
Network Ties	Links between actors that may be collaborative or coordinated.	[104]
Open Innovation	A model that advocates the use of external sources of knowledge to enhance internal innovation.	[79,107,109]

Table 9. Cont.

Term	Definition	Reference
Operand Resources	Tangible resources.	[82,110]
Operant Resources	Intangible resources, such as skills, knowledge, and information.	[82,110,111]
Orchestration	Coordination of resources, activities, and relationships by actors within an ecosystem to shape collective performance and benefit distribution.	[55,78]
Partnership	A relationship of collaboration and trust between the actors and partners involved.	[107,112]
Peer-to-Peer Transactions	Direct interactions between partners, facilitated by digital platforms, without the need for a traditional corporate.	[113]
Resource Integration	The combination of tangible and intangible assets to overcome individual limitations.	[85]
Role Theory	Used to examine the roles, positions, expectations, and behaviors of actors within the ecosystem, emphasizing that these roles are dynamic and evolve according to context.	[56]
Service Ecosystem	Dynamic and interrelated systems of actors that integrate resources and co-create value through value propositions.	[61,72,79,81,84,89,100,111]
Service-Dominant Business Model Radar	A circular visual tool that places co-created value-in-use at the center, surrounded by network actors and their respective value propositions, costs, and benefits.	[79,81]
Shared Logic	The ability of partners with different backgrounds and roles to coexist and work toward a common goal with minimal friction.	[94,100]
Sharing Ecosystem	Complex network of partners, platforms, regulators, and users who interact to create value in the digital space.	[113]
Social Innovation	Development of solutions that all actors/partners in the system, based on knowledge sharing.	[56]
Stakeholders	Refers to all interested parties.	[84,102]
Symbiosis and Co-Evolution	Refers to the interdependence between partners, processes, and technologies, generating synergies for the co-creation of value.	[55,101]
Value Capture	The process of securing profits or returns (financial or otherwise) from value creation, distributed among the participating actors.	[82,93,114]
Value Co-Creation	A process in which participants in an ecosystem collaborate to generate mutual benefits through dynamic networks.	[55,56,62,72,76,77,79–83,85–87,93,94,100,103,104,109,114,115]
Value Co-Destruction	Interaction process between service systems that results in a decline in the well-being of at least one of the systems.	[110,115]
Value Negotiation	Essential practice where stakeholders balance individual value capture versus network value capture to achieve acceptable compromises.	[82]
Value Proposition	A statement of how the platform will benefit stakeholders, serving to attract partners and maintain ecosystem cohesion.	[85]

3.4. Discussion of Findings

The results confirm a clear need to accelerate collaborative ecosystems in Engineering Asset Management (EAM), as increasing asset complexity, digital transformation, and sustainability pressures exceed the capacity of organization-centric governance models. While extensive research exists on business ecosystems, service ecosystems, digital platforms, and value co-creation, these contributions remain fragmented and rarely integrate governance, digital enablement, sustainability, and asset management into a unified framework. This gap motivates the present research, which aims to identify and analyze opportunities by positioning value, value networks, and multi stakeholder collaboration as core mechanisms for accelerating ecosystem performance in asset-intensive systems.

The assessment of models against EAM systems shows a pattern: while all offer useful theoretical resources for developing collaborative ecosystems in asset-intensive contexts, none are fully designed with EAM requirements in mind. Conceptual models like SDL and the Service Ecosystem offer strong foundations for understanding value co-creation and actor interdependence, but their assumptions of unconstrained resource integration and short interaction cycles clash with EAM's long lifecycle, budget constraints, and regulatory relationships. Operational models, especially Governance Models and Access-Over-Ownership, are directly transferable but need adaptation for liability asymmetries and public procurement in regulated infrastructure. Analytical models like Nash/Stackelberg/Pareto and fsQCA are suited for evaluating collaborative configurations in complex, resource-scarce EAM environments, but require EAM-specific calibration. Overall, this article not only affirms the relevance of existing models for EAM but also identifies where they fit, need adaptation, or reveal gaps, gaps that ongoing empirical research aims to address.

Value is conceptualized as systemic and co-created across interdependent actors, extending beyond economic outcomes to include environmental and social dimensions. Effective acceleration, therefore, depends on structured governance, coordinated ecosystem roles, trust-based collaboration, and digital platforms that enable integration while mitigating risks of opportunism and value co-destruction.

The ecosystem mapping proposed in this study integrates complementary models operating at different analytical levels. At the conceptual level, the Business Ecosystem, Service-Dominant Logic, and Service Ecosystem frameworks provide the theoretical foundation for understanding value co-creation among interdependent actors. At the operational level, platform governance mechanisms, ecosystem role structures (orchestrator, keystone, and complementors), and Participatory System Mapping enable the identification and coordination of stakeholders. Finally, sustainability-oriented frameworks such as the ESG co-creation model provide a multidimensional perspective integrating governance, strategy, technology, and human capital to ensure long-term value generation in asset-intensive systems. The theoretical framework integrates complementary models that address different dimensions of collaborative ecosystems. Business ecosystem theory provides the structural perspective for identifying stakeholders and their interdependencies, while service-dominant logic explains the mechanisms of value co-creation through resource integration. Service ecosystem theory further contextualizes these interactions within dynamic institutional environments. Operationally, ecosystem role models and platform governance frameworks define stakeholder responsibilities and coordination mechanisms, while participatory system mapping supports system-level analysis of complex infrastructure networks (Table 10).

Table 10. Theoretical models and ecosystem variables.

Application to EAM	Identifies the organizations and institutions participating in the asset management ecosystem	Explains how stakeholders combine knowledge, technology and capabilities to enhance asset performance	Describes the dynamic system of interactions supporting infrastructure lifecycle management	Defines the five actor categories of the EAM ecosystem and their relationship to sustainable innovation
Main limitations	Abstract; difficult to operationalize directly in regulated contexts	High level of abstraction; does not specify coordination mechanisms	Predominantly focused on services; less attention to long-lifecycle physical assets	Tends to underdevelop the coordination mechanisms between helices
Main advantages	Integrates competition and cooperation; explains the structure of interdependencies	Theoretically grounds co-creation; applicable to tangible and intangible contexts	Frames dynamic interactions in complex institutional contexts; includes sustainability logic	Integrates environmental and social dimensions absent in triple and quadruple helix models
Level of analysis	Meso	Micro/meso	Meso/macro	Macro
Key variables	Stakeholders, interdependencies, network relationships	Resource integration, service exchange, collaborative value creation	Actor networks, institutional arrangements, service interactions	Helix actors, knowledge flows, socio-ecological context
Analytical focus	Structure of interdependent actors	Value co-creation through resource integration	Dynamic interactions among actors	Multi-actor innovation dynamics
Central assumptions	Performance emerges from co-evolving interdependent actors, not isolated organisms	Value is always co-created by the beneficiary through resource integration; goods are service distribution mechanisms	Dynamic systems of actors integrate resources and co-create value within shared institutional arrangements	Innovation emerges from the interaction of academia, industry, government, civil society and the natural environment
Model name	Business Ecosystem	Service-Dominant Logic	Service Ecosystem	Quintuple Helix
Model type	Conceptual			
Application to EAM	Defines the responsibilities and contributions of each stakeholder in the EAM ecosystem	Defines the responsibilities and contributions of each stakeholder type in the EAM ecosystem	Enables coordination, transparency and data-driven decision-making across EAM actors	Enables sharing of assets, data, and competencies across EAM organizations without property transfer
Main limitations	Does not specify governance mechanisms between roles	Roles can be ambiguous in multi-institutional contexts	Tension between efficiency and inclusiveness complicates governance mode selection	Requires trust and robust governance mechanisms to function

Table 10. Cont.

Main advantages	Customer/beneficiary-centered; balances supplier and user perspectives	Operationalizes structural asymmetry between actors; guides organizational design	Empirically tested typology; covers structural and procedural governance dimensions	Reduces resource duplication; generates network effects; aligns with circular economy models
Level of analysis	Meso	Meso	Meso	Meso
Key variables	Customer, provider, enabler, innovator, regulator roles	Orchestrators, keystones, complementors, beneficiaries	Governance rules, data sharing mechanisms, digital infrastructure	Access modes, ownership structures, service orientation, circular logic
Analytical focus	Functional role distribution in ecosystems	Structural asymmetry and role allocation	Coordination mechanisms in networks and digital ecosystems	Resource access and utilization models
Central assumptions	Sustainable service ecosystems require the coordinated participation of five distinct functional roles	Different actors assume asymmetric and complementary roles in value creation and distribution	Networks of autonomous actors require explicit coordination mechanisms to overcome suboptimal equilibria	Value resides in resource utilization, not ownership; shared access generates systemic efficiency
Model name	Five Actor Model	Ecosystem Roles	Governance Models	Access-Over-Ownership Logic
Model type	Operational			
Application to EAM	Aligns asset management with sustainability objectives and long-term societal value	Supports collaborative mapping of infrastructure management systems	Quantifies potential gains from collaborative configurations versus non-cooperative arrangements	Identifies the combinations of conditions that distinguish high and low-performance EAM ecosystems
Main limitations	Recent model; limited empirical validation in infrastructure contexts	Time- and facilitation-intensive; results depend on participation quality	Assumptions of rationality and perfect information rarely hold in real ecosystems	Sensitive to calibration choices; does not establish effect magnitudes as regression does
Main advantages	Integrates ESG into the co-creation logic; applicable to long-lifecycle assets	Facilitates multi-stakeholder engagement; captures non-linear interdependencies	Provides formal benchmark for evaluating collaboration gains; captures power asymmetries	Suited to medium-N samples; captures causal complexity; complements quantitative and qualitative approaches
Level of analysis	Meso macro	Meso	Micro meso	Meso

Table 10. Cont.

Key variables	Governance, strategy, technology, human capital, risk, ESG dimensions	Stakeholder engagement, system dependencies, feedback loops	Payoff functions, equilibrium states, cooperation gains, power asymmetry	Causal conditions, outcome sets, necessity, sufficiency, coverage
Analytical focus	Sustainability integration in co-creation	System-level understanding of complex interactions	Strategic interaction and equilibrium analysis	Configurational causal analysis
Central assumptions	Sustainability is a co-creative and systemic process integrating economic, social and environmental dimensions	Participatory mapping of complex systems improves shared understanding and collective decision-making	Rational actors make strategic decisions under interdependence; collaboration can yield outcomes superior to non-cooperative equilibrium	Causality is configurational, asymmetric and conjunctural; multiple combinations of conditions can produce the same outcome
Model name	ESG Co-Creation Model	Participatory System Mapping	Nash/ Stackelberg/ Pareto	fsQCA
Model type	Operational			Analytical

4. Conclusions

In conclusion, this study demonstrates that accelerating collaborative ecosystems in engineering asset management is not merely desirable but structurally necessary in increasingly complex, asset-intensive, and sustainability-driven environments. By integrating business ecosystem theory, service-dominant logic, platform governance mechanisms, multi-actor sustainability models, and participatory system approaches, the article advances a unified conceptual framework that links value co-creation, governance design, digital enablement, and lifecycle coordination within asset management systems. Unlike fragmented prior research, this work consolidates ecosystem governance, sustainability imperatives, and digital transformation into a coherent perspective tailored to engineering asset management. The findings suggest that effective acceleration depends on clearly defined ecosystem roles (e.g., orchestrators and complementors), structured information governance, balanced multi stakeholder engagement, and dynamic value-network configuration. Ultimately, the proposed integrative approach provides both theoretical consolidation and practical guidance for modeling and accelerating collaborative ecosystems as foundational infrastructures for long-term resilience, innovation, and sustainable value generation in engineering asset management contexts.

The study presents the following limitations that do not compromise the results but should be taken into account in the interpretation and generalization of the conclusions: (i) Database coverage: the search was limited to Scopus and Web of Science, which may exclude relevant works indexed in other databases (e.g., IEEE Xplore). (ii) Linguistic restriction: only articles in English were considered, which may have excluded relevant literature, particularly in Iberian contexts. (iii) Keyword strategy dependence: despite the synonym normalization step in VOSviewer, emerging terms or alternative terminology may not have been captured. (iv) Document type: the review focused on peer-reviewed articles, excluding gray literature, technical reports, or conferences that may reflect emerging practices in EAM. (v) Sample size and lack of direct results: the 72 articles result from an expanded search after no direct results were obtained for ‘asset management’, which implies that the conclusions for the EAM domain result from a conceptual transposition from other sectors, still without direct empirical validation in EAM. (vi) Bibliometric clustering: the interpretation of the *VOSviewer* clusters is based on textual co-occurrence and may not fully capture deeper conceptual relationships between the themes.

The results of this study show that accelerating collaborative ecosystems in Engineering Asset Management is a structural necessity. The integration of ecosystem models allows for consolidating and unifying the ecosystem. Effectiveness depends on four essential conditions: (i) clear definition of roles, (ii) sharing of information and knowledge, (iii) balanced stakeholder involvement, and (iv) the dynamics of relationships and value sharing among the actors. This acceleration ensures co-creation of value, enabling better adaptability to current constant changes.

This article’s main contribution is the systematic mapping and analysis of models in collaborative ecosystems for engineering asset management. It analyses three model types—conceptual models (defining value co-creation and actor interdependence), operational models (translating principles into coordination and governance), and analytical models (tools for evaluating configurations)—to create a cohesive theoretical framework that consolidates fragmented research into a comparative structure. This preliminary work lays the groundwork for the future empirical development and validation of a collaborative ecological framework for EAM, forming part of an ongoing research program.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/systems14070807/s1>, Table S1: PRISMA Checklist.

Author Contributions: Conceptualization, N.M.d.A.; methodology, A.M., J.V. and E.T.; software, A.M.; validation, A.M., N.M.d.A. and E.T.; formal analysis, A.M., E.T. and J.V.; investigation, A.M.; writing—original draft, A.M.; writing—review and editing, A.M., E.T., J.V. and N.M.d.A.; visualization, A.M. All authors have read and agreed to the published version of the manuscript.

Funding: Accelerate_FutureHEI. Entrepreneurial & Innovative Universities Acceleration Programme, P. 101095083. HORIZON WIDERA-2022-ERA-01-51 Acceleration Services in support of the institutional transformation of higher education institutions. This research was funded in whole or in part by the Fundação para a Ciência e a Tecnologia, I.P. (FCT, <https://ror.org/00snfqh58>, accessed on 25 June 2026) under Grant UID/6438/2025 (<https://doi.org/10.54499/UID/06438/2025>) of the research unit CERIS.

Data Availability Statement: The original contributions presented in this study are included in the article/Supplementary Materials.

Acknowledgments: For the purpose of Open Access, the author has applied a CC-BY public copy-right license to any Author Accepted Manuscript (AAM) version arising from this submission, and by FCT/MCTES under the R&D Unit Institute for Sustainability and Innovation in Structural Engineering (ISISE), under the references UID/4029/2025 (<https://doi.org/10.54499/UID/04029/2025>) and UID/PRR/04029/2025 (<https://doi.org/10.54499/UID/PRR/04029/2025>), and under the Associate Laboratory Advanced Production and Intelligent Systems ARISE under reference LA/P/0112/2020.

Conflicts of Interest: J.V. from Infraestruturas de Portugal. The remaining authors declare there is no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

BMI	Business Model Innovation
CSV	Creating Shared Value
CNOs	Collaborative Networked Organizations
DBE	Digital Business Ecosystem
EAM	Engineering Asset Management
fsQCA	Fuzzi-Set Qualitative Comparative Analyses
GFAMAM	Global Forum on Maintenance and Asset Management
IAM	Institute of Asset Management
SDL	Service-Dominant Logic
UCCs	Virtual Customer Communities

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