Next Generation Business Ecosystems: Engineering Decentralized Markets, Self-Sovereign Identities and Tokenization

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Abstract

Digital transformation research increasingly shifts from studying information systems within organizations towards adopting an ecosystem perspective, where multiple actors co-create value. While digital platforms have become a ubiquitous phenomenon in consumer-facing industries, organizations remain cautious about fully embracing the ecosystem concept and sharing data with external partners. Concerns about the market power of platform orchestrators and ongoing discussions on privacy, individual empowerment, and digital sovereignty further complicate the widespread adoption of business ecosystems, particularly in the European Union.

In this context, technological innovations in Web3, including blockchain and other distributed ledger technologies, have emerged as potential catalysts for disrupting centralized gatekeepers and enabling a strategic shift towards user-centric, privacy-oriented next-generation business ecosystems. However, existing research efforts focus on decentralizing interactions through distributed network topologies and open protocols lack theoretical convergence, resulting in a fragmented and complex landscape that inadequately addresses the challenges organizations face when transitioning to an ecosystem strategy that harnesses the potential of disintermediation.

To address these gaps and successfully engineer next-generation business ecosystems, a comprehensive approach is needed that encompasses the technical design, economic models, and socio-technical dynamics. This dissertation aims to contribute to this endeavor by exploring the implications of Web3 technologies on digital innovation and transformation paths. Drawing on a combination of qualitative and quantitative research, it makes three overarching contributions: First, a conceptual perspective on ’tokenization’ in markets clarifies its ambiguity and provides a unified understanding of the role in ecosystems. This perspective includes frameworks on: (a) technological; (b) economic; and (c) governance aspects of tokenization. Second, a design perspective on ’decentralized marketplaces’ highlights the need for an integrated understanding of micro-structures, business structures, and IT infrastructures in blockchain-enabled marketplaces. This perspective includes: (a) an explorative literature review on design factors; (b) case studies and insights from practitioners to develop requirements and design principles; and (c) a design science project with an interface design prototype of blockchain-enabled marketplaces. Third, an economic perspective on ’self-sovereign identities’ (SSI) as micro-structural elements of decentralized markets. This perspective includes: (a) value creation mechanisms and business aspects of strategic alliances governing SSI ecosystems; (b) business model characteristics adopted by organizations leveraging SSI; and (c) business model archetypes and a framework for SSI ecosystem engineering efforts.

The dissertation concludes by discussing limitations as well as outlining potential avenues for future research. These include, amongst others, exploring the challenges of ecosystem bootstrapping in the absence of intermediaries, examining the make-or-join decision in ecosystem emergence, addressing the multidimensional complexity of Web3-enabled ecosystems, investigating incentive mechanisms for inter-organizational collaboration, understanding the role of trust in decentralized environments, and exploring varying degrees of decentralization with potential transition pathways.

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Contents

List of Abbreviations

2FA	Two-Factor Authentication
ACL	agent communication language
AM	additive manufacturing
AML	anti-money laundering
API	application programming interface
B2B	Business-to-Business
B2C	Business-to-Consumer
B2G	Business-to-Government
BEMI	BEM interface
BEM	blockchain-enabled marketplace
BESSI	business enabled by SSI
C2C	Consumer-to-Consumer
C2E	Conceptual-to-Empirical
CAD	Computer Aided Design
CAM	collaborative additive manufacturing
CBM	cooperative business model
CNC	computerized numerical control
DAO	decentralized autonomous organization
dApp	decentralized application
DCR	decision control rights
DeFi	Decentralized Finance
DF	design features
DGA	Data Governance Act
DHT	distributed hash table
DID	decentralized identifier
DIF	Decentralized Identity Foundation
DLT	distributed ledger technology
DMA	Digital Markets Act
DMR	decision management rights
DP	design principles
DSR	Design Science Research
E2C	Empirical-to-Conceptual

FT	Fungible Token
GDP	Gross Domestic Product
IDaaS	ID-as-a-Service
IDM	identity management
IdPs	identity platforms
IoT	Internet-of-Things
IPFS	InterPlanetary File System
IS	Information Systems
IT	information technology
KPI	key performance indicator
KYC	know-your-customer
ME	Market Engineering
Meta-REQ	Meta-Requirements
MFA	Multi-Factor Authentication
MPC	Multi-Party Computation
MR	mandatory requirements
NFT	Non-Fungible Token
OR	optional requirements
P2P	peer-to-peer
PoA	Proof-of-Authority
PoET	Proof-of-Elapsed-Time
PoH	Proof-of-History
PoS	Proof-of-Stake
PoW	Proof-of-Work
RQ	research question
SaaS	Software-as-a-Service
SC	smart contract
SDI	secure digital identities
SDK	software development kit
SSI	self-sovereign identity
SSO	single sign-on
TDM	tokenized decision making
TDR	tokenized decision rights
TEU	theory of effective use
TTP	trusted third party
UI	user interface
VC	verifiable credential
VP	verifiable presentation
W3C	World Wide Web Consortium

Part I

Fundamentals

Introduction

1

> *Enterprises are realizing that growth is limited if you are not becoming a platform. However, everybody wants to own the platform plus nobody wants to be locked in on other platforms. This results in small Business-to-Business (B2B) platforms without benefits of scaling networks. New concepts are needed to break this deadlock.*
>
> — **Dr. Michael Bolle**
> (Former Member of the Board of Management,
> CTO and CDO of Robert Bosch GmbH)

1.1 Motivation

Managing an organization's digital transformation is pivotal for today's business competitiveness, driving progress in audience attraction, process optimization, cost reduction, and revenue growth. The transformative process involves leveraging digital technologies to enhance various aspects of an organization, including product portfolios, operations, customer relationships, structures, and business models (Hanelt et al., 2021; Hess et al., 2016; Matt et al., 2015; Sebastian et al., 2017). Recent estimates indicate that digital technologies have accounted for over two-thirds of organization's productivity growth in the past decade (Hamady et al., 2022). As a result, digital transformation has become a challenging but vital endeavor, garnering considerable attention from executives and scholars alike (Chanias et al., 2019; Hess et al., 2016; Matt et al., 2015; Sebastian et al., 2017). Current literature predominantly focuses on the transformation of Information Systems (IS) within organizations. However, there is an emerging interest in comprehending digital transformation as a phenomenon that extends beyond organizational boundaries. This broader perspective emphasizes the importance of organizations adapting internally and engaging in inter-organizational collaboration within supply chain networks and ecosystems, where multiple actors cooperate to co-create value (Beverungen et al., 2022; Hanelt et al., 2021).

This shift from an industry-driven economy with economic value creation in individual organizations to a more technology-driven, co-creating ecosystem economy is already visible in consumer-facing industries (Weinhardt, Peukert, et al., 2021; Hein et al., 2019). Ecosystem strategies, as opposed to traditional industry-driven strategies, introduce a new paradigm of economic and strategic action that leverages technological advancements to shape the competitive landscape, allowing ecosystem orchestrators to establish, exploit, and expand their competitive position (Autio, 2022; Jacobides et al., 2018). Notable examples of such strategies can be observed in digital platform ecosystems like the Amazon Marketplace, Airbnb, and Uber (Bartelheimer et al., 2022). These platforms are reshaping the contemporary online landscape, characterized by an increasingly interconnected economy around a shared value proposition for value creation (Adner, 2017; Aaen et al., 2022). Building the center of those ecosystems, digital platform orchestrators play a pivotal role as intermediaries, matching complementors and harnessing external capabilities (Hein et al., 2019). They capitalize on network externalities and deploy highly centralized IS that rapidly disrupt various industries, including shopping (i.e., Amazon), lodging (i.e., Airbnb), and transportation (i.e., Uber).

However, despite the remarkable success of digital platforms and ecosystem concepts in consumer-facing industries, organizations remain cautious about participating in ecosystems and sharing data with external business partners (Kaiser et al., 2019; Prieëlle et al., 2022). While initiatives span from cross-sectoral endeavors like ‘Gaia-X‘ to industry-specific projects such as ‘Catena-X‘ in the automotive sector and ‘Manufacturing-X‘ in production, the impact of emerging B2B ecosystems on IS research and business practices is nascent. Notably, most established platform ecosystems in the B2B domain have failed to sustain long-term success (Sterk et al., 2022; Pauli et al., 2020), with the BCG Henderson Institute estimating that around 85% of failures can be attributed to weaknesses in ecosystem design, including erroneous configuration or governance choices (Pidun et al., 2020). Researchers, regulators, and practitioners posit that controversies over near-monopoly platform orchestrators squeezing both their competitors and ecosystem complementors (Khan, 2017; Weigl, Barbereau, Sedlmeir, et al., 2023), contribute to these tensions and raise concerns for organizations, impeding B2B adoption (Hoess et al., 2021; Kölbel and Kunz, 2020; European Commission, 2018; Hawlitschek, Teubner, et al., 2016). Recent geopolitical developments in digital markets, characterized by the rise of ‘Big Tech‘ companies classified as ‘gatekeepers‘ (European Commission, 2022b), further exacerbate these dynamics, with their revenues surpassing the Gross Domestic Product (GDP) of many countries (Weigl, Barbereau, Sedlmeir, et al., 2023), potentially hindering innovation and consumer welfare (Moore and Tambini, 2018; European Commission, 2022b). The resulting asymmetry and potential abuse of market power create structural challenges for organizations, jeopardizing contestability, and competition (Cabral et al., 2021). Consequently, the discourse on this subject, particularly within the European Union, is increasingly driven by demands for individual privacy, empowerment, and digital sovereignty (Beverungen et al., 2022; Sunyaev et al., 2021; Weigl, Barbereau, Sedlmeir, et al., 2023). This has prompted legislative initiatives like the Data Governance Act (DGA) and the Digital Markets Act (DMA), aimed at rebalancing competition in the digital market by advocating for digital sovereignty and preventing companies with dominant market positions from exploiting their power (European Commission, 2022b).

Technological innovations in *Web3* are considered potential facilitators for this strategic change and catalysts for user-centric and privacy-oriented *next-generation ecosystems*. These ecosystems are seen as an anti-thesis and challenger to the dominance of centralized gatekeepers, seeking to avert risks of over-centralization and pave the way for a more inclusive adoption of ecosystem concepts in business contexts (Hamady et al., 2022; Lacity, 2022; Beck, Müller-Bloch, and King, 2018). Web3 refers to a technological movement that strives to revolutionize the rules of the game by replacing 'trust in the platform' with Web3's motto 'don't trust but verify'. Organizations desiring to foster ecosystem innovations should thereby be enabled to develop business models that facilitate their digital transformation while mitigating data hegemony (Braud et al., 2021; Hoess et al., 2021; Sunyaev et al., 2021). At its core, this paradigm shift revolves around democratizing digital interactions, and decentralizing IS with decentralized markets based on bilateral connections and cryptographic protocols, thereby aiming to disrupt the disruptors (Kölbel, Dann, et al., 2022; Voshmgir, 2020). Core principles guiding the abstract concept of *decentralization* include openness and transparency, authenticity and trust, digital sovereignty and self-determination, and open market access (Lacity, 2022; Hoess et al., 2021; Beck, Müller-Bloch, and King, 2018; Kölbel and Kunz, 2020). In contrast to the current internet landscape dominated by a few Big Tech organizations, Web3 aims to govern ecosystems through their users, operating via distributed network topologies and built upon open protocols.

To facilitate this disruption, Web3 leverages technologies that empower individual sovereignty (Sunyaev et al., 2021; Beck, Müller-Bloch, and King, 2018; Kölbel, Dann, et al., 2022). A premiere technological innovation driving this shift is the concept of blockchain as a form of distributed ledger technology (DLT). Blockchains consist of interconnected blocks that are not stored on centralized servers managed by intermediaries. Instead, they are decentralized across multiple participants in peer-to-peer (P2P) networks. Trust among peers is established through a transparent, persistent, chronologically updated, and immutable transaction ledger. This shared ledger, characterized by pseudonymity, functions as an immutable append-only database (Notheisen, Hawlitschek, et al., 2017). It leverages decentralized consensus mechanisms and cryptographic elements to facilitate the recording, management, and execution of transactions, resulting in a reliable, transparent, and comprehensive record of interactions (Glaser et al., 2019; Voshmgir, 2020). Access to the ledger can be restricted based on predefined rules, depending on the type of blockchain ('public/private and permissioned/permissionless') and the chosen data storage method ('on-chain/off-chain'). Apart from its ledger capabilities, certain blockchain networks also support a smart contract (SC), which enables the automatic execution of program code and contract structures. This functionality is particularly valuable in business environments, as SCs can automate various processes and ensure the on-chain enforcement of agreements (Kölbel, Dann, et al., 2022).

Within the ecosystem context, Web3 technologies like blockchain offer several value propositions that align with the vision of next-generation ecosystems, including eliminating intermediaries, transparency, security, and creating tamper-proof transaction records. The role of the orchestrator is no longer limited to an exclusive and non-adversarial position, where data and services are under the central control of platform providers according to their terms of service but encompasses a competitive and dynamic role that fosters cross-organizational collaboration (Jovanovic et al., 2022; Hoess et al., 2021; Zavolokina et al., 2020; Jensen et al., 2019). While the superiority of Web3-driven approaches compared to alternative strategies is yet to be demonstrated, their emergence is expected to influence the digital transformation trajectories of organizations and redefine the nature of the concept of business ecosystems driving business innovation (Hoess et al., 2021; Allen et al., 2020; Chong et al., 2019; Jensen et al., 2019). Consequently, organizations embarking on this transformative journey must prepare for ecosystem interactions and integrate Web3 capabilities to capitalize on this innovation potential.

1.2 Towards Engineering Next Generation Business Ecosystems

Driven by its transformative potential, the concept of Web3 has emerged as a rapidly growing research field that intersects multiple disciplines. Although research is still in its early stages, the IS community has made noteworthy contributions researching various aspects and instruments that facilitate disintermediation. Pioneering work includes publications on different technological aspects of blockchain as the Web3 poster child on a technological level (e.g., Pytel et al., 2023), asset tokenization (e.g., Pawelzik and Thies, 2022; Sunyaev et al., 2021; Ante et al., 2023), literature reviews (e.g., Feulner et al., 2022; Honey et al., 2023), as well as research agendas aiming to provide structure to this complex and heterogeneous field (e.g., Beck, Müller-Bloch, and King, 2018; Risius and Spohrer, 2017; Rossi et al., 2019). Moreover, research has focused on exploring potential applications of Web3 in various industries. Most actively explored fields include finance (e.g., Notheisen, Willrich, et al., 2019; Gramlich et al., 2023), logistics and supply chain management (e.g., Jovanovic et al., 2022; Jensen et al., 2019), and energy (e.g., Kirpes et al., 2019; Mengelkamp et al., 2018; Richter, Mengelkamp, et al., 2018), among others (e.g., Chong et al., 2019; Schellinger et al., 2022). Additionally, scholars have studied the decentralization of electronic markets (e.g., Kollmann et al., 2020; Alt, 2020a; Notheisen, Hawlitschek, et al., 2017), governance aspects in blockchain systems (e.g., Zavolokina et al., 2020; Beck, Müller-Bloch, and King, 2018; Ziolkowski and Schwabe, 2022), blockchain technologies that facilitate trust (e.g., Dann et al., 2020), and the potential of the decentralized paradigm to contribute to ecosystem formation (e.g., Hoess et al., 2021). A novel research stream further explores blockchain-enabled marketplaces that aim to strengthen self-determined, privacy-preserving, and trusted B2B interaction (e.g., Hofmann et al., 2021; Stein et al., 2019).

However, despite the merits and appeal of Web3 for the business community, next-generation business ecosystems driven by Web3 present a novel and complex phenomenon that can be challenging to grasp. The inherent complexity of Web3 technologies, coupled with their rapid development, innovative components, and uncertain socio-economic impact, poses difficulties for both researchers and practitioners. As a result, in contrast to the widespread public attention, productive real-world Web3 applications appear to be scarce (Feulner et al., 2022; Guggenberger et al., 2021; Rossi et al., 2019) and the impact on businesses is not as disruptive as initially proposed (Fridgen et al., 2021). Furthermore, critics draw parallels between blockchain technology and speculative bubbles, expressing concerns that it is an innovative technology in search of viable use cases at an early stage of maturity (Risius and Spohrer, 2017). Thus, it remains unclear how organizations can successfully apply Web3 for value creation, particularly when shifting a traditional, linear business strategy towards an ecosystem strategy.

Consequently, engineering next-generation business ecosystems driven by Web3 is an important and challenging task. It requires market engineers to think beyond established approaches and recognize peer-to-peer technologies like blockchain as an infrastructure component that shapes the ecosystem characteristics and connects users but also influences behavioral patterns within and beyond the market. While research has made progress in understanding this area, there remains a need for theoretical convergence among scholars and practitioners to comprehensively understand the effects of Web3's unique properties and potential implications in ecosystem applications. Current research efforts fall short of overcoming scarce, opaque, and disconnected perspectives while addressing the challenges organizations face as they transition towards an ecosystem strategy, particularly concerning the dynamic interplay among different types of actors in fully realizing the potential of disintermediation in digital transformation endeavors. While the locus of digital innovation is shifting towards a vibrant ecosystem of interconnected actors, organizations still struggle with involving external partners in their initiatives to co-create value (Beverungen et al., 2022). Moreover, researchers and practitioners approach Web3 topics from isolated and disparate perspectives. Researchers primarily adopt a technology push-pull perspective, focusing on the infrastructure of Web3 technologies that shape the ecosystem. On the other hand, practitioners rely on experimental and unstructured approaches to Web3 business innovation. However, evidence from platform ecosystem research (e.g., Hein et al., 2019) and market engineering perspectives (e.g., Weinhardt, Holtmann, et al., 2003; Notheisen, Hawlitschek, et al., 2017) emphasizes the importance of understanding both the technical versatility and socio-technical dynamics involved in designing markets to leverage the potential of technologies while mitigating adverse side effects. This requires a structured approach to characterizing decentralized ecosystems, studying the technological design, and exploring economic models from both individual business and ecosystem perspectives. Therefore, a comprehensive and structurally connected understanding is needed. Unlike traditional IS design, the performance of ecosystems relies not only on individual actors, technical components, or government regulations but on the holistic integration and interaction of these elements.

When incorporating decentralization into the design of IS, it is thus crucial to intentionally engineer ecosystems and carefully consider various factors to achieve the desired market outcome of disintermediation. A few examples should illustrate this complexity: On the one hand, consumers seek cost-effective solutions and prefer to utilize decentralized networks without engaging in infrastructure innovation and development. On the other hand, decentralized systems rely on collaboration and value co-creation among multiple actors within the ecosystem. To incentivize and reward these actors for contributing and operating infrastructure components, appropriate incentive and reward mechanisms must be designed and implemented. Moreover, certain advantages of decentralized systems, such as transparency, may be disadvantageous in a business context, potentially hindering organizational participation if competitively relevant information is not desired to be stored on public ledgers. Therefore, striking a balance between the transparency provided by blockchain technology and the protection of sensitive information becomes a critical endeavor. Furthermore, maintaining decentralized IS becomes challenging when multiple social actors need to update their technical components independently. Coordinating and managing these updates without compromising the decentralized nature of the system requires efficient governance structures. However, decentralized governance itself presents challenges. If too many social actors have conflicting ideas, reaching an agreement may become difficult. Conversely, ostensibly decentralized systems may de facto become centralized if only a few actors participate in governance. Another aspect to consider is the risk of centralization when identity management (IDM) in decentralized systems is limited to a single network. This limitation can hinder the scalability and interoperability of decentralized systems, potentially leading to unintended centralization.

These examples highlight the diverse and heterogeneous requirements that need to be considered in ecosystem design, alongside numerous structural parameters that serve as adjustment mechanisms in engineering efforts. These include intentionally addressing elements such as tokenized incentives, decentralized markets, and identity mechanisms. With this in mind, this thesis aims to provide an empirically grounded and conceptually informative understanding of the implications of Web3 technologies on digital innovation and transformation paths towards next-generation business ecosystems for value co-creation.

1.3 Research Agenda & Research Questions

To comprehensively explore the interdisciplinary nature of engineering next-generation business ecosystems, this thesis addresses three primary research question (RQ) that provide insights into different aspects. These questions pertain to conceptual perspectives (RQ1), design perspectives (RQ2), and economic perspectives (RQ3). Each RQ thereby focuses on analyzing a distinct pillar of next-generation business ecosystems driven by Web3, namely ’tokenization’, ’decentralized marketplaces’ and ’self-sovereign identities’.

The first RQ delves into the conceptual perspective. It recognizes that Web3 literature is dispersed across disciplines, while studies integrating technological, economic, and governance aspects in the context of 'tokenization' remain scarce. Tokenization refers to the process of representing real-world assets or rights in the form of digital tokens on a blockchain network. Research providing low theoretical insights makes the concept ambiguous and challenging to grasp. However, the tokenization of assets builds the basis for decentralized markets and has various prospering business models in practice. A recent surge in popularity has sparked public interest in Non-Fungible Token (NFT), transforming them from a niche community of cryptocurrency experts to a relevant phenomenon across industries. Notably, prominent organizations have embraced the NFT movement to explore opportunities in the crypto world, and researchers believe that NFTs have the potential to revolutionize digital property and transform entire business sectors (Pawelzik and Thies, 2022; Kanellopoulos et al., 2021).

However, despite these developments, an interdisciplinary academic perspective that consolidates different concepts and elucidates the concept of tokenization remains elusive. This lack of a comprehensive view impedes our understanding of tokenization as a facilitator of next-generation ecosystems. Regner et al. (2019) argue that an in-depth understanding from an IS research perspective is crucial to developing descriptive knowledge about tokenization's general characteristics and enhancing prescriptive knowledge regarding the design and incentivization in decentralized markets. To address this issue, the first RQ of this thesis focuses on three aspects: (1) Structuring the technological elements of tokenization within the context of markets; (2) analyzing economic elements and business models; and (3) studying governance mechanisms in tokenized decision making. Doing so aims to clarify the ambiguity and vagueness surrounding the term 'tokenization' and establish a unified terminology for scholars. The research design conceptually combines insights from existing literature on tokenization and its underlying ecosystem with qualitative data derived from various real-world cases. Conclusively, the RQ can be summarized as follows:

Research Question 1: *Which conceptually and empirically grounded characteristics shape blockchain-enabled tokenization?*

Moving on to the second RQ, the focus of the thesis shifts to the design perspectives of next-generation business ecosystems, specifically holistically engineering 'decentralized marketplaces' as an interdisciplinary endeavor that is characterized by complex and interconnected constructs. However, extant literature on this topic appears to seek blockchain applications and tends to adopt a 'blockchain-fits-all' approach. Issues with this approach include the scalability and privacy challenges that blockchain-based systems face, particularly in the context of business interactions, which are not adequately addressed in prevailing concepts. Surprisingly, the technological repertoire of Web3 technologies beyond blockchain (e.g., Secure Multi-Party Computation (MPC), which share similar value propositions of disintermediation while addressing some of the challenges faced by blockchains, has largely been neglected. Additionally, it is crucial to acknowledge that reduced intermediation in Web3-based services places greater responsibility on individual users, such as securely storing their private keys that grant access to decentralized identities and wallets within decentralized ecosystems.

To address these tensions and move away from 'blockchain-fits-all' solutions, the second RQ emphasizes the need for an integrated understanding of decentralized markets and their interrelationships with interdependent micro-structures, business structures, and information technology (IT) infrastructures. Accordingly, this thesis aims to analyze and illustrate the limits of blockchain-enabled systems and propose a structured approach to guide the design, communication, and evaluation of next-generation marketplaces. The focus is thereby on three key aspects: (1) An explorative literature review, guided by the market engineering framework developed by Weinhardt, Holtmann, et al. (2003) and Gimpel et al. (2008), provides a structured analysis of the emerging field of blockchain-enabled marketplaces. This review reveals that the concept of blockchain is used ambiguously by scholars, highlighting the need for clarity and conceptual precision. (2) Next, design science research with different case studies and insights from practitioners expands upon the findings of the explorative literature review by developing requirements and tangible design principles (DP) specifically tailored for blockchain-enabled marketplaces. (3) In a subsequent design science project, a proof-of-concept subsequently illustrates and evaluates the design, architecture, and principles of blockchain-enabled marketplaces. This project includes the creation of an interface design prototype that serves as a practical demonstration of the proposed approach. Conclusively, the RQ can be summarized as follows:

Research Question 2: *Which pivotal elements guide the design of decentralized marketplaces for value co-creating business ecosystems?*

Lastly, the third RQ centers around the economic perspectives of next-generation business ecosystems, which play a pivotal role in shaping incentives and behaviors. Specifically, this thesis focuses on a specific micro-structural element of decentralized markets by examining business models within self-sovereign identity (SSI) ecosystems. As a complementary technology in the Web3 repertoire, these ecosystems enable individuals and businesses to access decentralized markets and connect with others. This focus acknowledges the economic and societal importance to understand the genesis and desire for data privacy, digital sovereignty, and user-centricity, as well as legislative efforts towards establishing a digital identity ecosystem that gives individuals full control over their data and allows organizations to enhance their product and service offerings (Kronfellner et al., 2021).

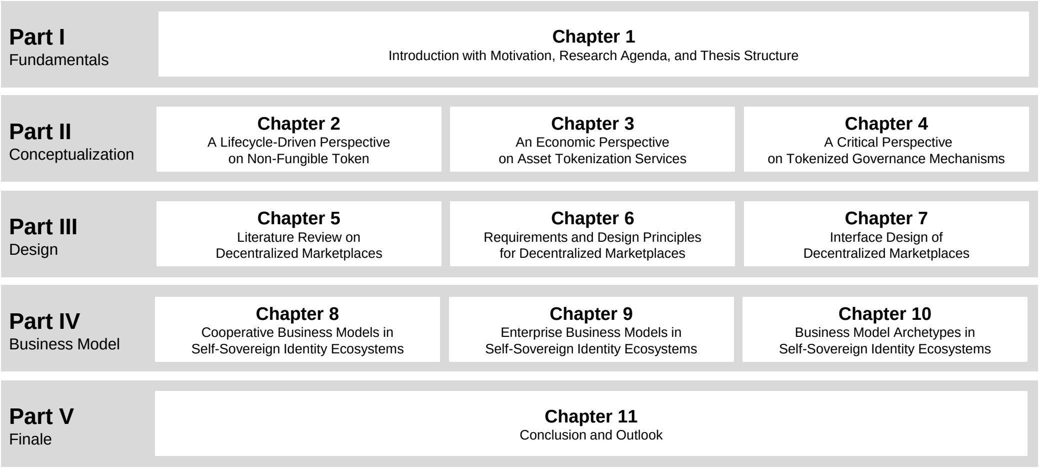
However, research on this topic is predominantly of technical nature, fragmented, and lacks a comprehensive economic perspective. As a result, it fails to provide practical guidance for organizations seeking to innovate, design, and transform their business models. It remains unclear how stakeholders co-create business value with ecosystem partners. To elaborate on those questions, the third RQ focuses on three economic aspects of next-generation identity ecosystems: (1) Identifying value-co-creating mechanisms and studying the business aspects of strategic alliances governing SSI ecosystems, as these alliances establish boundaries that create both opportunities and challenges for SSI providers and users. (2) Analyzing the distinctive characteristics of business models adopted by organizations leveraging SSI, which introduce an additional dimension to transformative efforts, influencing both the organizational and inter-organizational levels of product and service providers. (3) Analyzing business model archetypes in SSI ecosystems, illustrating business model innovations and developing a framework that highlights the collaborative efforts of diverse ecosystem complementors in co-creating SSI ecosystems. To achieve these objectives, the research design incorporates insights from existing literature on SSI and its underlying ecosystem, qualitative data derived from real-world cases, insights from practitioners, and quantitative analysis to examine business model characteristics and archetypes. Through an examination of economic incentives and value creation mechanisms, this RQ seeks to provide insights into the transformative potential of SSI in improving user control in digital interactions. Conclusively, the RQ can be summarized as follows:

Research Question 3: *Which collaborative efforts and business models characterize ecosystems with self-sovereign identities that improve user control in digital interactions?*

Answering these three RQs not only helps to generate a fundamental understanding of how Web3 applications are currently conceptualized in practice, but also points out design considerations that account for tensions that organizations face when shifting toward next-generation business ecosystems and ventures insights towards practice-oriented business models.

1.4 Thesis Structure

The cumulative dissertation is divided into five parts, as illustrated in Figure 1.1. PART I serves as an introduction, providing motivation and a research agenda for the field of engineering next-generation business ecosystems. It further presents a summary of the problem statement based on three RQs and outlines the structure of the thesis (see Section 1.3). Parts II, III, and IV consist of nine publications (P), which are organized according to the three RQs above (Table 1.1). The first three publications (PART II) initiate an exploratory analysis of Web3-enabled tokenization. Chapter 2 presents a lifecycle-driven analysis of properties related to non-fungible token, while Chapter 3 examines the business model aspects of organizations operating asset tokenization services. Chapter 4 conceptualizes Web3 governance mechanisms with a critical perspective on tokenized decision making.



Part I Fundamentals	**Chapter 1** Introduction with Motivation, Research Agenda, and Thesis Structure		
Part II Conceptualization	**Chapter 2** A Lifecycle-Driven Perspective on Non-Fungible Token	**Chapter 3** An Economic Perspective on Asset Tokenization Services	**Chapter 4** A Critical Perspective on Tokenized Governance Mechanisms
Part III Design	**Chapter 5** Literature Review on Decentralized Marketplaces	**Chapter 6** Requirements and Design Principles for Decentralized Marketplaces	**Chapter 7** Interface Design of Decentralized Marketplaces
Part IV Business Model	**Chapter 8** Cooperative Business Models in Self-Sovereign Identity Ecosystems	**Chapter 9** Enterprise Business Models in Self-Sovereign Identity Ecosystems	**Chapter 10** Business Model Archetypes in Self-Sovereign Identity Ecosystems
Part V Finale	**Chapter 11** Conclusion and Outlook		

Fig. 1.1.: Overall Thesis Structure.

Expanding upon these insights, the subsequent three publications (PART III) focus on the design of blockchain-enabled marketplaces in business environments. Chapter 5 provides an exploratory literature review, highlighting key issues in the extant literature. Based on these findings, Chapter 6 establishes requirements and DPs for blockchain-enabled marketplaces, with a particular emphasis on an additive manufacturing (AM) use case in the B2B context. Subsequently, Chapter 7 presents an interface prototype that instantiates and evaluates the previous contributions.

The remaining publications revolve around business models in SSI ecosystems (PART IV). Chapter 8 investigates business models governing SSI ecosystems, while Chapter 9 and Chapter 10 adopt an individual organizational perspective, focusing on organizations engaged in SSI-enabled business. Chapter 10 further proposes a framework to guide the engineering of SSI ecosystems.

Finally, PART V serves as a comprehensive summary of the results (Chapter 11). It discusses findings, provides implications for both research and practice, and highlights the limitations of the thesis. The thesis concludes with an outlook and suggests avenues for future research.

Table 1.1 below lists the publications that are part of this cumulative dissertation.

Tab. 1.1.: Publications embedded in this Dissertation.

RQ	No.	Authors	Title	Outlet
RQ1	P1	Kölbel, Joussen, Weinhardt	Between Hype, Hope, and Reality: A Lifecycle-Driven Perspective on Non-Fungible Token	ECIS 2023 (Published)
	P2	Kölbel, Lamberty, Sterk, Weinhardt	Spotlight on DeFi Centerpieces: Towards an Economic Perspective on Asset Tokenization Services	PACIS 2023 (Published)
	P3	Kölbel, Binder, Weinhardt	Are Blockchains Really Decentralized? A Multimodal Perspective on Tokenized Decision Making and Venture Capital Investments in Web3	HICSS 2024 (Under Review)
RQ2	P4	Kölbel, Dann, Weinhardt	Giant or Dwarf? A Literature Review on Blockchain-enabled Marketplaces in Business Ecosystems	WI 2022 (Published)
	P5	Kölbel, Linkenheil, Weinhardt	Requirements and Design Principles for Blockchain-enabled Matchmaking-Marketplaces in Additive Manufacturing	HICSS 2023 (Published)
	P6	Kölbel, Zekri, Weinhardt	Developing Blockchain-enabled Marketplace Interfaces: A Design Science Research Study	ICIS 2023 (Under Review)
RQ3	P7	Kölbel, Gawlitza, Weinhardt	Shaping Governance in Self-Sovereign Identity Ecosystems: Towards a Cooperative Business Model	WI 2022 (Published)
	P8	Kölbel, Härdtner, Weinhardt	Enterprise Business Models Leveraging Self-Sovereign Identity: Towards a User-Empowering Me2X Economy	HICSS 2023 (Published)
	P9	Kölbel, Schradi, Weinhardt	Empowering Users in Digital Identity Management – A Taxonomy and Archetypal Patterns of Business Models Leveraging Self-Sovereign Identity Ecosystems	Electronic Markets (Under Review)

Outlet:

ECIS:	European Conference on Information Systems
EM:	Electronic Markets Journal
HICSS:	Hawaii International Conference on System Science
ICIS:	International Conference on Information Systems
PACIS:	Pacific-Asia Conference on Information Systems
WI:	Wirtschaftsinformatik Conference

Part II

Conceptualization

2

A Lifecycle-Driven Perspective on Non-Fungible Token

This chapter is based on a peer-reviewed article titled "Between Hype, Hope, and Reality: A Lifecycle-Driven Perspective on Non-Fungible Token". The article was co-authored by Katrin Joussen and Christof Weinhardt and is published in the 31st European Conference on Information Systems (ECIS) Proceedings. The authors' accepted manuscript's supplementary material can be found in Appendix A.1. The tables, figures, and appendices were systematically renamed, reformatted, and appropriately referenced to align with the overall structure of the thesis. To further enhance clarity and consistency, formatting, and reference style were adapted and references were updated.

Publication details: *Kölbel, T., Joussen, K., & Weinhardt, C., Between Hype, Hope, and Reality: A Lifecycle-Driven Perspective on Non-Fungible Token, 31st European Conference on Information Systems Proceedings, 2023.*

Abstract: Advocates consider NFTs a potentially disruptive blockchain-enabled innovation. In light of surging popularity and low theoretical insights, we study NFTs from a lifecycle-driven perspective. We develop a taxonomy that adheres to a habitual method and draws on a five-step process of analyzing literature and real-world projects. Our taxonomy contributes to descriptive knowledge by structuring NFTs with 20 dimensions and 77 characteristics along the perspectives of origination, distribution, transfer, trade, and redeem. We enable researchers and practitioners to grasp the NFT phenomenon in a structured manner and demonstrate the applicability of our taxonomy through expert interviews and case studies.

Keywords: Web3, Blockchain, Non-Fungible Token, NFT, Taxonomy.

2.1 Introduction

To some, they are just pixelated JPEGs and digital images with no inherent value; to others, they are the ’next big thing’, the ’top tech innovation’ of 2021 (Baculard, 2021), a popular FinTech application, and an essential element for the Metaverse (Bao and Roubaud, 2022). Yet one thing is certain: NFTs are polarizing and have received much attention over the past two years. In particular, public interest in NFTs exploded after the digital artwork ’Everydays: the First 5000 Days’ was sold for $69 million at Christie’s auction house in March 2021 (Kanellopoulos et al., 2021). It ushered in a hype where, in 2021 alone, the overall NFT trading volume topped $23 billion, a staggering increase of more than 20.000% from less than $100 million in 2020 (Ponciano, 2022). Driving the boom were online marketplaces such as *OpenSea*, which facilitate access and trading of NFTs and remove market entry hurdles. They allow users to trade almost anything, from digital artworks to tweets (Howcroft, 2021), music (Fatemi, 2022), signed copies of scientific papers (Sanders, 2021), the source code of the World Wide Web (Kanellopoulos et al., 2021), and physical assets such as luxury cars (Kölbel, Lamberty, et al., 2022).

The surge in popularity and frictionless market access has sparked widespread interest in NFTs, evolving from a niche community of crypto experts to relevance across industries. Well-known companies such as Louis Vuitton and Nike, as well as celebrities like Tom Brady, have jumped on the NFT bandwagon to engage in the crypto world (Porterfield, 2021); and researchers believe that NFTs can potentially revolutionize digital property and transform sectors such as gaming, media, and the arts (Pawelzik and Thies, 2022; Kanellopoulos et al., 2021). Underlying these high expectations are the technological properties of NFTs. They are unique cryptographic tokens on a blockchain that are inherently non-interchangeable and thus represent a unique artifact with individual characteristics (Kanellopoulos et al., 2021). By twinning an NFT to a physical or digital asset, they are distinct from alternative versions, providing unique value and identifiable proof of ownership to the NFT holder (Regner et al., 2019).

However, despite considerable interest and positive sentiment among enthusiasts, NFTs are still at an early stage of development characterized by both great potential and uncertainty. That reflects in volatile trading volume, reports of fraudulent activities and rug pulls, and relatively scant attention from the academic community (Bao and Roubaud, 2022). While some publications (see Section 2.2) address general aspects (e.g., application potentials, legal and technical angles) and sector-specific studies (e.g., NFTs in the financial industry), it remains ambiguous how to characterize NFTs, what they have in common, and how they differ. Although there are non-scholarly (e.g., journalistic articles, blog posts) and non-peer-reviewed publications (e.g., Hartwich et al., 2023) that vaguely touch on this topic, an interdisciplinary academic perspective (such as Heines et al. (2021)'s and Kölbel, Lamberty, et al. (2022)'s studies on tokenization in general) that abstracts different concepts and clarifies the NFT phenomenon remains elusive. In this context, Regner et al. (2019) argue that a thorough understanding of NFTs from an IS research perspective is needed, which provides profound descriptive knowledge about NFTs general characteristics and improves prescriptive knowledge about the process of their development. However, to our best knowledge, no peer-reviewed study addresses this notion. Moreover, we are unaware of any scholarly publication that studies NFTs from a multimodal perspective and contributes to conceptual understanding. Therefore, this study aims to answer the following RQ:

Research Question: *How can NFTs be characterized and differentiated based on conceptually and empirically grounded characteristics?*

To answer our RQ, we propose a taxonomy that assists in classifying NFTs across different levels while identifying commonalities and differences. To this end, we iterate the taxonomy development process of Nickerson et al. (2013). We conduct five iterations, sequentially sourcing literature, startups, consulting reports, and companies. Structured along a five-stage token lifecycle, we derive 20 dimensions and 77 associated characteristics. We validate the usefulness of our multi-layered taxonomy by conducting preliminary expert interviews and classifying a sample of NFT projects.

We aim to address two audiences: First, researchers who analyze NFTs and develop theories, and second, practitioners who design or evaluate NFTs and service offerings. Both groups can use our taxonomy to gain a deeper understanding of the NFT phenomenon, identify typical characteristics and core dimensions, and analyze the NFT market. In doing so, our theoretically derived and empirically adapted taxonomy can serve as an overview of the status quo and a basis for further research.

The remainder of this paper is organized as follows. First, we provide background information on NFTs and related work. Second, we outline our research methodology. Third, we present our lifecycle-driven NFT taxonomy. Fourth, we preliminary evaluate our findings by experts and apply the taxonomy to real-world examples. Fifth, we discuss the implications and limitations of our work. Finally, we conclude with an outlook on future research avenues.

2.2 Background & Related Work on Non-Fungible Token

Adherents of a tech movement known as *Web3* argue for a trustless online world where blockchain-based applications form the backbone of new markets without digital gatekeepers but with empowered users (Kölbel, Dann, et al., 2022). Using automated software termed ’smart contracts’ (SCs), interactions should operate without the need for intermediaries, with consensus protocols ensuring proper execution across a peer-to-peer network of nodes (Regner et al., 2019). Cryptographic tokens that are defined in SCs and represent arbitrary information and rights (e.g., payment/cryptocurrency, programmable assets, access, or voting rights), are an essential part of blockchain networks. As such, we distinguish between *Fungible Token (FT)* and *NFTs*. FTs are exchangeable and divisible, meaning that any unit representing an asset (e.g., cryptocurrencies such as ’Bitcoin’) can be exchanged with the same amount of any other unit of the same asset without profit or loss. NFTs, on the other hand, are neither exchangeable nor divisible, meaning they have individual information and properties that make each token unique. As such, they intend to represent the physical world with its economic properties (i.e., there can be multiple cars of the same type, but not the same car twice) in the digital realm and enable digital scarcity (Pawelzik and Thies, 2022). Standards such as ’Ethereum Request for Comments’ 721 (ERC-721) thereby specify that each NFT has a unique ID, token contract address, and creator address, is transferable on the ’Ethereum’ network, and can optionally contain metadata, qualifying it to represent utility and ownership of physical and digital assets in a variety of use cases (Guadamuz, 2021; Fai, 2021; Regner et al., 2019).

Initially, leading actors in NFT development were practitioners from crypto communities, who, for example, developed the virtual online game ’CryptoKitties’ as an NFT application in 2017 (Regner et al., 2019), and subsequently explored other domains and use cases (e.g., digital collectibles, artworks, software licensing, real estate). On the academic horizon, research on NFTs has also been slowly picking up momentum over the past two years following NFTs increasing relevance and popularity on the one hand and the challenges of the novel technology (e.g., cross-chain interoperability, ’pull the rug’ dilemma, sustainability) on the other. While Regner et al. (2019) reference few peer-reviewed studies, we identified several more recent publications that address the NFT phenomenon. They range from application areas (e.g., Ante, 2021; Kugler, 2021; Mazur, 2021; Rehman et al., 2021; Regner et al., 2019), technical properties (e.g., Karandikar et al., 2021; Uribe, 2020), and legal implications (e.g., Murray, 2022; Okonkwo, 2021; Di Bernardino et al., 2021; Çağlayan Aksoy and Özkan Üner, 2021; Chirtoaca et al., 2020) to marketing aspects (e.g., Colicev, 2023; Chohan and Paschen, 2023), challenges and opportunities (e.g., Fowler and Pirker, 2021; Popescu, 2021; Rehman et al., 2021; Valeonti et al., 2021). In addition, scholars explore NFTs in the financial sector, studying market and pricing mechanisms (e.g., Dowling, 2022a; Dowling, 2022b; Horky et al., 2022; Pinto-Gutiérrez et al., 2022), potentials as alternative investments (e.g., Borri et al., 2022; Schaar and Kampakis, 2022; Xia et al., 2022), and the impact of NFTs on the price of physical products (e.g., Kanellopoulos et al., 2021). Finally, the risk-return characteristics of NFT startups relatively and compared with other alternative assets have also been investigated (e.g., Kong and Lin, 2021). In sum, NFTs may disrupt existing business models and creates new ones in multiple domains. However, research lacks an interdisciplinary perspective that characterizes NFTs and abstracts their concepts. We argue that a taxonomy is an effective method for structuring the results of previous research, facilitating the handling of individual cases, and allowing general statements about the interrelationships or differences between certain objects (Doty and Glick, 1994).

2.3 Methodological Research Design

In our study, we combine qualitative and quantitative research. We develop a taxonomy that, as essential prerequisites for understanding a domain (Szopinski et al., 2019), helps to empirically analyze the types, characteristics, and dimensions of NFTs. As such, it serves both researchers and practitioners in explaining similarities and differences between objects and provides order to the complex and rapidly growing field of NFTs (Nickerson et al., 2013). We use examples from real-world projects to classify NFTs and evaluate our taxonomy. Methodologically we build on the iterative taxonomy development process as per Nickerson et al. (2013), which combines practicality with scientific rigor while being used in similar research endeavors in IS research (e.g., Kölbel, Lamberty, et al., 2022; Weking et al., 2020). In a nutshell, the process comprises seven steps, which we iterated five times (see Figure 2.1).

Meta-Characteristics. As a first step, we defined foundational characteristics to guide all other attributes of the taxonomy (Nickerson et al., 2013). In doing so, we draw on two sources (Karandikar et al., 2021; Stefanoski et al., 2020) that classify NFTs in a lifecycle relative to their value creation, thereby forming five meta-characteristics: Origination, Distribution, Transfer, Trade, and Redeem (see Table 2.1).

Tab. 2.1.: Definition of Meta-Characteristics.

Meta-Characteristic	Description
Origination	Specifies NFT origination and token properties defined during the minting process.
Distribution	Specifies NFT distribution and corresponding options for decision-making.
Transfer	Specifies NFT transfer processes and parameters between seller and buyer.
Trade	Specifies NFT trading on both primary and secondary markets.
Redeem	Specifies the owner's redemption, including purpose and domain of an NFT.

Ending Conditions. In the second step, we defined subjective and objective ending conditions. In doing so, we followed Nickerson et al. (2013)'s proposal for objective ending conditions (e.g., "at least one object is classified under every characteristic of every dimension," "no new dimensions or characteristics were added in the last iteration," "no dimensions or characteristics were merged or split in the last iteration"). If the taxonomy is concise, robust, comprehensive, extendible, and explanatory, we assumed subjective ending conditions to be met (Nickerson et al., 2013).

Iteration Phase. After setting our baseline, we iteratively developed the taxonomy using mixed data (Steps 3-7) and therefore adopted both empirical-conceptual and conceptual-empirical approaches. In the conceptual-empirical, we deductively analyzed authors' knowledge in the literature on NFTs, derived characteristics, and grouped them into dimensions, which we then linked to real-world objects. In the empirical-conceptual approach, we operated vice versa, inductively evaluating real-world objects for shared characteristics and dimensions to expand our taxonomy. After each iteration, we revised the taxonomy and repeated the process until the ending conditions were met.

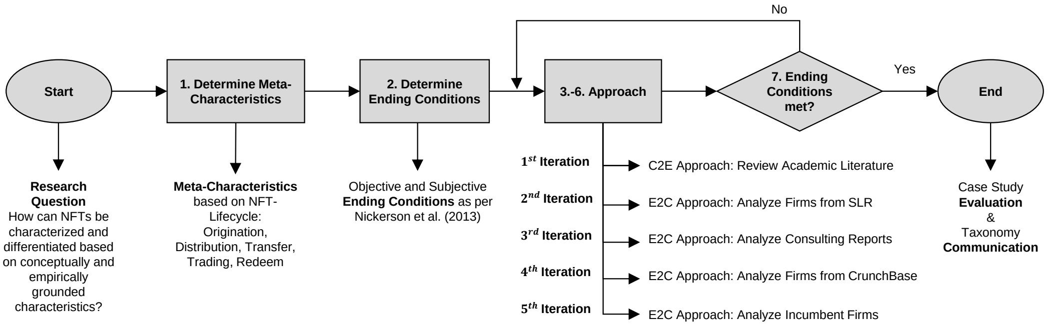


Fig. 2.1.: Research Model in Accordance with Nickerson et al. (2013).

Conceptual-to-Empirical (C2E). The first iteration draws on a literature review that establishes a knowledge base on NFTs and provides scientific rigor. We followed the methodological suggestions of Webster and Watson (2002) and reviewed publications in journals and conference proceedings published until August 2022. To define our inclusion and exclusion criteria, we followed a similar approach to other scholars in blockchain research (e.g., Jørgensen and Beck, 2022), as we did not limit our search to the 'VHB-JOURQUAL3' ranking or peer-reviewed articles. As such, we intend to account for the short history of NFTs, ensure that our study is as comprehensive and up-to-date as possible, and critically assess non-peer-reviewed material. However, we only considered publications that explicitly focus on attributes or design considerations of NFTs along our meta-characteristics. In total, our literature review search (see Figure 2.2) yielded 41 relevant articles that form the basis for the taxonomies' first draft.

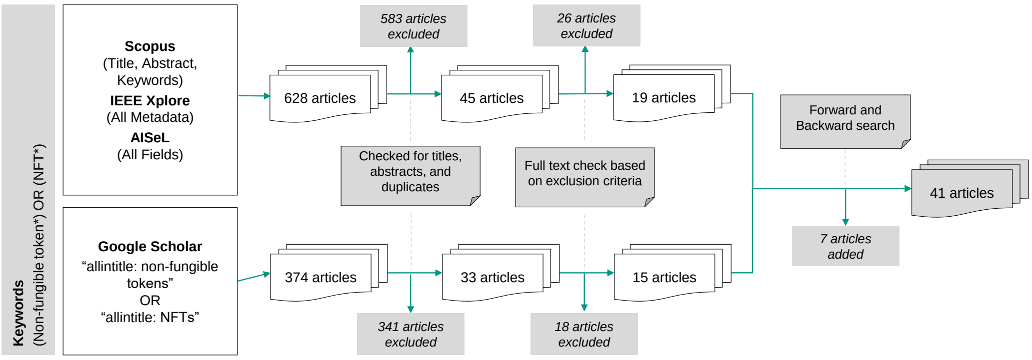


Fig. 2.2.: Literature Review Search Strategy following Webster and Watson (2002).

Empirical-to-Conceptual (E2C). We adopted the empirical-to-conceptual approach in iterations 2 to 5 and analyzed NFT firms from four sources. To efficiently build an initial dataset, we first included all ventures emerging from our literature review (**Iteration 2**). In doing so, we initially identified 59 firms, but excluded 16 as they no longer exist, have been acquired (e.g., Niftex), or did not provide sufficient information (e.g., NFTfi). In total, we analyzed 43 remaining firms (see Appendix Appendix A.1). Subsequently, we expanded our sample with consulting reports to capture both strategic and practice-oriented knowledge (Iteration 3). Our database drew on two sources: First, the Vault Consulting Rankings (2021) ranking of the top 15 consulting firms worldwide by revenue (as of 2021), and second, the Ritter (2021) ranking of consulting firms in North America. We compared and merged both lists, resulting in a total of 21 firms, and searched their databases for the query "NFT" OR "Non-Fungible Token". We identified 16 relevant reports (see Appendix Table A.2) that add to our taxonomy. Afterwards, we searched publicly available databases for NFT ventures (**Iteration 4**). In doing so, we analyzed a sample of the first 50 firms listed in the CrunchBase database (out of 925 hits on May 8, 2022) classified by the keywords “NFT” OR “Non-Fungible Token”. As a result, we included 44 new firms in our sample that were not reflected in previous sources (see Appendix Table A.3). Finally, we analyzed companies that launched NFT projects in 2021 to gather incumbents’ perspectives on the novel and potentially disruptive NFT phenomenon (**Iteration 5**). Since we could not find a database focused on this cohort, our source was a report from Activate Consulting (2021). It contains a timeline of 57 companies in different industries that launched NFT projects between January and October 2021 (see Appendix Figure A.1). We analyzed their cases but could not derive any additional characteristics in this iteration. The sample confirms the existing characteristics and dimensions of our taxonomy. Thus, all objective and subjective ending conditions were met. Based on the aforementioned sources, we are confident that our taxonomy covers the NFT phenomenon comprehensively.

2.4 A Lifecycle-Driven Taxonomy of Non-Fungible Token

Figure 2.3 introduces our taxonomy of NFTs with 20 dimensions and 77 characteristics. It also indicates whether a dimension is exclusive (E) or non-exclusive (N) and in which iteration the attributes were added or revised. For exclusive dimensions, exactly one characteristic is observable at a time; for non-exclusive dimensions, multiple characteristics can be observed simultaneously. Structured along our lifecycle-driven meta-characteristics (see Table 2.1), we provide details for the dimensions and characteristics below and reference appropriate examples to illustrate and substantiate our findings.

2.4.1 Origination

The first meta-dimension depicts the general purpose and (technical) properties of NFTs that are specified throughout the minting process. We describe corresponding dimensions below.

First, **asset substance** and **value representation** describe the object and content represented by an NFT. It can be a tangible and physical object or an intangible asset of digital nature (Hartwich et al., 2023; Valeonti et al., 2021; Regner et al., 2019). The asset token category includes use cases such as real estate (Fairfield, 2021),

	Dimension	Characteristic											N/E*
Origination	Asset substance[1]	Digital[1]	Physical[1]										N
	Value representation[1]	Asset token[1]	Utility token[1]										N
	Type[3]	Static NFT[3]	Dynamic NFT[3]	Generative NFT[3]	Intelligent NFT[3]	Fractional NFT[3]							N
	Blockchain[1]	Layer 1[2]	Layer 2[2]										E
	Network standard[2]	Ethereum[2]	Flow[2]	Tezos[2]	Zilliqa[2]	NEAR[2]	BSC[2]	TRON[2]	Algorand[2]	NEO[2]	Other Standard[2]	No Standard[3]	E
	Consensus mechanism[1]	Proof-of-Work[1]	Proof-of-Stake[1]	Delegated PoS[1]	Proof-of-Authority[2]	Proof-of-History[2]							N
	Composability[2]	Bottom-up composable[2]	Top-down composable[2]	Not composable[2]									N
	Content storage[1]	On-chain storage[1]	Decentralized storage solutions[4]	Centralized cloud[4]									N
Distribution	Key channel[1]	Open marketplace[1]	Collection-based marketplace[1]	Curated marketplace[1]									N
	Exclusiveness[2]	One-of-a-kind[2]	Limited edition[2]	Open edition[2]									E
	Price formation[1]	Fixed price[1]	Timed auction[1]	Open auction[2]									E
Transfer	Transfer methods[4]	Sell[4]	Lease[4]	Gift[4]	Airdrop[4]								N
	Interoperability[4]	Single-chain NFTs[4]	Multi-chain NFTs[4]										N
	Wallet[1]	Custodial wallet[1]	Non-custodial wallet[2]	Semi-custodial wallet[4]									N
	Copyright[1]	Creator retains copyright[2]	Creator transfers copyright[2]	Licenses[2]									N
Trading	Payment method[1]	Cryptocurrency[1]	FIAT[1]										N
	Fee[2]	Gas fees[2]	Royalty fees[2]	Service fees[2]									N
	Fee composition[2]	Fixed[2]	Variable[2]										N
Redeem	Purpose[3]	Investment[3]	Display[3]	Access[3]	Engagement[4]	Burn[4]	Not Specified[4]						N
	Project category[1]	Art[1]	Collectible[1]	Sport[1]	Utility[1]	Games[1]	Music[2]	Fashion[2]	Avatars[2]	Usability[4]	Other[4]		N

*E = Exclusive dimension (one characteristic observable); N = Non-exclusive dimension (More than one characteristic observable)
Dimensions and characteristics added or revised in the following iteration: [1] first, [2] second, [3] third, [4] fourth iteration

Fig. 2.3.: Lifecycle-Driven Taxonomy of Non-Fungible Tokens (NFTs).

digital art (Christie's, 2021), games like CryptoKitties (Evans, 2019), intellectual property digitization (Bamakan et al., 2022; Rafli, 2022),, and supply chain tracking (EY Global, 2021). Utility tokens are typically used to represent non-investment purposes such as products or services or a token holder's authorization to access them (Wang, Li, et al., 2021; Angelo and Salzer, 2020).

Second, **type** describes the design options and adaptability of NFTs. We distinguish five characteristics: static, dynamic, generative, intelligent, and fractional. For static NFTs, which are often defined via the ERC-721 standard, the metadata is fixed as soon as the NFT is minted on a blockchain. As a result, their storage is immutable and traceable, making them particularly suitable for use cases such as play-to-earn games and digital collectibles (Christie's, 2021; Foundation Labs, 2021; Axie Infinity, 2018). Dynamic NFTs, on the other hand, allow metadata modifications by following the ERC-1155 standard. While unique identifiers are maintained, SCs facilitate ex-ante adaptation based on previously defined conditions. These conditions can occur either within a blockchain network or outside of it. For example, to account for external conditions, Chainlink provides a service that uses data and computation services outside the chain as inputs and triggers for NFT updates (Chainlink, 2022). In addition, generative NFTs facilitate NFT creation as a whole or in parts by autonomous systems and artificial intelligence (PwC, 2022). This allows, for example, that the characteristics of an NFT artwork are defined autonomously, which would otherwise be determined by the artist. As a result, many unique NFTs can be created in a short time as this type of NFT is popular with buyers due to the unpredictable outcome (Chandra, 2022). Well-known examples include Bored Ape Yacht Club (2021) NFTs and CyptoPunks (2017). Intelligent NFTs (iNFTs) are digital assets powered by artificial intelligence (AI) that can embody their own personalities and property rights, bringing NFTs “to life” (Alethea AI., 2022). They are managed on the blockchain and of particular interest for interactions in the Metaverse. For example, Alethea AI. (2022) created and sold the virtual “Alice” at the Sotheby’s auction house, which can engage in live conversations with vivid animations (Rasmussen, 2021). Through platforms and protocols, third-party NFT projects (such as BAYC) can also be extended with intelligent functionalities (Altered State Machine, 2021). Finally, we refer to fractional NFTs to describe the concept of splitting NFTs into smaller “shards” (Popescu, 2021). From a technical perspective, an NFT is divided into multiple FTs representing a portion of the original asset, with the creator determining the number of tokens, metadata, and NFT properties (Bamakan et al., 2022; Martinod et al., 2021). This facilitates access, allows different people to own a piece of the same high-priced NFT that would otherwise be difficult to acquire (Di Bernardino et al., 2021; Pudgy Penguins, 2021), and thus increases market liquidity (Popescu, 2021; Singh and Singh, 2021).

Third, the dimensions of blockchain, network standard, consensus mechanism, and composability describe technical characteristics and fundamental decisions when creating NFTs. As an initial design decision, creators must decide on the **blockchain** to mint an NFT. In theory, any blockchain network that provides protocol definitions and network standards is applicable. However, most commonly, creators (The Sandbox Game, 2021; Rarible, 2023; Sorare, 2019) reside in Layer 1 blockchains of the Ethereum network (Bamakan et al., 2022; Kong and Lin, 2021; Valeonti et al., 2021; Fowler and Pirker, 2021). To address anticipated issues of Ethereum (scalability, throughput, high transaction costs), projects such as Audius, NBA TopShots, and Bitsong use alternative Layer 1 blockchains such as Avalanche, Flow, Cosmos, and Solana or Layer 2 solutions like Polygon, Immutable X, or Ronin (e.g., Axie Infinity, Cent, Gods Unchained). In addition, creators can decide which NFT **network standard** they use. Here, they have several options within a given blockchain ecosystem. For example, while ERC-721 is the commonly used standard for Ethereum-based NFTs, alternative standards enable the combination of FTs and NFTs (Ali and Bagui, 2021; Kong and Lin, 2021) within a SC (e.g., ERC-1155, ERC-998) or provide interoperability between blockchain ecosystems (e.g., EIP-2981). Depending on blockchain network choice (e.g., Ethereum, Flow, Tezos), the usability of standards also influences the nature of **consensus**. We distinguish five options: Proof-of-Work (PoW), Proof-of-Stake (PoS), Delegated PoS, Proof-of-Authority (PoA), and Proof-of-History (PoH). In addition, the **composability** dimension specifies if an NFT can be bundled to represent hierarchy levels. We differentiate three characteristics: top-down composable NFTs store information about subordinate tokens. For example, an ERC-721 NFT may hold other tokens bundled into a top-down composable. bottom-up composables, on the other hand, store information about parent tokens but do not store information about child tokens (Ross et al., 2021; Uribe, 2020).

Fourth, **content storage** specifies where the metadata of an NFT is stored. While the storage location is initially determined during the minting process of an NFT, it can be adjusted during its lifecycle depending on the NFT type and preferences (Hartwich et al., 2023). We distinguish three approaches (Wilson et al., 2022; Valeonti et al., 2021; Karapapas et al., 2021). First, creators can store metadata directly on a blockchain (on-chain), which ensures high data availability; however, storage costs can be very high and the data is publicly and transparently accessible. Second, metadata can be stored off-chain on a central server such as Google Cloud or Amazon Web Services. Here, token purchases and sales are recorded in blockchain ledgers, but the underlying metadata of an NFT can be manipulated without the owner's consent. Third, off-chain storage solutions with decentralized servers such as InterPlanetary File System and Arweave enable hybrid solutions. Through a P2P storage network and hashing, they promise both the performance of centralized servers and the immutability of blockchain networks.

2.4.2 Distribution

The second meta-dimension depicts the distribution of NFTs. Our taxonomy characterizes key channels, the level of exclusiveness and price formation of an NFT.

The **key channel** dimension addresses NFT sales and is not limited to a specific characteristic. We distinguish three types where NFTs are either specifically distributed or represent an additional feature of an existing brand or auction house (Bodó, Giannopoulou, et al., 2022). First, open marketplaces allow the minting and trading of both NFTs created directly on the platform and otherwise designed NFTs. A prominent example of this category is OpenSea, which is available to anyone. Second, there are collection-based marketplaces such as CyptoPunks (2017), NBA Top Shot (2019), and Christie's (2021), where NFT collectibles are tied to the creators' infrastructure and cannot be traded on other venues. These marketplaces “create, curate, mint, and promote specific, unique NFT based digital collectibles” (Bodó, Giannopoulou, et al., 2022). For example, by setting access conditions and formulating community norms for the behavior of artists, rights holders, users, buyers, and sellers, they assert strict control. Likewise, the third category of curated marketplaces also exhibits a high degree of control over the artists who create, design, and trade NFTs through their service. However, they do not claim exclusive privileges to create and sell NFTs. Instead, they determine who can trade on their platform via ex-ante review mechanisms for both types and content. Examples include SuperRare (2018) and Nifty Gateway (2018).

The **exclusiveness** dimension indicates whether an NFT is released as a single piece or in a limited or open edition. For unique pieces, the number of NFTs of the same type is fixed at one, which means that only one collector can own the piece. Being digitally scarce, creations with this characteristic (e.g., digital artwork, Christie’s, 2021) can fetch high selling prices. When an NFT is produced in a limited edition, ownership can be distributed among multiple collectors (Hartwich et al., 2023; MakersPlace, 2018). The number of units available is determined during the minting process. In contrast, an open-edition NFT is designed so that new NFTs of the same type can be minted dynamically depending on their demand, generally qualifying these NFTs as less rare or prestigious (Nifty Gateway, 2018).

The dimension **price formation** separates three mechanisms, where NFT sellers may choose their preferred method (Mukhopadhyay and Ghosh, 2021; Ross et al., 2021). First, the fixed pricing option allows to set a price for a certain period and allows for negotiation. However, the seller is not obligated to settle at a lower price. Second, marketplaces such as OpenSea (2022) allow for various timed auction procedures. Here, sellers typically have a choice between an English auction, where the highest bidder receives the NFT after a certain amount of time has elapsed, and Dutch auction procedures, where the price for an NFT decrease (up to a certain limit) until a buyer’s willingness to pay is reached. Third, platforms such as Rarible (2023) enable open auctions, where an NFT can be indexed as ’open for bidding’ so that bids can be submitted at any time and accepted or rejected by the owner.

2.4.3 Transfer

The third meta-characteristic depicts the process of introducing an NFT to public markets. We distinguish four characteristics, namely transfer method, interoperability, wallet, and copyright.

First, the **transfer method** specifies how an NFT is disseminated. We discern a permanent transfer (i.e., sell, gift, airdrop) and a temporary transfer (i.e., lease). In the first case, an NFT is transferred from one owner to another. For example, NFTs can be sold directly (Schaar and Kampakis, 2022) or on a pre-approved sale (Hartwich et al., 2023), gifted to registered collectors (OneOf, 2021), or airdropped for free to (whitelisted) community members as a marketing strategy (Chandra, 2022). In the second case, an NFT is leased for a specified period, either restricted or unrestricted. For example, an NFT cannot be sold but only leased if it serves as an authorization key for linked data that is shared (Musan et al., 2020).

Second, **interoperability** concerns whether NFTs are connectable, exchangeable, and tradable only within a blockchain network (i.e., single-chain) or across multiple networks (i.e., multi-chain). For example, in a Web3-enabled Metaverse, it is critical to port data NFTs as digital avatars from one virtual world to another (Elmasry et al., 2022). In single-chain networks, common standards enable interoperability within an ecosystem but are primarily limited to that environment (Martinod et al., 2021; Mofokeng and Matima, 2018). While approaches such as bridges enable Ethereum-minted NFTs to be accessible on other blockchain networks (e.g., Solana), these solutions might require reliance on trusted third party (TTP) and pose security trade-offs (Pillai et al., 2022). Multi-chain networks, including Cosmos and Polkadot, address these challenges by developing open networks of interoperable blockchains that enable cross-chain communication, where NFT projects can leverage a shared infrastructure (e.g., for consensus), have interacting SCs, and share value directly.

Third, **wallets** specify the repository of NFTs, where token custody can be managed by the holder itself or a service (i.e., custodian) that holds an NFT's private key governing its access and ownership (OpenSea, 2022; Valeonti et al., 2021; Rarible, 2023). If holders prefer not to be responsible for the custody of their keys, they can use custodial wallets where platform services provide key custody (Art Blocks, 2020). This allows password recovery and account retrieval mechanisms. However, holders must rely on and become dependent on the custodian's security mechanisms. If users prefer to determine the storage of their private keys themselves, they can use non-custodial wallets (OpenSea, 2022). Here, secure storage resides entirely to NFT holders, who must remember their private keys and a backup seed phrase, which they can store in software or hardware wallets. If holders lose this information and thus access to their wallet, their NFT is no longer accessible. In addition, non-custodial wallets are blockchain-specific (e.g., Metamask for Ethereum; Phantom for Solana). If a user wants to use both wallet types, he can resort to semi-custodial wallets, where custody is managed by both the NFT holder and a third party (Mojito, 2021).

Fourth, **copyright** characterizes the ownership and exploitation rights of NFTs. A principal owner (e.g., minting creator) may transfer ownership to a subsequent owner (e.g., NFT consumer) or only grant rights to a particular NFT. If creators retain rights to an original, they may reproduce other NFTs based on the same original (Chohan and Paschen, 2023). Examples without a copyright transaction include well-known NFTs such as CryptoKitties and CryptoPunks (Evans, 2019). Some platforms (e.g., Mintable, 2018) offer creators the ability to include copyrights in the SC of a sale and transfer intellectual property to buyers (Guadamuz, 2021). Furthermore, NFT rights can also be licensed. Typically, creators grant buyers a license to use, exploit, and display their NFT for a limited period (Guadamuz, 2021) and may also transfer marketing rights (Lee, 2022). An example includes BAYC, where buyers receive a license to use their NFT personally and commercially (Guadamuz, 2021).

2.4.4 Trade

The fourth meta-characteristic addresses the trading of NFTs in primary and secondary markets. We distinguish three characteristics, namely payment method, fee, and fee composition.

First, the **payment method** characterizes the currency used to purchase an NFT. A prevalent option are cryptocurrencies (Dowling, 2022b; Chohan and Paschen, 2023), which are either subject to price fluctuations (e.g., Ether in the Ethereum ecosystem, Fairfield, 2021; Valeonti et al., 2021) or pegged to a FIAT currency (e.g., stablecoins such as DAI, Ante, 2021; Regner et al., 2019). In addition, platforms such as Nifty Gateway (2018) also enable payments with FIAT money, which are processed via credit or debit card, and services such as PayPal (Ross et al., 2021).

Second, **fees** capture NFT-related expenses incurred as part of a transaction, for providing a service, or as a license fee. By transaction fees, we group expenses that arise using a blockchain infrastructure (e.g., consensus, transaction recording, Reijsbergen et al., 2021). They depend on the network used and can be higher than the price of the transacted asset in some cases. For example, BAYC buyers had to pay gas fees that were more than five times the NFTs purchase price (Nover, 2022). In addition, costs depend on whether the transaction is an initial sale or a sale of an NFT on the secondary market (OpenSea, 2022; Mintable, 2018). Secondary market transactions may also involve royalties, which are included as an automatic interest in a SC that allows creators to participate by reselling their NFTs (Hartwich et al., 2023; Popescu, 2021; Chohan and Paschen, 2023). A third characteristic is service fees, which include marketplace- or platform-related costs such as registration and account fees. For example, first-time buyers on OpenSea (2022) must pay a one-time gas fee that flows to the marketplace operator. However, not every marketplace charges service fees (BYBIT, 2022).

Third, the **fee composition** specifies whether fees are fixed or variable. While transaction fees are variable as they depend on factors such as network utilization and cannot be adjusted by creators, the magnitude of royalty fees is usually at their discretion (Guadamuz, 2021). Creators can set royalties as a fixed amount or as a percentage of the sales price. Variable royalties oriented towards resale value are prevalent and range from 0-10% (OpenSea, 2022; Rarible, 2023; Mintable, 2018). Service fees, on the other hand, often occur as a fixed amount. For example, Nifty Gateway (2018) charges a one-time registration fee on their service of 15%.

2.4.5 Redeem

The fifth and final meta-characteristic concerns the applicability of NFTs. We distinguish two characteristics, namely purpose and project category.

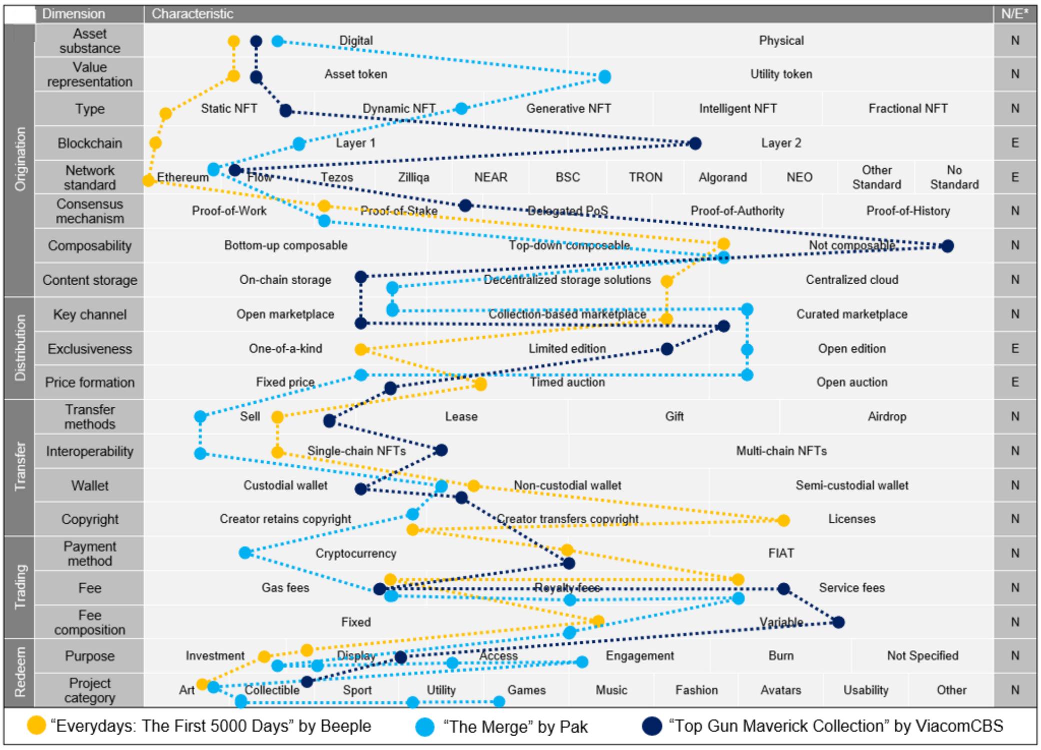
First, **purpose** indicates the intended utilization of an NFT. For example, they may serve as a speculative asset where buyers want to increase the value of their investment. This category is closely related to Decentralized Finance (DeFi) ecosystems, where owners can use various DeFi mechanisms (e.g., stake, lend, collateralize) to generate attractive profits (Hartwich et al., 2023). NFTs may also serve as a display mechanism in communities to engage with brands and other users. We distinguish between social engagement NFTs (e.g., badges, emblems, GIFs, and emojis), identity NFTs (e.g., cross-platform avatars or interactive characters), and profile picture NFTs (e.g., on social networks). For example, the BAYC NFTs appear on various social media platforms, being considered a digital symbol of social status (Chalmers, Fisch, et al., 2022). We further identify access NFTs that provide permanent or temporary benefits to their holders. These include access to communities, events, music, or exclusive content in both digital and physical realms only NFT holders can access (Hartwich et al., 2023). As such, they grant their holders trademark or commercial rights, licenses, copyrights or voting rights that automatically expire when an NFT is resold (Ante, 2021). They can also allow participation in exclusive programs and provide credentials to unlock services and rewards. These range from redeemable rewards to discounts on merchandise and new product offerings (Baculard, 2021; Autograph, 2023). Community-organized gatherings are thereby aimed at increasing the perceived value of an NFT. In addition, NFT-based tickets exist where the token contains credentials for a specific event (Regner et al., 2019). After the event, an NFT may serve as proof of attendance and a digital certificate of participation (Zhao and Si, 2021). Furthermore, we consider engagement NFTs to interact in interactive environments such as the Metaverse or virtual games (Hartwich et al., 2023; Lee, 2022). Here, NFTs can represent virtual clothing or digital accessories that their holders can use to dress up their avatar NFTs (Brooks, 2022). We also see immersion between virtual and digital worlds. In games, NFTs can represent characters, skills, and items that subsequently serve as assets to generate income by selling them to other players or collectors or holding them as passive income. Also, NFTs can represent fantasy sports trading cards (Lee, 2022; PwC, 2022; NBA Top Shot, 2019). Lastly, the burn characteristic describes a method to reduce the supply of a circulating quantity of NFTs, thereby increasing scarcity and stimulating prices (McDowell, 2022). Given that NFTs minted on a blockchain are immutable and cannot be erased, each token to be burned is thereby sent to an inaccessible address (McDowell, 2022). The transaction is irreversible because the token still exists on the blockchain but is no longer accessible.

Second, the **project category** specifies the use case that an NFT aims to represent. Extant literature distinguishes seven main segments: arts, collectibles, sports, digital fashion, utility, and games (Hartwich et al., 2023; Osivand, 2022; Mukhopadhyay and Ghosh, 2021; Ante, 2021; Musan et al., 2020). Use cases that prior literature did not consider include NFTs for music (Rumburg et al., 2020; Bitsong, 2017), and avatars (Decentraland, 2017). We further identify NFTs to reduce the complexity of blockchain addresses while enhancing usability (Hartwich et al., 2023; Unstoppable Domains, 2018).

2.5 Taxonomy Application & Evaluation

We evaluated the applicability of our taxonomy ex-post by following a threefold approach, drawing on the methodological guidance of Szopinski et al. (2019). **First**, we conducted three preliminary expert interviews with academics and practitioners, which is a widely used tool for taxonomy evaluation in the IS domain (Szopinski et al., 2019). Hereby, we aim to validate the taxonomy's comprehensibility, completeness, and perceived usefulness. When selecting the experts, we focused on the proven NFT expertise and experience as the decisive criterion. We conducted semi-structured interviews using evaluation-typical questions (e.g., "Is the taxonomy adequate and complete? Are all relevant objects included in the taxonomy? Would you suggest modifying the taxonomy? Which dimensions and characteristics should be deleted?

Which dimensions or characteristics should be added?", Szopinski et al., 2019). The interviews lasted an average of 51 minutes and were transcribed and analyzed in an iterative process (Corbin and Strauss, 2008) using 'MAXQDA2020' software. **Second**, three individual raters classified 25 randomly selected empirical objects from our corpus (see Appendix Appendix A.1) using our taxonomy. The characteristics and dimensions from the preceding sections served as a codebook for the classification. We then calculated the Fleiss kappa (Fleiss, 1971) as a measure of rater agreement and comparability of results, which is also used in other IS publications to evaluate taxonomies (Kölbel, Lamberty, et al., 2022; Weking et al., 2020). The analysis yielded a kappa value of 69%, which corresponds to "substantial agreement" (Landis and Koch, 1977) and thus indicates that our taxonomy is suitable for a coherent classification and concise description of NFTs.



● "Everydays: The First 5000 Days" by Beeple ● "The Merge" by Pak ● "Top Gun Maverick Collection" by ViacomCBS

Fig. 2.4.: Taxonomy Application and Evaluation with three Real-World NFT Projects.

Third, to substantiate the results and demonstrate the applicability of the taxonomy, we classified three real-world NFT projects using our taxonomy (see Figure 2.4). Through this illustrative scenario analysis, we aim to evaluate the practical applicability and usefulness for classifying, differentiating, and comparing NFT projects (Szopinski et al., 2019). The selection of cases followed three rationales: (1) Cases represent different approaches, as they portray NFT projects from different domains. Beeple's 'Everydays: the First 5000 Days' (Christie's, 2021) is arguably one of the most famous and lucrative digital artworks (Hartwich et al., 2023), and 'The Merge' (Nifty Gateway, 2018) also belongs to the domain of NFT art collectibles. In addition, we consider these two works highly relevant, as they are the most expensive NFT ever sold Hale (2022, $69.3 million and $91.8 million). 'The Top Gun: Maverick Collection' (OpenSea, 2022), on the other hand, represents an NFT project from the entertainment and media industry, where most NFT projects were initialized in 2021 (see Appendix Figure A.2). (2) Cases represent different types of NFTs. While 'Everydays: the First 5000 Days' and 'The Top Gun: Maverick Collection' are static NFTs following the ERC-721 token standard, 'The Merge' is a dynamic NFT according to the ERC-1155 standard. (3) All three cases provide sufficient information that allows us to analyze them in detail and classify them according to the attributes of our taxonomy. Figure 2.4 illustrates each case and describes whether and how they fit into our taxonomy.

2.6 Discussion & Conclusion

Our study contributes to descriptive knowledge about the NFT phenomenon by proposing a theoretically grounded and empirically validated taxonomy that focuses on characterizing NFTs along their lifecycle and synchronizes findings from academia and practice. We argue that our broad perspective complements non-peer-reviewed NFT classifications, providing more general applicability that accurately captures the rapidly growing NFT industry. Although previous articles help to initiate a discourse on NFTs, they abstract their mechanisms. Our scientifically grounded perspective, which consists of a five-step research approach incorporating both qualitative and quantitative methods, not only allows us to describe NFTs more comprehensively than previous work (Hartwich et al., 2023), but also explains previously undocumented phenomena. For example, while extant literature separates core NFT use cases into arts, collectibles, sports, digital fashion, utility, games, and domains, we identify further applications that have not been considered before (e.g., music NFTs, avatar NFTs). Similarly, we identify static, dynamic, generative, intelligent, and fractional NFT types, while alternative classifications only report two characteristics (i.e., static and dynamic NFTs; Hartwich et al., 2023). We also describe uncharacterized characteristics (e.g., distribution channel, exclusiveness, price formation, wallet, copyright) and specify the technical origins of NFTs (e.g., composability, blockchain, network). Furthermore, we classify NFTs across the domain-independent category of 'purpose' and distinguish NFTs for investment, display, access, engagement, and burn mechanisms.

Like any research project, our study is beset with **limitations**. First, given the fast-growing nature of the NFT sector, we do not expect our sample of NFT projects and start-ups to be exhaustive. We aimed to address this by referring to different literature sources, reports, and the CrunchBase database. Second, emerging NFT types may be underrepresented in the current sample. For example – given the growing interest in the Metaverse – we assume that iNFTs with AI-supported applications will be more prevalent in the future. Therefore, we have developed our taxonomy to be revisable and expandable to include new perspectives, characteristics, and dimensions (Nickerson et al., 2013). Third, our taxonomy relies on an evaluation process that is notoriously difficult but particularly challenging at the beginning of a new research field (Szopinski et al., 2019). Accordingly, we see our three-stage endeavor as a first step towards evaluation, where follow-up interviews with further experts, and an evaluation with more NFT projects might further confirm or iteratively revise our findings.

Despite these limitations, our study entails **implications** for academia and practitioners that contribute to the scholarly understanding of NFTs. In each of the five lifecycle perspectives, we identify attributes that reflect NFTs' multiplicity and offer a starting point for in-depth understanding. These can serve as a reference for future research. Bapna et al. (2004, p.23) also note that "a robust taxonomy can be used for ex-post theory building". We argue that our taxonomy enhances the understanding of the NFT domain and thus embodies the most basic form of a theory ("taxonomic theory", Gregor, 2006), which provides a necessary foundation for more advanced theories (Szopinski et al., 2019; Gregor, 2006). In these efforts, varying levels of abstraction inherent in the dimensions of our taxonomy can have repercussions in downstream theorizing activities, as certain dimensions are more empirical and subject to change (e.g., network standards), while others operate at a higher level of conceptual abstraction (e.g., composability, type). Considering managerial implications, our taxonomy supports practitioners with a status-quo analysis of NFTs, providing a granular overview of design and comparability. For example, NFT developers obtain abstracted knowledge about characteristics and interaction points with potential customers and learn about different NFT applications and purposes. Building on this knowledge, they can design new NFTs, evaluate business ideas, analyze individual offerings of existing projects, and compare competing and non-competing products within and across functional areas. Similarly, NFT clients can use our taxonomy as a tool to compare diverse market offerings to guide informed purchasing decisions. In addition, our taxonomy can support regulators in their standardization efforts.

Our results also motivate **future research**. Amidst dynamic NFT evolutions and rapid technological developments, our taxonomy may serve as a temporary snapshot that can be reviewed iteratively for completeness. Besides, our taxonomy provides a foundation for developing archetypes that may help to derive successful or sustainable NFT DPs. Furthermore, ecosystem aspects (e.g., platforms business models) and NFT-related value co-creation may be analyzed. Given the full transparency of blockchain-based systems (Sedlmeir, Barbereau, et al., 2022), we also consider the applicability of NFTs in corporate contexts to be an exciting research topic. Focusing on a specific domain, use case or sub-aspect of NFTs might also add to our taxonomy's level of detail. In this context, it would be interesting to study, for example, how NFTs work within the Metaverse or how NFT-based identities can be compared with dedicated identity solutions such as SSI (Sedlmeir, Smethurst, et al., 2021).

3

An Economic Perspective on Asset Tokenization Services

This chapter is based on a peer-reviewed article titled “Spotlight on DeFi Centerpieces: Towards an Economic Perspective on Asset Tokenization Services”. The article was co-authored by Felix Sterk, Ricky Lamberty, and Christof Weinhardt and is published in the 26th Pacific Asia Conference on Information Systems (PACIS) Proceedings. The authors’ accepted manuscript’s supplementary material can be found in Appendix A.2. The tables, figures, and appendices were systematically renamed, reformatted, and appropriately referenced to align with the overall structure of the thesis. To further enhance clarity and consistency, formatting, and reference style were adapted and references were updated.

Publication details: *Kölbel, T., Sterk, F., Lambert, R., & Weinhardt, C., Spotlight on DeFi Centerpieces: Towards an Economic Perspective on Asset Tokenization Services, 26th Pacific Asia Conference on Information Systems Proceedings, 2022.*

Abstract: Experts consider tokenization a potentially disruptive blockchain-based innovation. Cryptographic tokens can represent ownership of tangible and intangible assets in the digital space, serve as a store of value and proof of ownership, and enable investments in historically illiquid assets. While there are promising use cases for these new technological capabilities, research on economic perspectives is still in its infancy. Therefore, we focus on asset tokenization services, develop a taxonomy following Nickerson et al. (2013), and align our analysis with established business model dimensions. Our dataset is based on a three-stage approach incorporating academic literature, consulting reports, and real-world projects. As a result, we identify 16 dimensions, 14 sub-dimensions, and 101 characteristics that improve our understanding of asset tokenization services and provide a starting point for further research.

Keywords: Blockchain, DeFi, Tokenization, Token Economy, Taxonomy.

3.1 Introduction

The rise of the cryptocurrency Bitcoin has opened a new realm of opportunities and potentially revolutionizes how people exchange, manage and transact investments and assets in the digital age. As the technological backbone of Bitcoin and other cryptocurrencies, blockchain is a type of DLT that paves the way for various investment opportunities among agents (i.e., individuals, organizations). One of the most recent – and potentially most disruptive (van Gysegem, 2021) – blockchain-based innovation is the tokenization of assets as a centerpiece of DeFi.

Tokens allow assets to be easily fragmented into smaller units. They represent ownership of physical assets in the digital space, act as a store of value and proof of ownership, and enable investments in historically illiquid commodities. From traditional assets such as venture capital funds, company shares, bonds, commodities, and real estate to exotic assets such as sports teams, racehorses, artwork, or membership rights – theoretically, almost any asset can be tokenized (Heines et al., 2021; OECD, 2020). The bridge between the physical and digital world forms a process called tokenization, in which an issuer creates cryptographic tokens on a blockchain that represent the value stored in a tangible or intangible asset (OECD, 2020). Cryptographically secure tokens can be described as a piece of software that has unique asset references, properties, and/or legal rights (Sunyaev et al., 2021). Digital signatures verifiable and authorizable by the blockchain guarantee that the purchase of tokens does not need to be mediated by a TTP such as banks or notaries. It is commonly believed that tokenization via decentralized platforms and DeFi in a broader sense could avoid costs associated with intermediaries, lengthy processing times, and the presence of a single point of failure (van Gysegem, 2021; Heines et al., 2021; Sunyaev et al., 2021). Decentralized platforms offer services to tokenize assets and represent the shift from a product-dominant to a service-dominant logic (Lusch and Nambisan, 2015). The emerging token economy (Sunyaev et al., 2021) presents vast transformative value (Benlian et al., 2018). Organizations and celebrities may tap into new revenue streams by tokenizing previously illiquid assets (e.g., licensing digital content or art), and even ourselves may monetize our online data (Sunyaev et al., 2021). In each case, the reason for tokenization (e.g., improved transparency, increased liquidity) and the individual token design (e.g., FT, NFT) may differ (Oliveira et al., 2018). Studies predict that assets worth ten percent of global GDP will be tokenized by 2027 (World Economic Forum, 2015), and tokenization of equity post-trading alone could lead to gains of €4.6 billion by 2030 (van Gysegem, 2021).

To address the resulting dynamics from existing and anticipated use cases, both practitioners and academics call for more classifying representations of asset tokenization (Ferreira and Sandner, 2021; Sunyaev et al., 2021; Deloitte, 2019). Previous research in this context has mainly focused on two strands: approaches to describe tokens (Ankenbrand et al., 2020; Freni et al., 2020; Oliveira et al., 2018) and their applicability (Heines et al., 2021). Both research streams are predominantly addressing technical token properties. However, Sunyaev et al. (2021) note a need for interdisciplinary research that does not focus solely on technical aspects. Heines et al. (2021) also observe that the field of tokenization is heavily concentrated on crypto assets and influenced by gray literature without truly adopting an operational and business model perspective. To the best of our knowledge, studies responding to this call have been few. Moreover, we are not aware of any publication that scrutinizes tokenization from a service-dominant logic perspective and examines services for asset tokenization. Given its interdisciplinary nature, IS research seems particularly well suited to address these two research streams holistically. In this context, this publication attempts to add economic dimensions to existing taxonomies and thereby focus on asset tokenization services. In doing so, we pursue insights from leading business consultancies that address asset tokenization as the value creation potential of tokens on blockchain-based platforms can only reach their full potential if business model influences are taken into account (van Gysegem, 2021). Against this backdrop, we pose the following RQ:

Research Question: *What economic key dimensions and characteristics distinguish asset tokenization services?*

To make a contribution that is relevant not only to the academic community but also to practitioners and potential investors, we first develop our taxonomy using the established taxonomy development process of Nickerson et al. (2013) and second align our analysis along the business model dimensions of value proposition, value creation and delivery, and value capture. Our dataset is based on a three-step process that incorporates academic literature as well as practitioner publications, consulting reports, and the analysis of real-world projects, thus responding to the call for empirical blockchain research (Treiblmaier, 2019; Risius and Spohrer, 2017). Our framework attempts to extend the polyhedral nature of tokens by adding an economic perspective, merging existing approaches, complementing these with empirical data, and focusing on a service perspective. This has several theoretical and practical implications. On the one hand, researchers could benefit from our tool to model economic aspects of asset tokenization and thus systematically compare different services. The benefits are reproducible, comparable results, and higher scientific rigor. On the other hand, practitioners could benefit from our taxonomy that reduces the complexity of asset tokenization and supports the selection of viable services. The remainder of the paper unfolds as follows. Section 3.2 sets foundations on the blockchain-enabled token economy and presents related work on asset tokenization. In Section 3.3, we describe our research methods, precisely the taxonomy development process according to Nickerson et al. (2013) to increase scientific rigor and our data sources to ensure practical relevance. In Section 3.4, we discuss our taxonomy and its implications. A short conclusion, limitations, and an outlook for proposed future research complete our paper.

3.2 Background

3.2.1 Blockchain-enabled Token Economies

Blockchain technology consists of a transaction protocol that is shared in a decentralized, transparent, and time-stamped format across a P2P network. Users trust the underlying code, distributed database, consensus mechanism, and cryptography that open up new ways to organize economic activities. This includes removing intermediaries and TTPs in value exchange (Sunyaev et al., 2021; Easley et al., 2019).

One way of disintermediating digital asset values is by tokenization (Freni et al., 2020). In this digitization process, tangible and intangible assets can be integrated into the distributed ledger of a blockchain by creating a digital representation of those assets via cryptographically secure tokens. The economic value and rights associated with that asset are linked to tokens through conventions (OECD, 2020). Tokens are issued, managed, and controlled through SCs whose correct execution is verified by a consensus protocol. Created tokens represent a reference to the underlying asset and serve as unique identifiers (Schaer, 2020). The functionality of a token depends on the characteristics of the underlying blockchain, specific data structure, and logic (Roth et al., 2019). Generally, two classes of tokens can be distinguished: FTs, which are exchangeable and divisible (i.e., each arbitrarily divisible unit has the same market value and validity); and NFTs, whose underlying asset is non-exchangeable, non-divisible, and thus unique (i.e., tokens of the same type differ and have individual information and properties). Since tokens can be individually designed and programmed for diverse purposes, various approaches exist to categorize them further (Weingaertner, 2019). For example, Oliveira et al. (2018) propose the nomenclature of payment, cryptocurrency, funding, asset, equity, voting, work, and consensus tokens, whereas OECD (2020) primarily distinguishes tokenization of ’off-chain’ and ’on-chain’ assets. Off-chain assets have inherent value outside blockchains (e.g., gold, bonds), while on-chain assets represent native tokens with intrinsic value (e.g., Bitcoin) or function (e.g., governance tokens) that exist only within blockchain networks. Synthesizing, we note that there is a class of tokens that have the character of a currency and function as a financial instrument, medium of exchange, or unit of account; tokens that provide their owners with access to specific products, services, or rights and focus on utility purposes; and tokens that serve as a store of value representing assets and intellectual property. The latter are often referred to as asset tokens, have attracted significant attention since the beginning of 2021 (e.g., NFTs), and represent the primary focus of this paper.

3.2.2 Related Work on Asset Tokenization

Tokens in general and asset tokens in particular have widely been considered and characterized differently from academic and legislative perspectives. Alongside Freni et al. (2020), Euler (2018), and Oliveira et al. (2018), who pursue general token classification approaches, publications consider the assimilation of token properties into traditional finance (Ankenbrand et al., 2020), token categorizations as vehicles for alternative project funding (Chanson et al., 2018), and deliberations on applications, potentials, and challenges of tokenization in different industries (Heines et al., 2021). In addition to the academic world, several publications deal with regulatory and adoption aspects for real-world tokenization. These include, for example, technical standardization efforts of specific token types (Tapscott, 2020), general type classification efforts (Ketz and Sandner, 2009), analyses of available token options and incentive mechanisms (Marshall, 2018), or open-source tools for the technical design of tokens (InterworkAlliance, 2020). Reflecting on a large number of publications, several efforts have already been made to structure blockchain-enabled tokenization. However, so far, we have not been able to identify a framework that approaches asset tokenization from an economic perspective and empirically analyzes possible service offerings related to asset tokenization.

3.3 Methodological Approach to Taxonomy Development

We adopted Nickerson et al. (2013) taxonomy development method as the basis for our research endeavor. This method applies across disciplines and objects, allows for a firm formalization of processes, and facilitates combining theoretical knowledge from the literature and empirical findings from practice (Beinke et al., 2018). It can help researchers and practitioners to understand a complex domain (Nickerson et al., 2013), is well established in IS research, and has been applied in high-level journal articles and conference papers in various contexts (Tönnissen et al., 2020; Beinke et al., 2018). The objective of taxonomy development is a well-documented and systematically guided process for defining dimensions and characteristics that are exhaustive (Nickerson et al., 2013).

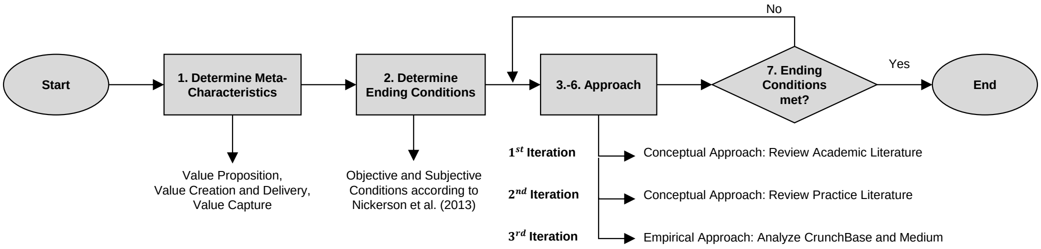


Fig. 3.1.: Applied Taxonomy Development Process following Nickerson et al. (2013).

We present an iterative approach to taxonomy development (see Figure 3.1) that consists of seven steps inspired by Nickerson et al. (2013). In the first step, we defined the 'key dimensions and characteristics of asset tokenization services from an economic perspective' as meta-characteristics that reflect the purpose of our taxonomy and serve as a navigator throughout the process (Step 1). In doing so, we considered the business model elements of value proposition, value creation and delivery, and value capture as persuasive guidance for this process, as they have been used in other business-related taxonomies (Täuscher and Laudien, 2018; Remané, Nickerson, et al., 2016). In the second step, we identified ending conditions for our iterative method by following Nickerson et al. (2013) suggestions. After establishing the baseline for developing the taxonomy, we identified sub-dimensions and features through an iterative approach (Steps 3-6), choosing between inductive or deductive reasoning. Whereas empirical findings guide the conceptual-empirical approach, the empirical-conceptual approach focuses on extracting characteristics and dimensions from the scientific knowledge base (Nickerson et al., 2013). Our research process addressed both choices and followed a three-stage process. During each iteration, we discussed, added, or removed dimensions and features. We illustrate the iteration process below.

1st iteration. The starting point of our taxonomy development process forms the conceptual-empirical approach (Nickerson et al., 2013) of a structured literature review. With this procedure, we strive to increase scientific rigor and build a knowledge base on asset tokenization. The structured literature review follows the methodological suggestions of Webster and Watson (2002) and includes publications in journals (e.g., International Journal of Information Management, Journal of Financial Economics) and conferences (e.g., International Conference on Information Systems, Pacific Asia Conference on Information Systems) published between January 2008 and December 2021. We queried the databases EBSCOhost, Web of Science, AIS Electronic Library, Science Direct, and IEEE Xplore for the search term "asset" OR "commodit*" AND "distributed ledger" OR "blockchain" AND "token" OR "tokenization" and identified a total of 140 publications. Due to the relatively short history of tokenization, we did not narrow our search by quality rankings such as the VHB-JOURQAUL3 but only considered peer-reviewed articles. Subsequently, we screened titles and abstracts and removed irrelevant articles and duplicates, resulting in 23 remaining articles. The remaining documents formed the basis for the forward and backward search, which returned in 12 additional articles. In total, the structured literature review yielded 35 relevant articles. Appendix Figure A.3 illustrates the structured literature review search strategy that provided the basis for our initial taxonomy. As part of this process, we refined four dimensions: underlying asset, token function, asset governance, and token characteristics.

2nd Iteration. The second iteration builds on an empirical-conceptual approach by incorporating consulting reports into our taxonomy development process to consider both strategic and practice-oriented knowledge. As a database, we considered the top ten global consulting firms in terms of revenue (reference: 2020), whose libraries we searched for the query "token" OR "tokenization" OR "asset tokenization" in February 2022. Initially, we identified 44 reports, including 16 relevant documents by checking the abstract, table of contents, and introduction (see Appendix Figure A.3). Based on these reports, we identified five additional dimensions: value classification, ecosystem role, customer segment, key partner, and payment channel.

3rd Iteration. As tokenization is a new kind of technology where empirical research appeals (Treiblmaier, 2019; Risius and Spohrer, 2017), we follow an empirical-conceptual approach in the third interaction by identifying relevant companies and projects dealing with our meta-characteristic. By focusing on new companies, we analyze emerging business models and aim to provide a reasonably complete picture of real-world asset tokenization services. To efficiently build a large dataset, we initially included all companies that emerged from the structured literature review. In addition, the world's largest startup database CrunchBase (Beinke et al., 2018), and the online publishing platform Medium, which is popular in the token economy, were searched for projects that consider asset tokenization as the central part of their business. Excluded were pure wallet providers, miners, and DLT infrastructure projects (such as Ethereum). In addition, we eliminated duplicates and businesses that are no longer active, do not offer a website in English, or do not have enough publicly available information. In total, we identified 51 projects (see Appendix Figure A.4). Next, we compared all businesses in our sample one by one (Step 4) to the current taxonomy, identified new characteristics (Step 5), partially grouped these characteristics into dimensions, and revised the taxonomy (Step 6). In this coding process, we included company websites, white papers, and information from CrunchBase and Medium to ensure data triangulation. This process resulted in seven new dimensions: trust structure, service openness, key channel, monetization, revenue source, revenue stream, and network costs.

During the iteration processes, we evaluated the taxonomy according to the objective and subjective ending conditions (Step 7) of Nickerson et al. (2013). These include, for example, the condition that "all objects or a representative sample of objects have been examined, no object was merged with a similar object or split into multiple objects in the last iteration, and at least one object is classified under every characteristic of every dimension" (exemplary objective ending conditions according to Nickerson et al., 2013). As a result, after the third iteration, we were able to distinctly classify 20 randomly selected companies from our sample in our taxonomy following the ending conditions (see Appendix Figure A.4). As a result, our taxonomy development process was complete. Drawing on the iteration steps outlined above, we are confident that our taxonomy provides value, validity, and applicability and serves as a valuable indication of the economic aspects of asset tokenization services.

3.4 An Economic Perspective on Asset Tokenization Services

This section presents our taxonomy of asset tokenization services from an economic perspective. Figure 3.2 illustrates the 16 key dimensions, 14 sub-dimensions, and 101 characteristics. The right column of Figure 3.2 indicates whether an element is exclusive (E) or non-exclusive (N). For exclusive dimensions, exactly one feature is observable. For non-exclusive dimensions, potentially multiple characteristics are observable at the same time. For example, tokens may exhibit different functions at once or change their function over time (Pang et al., 2020). In addition, the superscripted numbers in Figure 3.2 indicate the iteration in which a dimension or characteristic was added or revised. We present the dimensions and characteristics in detail below and structure our findings along with the business model elements of value proposition, value creation and value delivery, and value capture.

3.4.1 Value Proposition

The first perspective addresses the value propositions provided by services offering asset tokenization to satisfy diverse customer needs. It comprises five dimensions: underlying asset, value for customer, trust structure, value classification (including the sub-dimensions service provisioning, customization, market type, and token function), and service openness (including the sub-dimensions network accessibility, geographic targeting, and verification level).

1. **Underlying asset** deals with the asset for which a tokenization service is offered. Here, a fundamental distinction can be made between two characteristics: tangible-physical assets and intangible-virtual assets. As Heines et al. (2021) note, theoretically, there are few limits to possible applications, thus making it difficult to provide a holistic enumeration. Nevertheless, a non-disjunctive list of examples includes tangible-physical assets such as commodities, artworks, or oldtimers (Curioinvest, 2023; Kim, 2020; Smith, Vora, et al., 2019) or intangible-virtual assets such as membership rights, NFT-collectables, and financial instruments for stocks, bonds, and real estate (Brickblock, 2023; Definder, 2023; Baum, 2021; Ciriello, 2021; Pang et al., 2020).
2. **Value for customer** addresses benefits that services offer as value propositions to their customers. These include liquidity by granular unitization into tradable tokens, mass investment opportunities and financial inclusion by removing

	Dimension		Characteristic								E/N*
Value Proposition	Underlying Asset^1		Tangible-physical^1	Intangible-virtual^1							N
	Value for Customer^1		Intermediation Improvement^1	Increased Liquidity^1	Financial Inclusion^1	Digital Scarcity^1	Process Improvement^1	Security Enhancement^2	Tracability and Verification^1		N
	Trust Structure^3		Intermediary-based^3	Code-based^3	Reputation-based^3						N
	Value Classification ^{2}	Service Provisioning^3	Intrinsic Stand-alone^3	Reference Add-on^3							N
		Customization^3	Full^3	Modular^3	Not Allowed^3						E
		Market Type^2	One-sided^2	Two-sided^2							N
		Token Function^1	Store of Value^1	Voting Rights^1	Right to Use^1	Dividend Right^1	Collectible^1	Speculation Object^1	Tracking^1		N
	Service Openess^3	Network Accessibility^1	Public^1	Private^1							E
		Geographic Targeting^2	Global^2	Selected Countries^2							E
		Verification Level^3	High Verification^3	Low Verification^3	No Verification^3						E
Value Creation and Delivery	Ecosystem Role^2		Service Provider^2	Infrastructure Provider^2							N
			Token^2 Issuance	Brokerage^2	Clearing and Settlement^2	Safekeeping Custody^2	Assurance or Consultancy^2	Analytics^3	Hardware Producer^2	Software Producer^2	N
										Platform Operator^2	
	Customer Segment^2		B2B^2	B2C^2	C2C^2						N
	Key Partner^2		Minting Creator (Seller Side)^2	Technological Service Provider^2	Blockchain Network^2	Influencer^3					N
	Key Channel^3		Mobile Application^3	Desktop Website^3	Technology Provision without Channel^3						N
	Token Characteristic^1	Unit^1	Whole or One Token^1	Multiple Tokens Separable^1	Not Separable^1						E
		Properties^1	Portability^1	Fungibility^1	Destructibility^3	Tradeability^1					N
			Portable^1	Not Portable^1	Fungible^1	Non-fungible^1	Destructible^3	Not destructible^3	Tradable^1	Not Tradable^1	N
		Supply^1	Limited^1	Variable^1	Unlimited^1						E
		Creation^1	Singular^1	Conditional^1	Flexible^1						E
	Asset Governance^1	Asset Safekeeping^1	Self-administration^1	Third-party Management^1							N
		Private Key Custody^2	Self-administration^2	Third-party Management^2							N
		Interface^3	Qualitative^3	Quantitative^3	No Interface^3						E
Value Capture	Monetization^3		Upfront^3	Pay-as-you-go^3	Not specified^3						N
	Revenue Source^3		Minting Creator (Seller Side)^3	Customer (Buyer Side)^3	Third Party^3	Not specified^3					N
	Revenue Stream^3		Advertising^3	Fixed Service Fee^3	Transactional Fee^3	Value-based Fee^3	Second. Market Fee^3	Auction^3	Not specified^3		N
	Payment Channel^2		Own Token^2	Multiple Cryptocurrencies^2	Fiat Currency^3						N
	Network Costs^3		Use External Blockchain Network^3	Use Own Consensus Network^3							E

*E = Exclusive dimension (one characteristic observable); N = Non-exclusive dimension (more than one characteristic observable)
Dimensions and characteristics were added or revised in the following iteration: ^{1} first, ^{2} second, or ^{3} third iteration

Fig. 3.2.: Asset Tokenization Service Taxonomy.

barriers to market entry (e.g., high capital investment, Chen, 2018; Schaer, 2020), and disintermediation by eliminating the need for TTPs (Sunyaev et al.,

2021) such as auction houses when selling rare cars (Curioinvest, 2023). Property rights defined in a blockchain through SCs also facilitate digital scarcity that previously did not exist across digital data files (Gourévitch et al., 2021; Schaller et al., 2020). In general, tokenized assets can be replicated by 'copy and paste' if they represent a digital file. However, this does not apply to the SC, which is linked to the digital representation of the asset on the blockchain through the minting process and verifies and records the owner. Each digital file is uniquely identified by a different nonce, address, and contract code in an asset's metadata, which means it is easy to tell when a copy is being used rather than the original token. The SC thus creates value and trust in the cryptographically secured asset token as it cannot be replicated. Especially for the tokenization of physical assets, this transparency further enables traceability, verification of ownership, and provenance, which may be necessary, for example, within supply chains (Varghese and Goyal, 2018). Process optimizations like automated dividend payments (Baum, 2021; Ferreira and Sandner, 2021) or digital capital increases (Daura, 2023; Tokenstate, 2023) also create new opportunities.

3. **Trust structure** describes the mechanism for establishing trust in a service. Options include intermediary-based trust (e.g., in operators of asset tokenization suites such as Bitbond), code-based trust (e.g., cryptographic mechanisms such as SCs), or reputation-based trust (e.g., disclosure of historical transactions by sellers).

4. **Value classification** focuses on the specific service being offered. We distinguish service provisioning (i.e., asset tokenization as an intrinsic stand-alone or as an add-on as a digital counterpart to a physical object in the real world), market type (i.e., one-sided or two-sided), and token functionality. Token functions, which may depend on technological characteristics, may include store of value (Heines et al., 2021), usage rights (e.g., to drive a vintage car), and voting rights (e.g., as part of governance processes; Freni et al., 2020; Rarible, 2023), and financial capabilities such as dividend right (e.g., the expectation of recurring cash flows), speculation objects, and collectibles (Liquiditeam, 2023; Masterworks, 2023; OpenSea, 2022). Morrow and Zarrebini (2019) argue that tokens also have a tracking functionality within supply chains, for example, to verify the origin of raw materials and prevent potential fraud.

5. **Service openness** describes the availability and accessibility of a service (e.g., know-your-customer (KYC) and anti-money laundering (AML) procedures). Here, we distinguish between network accessibility (i.e., public and

unrestricted for all users; accessible only to a select, private group of users), geographic targeting (i.e., service accessible globally or only in certain countries), and verification level (high/low/no verification necessary to access service) to prevent money laundering, terrorist financing, economic sanctions or other illegal activities (Curioinvest, 2023; Nasdex, 2023; Tokenstate, 2023).

3.4.2 Value Creation & Delivery

The second perspective describes how services create and deliver value to their customers. It comprises six dimensions: ecosystem role, customer segment, key partner, key channel, token characteristic (including the sub-dimensions unit, properties, supply, and creation), and asset governance (including the sub-dimensions asset safekeeping, private key custody, and interface).

6. **Ecosystem role** describes specific actor groups, where we identify two types of services. First, service providers that support asset token issuance, operate a brokerage service, provide a service for clearing and settlement, or safekeeping of tokenized assets (Bitbond, 2023). Likewise, they offer solutions for assurance, general consulting, or analytic services (Masterworks, 2023; Templum, 2023; Liquiditeam, 2023). Second, infrastructure providers, including software and hardware producers as technology providers who, for example, develop and distribute wallets for secure asset storage or offer backend technologies for asset tokenization (Brickblock, 2023). Other players are platform operators that provide an exchange platform for sharing, buying, and selling assets on multi-sided marketplaces (Autograph, 2023; Bitbond, 2023; Liquiditeam, 2023; OpenSea, 2022).
7. **Customer segment** refers to the primary target group (i.e., individuals or organizations) to whom a service is provided. We distinguish between B2B, Business-to-Consumer (B2C) and Consumer-to-Consumer (C2C). Asset tokenization services can also address multiple audiences. For example, Bitbond (2023) operates a service that is only available to enterprise customers (B2B), whereas their token pool for creating, managing, and distributing tokens on multiple blockchains is offered both as a Web3 app (B2C) and an enterprise version (B2B).
8. The **key partner** dimension characterizes complementary actors involved in a service. First, we consider the creators of the seller side, who mint a token. Second, ancillary like technological service providers and a blockchain

network are needed for different technical aspects (e.g., token custody in wallets, consensus mechanisms, SCs). In addition, influencers may help to promote a service (Artpool, 2023; Autograph, 2023; Liquiditeam, 2023).

9. **Key channel** describes the primary distribution channel for offering a service. We distinguish between mobile application, desktop website, and technology provision without channel.
10. The **token characteristics** dimension delineates the technical parameters of a service. Included is the token unit, which indicates whether one single token represents an asset, whether it can be subdivided into smaller fractions representing fractional ownership (Freni et al., 2020; Whitaker and Kräussl, 2020; Heines et al., 2021), or whether it is represented by a quantity greater than one and allows for multiple instances, e.g., to represent multiple ownership structures (Maxima, 2023). In addition, the supply indicates how many token instances an asset may have during its lifetime (i.e., limited, variable, or unlimited). Furthermore, creation specifies whether the genesis of a token is one-time (i.e., maximum of one token issuance), conditional (i.e., token issuance based on SCs), or flexible (Ankenbrand et al., 2020; Hamledari and Fischer, 2021). Also, the transferability of ownership (e.g., vesting periods for tokenized shares), exchangeability (i.e., fungible token or NFT), and destructibility (e.g., persistence of a token in a metaverse, even if the physical equivalent no longer exists, Maxima, 2023) of tokens are distinguishable (Oliveira et al., 2018).
11. **Asset governance** indicates whether token custody is managed by the holder himself (Garcia-Teruel and Simón-Moreno, 2021) or whether a service (i.e., custodian) is offered that handles safekeeping (distinct for real-world assets and private keys for token access) (Masterworks, 2023; Bruschi et al., 2022). In addition, the interface specifies how the information exchange (e.g., purchase or sales transactions) is designed (Ankenbrand et al., 2020; Weingaertner, 2019), either via a qualitative (e.g., user interface (UI) dashboard), quantitative (e.g., application programming interface (API)), or no interface.

3.4.3 Value Capture

The third perspective represents how asset tokenization service providers derive revenue through their business model. We distinguish five dimensions: monetization, revenue source, revenue stream, payment channel, and network costs.

12. **Monetization** describes whether consumers pay for a service before it is provided (i.e., upfront) or during the process (i.e., pay-as-you-go). Upfront includes offerings that allow subscriptions to their services (Crowlitoken, 2023; Liquiditeam, 2023). Payments during the process involve, for example, transaction costs as a monetization strategy (Blockimmo, 2022; Tokencity, 2022).

13. **Revenue source** indicates which actor is the leading revenue contributor to a service. Here we distinguish between minting creators on the seller side, consumers on the buyer side, and third parties that are not directly involved in the transaction.

14. **Revenue stream** represents the structure of how a service generates revenue or income. For example, a popular means in asset tokenization are transaction costs, auctions, and value-based fees, where ownership of an asset is transferred in exchange for money or usage rights are granted on a pro-rata basis (e.g., time-dependent) with a fee dependent on the amount being paid to involved service providers. Another possibility is fixed service fees, which are not reliant on the sum transferred (e.g., payment for subscription services; Crowlitoken (2023) and Liquiditeam (2023). Another option is secondary market fees, where a service provider sets a fee for each future sale of a tokenized asset (known in the Web3 community as a royalty) and earns passive income over time as an asset gets sold on the secondary market (Masterworks, 2023; Regner et al., 2019). Additionally, there is the possibility of revenue through advertising opportunities on the service provided (Liquiditeam, 2023; Rarible, 2023; OpenSea, 2022).

15. As a **payment channel**, services can either use their own token, enable payments through other cryptocurrencies (Brickblock, 2023; Nasdex, 2023), or accept traditional fiat currencies (Autograph, 2023; Bitbond, 2023; Masterworks, 2023).

16. In terms of **network costs**, services can either use an external blockchain network and then depend on it, or they can build their own consensus network whose characteristics (e.g., transactions per second, transaction costs) they can design according to their needs.

3.5 Discussion & Implications

Our analysis indicates considerable similarities and differences on the economic perspective of asset tokenization services (see Appendix Figure A.4). First, the two-sided market type is prevalent, where buyers and sellers come together. A service offering in this context involves asset tokenization platforms where two user groups or agents interact for the benefit of both parties. It is noticeable that these intermediaries often influence the trust structure, supplemented by a code-based trust. Therefore, the customer value is not primarily advertised as the intermediation improvement but rather the increased liquidity through the tokenization of previously illiquid assets, which can be both tangible and intangible in nature. In the case of tangible assets, digital tokens are often used as a reference add-on to the physical counterpart to increase cash flow and create an additional speculation object or store of value. Within the value proposition dimension, the tracking function of tokens, for example, through SCs, represents a unique feature that allows service providers to differentiate themselves from their competitors. Concerning service openness, we note that a high verification level by means of KYC and AML plays a significant role. When considering the ecosystem role, the characteristics of platform operator services and the issuance of tokens are predominant. Asset safekeeping and various assurance and consultancy services also represent a relevant share. We also observe that some service providers address both private and business customers as potential customers, while only a few companies target the C2C segment. Key partners of service providers are mainly blockchain networks, technological service providers (e.g., wallet providers), and creators minting tokens. In terms of value capture and monetization strategies, it is noticeable that many service providers resort to pay-as-you-go. As their primary revenue source, they obtain a value-based fee, which adds to the transaction costs incurred by blockchain networks. Secondary market fees on royalties are also applicable, while fixed service fees (e.g., monthly subscriptions) are rarely utilized. We observe an indifferent structure regarding payment channels, as service providers offer their own cryptocurrencies, existing cryptocurrencies, and fiat currency payments.

Our publication highlights the economic aspects of asset tokenization, focuses on predominant services, and provides insights for academics and practitioners alike. We present a comprehensive market overview and a status-quo analysis of the ecosystem around asset tokenization based on academic and practitioner literature and an empirical development with 51 actual cases. We analyze and abstract individual business models and highlight differences. For startups and established companies developing products and services in this area, our taxonomy provides an overview of existing business models. As a result, they can identify competitors and systematically analyze niches of not yet offered (service) provisionings. Furthermore, our taxonomy dimensions and characteristics can inspire practitioners of established companies to innovate their business model and enable decision-makers to identify potential market entry opportunities. The taxonomy and associated cases thus serve as a technology-specific support tool for business model innovation in the token economy. It allows to evaluate different tokenization services, adds value for comparing viable solutions, and enhances management practices for entering this highly innovative space. Furthermore, relevant startups can be quickly ranked and evaluated for planned acquisitions.

As the analyzed market is still at an early stage and rather unexplored, our work can also serve as a starting point for further discussions on tokenization services and applicable business models - both in practice and academia. To identify the role of asset tokenization as part of a broader business model, we have expanded the perspective of previous work beyond token properties and possible applications. We add an economic perspective to existing knowledge and propose a common language and structure for the investigated research field. Thus, we contribute to a common understanding of this complex topic and suggest a tool for describing, classifying, visualizing, and analyzing asset tokenization services as a basis for future research. In doing so, we follow the call of several researchers (Sunyaev et al., 2021; Heines et al., 2021) for a more nuanced approach to the topic of asset tokenization that examines economic aspects and business model implications in addition to technological features.

3.6 Conclusion, Limitations & Future Research

Blockchain is a modern technology that claims to have the potential to disrupt business models (Iansiti and Lakhani, 2017; Tapscott and Tapscott, 2016). However, there is a large gap between promised and actual business value (Risius and Spohrer, 2017). Our taxonomy strives to contribute to this gap and investigate asset tokenization services, where tokenization can be considered a principal use case of blockchain technology. Our main contribution is a taxonomy following an established research approach (Nickerson et al., 2013). It is based on both the analysis of academic literature and the consideration of practitioner publications and involves 51 companies that use asset tokenization as a fundamental component of their business. Our research builds on the descriptive knowledge of tokenization and related frameworks and contributes to exploring this young research area. Our study demonstrates that asset tokenization requires an interdisciplinary and multi-faceted approach. The 16 included dimensions, 14 sub-dimensions, and 101 characteristics offer a first attempt toward the formal descriptions of tokenization service businesses and support the multi-perspective discussion on the value of the blockchain-based token economy.

When interpreting our results, we consider some **limitations** that inherently constrain our study. First, the tokenization ecosystem faces rapid technological developments, which means that concepts and services constantly evolve. Therefore, our taxonomy is a temporary snapshot that must be updated regularly to remain relevant and iteratively incorporate new dimensions and characteristics as they emerge. Second, the taxonomy is based on the analysis of multiple academic and practitioner sources by the author team. As such, the collection is open to interpretation. The absence of a universally accepted definition of asset tokenization further complicates the identification of specific characteristics and dimensions so that other researchers might derive different perspectives depending on their individual influences and preferences. To address this issue, the author team conducted the analyses independently. In addition, they could potentially find other data sources that we have not previously considered. Considering that 23 relevant articles were identified in the initial literature search and 12 additional publications were found in the backward and forward search might indicate that other search strings or databases would have yielded further articles. Thus, we propose to extend the literature search to more databases (e.g., Taylor & Francis, ACM Digital Library) and additional keywords (e.g., Web3, Crypto, NFT) to compare the results with ours. Since only 51 services were analyzed in this article, extending the company analysis could also yield interesting results. We note that we analyzed only companies with an English website.

However, these limitations point to **opportunities for future research** directions. For example, the analysis of services could be extended to other companies or business models in industries similar to asset tokenization (e.g., blockchain security and auditing services). Also, the same services as we analyzed could be revisited at a later time to explore possible changes in their business model. Companies with missing data could be contacted to obtain more data points than the official websites we used. Future research could evaluate the dimensions and characteristics of our taxonomy through expert interviews with representatives from research and practice to further confirm or iteratively revise our findings. This qualitative review for completeness and applicability would improve the validity of our results. A quantitative evaluation of our taxonomy by individual raters whose assessment could be measured by Fleiss' kappa (Fleiss, 1971) could also provide an additional evaluation approach. The 'trust structure’ of asset tokenization services potentially represents an up-and-coming area of research and should be explored in detail. Addressing blockchain-based systems, Sedlmeir, Barbereau, et al. (2022) note the inherent tension between digital identities, trust structures, and privacy challenges in decentralized ecosystems. This tension is also reflected in our taxonomy’s intermediary-based, code-based, and reputation-based trust elements. Accordingly, the role of issuers in tokenization services and their connection to digital identities presents a persuasive research endeavor. Highlighting challenges in tokenization, this topic is directly related to monetization strategies in decentralized networks. Exploring business models and the level of institutional trust that is still required to ensure, for example, that an object is not tokenized more than once, regardless of disintermediation in decentralized systems, might be of interest. Similarly, the influence of tokenization in the metaverse represents an attractive research avenue. Another common direction in IS taxonomy research is to derive archetypal patterns of asset tokenization services. Building on the identified archetypes, DPs could be derived to guide, for example, particularly successful, popular, or sustainable services. Also, the ecosystem, possible platforms, and value co-creation of asset tokenization services could be investigated in more detail from the service-dominant logic perspective (Lusch and Nambisan, 2015), or a service artifact could be developed using Design Science Research (DSR) (Hevner, March, et al., 2004).

4

A Critial Perspective on Tokenized Governance Mechanisms

This chapter is based on a submitted article titled "Are Blockchains Really Decentralized? A Multimodal Perspective on Tokenized Decision Making and Venture Capital Investments in Web3". The article was co-authored by Kai Binder and Christof Weinhardt and is currently under review at the 57th Hawaii International Conference on System Sciences (HICSS). The tables and figures were systematically renamed, reformatted, and appropriately referenced to align with the overall structure of the thesis. To further enhance clarity and consistency, formatting, and reference style were adapted and references were updated.

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Abstract: Decentralization in Web3 projects is a polarizing topic, with proponents and critics presenting divergent views on blockchain governance. To navigate these tensions, this study employs an exploratory design science research approach. It utilizes a multiple-case study methodology to develop a framework for tokenized decision making and analyze venture capital investments in Web3 projects. We enable researchers and practitioners to grasp the phenomenon in a structured manner and address a critical sub-field of information systems research, which focuses on power concentration in Web3 ecosystems.

Keywords: Blockchain, Web3, Decentralization, Venture Capital, Case Study.

4.1 Introduction

Technological innovations involving blockchains and related DLTs are at the center of the academic and public discourse. Praised as a 'trust machine' (The Economist, 2015) that replaces human trust with technological system properties and community-based governance (Beck and Müller-Bloch, 2017), researchers and practitioners have highlighted the disruptive potential and impact on society, businesses, and individuals (Hamady et al., 2022; Lacity, 2022). The technology is considered an anti-thesis and challenger to the dominance of digital platform titans and is discussed as a disruptive innovation reshaping business models and industries (Frizzo-Barker et al., 2020; Beck, Müller-Bloch, and King, 2018). At its core, this paradigm shift aims to democratize digital interactions and decentralize IS through bilateral connections and cryptographic protocols governed by their users (Kölbel, Linkenheil, et al., 2023). Unlike the current internet landscape, which is characterized by the dominance of a few organizations, blockchain's decentralized design enables a network of participants to collectively agree on the state of a shared ledger without relying on human intervention or a central point of control. Thus, removing intermediaries through the design objective of *decentralization* is noted a pivotal aspect of blockchains (Chalmers, Matthews, et al., 2021; Werner, Frost, et al., 2020; Kölbel and Kunz, 2020), paving the way for a plethora of applications that fall under the umbrella term *Web3* (Kölbel, Dann, et al., 2022; Voshmgir, 2020).

However, the promising potential of decentralized socio-technical systems is accompanied by new challenges that impede the adoption and implementation of Web3 in various industries (Beck and Jain, 2023). This paper focuses on one specific, non-technical challenge that increasingly attracts interest from both academic and practical communities: the coordination efforts required for governing the polycentric Web3. Researchers perceive these systems as a combination of on-chain protocols and off-chain agents (Beck and Jain, 2023) aiming to provide a more democratic and inclusive alternative to corporate governance. Yet, they also highlight the need to examine the limitations of trust-free systems (Hawlitschek, Notheisen, et al., 2018; Glaser et al., 2019). A notable example highlighting the fundamental challenges associated with decentralized governance is a tweet by serial entrepreneur Jack Dorsey, which sparked controversy and went viral. In the tweet, Dorsey suggests that users do not truly own Web3 and asserts that venture capital firms and limited partners ultimately control it, casting doubt that a decentralized Web3 may be illusory as project funding leads to de facto centralization (Dorsey, 2021). This statement aligns with early research that questions the level of decentralization in Web3 systems (Feulner et al., 2022; Werner, Freudiger, et al., 2022; Schneider, 2019;

Gochhayat et al., 2020), suggesting *"the illusion of decentralization"* (Aramonte et al., 2021).

This study aims to explore these tensions between criticisms of decentralization and the claims made by Web3 movement proponents. As blockchain governance has been identified as lacking sufficient research, particularly in practical applications (Beck, Müller-Bloch, and King, 2018; Liu, Lu, Zhu, et al., 2023), we focus on this area. Typically, Web3 projects are governed by coders and unregistered token holders who facilitate tokenized decision making (TDM) utilizing governance tokens by following the principle of 'one token, one vote'. Venture capital firms acquire tokenized decision rights (TDR) within private token sales and are thus involved in governance. Consequently, the allocation of TDRs is crucial for determining the level of decentralization in Web3 systems (Liu, Lu, Zhu, et al., 2023). While decentralized governance has been explored in various aspects, research on TDM remains largely unexplored. Although some studies exist, particularly in the context of DeFi (Barbereau, Smethurst, Papageorgiou, Sedlmeir, et al., 2023; Barbereau, Smethurst, Papageorgiou, Rieger, et al., 2022), there is a notable lack of empirically supported research on the impact of venture capital funding on the decentralization of Web3 projects. This is surprising considering the growth rate of venture capital investments in Web3 of over 700%, exceeding $25 billion in 2021 alone (Pitchbook, 2023), as investors receive TDRs in exchange for funding through private token sales. In response to this notable gap and Web3's contested governance, our research objective is multimodal. After conceptually elaborating on the shadowy phrase of decentralization with a special emphasis on governance (Section 4.2), we first state our methodological approach (Section 4.3) to develop a framework for analyzing TDM in Web3 projects (Section 4.4), building on ongoing efforts to understand governance artifacts (van Pelt et al., 2021), and bridging the gap that *"little is known about what and how decisions are made and enforced in blockchain systems"* (Ziolkowski and Schwabe, 2019). Second, we empirically discuss our framework by examining the extent and manner in which venture capital firms exert influence on blockchain governance (Section 4.5), potentially posing a threat to Web3's decentralization. In summary, we address two RQs:

Research Question 1: *What conceptualizes TDM and which trajectories impact Web3's decentralization?*

Research Question 2: *What influence do venture capital firms have on TDM in Web3?*

Motivated by the topic's novelty and the tension between decentralization and concentrated token power, we conducted an exploratory DSR project with a multiple case study approach to develop our framework artifact. We therefore sourced both academic literature and qualitative data to derive knowledge about TDM entitlements and distribution strategies. Our study primarily addresses a critical subfield of IS research, which focuses on power relations and critical, interdisciplinary research that studies socio-technical topics related to Web3 ecosystems.

4.2 Blockchain & Web3 Decentralization

The blockchain concept enables decentralized consensus among independent computing devices, referred to as nodes, without the need for a central authority. Nodes communicate in P2P networks, where each peer acts as both client and server. Techniques such as time-stamping and cryptographic puzzles are employed to ensure the integrity of transactions and prevent double-spending. SCs expand the functional capabilities of blockchain beyond cryptocurrencies, facilitating the development of a decentralized application (dApp) and decentralized autonomous organization (DAO). However, this 'decentralization' is a non-binary and multimodal concept influenced by technical, social, political, and economic factors reshaping existing power dynamics (Pfister et al., 2022; Bodó, Brekke, et al., 2021; Sai et al., 2021).

Technical decentralization refers to the extent to which a system is distributed among interconnected nodes operating independently, without a central authority (Sunyaev et al., 2021). A high degree of technical decentralization is achieved when multiple nodes communicate and participate in consensus mechanisms with equal influence, geographical distribution, and client diversity (Pfister et al., 2022; Lee et al., 2021; Sai et al., 2021; Buterin, 2017). In PoW networks, miners are selected as block-proposing leaders based on their computational contribution, while in PoS networks, validators are selected with a probability proportional to their economic capabilities, such as token stakes. Cryptoeconomic mechanisms incentivize nodes to join and contribute to the network by distributing block rewards (PoW) or staking rewards (PoS), incorporating principles of game theory (Lamberty et al., 2023).

Socio-political, economic decentralization refers to the extent of equal distribution of permissions and responsibilities among independent actors acting according to their individual incentives (Sunyaev et al., 2021). This aspect encompasses the decision making processes within DAOs, where improvement proposals determine the course of action (Barbereau, Smethurst, Papageorgiou, Sedlmeir, et al., 2023; Hassan and De Filippi, 2021). Ownership and TDM strongly influence this perspective of decentralization, as they describe the distribution of tokens among different addresses and ultimately assess the phenomena of wealth concentration, with high concentrations leading to centralization at the blockchain level (Sai et al., 2021; Liu, Lu, Zhu, et al., 2023).

4.3 Methodological Approach

Aligned with the blockchain research agenda of Treiblmaier (2019), our study adopts a DSR approach to develop a theoretically grounded and practically evaluated artifact that contributes to the understanding of blockchain governance. DSR is a pragmatic research paradigm that focuses on creating innovative artifacts to address real-world problems (Hevner and Chatterjee, 2010). In our case, the artifact takes the form of a conceptual framework for TDM, which captures the the various perspectives and trajectories impacting decentralization within the Web3 context. To ensure rigor and relevance in our study, we employ a twofold approach: **First**, we build on Smit et al. (2020), conduct a review of the existing knowledge base and incorporate state-of-the-art research on blockchain governance. This includes academic literature as well as qualitative data, such as project documentation, white papers, and grey literature. The findings from this review serve as iterative inputs in the development of our artifact. **Second**, to account for the topic's novelty and rapid technological developments, we follow the recommendations of Smit et al. (2020) and adopt a multiple case study approach. Given that our focus is on assessing the impact of venture capital firms on Web3 decentralization, we align with the recommendations of Yin (2009) for case study designs, specifically employing the 'Gaps and Holes' approach. Our rationale for selecting the case study design is as follows: Decentralization depends both on technical and socio-political perspectives. Technical decentralization involves analyzing infrastructure properties like consensus mechanisms and blockchain nodes, while socio-political decentralization entails examining processes like developers' improvement proposals and token holders' wealth concentration (Beck, Müller-Bloch, and King, 2018; Pfister et al., 2022). Decision-making in blockchains has evolved into a collaborative process with delegative decision-making, where governance mechanisms allocate TDRs to participants based on token ownership (Barbereau, Smethurst, Papageorgiou, Rieger, et al., 2022; Smit et al., 2020). These governance mechanisms can impact both technical decentralization (e.g., consensus mechanism) and socio-political decentralization (e.g., improvement proposals), with the distribution of TDRs determining the level of centralization (Liu, Lu, Zhu, et al., 2023). Venture capital firms have the ability to acquire and exercise TDRs, thereby influencing the decentralization of blockchain networks.

Case Selection. We conducted an embedded case study design on Web3 projects receiving venture capital investments, employing multiple units of analysis to develop inductive theory (Yin, 2009). The units of analysis were identified as ’elements influencing decentralization’. By selecting multiple cases, we aimed to achieve a suitable level of generalization, eliminating single-case bias, and enabling transparent observation of emerging relationships and constructs. To ensure adequate sampling, we utilized the purposeful sampling technique (Yin, 2009) based on the following criteria: (1) *Capital:* Projects with high funding (at least $150 million) and low funding (below $20 million). (2) *Market Relevance:* Projects ranked within the top 30 by market capitalization. (3) *Blockchain Heterogeneity:* Projects utilizing different blockchain networks.

Through various levels of analysis, including projects from Layer 1 (L1) and Layer 2 (L2) blockchains, DAO-governed and non-DAO governed projects, infrastructure and application projects, and variations in market capitalization and venture capital-funding, we were able to triangulate findings with insightful results (Yin, 2009). In total, we analyzed four distinct projects:

(1) *Polygon:* A DAO-governed project that raised $450 million in funding through a private sale in February 2022. It is an Ethereum L2 scaling solution that utilizes sidechains while ensuring asset security and decentralization through PoS validators.

(2) *Solana:* Completed a $314.15 million private token sale in June 2021, led by venture capital firms such as Andreessen Horowitz (a16z) and Polychain Capital. Solana’s developments are driven by Solana Labs Inc. It is a L1 chain that aims for fast transactions at low network fees.

(3) *Uniswap:* A DeFi application known as the first non-custodial crypto-exchange to surpass $100 billion in trading volume (Barbereau, Smethurst, Papageorgiou, Rieger, et al., 2022). Unlike other projects, Uniswap did not provide governance tokens to investors in exchange for their capital. Instead, equity was sold to Uniswap Labs LLC, which launched the native network token and airdropped 15% of the total supply to early users and liquidity providers.

(4) *Cosmos Hub:* A PoS-based project that develops a blockchain ecosystem with multiple interconnected and independent networks. As the Cosmos project only raised $17.6 million of venture capital funding, it is included for comparative purposes, providing contrasting results by examining this low-funded project.

Data Collection. We collected both qualitative and quantitative data. Qualitative data includes official project documentation and white papers. Quantitative data was obtained from publicly available sources like the projects' blockchain explorers for node information and information on venture capital funding. To analyze the current holdings of venture capital firms, the 'Arkham intelligence blockchain analytical tool' was utilized as well. The data collection period spanned from March to May 2023.

Data Analysis. By an exploratory approach combining within-case and cross-case analyses, we followed an iterative process without initial hypotheses. Each case was individually examined, and the gathered information was documented and organized for comparative analysis. The preliminary theories were tested using replication logic (Yin, 2009), comparing empirical patterns with theoretical assumptions in the design artifact. The iterative process continued until theoretical saturation was reached, indicating that further iterations would not yield additional insights. We thereby exposed 'Gaps and Holes', which inform the refinement of the design artifact. This process, guided by the pattern-matching logic (Yin, 2009), ultimately led to the TDM framework (see Section 4.4).

4.4 Tokenized Decision Making Framework

Our TDM framework (see Figure 4.1) provides a conceptual understanding of blockchain governance, specifically focusing on decision-making mechanisms that influence decentralization in Web3 projects. The framework dissects TDMs into two components: **decision management rights (DMR)** and **decision control rights (DCR)**, which respectively encompass the rights for creating and implementing proposals, and the rights for approving and monitoring proposals (Beck, Müller-Bloch, and King, 2018; Pfister et al., 2022; Smit et al., 2020). These DMR and DCR rights are granted through three major decision-making governance mechanisms: (1) *Block proposal* voting on the consensus layer (Pfister et al., 2022; De Filippi et al., 2018). (2) *Improvement proposal* voting on the protocol layer (Azouvi et al., 2019; Beck, Müller-Bloch, and King, 2018). (3) *Governance proposal* voting on the protocol and application layer (Barbereau, Smethurst, Papageorgiou, Sedlmeir, et al., 2023).

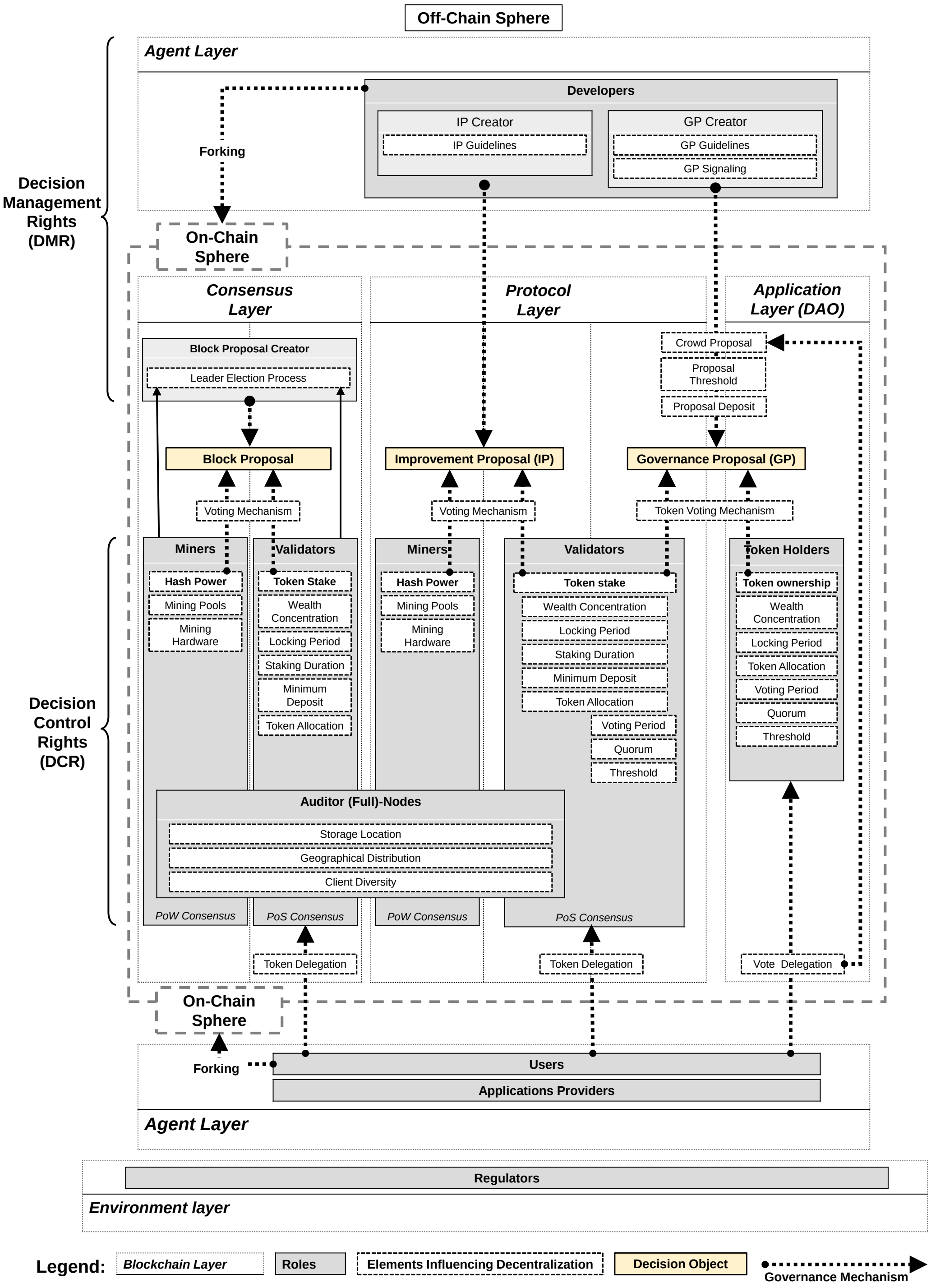

Fig. 4.1.: Tokenized Decision Making Framework.

4.4.1 Layers & Spheres

DMR and DCR are distributed among multiple stakeholders operating on different layers within a blockchain system's governance structure (De Filippi et al., 2018; Notheisen, Cholewa, et al., 2017; Reijers et al., 2021).

The **on-chain governance sphere** refers to the rules that are directly encoded into the blockchain infrastructure and are executed through formal mechanisms (De Filippi et al., 2018). This sphere involves actors such as miners, validators, and token holders, who operate within their respective layers. In contrast, the **off-chain governance sphere** encompasses all other actors who operate on the agent layer and the environment layer rather than at the technical level (De Filippi et al., 2018; Reijers et al., 2021). These actors include (software) developers who implement code, the legal entity or DAO of a project, application providers or complementors who offer services that support the ecosystem, and users who form the most decentralized group among all actors (Liu, Lu, Zhu, et al., 2023; Buterin, 2017). On-chain governance, embedded in the technology itself, follows the 'rule of code' and is hard to bypass (De Filippi et al., 2018). Compared to off-chain governance, which relies on informal procedures and social norms, on-chain governance is more transparent, verifiable, and auditable (De Filippi et al., 2018).

Both spheres are governed by rules that can be endogenous or exogenous (De Filippi et al., 2018). In the off-chain sphere, *endogenous rules* pertain to decision-making on protocol changes, including the decision to fork a network or implement a proposals, originating from the agent layer and enforced in the on-chain sphere (Beck and Jain, 2023). Improvement proposals are created off-chain by developers and implemented on-chain through formal voting. The off-chain decision-making process can be supported by a community voting scheme. *Exogenous rules*, on the other hand, consist of technology standards or regulations imposed by third parties such as regulators (De Filippi et al., 2018; Reijers et al., 2021).

Our framework further captures multimodal **blockchain layers**, that are interdependent and form a hierarchy. The protocol layer dominates the consensus and application layers by establishing the on-chain rules (Rauchs et al., 2018). The agent and environment layers are off-chain and considered exogenous to the blockchain. The on-chain layers can be enhanced by connecting dependent, interfacing, or external systems, such as dApps (Rauchs et al., 2018). We incorporate the following elements: (1) users' and developers' DMRs on the agent layer, (2) regulatory restrictions on the environment layer, (3) decision-making within SC-based applications on the application layer, (4) decision-making within the consensus mechanism on the consensus layer, and (5) decision-making in the form of proposals on the protocol layer.

4.4.2 Governance Mechanisms affecting Web3 Project Decentralization

Next, we highlight the impact of distinct TDM elements on the decentralization of Web3 projects. Our analysis centers on the influence of network actors on TDM's mechanisms and concepts. Specifically, we examine the role of miners' hash power (PoW) and validators' token stake (PoS) at both the application and protocol layers, as well as the wealth concentration of token holders at the application layer. The concept of 'one token, one vote' allocates more TDM rights to top validators and token holders in proportion to their holdings, thereby impacting decentralization dynamics.

Block Proposal Voting on the consensus layer determines the assignment of DMRs to the creator of a block proposal (Kannengießer et al., 2020). The decentralization of auditor (full-)node thereby depends on the storage location of their hardware and software components (Gochhayat et al., 2020), their geographical distribution (Lee et al., 2021; Sai et al., 2021), and their client diversity (Buterin, 2017).

In the PoW consensus, miners may further influence decentralization through three factors: (1) DCRs are allocated to miners based on their *hash power*, along with the auditor (full-)node role responsible for storing and verifying proposed blocks (Pfister et al., 2022). (2) *Mining pools* consolidate computing resources of multiple miners, distributing a fraction of the block reward to participants based on their hash power within the pool (Gochhayat et al., 2020; Lee et al., 2021). Venture capital firms can acquire hash power either by controlling a mining pool provider or by establishing their own mining pool through investments in hardware and node operations. (3) Specialized *mining hardware* designed for efficient hash function calculations can serve as a potential single point of failure and requires significant capital investment. Notably, it is estimated that a single company, Bitmain, manufactures 75% of Bitcoin mining hardware (Arnosti and Weinberg, 2022).

In the PoS consensus, decentralization may be influenced by six factors: (1) The *token stake* held by a validator determines their likelihood of being selected as a block proposal creator. Validators with higher token stakes have a greater chance of being chosen as leaders granted with DMR. (2) The *wealth concentration* captures the distribution of token stakes, which can often be concentrated among a few entities. A more evenly distributed token wealth leads to greater decentralization (Werner, Freudiger, et al., 2022). (3) The *initial token allocation* at launch of a project determines the number of addresses that initially exert control over the project and the corresponding voting power possessed by these wallet addresses (Barbereau, Smethurst, Papageorgiou, Sedlmeir, et al., 2023). (4) The *validators' staking duration* can impact the leader election process in PoS. (5) The *locking period* that ensures the validators' commitment to a network for specific time period (Liu, Lu, Yu, et al., 2023). (6) The *minimum deposit* refers to the threshold for the minimum stake that must be locked. A lower minimum deposit threshold allows for more participants to join the validator role, thereby enhancing decentralization. However, it also poses a potential risk to network security if only a small amount of token stake is contributed.

Improvement Proposal Voting involves the distribution of TDM across on-chain and off-chain spheres. In this mechanism, DMRs are distributed among off-chain proposal creating developers and on-chain record producing DCRs at the protocol layer. This means that off-chain governance influences on-chain governance (De Filippi et al., 2018). While anyone with sufficient technical knowledge can submit a DMR proposal in governance forums, DCRs are typically assigned to auditor (full-)nodes, who independently decide whether to perform a client upgrade to accept a proposal (Kannengießer et al., 2020; Pfister et al., 2022).

Governance Proposal Voting involves the distribution of power among token holders (Barbereau, Smethurst, Papageorgiou, Rieger, et al., 2022). These token holders have exclusive voting rights and vote for or against governance proposals (Barbereau, Smethurst, Papageorgiou, Sedlmeir, et al., 2023). Their influence on a project's decentralization differs between DMRs and DCRs.

Factors affecting DMR include: (1) *Guidelines* established on governance forums or social communities like GitHub. (2) *Signaling procedures* that gather sentiment through off-chain polling applications, allowing for discourse and enhancing decentralization. (3) *Proposal thresholds* required to submit a proposal. (4) *Autonomous crowd proposals*, created by small token holders through SCs, which can be used to meet the proposal threshold when other token holders delegate their voting rights. (5) *Proposal deposits*, which may be required to enter the voting process and serve as protection against spam and a potential barrier for less wealthy proposal creators.

Factors affecting DCR include: (1) *Token ownership* on the application layer, determining the voting rights and influence of token holders. (2) The *duration* of the voting period, which provides more opportunities for voters to recognize proposals and cast their votes. (3) The *quorum*, which represents the minimum percentage of voting power required for a proposal to have a valid result, ensuring a minimum level of participation. (4) The *threshold* of ’yes’ votes needed for a proposal to pass, highlighting the potential concentration of power in a single token holder to pass a proposal.

Above all, the **Token & Vote Delegation** mechanism allows for the assignment of proxy votes to community members (Brekke et al., 2021; Liu, Lu, Zhu, et al., 2023). Tokens can be delegated to either validators in the consensus layer or other token holders in the application layer, depending on the protocol’s permissions. On the *consensus layer*, when users delegate their tokens to validators, they become delegators and receive a proportionate share of the staking reward. The delegators’ responsibility to vote is (temporarily) transferred to the validator. On the *application layer*, users delegate their tokens to representatives and their voting rights are executed by invoking the corresponding delegation SC of the DAO. Delegators, in this case, do not receive any reward for their vote delegation and are not required to evaluate proposals. Overall, token delegation has the potential to enhance the effectiveness of governance decisions and increase the participation of token holders. However, it may also contribute to token concentration among top validators and representative token holders, posing centralization risks.

4.5 Discussion

Motivated by calls for research on blockchain decision rights (Beck, Müller-Bloch, and King, 2018; Liu, Lu, Zhu, et al., 2023), we contribute to the theorizing about decentralized system governance by providing a conceptual perspective on the dual nature of blockchain governance, both as an object of TDM and as an instrument for executing governance. Our framework specifically focuses on the governance of the blockchain itself rather than governance through the blockchain. Previous research on blockchain governance has recognized the importance of decision rights but has not systematically differentiated between DMR and DCR. Additionally, there has been a lack of a comprehensive framework encompassing the various cooperative and competitive governance mechanisms used in Web3 projects. To address these gaps, our framework dissects the nature of decision rights and the mechanisms that grant these rights, thereby influencing decentralization. We consider project-based and community-based characteristics and acknowledge the interdependency between social and technical aspects by examining internal and ecosystem factors influencing governance decisions. This analysis considers two interconnected spheres: the on-chain and off-chain spheres. Actors within these spheres primarily influence three decision objects in TDM: (a) block proposals, (b) improvement proposals, and (c) governance proposals.

Employing an exploratory multiple case study approach, our multimodal perspective further analyzed venture capital investments in Web3 projects. By combining qualitative and quantitative data and applying our framework, we studied TDM in four projects: Polygon, Solana, Uniswap, and Cosmos. Our interpretation of the findings is descriptive and non-evaluative. The principal findings reveal that the ownership structures of TDM impact blockchain governance and play a crucial role in determining the level of decentralization in Web3 projects. Contrary to the notion of distributed governance in Web3, our analysis indicates that TDM, as part of blockchain governance mechanisms, tends to concentrate power among a select few, resulting in quasi-oligopoly dynamics. Our findings align with Chainalysis (2022) study, which analyzed the governance token distribution of DAOs and finds that *"less than 1% of all holders have 90% of the voting power"*. For instance, our study on the distribution of tokens shows that venture capital firms exert influence by acting as validators or holding substantial amounts of tokens. We thereby support Barbereau, Smethurst, Papageorgiou, Rieger, et al. (2022) that major protocols exhibit an uneven distribution of voting power, with large token holders exerting strong influence while the concentration of token wealth arises from substantial initial token allocations during private funding sales. In the case of Solana, venture capital obtained 35.4% of SOL tokens while receiving 3.8% in Polygon and 12.1% in Cosmos. Polygon further limits validators to 100, while Cosmos limits them to the top 175 stakers, making it difficult or costly for new validators to join. As a result, further token delegation to validators occurs, leading to wealth concentration. Centralized exchanges operate the top validators on Polygon and Cosmos. Interestingly, Solana stands out as the only network without caps or limitations on validators. Its Nakamoto coefficient of 33 indicates greater decentralization among validators. Token and vote delegation mechanisms further strengthen venture capital firms' voting rights, limiting project decentralization. Regarding political decentralization, validators hold voting rights in block proposal voting and improvement proposal voting mechanisms. The allocation of voting rights is proportional to the token stake, with most venture capital validators in the Solana network. However, quorum minimums primarily consider the number of tokenized voting rights engaged rather than the number of voters, intensifying the influence of token-holding venture capital. The top five token holders' addresses in Uniswap possess enough tokens to achieve the quorum required to pass proposals. Among them, the venture capital firm a16z owns 15 million UNI tokens, with other venture capitalists such as Jesse Walden and Gauntlet also holding large amounts. Collusion among the top five token holders could grant access to the Uniswap DAO, which has a treasury value of $1.6 billion. In this vein, a16z's voting power played a role in a controversial governance proposal in June 2021, where the venture capitalist single-handedly passed a proposal to create a 'DeFi Education Fund' by allocating $20 million from the Uniswap treasury.

While our case study analysis aligns with the assertion of the *"illusion of decentralization"* (Aramonte et al., 2021), we see a potential **trajectory towards decentralization**. In general, achieving a high level of decentralization in blockchain networks involves trade-offs, as these networks can only prioritize two out of three properties: decentralization, security, and scalability (Kannengießer et al., 2020). Bitcoin and Ethereum, for instance, prioritize decentralization and security over scalability on their core L1 layer (Barbereau, Smethurst, Papageorgiou, Sedlmeir, et al., 2023). However, high socio-political decentralization can lead to delays in governance decision making (De Filippi et al., 2018). To address this, we propose a trajectory for socio-political decentralization, starting with low decentralization during the project's creation phase and gradually moving towards a desired high decentralization during the operational phase (Pfister et al., 2022; Sunyaev et al., 2021). Early-stage projects often require a 'founder dictatorship' to facilitate efficient decision-making and address code vulnerabilities (Beck, Müller-Bloch, and King, 2018; Buterin, 2017). This role is often fulfilled by founders and core developers (Liu, Lu, Yu, et al., 2023). In some cases, venture capitalists, like Multicoin Capital in the Solana project, may also act as benevolent dictators. During the operational phase, vulnerabilities can be addressed by transitioning towards decentralized stakeholder governance and utilizing on-chain governance mechanisms (Pfister et al., 2022). Alternative voting mechanisms, such as quadratic voting, can facilitate further decentralization. For example, DAOs could employ quadratic voting, where the number of votes is determined by the square root of the number of tokens held (Barbereau, Smethurst, Papageorgiou, Sedlmeir, et al., 2023; Liu, Lu, Yu, et al., 2023). This approach reduces the influence of wealthier token holders as the cost of additional votes increases quadratically.

Regulators can employ our framework to structure, establish, and monitor Web3 projects that encompass the diverse mechanisms involved in TDM. By considering regulatory characteristics such as anti-trust, anti-monopoly, and anti-concentration laws, rules and compliance systems can be developed to govern both the on-chain sphere, as an IT artifact, and the off-chain sphere, encompassing the social system with its associated rules and practices influencing Web3. Moreover, developers are provided with guidance on addressing decentralization in the design and implementation of their systems.

Limitations & Research Avenues. When interpreting our results and despite carefully selecting multiple units of analysis, specifying decentralization is challenging. Thus, our findings' generalizability and external validity (Yin, 2009) are inherently limited, providing avenues for future research. First, the selected cases are subject to frequent changes, particularly in project documentation. Therefore, the validity of our qualitative data depends on the extraction time, and any subsequent implementation of proposals may undermine our findings. Thus, our results are context-specific and time-specific. Consequently, our findings should not be regarded as exhaustive or universally applicable to every Web3 project, as our theoretical contribution is descriptive and does not establish causality. However, our framework can be applied to a broader range of cases. By utilizing the TDM framework as a common thread, governance patterns can be identified among different cases. Second, while the authors of this paper have mapped characteristics per mechanism, drawing from relevant literature and discussing any deviations, empirical testing is crucial to evaluate the robustness of conceptual research. Validation research can involve techniques such as surveys, interviews, and focus groups, ideally triangulated for a comprehensive understanding of the framework's validity and applicability. Feedback from these methods can contribute to the incremental refinement of the framework. Third, it is worth noting that our research primarily focuses on governance within the specific context of Web3 projects, and further investigation is needed to explore the effects of laws and regulations on blockchain governance. Additionally, existing literature on blockchain governance often centers around public permissionless networks, whereas our selected cases do not differentiate between public and private permissioned blockchains. Comparing the results when applying the framework to both types of blockchains can provide valuable insights into the differences in governance. Finally, an intriguing area for future research would involve defining criteria for *good* decentralization in Web3 projects. As our study demonstrates, the definition of good decentralization can vary depending on the context and various quality properties, such as project level, transparency, efficiency, and balance of power.

Part III

Design

5

Literature Review on Decentralized Marketplaces

This chapter is based on a peer-reviewed article titled "Giant or Dwarf? A Literature Review on Blockchain-enabled Marketplaces in Business Ecosystems". The article was co-authored by David Dann and Christof Weinhardt and is published in the 17th International Conference on Wirtschaftsinformatik (WI) Proceedings. The tables, figures, and appendices were systematically renamed, reformatted, and appropriately referenced to align with the overall structure of the thesis. To further enhance clarity and consistency, formatting, and reference style were adapted and references were updated.

Publication details: *Kölbel, T., Dann, D., & Weinhardt, C., Giant or Dwarf? A Literature Review on Blockchain-enabled Marketplaces in Business Ecosystems, 17th International Conference on Wirtschaftsinformatik Proceedings, 2022, 3.*

Abstract: While advocates argue for the disruptive impact of marketplace business models and blockchain in various regards, their practical effects on today's organizations are still limited. This study reviews the current body of literature on blockchain-enabled marketplaces in business ecosystems, outlines present scopes, and disregarded topics. Our review shows that publications predominantly focus on conceptual models that favor blockchain-for-all-solutions and neglect several fundamental marketplace dimensions. We raise a critical voice regarding the status quo and outline paths for future research.

Keywords: Blockchain, Marketplace, Business Ecosystem, Literature Review.

5.1 Introduction

> *"How can a major business segment be invaded and conquered in a matter of months by an upstart with none of the resources traditionally deemed essential? And why is this happening today in one industry after another?"* (Parker, Van Alstyne, et al., 2016, p.3)

As Parker and colleagues illustrate, today's organizations face a multitude of challenges. Besides addressing the digital transformation, new market competitors challenge established players with their ecosystems and disrupt industry dynamics. Prime examples of this paradigm are sharing services like Uber or Airbnb, which effectively allocate resources among users. They act as 'Matchmakers' (Evans and Schmalensee, 2016) between two (or more) customer groups that play different roles in a two-sided market (Rochet and Tirole, 2003), usually represented by a supply-side and demand-side (Täuscher and Laudien, 2018). At the center of a two-sided market ecosystem is a digital infrastructure, often orchestrated by one dominant firm. Their primary goal is to convince as many users as possible of their concept and generate network effects (Evans and Schmalensee, 2016). However, to establish a solid user base, the most crucial endeavor for matchmakers is building trust (Hesse et al., 2020). Consequently, scandals involving data sovereignty have shaken this trust (Vanian, 2018). As a result, more and more voices call for alternative models to today's 'winner-takes-all' favoring platform economy (Parker, Petropoulos, et al., 2020; Federal Ministry for Economic Affairs and Energy (BMWi), 2020; Moore and Tambini, 2018), especially in business interactions (European Commission, 2018).

In the context of decentralization, a new technology has emerged that offers an alternative to toady's oligopoly structures: blockchain. It is often used as a prime example of a movement aiming to disrupt the disruptors, also referred to as the *decentralized web* or *Web3* (Voshmgir, 2020). The basic idea of this paradigm shift is to democratize the web by leveraging technologies like blockchain, MPC and others, that rely on cryptographically secured mechanisms and empower individual sovereignty. In Web3, the system itself, data, and interaction rules are not managed by a few companies or organizations that rule the internet as it exists today. Instead, ecosystems are governed by their users, operated via a distributed network topology, and built upon open protocols.

Since the last decade, a highly diverse and steadily growing community of scholars studies blockchain phenomena. Researchers analyzed various technological aspects

(Antonopoulos, 2014), its potential in different application domains (Casino et al., 2019), application frameworks (Pedersen et al., 2019), and how the technology could potentially be disruptive for intermediaries (Glaser et al., 2019). Despite these efforts, scholarly publications on blockchain-related markets seem to focus primarily on generic or consumer perspectives (Dann et al., 2020; Notheisen, Hawlitschek, et al., 2017). We also note these foci among literature reviews (Notheisen, Cholewa, et al., 2017). Driven by expectations about blockchain's transformational impact on businesses, recent IS conferences indicate an increased community interest to focus both on the IT-artifact and surrounding (economic) structures of blockchain-based ecosystems. Following this research stream, we argue it is time to explore a blockchain-enabled marketplace (BEM) in business ecosystems, where a variety of organizations interact with each other. Towards this end, our study structures extant contributions on this topic in a concept-centric literature review. Following Leidner (2018)'s polylithic framework, we set out to conduct an organizing literature review that focuses on synthesis rather than theorizing. We adopt a holistic perspective and aim to evaluate whether future inquiries build on the shoulders of giants or dwarfs. Against this background, we address the following RQ:

Research Question: *How to synthesize and structure available literature on BEMs in business ecosystems?*

In the remainder of the paper, we draw rich contextual insights that both practitioners and researchers hopefully deem fruitful. We start with a brief overview of marketplace and blockchain fundamentals (see Section 5.2) and the methodological design of our literature review (see Section 5.3). Then, we provide a holistic overview and unified basis for research related to BEMs in business ecosystems, summarizing design concepts across studies (see Section 5.4). To avoid heterogeneous understanding, we analyze and structure each concept along Weinhardt, Holtmann, et al. (2003)'s and Gimpel et al. (2008)'s Market Engineering (ME) Framework. We also derive specific questions for future research that are rooted in shortcomings of available publications and show how our understanding of BEMs can be enhanced (see Section 5.5). Concluding, we encourage scholars to focus on a holistic view of BEMs that respects its multidimensional nature (see Section 5.6). Besides scholarly contributions, our study is relevant to practitioners as it pinpoints which artifacts need to be considered when designing BEMs in business ecosystems.

5.2 Foundations

5.2.1 Marketplaces as Matchmakers

Research on marketplaces as matchmakers is a diverse and interdisciplinary discipline that receives considerable attention in academic discourse (Täuscher and Laudien, 2018). Aligned with the definition of Ströbel and Weinhardt (2003), we define a marketplace as a logically central point, where transactions are coordinated through agent interactions, aiming to transfer tangible or intangible transaction objects from one agent to another and vice versa. Agents represent instances of acting stakeholders, have tasks, goals, and responsibilities, and communicate with other agents via protocols. For the classification of agents in marketplaces, Veit (Veit, 2003) distinguishes between two types: (1) *software agents* that represent the participating stakeholders and interact based on standardized communication protocols and (2) *middle agents* that mediate between offering and requesting agents and thus provide a coordination mechanism that supports transactions. Agents operating in a marketplace can be further characterized as buyers and sellers (instantiated by software agents) or intermediaries (instantiated by middle agents) (Ströbel and Weinhardt, 2003). Within a marketplace, different interaction phases and market mechanisms can be distinguished (Ströbel and Weinhardt, 2003; Veit, 2003; Schmid and Lindemann, 1998). First, a buyer requests a service and receives information about an offer provided by a seller. Then, sellers submit an offer and may negotiate with the buyer. Finally, a transaction concludes with a binding contract, followed by exchanging goods/services and payments.

5.2.2 Blockchain & Web3 technologies

In response to a loss of trust in intermediary third parties, Satoshi Nakamoto developed a cryptocurrency named Bitcoin, thereby introducing blockchain as its technological basis (Nakamoto, 2008). In generic form, blockchain is a distributed, shared, pseudonymous, digital ledger that manages transactions between multiple participants (nodes) of a network (Antonopoulos, 2014). Its structure corresponds to a chained list of blocks that are not stored on central servers and managed by intermediaries but instead decentralized between numerous participants in peer-to-peer networks (Nakamoto, 2008). Trust between peers is characterized by a transparent, persistent, chronologically updated, and immutable transaction ledger, a combination of established cryptographic technologies, and consensus mechanisms that validate new transaction blocks before being added to the chain (Antonopoulos, 2014). A frequently used validation method is the proof-of-work consensus, whereby competing miners solve complex mathematical puzzles (Nakamoto, 2008). Depending on the type of blockchain ('public/private' and 'permissioned/permissionless') and data storage ('on-chain/off-chain'), access to the ledger can be restricted based on rules. Complementary SCs allow for automatic execution of program code and contract structures, for instance, in business environments (Buterin, 2014). The term Web3 describes the decentralization movement and encompasses all related technologies (Voshmgir, 2020). The technology's value propositions (e.g., intermediary-free, transparent, secure, and tamper-proof record of transactions; Voshmgir, 2020; Glaser et al., 2019) will thereby facilitate the vision of BEM. These may be considered as a multi-layer perspective with four dimensions (Notheisen, Hawlitschek, et al., 2017): First, an environment layer describing external contingencies of a market; second, an infrastructure layer with blockchain-specific protocols; third, an application layer for economic value creation; and fourth, an agent layer characterizing the behavior of economic agents.

5.3 Literature Review Design & Methodology

In this review, we collected literature on BEMs in business ecosystems and structurally analyzed the body of research (see Figure 5.1). To this end, we screened relevant outlets following the methodological approaches suggested by Webster and Watson (2002) and vom Brocke, Simons, Niehaves, et al. (2009) and vom Brocke, Simons, Riemer, et al. (2015).

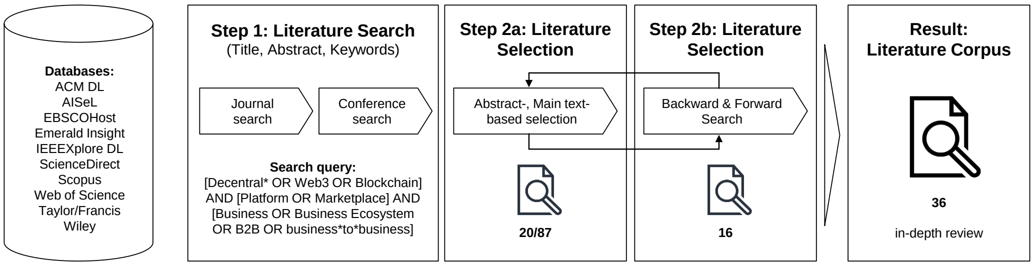

Fig. 5.1.: Literature Search Strategy, adopted by Webster and Watson (2002), vom Brocke, Simons, Niehaves, et al. (2009), and vom Brocke, Simons, Riemer, et al. (2015).

Search Strategy. We included publications in our review that comprise the following. First, they must focus on BEM as the unit of analysis and derive explicit or implicit insights on designing BEM. More precisely, models, frameworks, or protocols for mediating supply and demand through blockchain and other Web3 technologies (Hoffman et al., 2020) and thereby, taking care of allocation problems. Second, publications must focus on business ecosystems and its business actors. Consequently, we excluded papers that solely recognize blockchain as a database (i.e., for traceability reasons). Next, we neglect scenario analyses, blockchain applicability frameworks for specific use cases or industries and manuscripts examining overall blockchain fundamentals or limitations. Furthermore, we disregard technical papers improving or proposing algorithms without focusing on mediating BEM and only consider peer-reviewed publications (i.e., no working papers, early-stage drafts, or white papers).

Our initial literature base builds on querying a wide range of interdisciplinary research databases[1] over the period 2008-2021. Thereby, we extend our search to outlets outside the IS discipline (Webster and Watson, 2002), reflecting the topic's interdisciplinary character. For the database search, we constructed a query consisting of several topic-related key terminologies[2]. We conducted the first database search in January 2021 and repeated the process in July 2021. We obtained a total of 946 studies. Examining titles and abstracts of all papers matching our inclusion criteria resulted in 87 articles. Studies that did not contain any previously specified keywords or belong to the outlined above exclusion criteria. were removed from the analysis corpus. Reviewing the 87 retained articles' full text yielded 20 relevant manuscripts. Subsequent iterative backward and forward search (Webster and Watson, 2002) revealed 16 additional relevant articles, resulting in a final set of 36 articles for in-depth review.

Analysis and Conceptualization. We follow an exploratory and concept-centered approach by classifying each publication in our literature corpus using a concept matrix (Webster and Watson, 2002). By summarizing findings along dimensions that relate to the design of business models, we identify focal elements in existing research and identify areas for future inquiries. To ensure that our dimensions are structured, analytical sound, coherent, and sufficiently distinguishable from each other, we propose to align them towards Weinhardt, Holtmann, et al. (2003)'s and Gimpel et al. (2008)'s ME Framework. This approach appears to be appropriate, as it reasonably reflects the interdisciplinary character of BEM, which constitute both a resource allocation mechanism (Hayek, 1945), and a networked information system (Bakos, 1991). It embraces both business and IT perspectives as well as disciplines influenced by economics (i.e., mechanism design). Accordingly, we reflect this interdisciplinary character in our review's concept matrix dimensions.

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[1] ACM DL, AISeL, EBSCOHost, Emerald Insight, IEEEXplore, ScienceDirect/Scopus, Web of Science, Taylor/Francis, Wiley.

[2] [Decentral* OR web3 OR Blockchain] AND [Platform OR Marketplace] AND [Business OR Business Ecosystem OR B2B OR business*to*business].

5.4 Literature Review Results

Our literature corpus comprises 20 journal articles and 16 conference proceedings and was published within the last six years: 2021 (n=5), 2020 (n=9), 2019 (n=8), 2018 (n=12), 2017 (n=1), and 2016 (n=1). About the research methods[3] used we found that a majority of contributions is based on qualitative research, whereof 30 studies focus on concepts and frameworks. Of these, twelve authors evaluate their assumptions using case studies and proofs of concepts. Other less frequent methods include literature analyses (n=6), interviews (n=3) and content analyses (n=1). Quantitative insights are presented in one study where researchers apply mathematical models. We classify three publications as speculation/commentary as their research derives from weakly supported arguments or opinions with little or no evidence. According to Edmondson and Mcmanus (2007), who assess the maturity of research fields, the low number of quantitative studies shows that the topic under investigation can currently be considered a nascent research field.

In terms of the domains, we identify a clear focus on manufacturing (n=18). However, some researchers also deal with logistics (n=5), while isolated articles exist in the realms of aircraft (n=1) and chemistry (n=1). In addition, a small number of publications (n=4) do not focus on a specific domain but approach data sharing through BEM as a generic issue. Finally, five publications appear too general to be categorized in a particular field.

Following, we analyze our literature corpus using concept matrix dimensions guided by the ME Framework[4]. It consists of interdependent structures and protocols (micro-structure for marketplace mediation, business structure, IT infrastructure), auxiliary services, agent behavior, market outcomes and performance, which all relate to a transaction object embedded in a market environment (Gimpel et al., 2008). Moving forward, these dimensions are clustered as structural guidelines to analyze BEM in institutional settings.

5.4.1 Market Environment & Transaction Objects

Market Environment. This dimension defines the problem space in which the phenomena of interest reside (Hevner, March, et al., 2004). It is characterized by laws, rules, regulations, and social norms and beyond a market engineer's

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[3] Note that the total methodologies used sum up to 54 as some articles use more than one method.

[4] Since our categorization is not disjunctive, each publication may be assigned towards more than one dimension.

control (Weinhardt, Holtmann, et al., 2003; Gimpel et al., 2008). Among our literature corpus, about a third (n=11) addresses the market environment. Referring to the total addressable market, some authors recite a strong market growth in the field of additive manufacturing (Zareiyan and Korjani, 2018b). Others focus on challenges faced by industry domains and present both the capabilities and potential of blockchain solutions (Teslya and Ryabchikov, 2018; Kuhle et al., 2021; Li, Maiti, et al., 2020; Bai et al., 2019). In addition, seven publications deal with requirements for BEM. For example, in the context of commercial aircraft leasing, Kuhle et al. (2021) discuss regulatory requirements and business needs. Some scholars address detailed functional and non-functional requirements through qualitative approaches (Beck, Kildetoft, et al., 2020; Herm and Janiesch, 2021). Others formulate requirements without a structured modeling approach (Teslya and Ryabchikov, 2018; Ozyilmaz et al., 2018; Zareiyan and Korjani, 2018a). Some manuscripts further present blockchain projects that deal with BEM in a relatively unstructured manner (Ozyilmaz et al., 2018; Bajoudah et al., 2019; Ranganthan et al., 2018; Sikorski et al., 2017), while others follow a more analytical approach based on a literature review (Miehle et al., 2019).

Transaction Objects. Regarding BEM, we identify two types: generic and specific.

Generic refers to interactions that do not focus on one a dedicated use case. Depending on the domain, traded data can vary and is thus highly heterogeneous. Among our literature corpus, the majority of studies (n=30) belong to this category. These include BEM with a business-specific focus, targeting the exchange of Internet-of-Things (IoT) data between organizations (Ozyilmaz et al., 2018; Bajoudah et al., 2019; Knapp et al., 2020) or capacity matching in collaborative manufacturing (Hofmann et al., 2021).

Specific include objects that represent a physical commodity (n=6). Five of these papers stem from the manufacturing domain. Hasan and Starly (2020) and Angrish et al. (2018) outline transactions involving computerized numerical control (CNC) machined parts, while Vatankhah Barenji et al. (2020) discuss 3D printing use cases. Other scholars address equipment sharing, and predictive maintenance (Bai et al., 2019), as well as maintenance services in general (Miehle et al., 2019). In addition, Kuhle et al. (2021) deal with leasing contracts for aircrafts.

5.4.2 Design of Blockchain-enabled Marketplace Mediation

The micro-structure dimension covers the core process of marketplace transactions – the mediation between supply and demand to allocate a transaction object (Ströbel and Weinhardt, 2003). Input to this function is a set of offers and a request (one-to-many relationship) yielding a ranked list of offers best matching a request. Our concept matrix introduces three subcategories: (1) *Identity and Participation*, which describes market participants and applicable participation rules; (2) *Mediation Type*, which distinguishes different marketplace models; and (3) *Mechanisms*, which describes the interaction phases of a marketplace transaction.

Identity and Participation. The *IDM* describes attributes related to actors within a BEM. Overall, it appears that explicit specification of IDM attributes is not a central subject in our literature corpus' BEM concepts. Two scholars briefly mention BEM agent identification but do not elaborate further on it (Liu and Jiang, 2020; Ouyang et al., 2019). About a quarter of our literature corpus (n=11) outlines a rough IDM concept but does not address essential IDM attributes in organizational settings (e.g., certificates for identity attestation). Of these publications, nine draws on the asymmetric cryptographic system of public and private key (Wester and Otto, 2021; Kuhle et al., 2021; Bai et al., 2019; Knapp et al., 2020; Hasan and Starly, 2020; Li, Wang, et al., 2018; Soska et al., 2016; Rožman, Diaci, et al., 2021; Rožman, Vrabič, et al., 2019). To assign these pairs, some authors propose the use of SCs (Bai et al., 2019; Rožman, Vrabič, et al., 2019), others use Ethereum addresses without specifying their allocation (Angrish et al., 2018). Hofmann et al. (2021) design an ERC-20 token contract to represent a machine in their collaborative manufacturing marketplace. Certificates associated with business partner IDs are considered in three publications (Angrish et al., 2018; Ouyang et al., 2019; Hofmann et al., 2021). Two authors remark them as essential for business interactions but, however, do not describe how certificates can be integrated into their BEM concept (Hofmann et al., 2021; Ouyang et al., 2019). Equally shallow and without an implementation concept, Angrish et al. (2018) describe that they include an ISO quality certification authority in their network that can independently verify the validity of a manufacturer's certificate. To foster trust between entities, Innerbichler and Damjanovic-Behrendt (2018) propose a concept based on the distinction between delegated and federated IDM. In the former (delegated IDM), identification is outsourced and curated by another system; in the latter (federated IDM), each participant retains its entity information and stores it in multiple nodes. Economically, it is noteworthy that so far, only one paper (Soska et al., 2016) explicitly states that registration fees are charged in connection with BEM registrations.

Likewise, *Participation Rules*, representing a BEM governance, seem to take on a subordinate role. In principle, one-third of our LC (n=12) emphasize this aspect. However, scholars only mention BEM rules as necessary without further specification (Narang, 2019; Yu et al., 2020), reference their implementation in external systems (Bai et al., 2019), or provide a limited amount of rules, which does not represent a BEM in toto (Wester and Otto, 2021; Kuhle et al., 2021; Ozyilmaz et al., 2018; Miehle et al., 2019). For separation of concerns in rules execution, Hasan and Starly (2020) propose three different SC architectures to control permissions, behavior, attributes of stakeholders, assets, and the core system. Regarding the rule's governance, we identify two approaches: One research stream proposes governance structures through a third party that grant access to known participants and automates this process via SCs (L'Hermitte and Nair, 2020; Liao et al., 2020). Other approaches emphasize consortia collaboration for governance in BEM (Beck, Kildetoft, et al., 2020; Hofmann et al., 2021). This involves authorities (e.g., a consortium of industry leaders represented by an association) that are not part of a respective BEM (Beck, Kildetoft, et al., 2020).

Mediation Type. The coordination mechanism that matches supply and demand and thus facilitates the marketplace middle agents intermediation may be categorized threefold (Veit, 2003): First, *Broker agents* collect both offers and requests and represent a ranked list to respective counterparts. Second, *Matchmaker agents* solely collect offers and provide ranked lists of offers to requesting agents. Third, *Blackboard agents* collect requests and provide ranked lists to offering agents. Analyzing our literature corpus, we note that no publication provides a concept for a ranked list of offers. If we disregard the ranking function, seven papers can be classified as brokering BEM (Bai et al., 2019; Miehle et al., 2019; Hasan and Starly, 2020; Rožman, Diaci, et al., 2021; Rožman, Vrabič, et al., 2019; Yu et al., 2020; Xu et al., 2019), four papers as matchmaking BEM (Ozyilmaz et al., 2018; Bajoudah et al., 2019; Sikorski et al., 2017; Soska et al., 2016), and two as blackboarding BEM (Wester and Otto, 2021; Gumzej and Čišić, 2018). In more than half of our LC (n=23), the BEM's role is not apparent.

Marketplace Mechanisms. Various approaches exist that describe a holistic view of offer and request coordination. We distinguish three formalized phases and adopt that generic model to analyze our literature corpus (Ströbel and Weinhardt, 2003; Veit, 2003): Approach, Intention, and Agreement.

In the *Approach phase*, demand and supply sides exchange information about trading assets, a process considered in more than half of our literature corpus (n=20). Fourteen publications propose to publish essential information directly on a blockchain ledger, without further specifying how transaction partners can find each other (e.g., Angrish et al., 2018; Baumung and Fomin, 2019; Rožman, Diaci, et al., 2021). One concept describes a mechanism to update transactions once they have been published, for instance, when an offer is sold out (Soska et al., 2016). Hofmann et al. (2021) do not provide mechanisms to modify or cancel an order but emphasize its relevance for future work. More sophisticated approaches draw on the possibility of external databases for storage, depending on the sensitivity of data and the importance for the transaction process (Beck, Kildetoft, et al., 2020; Wester and Otto, 2021; Kuhle et al., 2021).

In the *Intention phase*, trading partners specify and submit offers (i.e., capabilities) and requests (i.e., preferences), which are then evaluated by mediating marketplace agents regarding completeness and compliance with BEM rules. However, about two-third of our literature corpus (n=21) did not provide a concept to implement this aspect in their BEM. A considerable amount of publications (n=13) implement specifications and submissions directly via a blockchain ledger and SCs but omit the evaluation step. For instance, Angrish et al. (2018) propose to write all data in a transaction block, other authors propose encrypted lists for requests and offers (Soska et al., 2016), which are restricted in some cases (Wester and Otto, 2021). Evaluations by mediating BEM agents were partially addressed by two publications, while the others did not provide that function. One concept proposes that producers have to apply for a list of service requests (Wester and Otto, 2021). Based on submitted information (identity, deposited money, completed contracts history), consumers decide whether to let the producer submit an offer or reject it. Another concept envisages that producers publicly register their offering, enabling consumers to browse a ledger to purchase a product with a transaction (Soska et al., 2016).

The first step of the *Agreement phase* is the supply and demand matching. This involves, for instance, the identification of counterparts, scoring, and price discoveries. However, this aspect has not found much attention by scholars so far. While a large majority of publications state that their BEM induce a match, they do not explain how exactly this is supposed to work (Hasan and Starly, 2020; Angrish et al., 2018; Vatankhah Barenji et al., 2020; Rožman, Diaci, et al., 2021; Baumung and Fomin, 2019). In publications where all match-relevant data is published on a blockchain ledger, authors perform the matching function not by BEM agents but by one of the respective parties. Miehle et al. (2019), for instance, propose a function for ranking offers and selecting suppliers that are executed by a machine at their market's buyer-side. Some authors suggest that users could handle the matchmaking themselves, as they browse a list of service requests (Wester and Otto, 2021; Ozyilmaz et al., 2018). Others propose to deal with matching bilaterally between involved parties and only publish the results on a blockchain ledger (Rožman, Diaci, et al., 2021). An approach that respects user privacy is proposed by Hofmann et al. (2021). They suggest a distributed matching engine based on dark pool protocols. However, a precise concept including protocols for their BEM scenario is not specified. Furthermore, steps two and three of an agreement, where counterparts are informed about trading partners and negotiate terms and conditions, are described in one-third of the literature corpus publications (n=12). The most frequently suggested solution is an implementation via SC that executes on a blockchain network. Hasan and Starly (2020), for example, use blockchain events to issue a request, submit a quote and trigger the production or distribution of a product. Other authors suggest an additional (negotiation) layer where users can encrypt data throughout the process (Wester and Otto, 2021; Hofmann et al., 2021), which is more in line with business needs (Narang, 2019; Gelhaar and Otto, 2020).

5.4.3 Concepts for Business Structure, IT Infrastructure & Auxiliary Services

Business Structure. This dimension describes economic parameters of marketplaces (Weinhardt, Holtmann, et al., 2003; Gimpel et al., 2008) and is the least considered aspect among our literautre corpus. While some publications briefly discuss trading fees associated with blockchain transactions (Knapp et al., 2020; Xu et al., 2019), no one offers a holistic view of *business models* in BEM so far. Closest to this are the considerations by Ozyilmaz et al. (2018), describing business models such as pay-as-you-go and subscription-based fees for consumers but do not further elaborate on them either. *Incentive mechanisms* to participate in BEM are discussed by only two authors. Angrish et al. (2018) emphasize their relevance to blockchain systems and call for research in this context, but do not elaborate more. Bai et al. (2019) cursorily discuss incentive strategies for miners involved in the consensus process and motivate token rewards.

IT-Infrastructure. Marketplace functions are connected by technical frameworks of IT infrastructures that implement micro- and business structures and provide an interface allowing agents to connect to marketplaces (Gimpel et al., 2008). Regarding our literature corpus, we note that all publications rely on blockchain technology as their IT infrastructure. The vast majority (n=26) pursue an approach that we would describe as *Blockchain-fits-all-solution*. Here, blockchain networks provide all BEM functions. Authors following this approach propose to store all data on a blockchain ledger and handle BEM mediation via SCs (e.g., Teslya and Ryabchikov, 2018; Liu and Jiang, 2020; Rožman, Vrabič, et al., 2019; Li, Barenji, et al., 2018; Barenji, Li, et al., 2018). A few publications (n=8) pursue an alternative path, where only (encrypted) anchor data is stored on blockchains so that, for example, competition-relevant data can be kept private. Authors following this path suggest storing identities, access rights, and references on a ledger, which in turn point to external databases or systems. For this purpose, Bai et al. (2019) use a distributed hash table (DHT), Ozyilmaz et al. (2018) a Swarm, and Wester and Otto (2021) an InterPlanetary File System (IPFS). Besides, other authors suggest storing product-specific data in the stakeholders' legacy IT systems and incorporate it automatically via SC oracles (Kuhle et al., 2021; Angrish et al., 2018). However, they do not describe how this should operate. Neither do Rožman, Diaci, et al. (2021) for their segmentation between main- and sidechain.

Concerning blockchain types, a fundamental distinction can be made between public and private blockchains (Antonopoulos, 2014). About half of our literature corpus does not specify what kind they use. Eleven publications base their concept on a public blockchain, with nine concepts implemented on Ethereum. For example, Wester and Otto (2021) use a combination of Ethereum and IOTA, while Soska et al. (2016) rely on Bitcoin for their considerations. Apart from that, seven publications use a private or consortium blockchain. Kuhle et al. (2021) use Hyperledger Sawtooth, Li, Maiti, et al. (2020) Hyperledger Fabric, and five authors do not specify their choice.

Apart from blockchain technologies, we note that only three publications refer to other Web3 technologies as an IT artifact in their BEM concept. Narang (2019) deal with MPC, limit their concept to decentralized reputation systems, and describe other BEM dimensions peripherally. Bai et al. (2019) want to use MPC as part of their BEM and outline its basic functionality. However, they do not specify beyond the fact that data query and calculation are distributed to different nodes. Hofmann et al. (2021) draw on a concept that uses MPC to match supply and demand without specifying it precisely.

Auxiliary Services. This category includes services that are not core elements of a marketplace mechanism but support actors in their interactions (Gimpel et al., 2008). These include *Transaction and Settlement Clearing* after two parties have reached an agreement and accepted negotiated terms and conditions. More than two-thirds (n=24) of our literature corpus does not contain a statement concerning the design of this support system. Ten papers provide conceptual considerations in which clearing is implemented through SCs. This allows for the automatic execution of the contract to be linked to events. If a service is completed, the blockchain ledger could record an event, which automatically creates a SC that initiates a payment after the agreed conditions have been fulfilled (e.g., Wester and Otto, 2021; Hasan and Starly, 2020; Xu et al., 2019). Eleven of our literature corpus' cases realize payment through a token transfer (e.g., Wester and Otto, 2021; Hofmann et al., 2021). Hofmann et al. (2021) advocate for privacy tokens and propose cryptocurrencies like Monero.

By providing rating mechanisms, *Reputation Systems* can foster trust among transaction partners and eliminate uncertainties (Gimpel et al., 2008; Hesse et al., 2020). While 26 publications do not deal with this at all, five authors recognize its relevance without proposing a concept for their BEM (L'Hermitte and Nair, 2020; Wester and Otto, 2021; Ozyilmaz et al., 2018; Bajoudah et al., 2019; Xu et al., 2019). Some describe that reputation exists in their concept without elaborating on its implementation (Rožman, Vrabič, et al., 2019), others propose to store all historical data (i.e., on past orders) on a blockchain ledger to create transparency and hence reputation that is visible to all network participants (Angrish et al., 2018; Baumung and Fomin, 2019). This contrasts with research that deals specifically with reputation systems and focus primarily on privacy-preserving aspects, meaning that not all transactions are stored on ledgers for all to see (Narang, 2019; Soska et al., 2016). In line with business needs that require privacy-preserving techniques, Narang (2019) implement their concept by using MPC and build their design considerations on game-theoretical studies.

Procedures for *Agent Communication* between BEM participants are not specified by the majority of our literature corpus (n=32). The authors who address this topic suggest standard protocols such as APIs (Hasan and Starly, 2020; Baumung and Fomin, 2019), or refer to more specialized frameworks such as Hyperledger Sawtooth (Kuhle et al., 2021). To propose a solution particularly suited for agents, Gumzej and Čišić (2018) use agent communication language (ACL) and the FIPA Contract Net Protocol.

5.4.4 Perspectives on Agent Behavior, Market Outcome & Performance

Agent Behavior. Based on market structures, a market participant's behavior influences market outcomes and performances of marketplaces (Weinhardt, Holtmann, et al., 2003) and needs to be analyzed (Gimpel et al., 2008). However, a microeconomic analysis, which might include agents' utility functions, risk aversions, incentives for truth revelation, or conflicts of interest, is only addressed by two literature corpus authors. Xu et al. (2019) propose dispute resolution mechanisms in SCs, assuming that either a service provider or client will try to cheat the other side. Narang (2019) study different types of agent behavior by using game-theoretical models. Across a spectrum of pricing and punishment strategies, they discover that trusted seller ratings lead to desirable equilibrium behavior by strategic buyers and sellers.

Market Outcome and Performance. By designing a marketplace, engineers aim to achieve a specific *Market Outcome* (Weinhardt, Holtmann, et al., 2003; Gimpel et al., 2008). However, only two publications specify how this might look like. Rožman, Vrabič, et al. (2019) study overall allocation efficiency and find out that, over time, parcel distribution in warehouse converge to an expected equilibrium. Narang (2019) focus on privacy-preserving cooperations between different organizations and aim to support this with an MPC-based reputation system.

To achieve a desired *Market Performance*, a substantial number of authors (n=15) perform specific analyses. While Hofmann et al. (2021) conduct a qualitative evaluation based on interviews with three domain experts, most authors simulate different parameters of their BEM approach. For example, by comparing three different Ethereum test networks with different consensus mechanisms, some analyze mining times for different SCs (Hasan and Starly, 2020). Other authors focus on block confirmation time and transaction latency (Bajoudah et al., 2019; Ranganthan et al., 2018; Angrish et al., 2018; Soska et al., 2016; Xu et al., 2019), distinguishing different numbers of users (Li, Barenji, et al., 2018) or transaction costs in blockchain networks (Wester and Otto, 2021; Li, Maiti, et al., 2020; Bajoudah et al., 2019; Ranganthan et al., 2018; Rožman, Diaci, et al., 2021; Rožman, Vrabič, et al., 2019; Yu et al., 2020; Liao et al., 2020; Xu et al., 2019) and different consensus mechanisms (Vatankhah Barenji et al., 2020; Liao et al., 2020). Hasan and Starly (2020) compare the technical complexity of their SC code with existing implementations and show that their separation of concerns leads to lower complexity and lower transaction costs. Li, Maiti, et al. (2020) examine business metrics like Customer Lifetime Value, Business Reference Value, and Customer Referral Value and claim that BEM outperform conventional solutions in these categories.

5.5 Discussion & Research Opportunities

In this paper, we synthesized and reviewed available literature on BEM in business ecosystems. We analyzed methodologies applied and domains represented by the studies. To relate to BEM design deliberations, we structured each publication along ME dimensions. Overall, we raise a critical voice and encourage a discourse with current literature on BEM in business ecosystems, as we consider it not quite mature. Referring to the title of the paper at hand, this stream of literature might rather be described as a dwarf than a giant.

First, an explicit limitation certainly is that a considerable proportion of the available literature rarely meets scientific standards as some findings appear arbitrary in terms of transparency and documentation, prohibiting reproduction (e.g., Subramanian, 2018; Teslya and Ryabchikov, 2018; Zareiyan and Korjani, 2018a). Furthermore, a large share of work is based on frameworks and conceptual models. Only seven publications substantiate their considerations with previously identified BEM requirements, while only two scholars provide a well-documented approach (Beck, Kildetoft, et al., 2020; Herm and Janiesch, 2021). As requirements are the fundamental basis of any market design belonging to any marketplace concept, they deserve more attention (Gimpel et al., 2008). Similarly, the majority of our literature corpus does not state what kind of BEM mediation they pursue (e.g., Rožman, Diaci, et al., 2021; Zareiyan and Korjani, 2018b). Considering that this distinction is fundamental in marketplace designs (Veit, 2003), this well reflects the lack of rigor in extant work. Observations regarding the methodologies used confirm this impression, as data-driven studies are underrepresented. Moreover, no study approaches user motives and trusting relationships on BEM leveraging experimental study designs. As experiments reveal insights into actual, non-hypothetical behavior and represent established tools designing marketplaces (Gimpel et al., 2008), this is a natural next step for future work.

Second, we note that a holistic view of BEM seems mostly absent by now. Besides exceptions like Hofmann et al. (2021), who shape their BEM concept around DSR, it appears that scholars seek potential blockchain applications (e.g., Teslya and Ryabchikov, 2018; Zareiyan and Korjani, 2018a) rather than evaluating how specific marketplace functionalities could be decentralized. As they devote their attention to *blockchain-fits-all* marketplaces, we identify three main issues with this approach: (1) Storing data transparently on a blockchain ledger (e.g., Liu and Jiang, 2020; Li, Barenji, et al., 2018) inevitably leads to privacy concerns that are not reflected in most market designs. Especially in business ecosystem interactions, confidentiality of sensitive and competition-relevant information is crucial (Narang, 2019; Gelhaar and Otto, 2020). A few authors already stressed this need and contributed to research (Narang, 2019; Soska et al., 2016; Hofmann et al., 2021). However, their work either considers partial aspects of BEM and touches on others relatively sparsely or merely addresses ideas without concrete steps. Further analyses might concertize this. To avoid *blockchain-fits-all* solutions, scholars might also take a step back and review where decentralization actually improves marketplaces. In this context, examining the impact of trust abuse scenarios (such as data leaks by intermediary operators; Vanian, 2018) on user behavior appears as an interesting research endeavor. (2) Blockchain systems face technical challenges (e.g., scalability, latency, and size) that must be considered while designing BEM. We emphasize that Web3 offers other decentralized technologies that share similar value propositions to blockchain while solving some of its challenges. (3) We allude to the integral understanding of markets and their interrelationships. In this context, micro-structure, business structure, and IT infrastructure are interdependent (Gimpel et al., 2008). For example, scaling problems (e.g., increased bidding volume at the end of auctions) may be addressed either by technical means (e.g., adjusting the IT) or by changes in the business structure (e.g., introducing higher bidding fees towards the end of an auction). None of our literature corpus' articles shows comparable connections. Without a structured reconciliation of all marketplace aspects, it is challenging to derive design decisions, put existing research into perspective, and draw valuable implications.

Third, we outline directions in specific dimensions that future research should address: (1) Given that digital sovereignty is increasingly considered a crucial core element in platform strategies by the European Union (Federal Ministry for Economic Affairs and Energy (BMWi), 2020), we see a need to study **BEM micro-structures**. In particular, we emphasize the relevance of IDM, forming the basis of BEM interactions, but it has only received minor attention. Especially the connection with certificates for attestation purposes might be of great importance in business ecosystems (Hofmann et al., 2021). In this regard, the symbiosis of SSI and BEM appear promising. Beyond using SSI for individuals, this may include assessing its relevance for legal entities (i.e., organizations) or things (i.e., machines). Further analyses might elaborate on this. (2) Few scholars focus on **BEM governance structures**. Approaches that leave the governance to a third party and allow them to control market access (L'Hermitte and Nair, 2020; Liao et al., 2020), are critical, as this would lead to centralization and single points of failure, both of which should be prevented with decentralized systems. Beck, Kildetoft, et al. (2020) approach of establishing governance through a consortium of industry leaders represented by an association appears promising. Further research could build on these reflections and explore, for instance, collaboration patterns and business models in BEM. We also see potential in investigating how organizational and technical decentralization goes hand in hand. This may include assessing which BEM functionalities could be implemented through organizational decentralization and which need to be secured technologically. At both levels, the impact of consortia could be exciting avenues for future research. (3) Concerning **BEM mechanisms**, previous publications rigorously considered the approach phase. However, we criticize the prominent strategy of writing data directly on a blockchain ledger. Again, we emphasis scalability issues and the importance of data privacy. Accordingly, we suggest evaluating 2^{nd} layer solutions and approaches such as MPC and support efforts already dedicated to this (e.g., Hofmann et al., 2021; Narang, 2019). The same applies to the intention and agreement phases. Only a few scholars describe these in more detail. Finally, algorithms for solving allocation problems, including identifying appropriate transaction partners or the ranking of offers, are core elements of BEM and should be investigated in greater detail. (4) Moving forward, our review indicates dimensions that have barely received attention in the past research discourse. This includes, for instance, **BEM business structure**. Besides business models and their specifics, incentive mechanisms such as **tokenization** might represent exciting research areas. Regarding individual **BEM agent behavior**, game-theoretical analyses might provide insightful results. We also note that the desired **BEM market outcome** was only addressed by two publications (Rožman, Vrabič, et al., 2019; Xu et al., 2019). Since this constitutes the foundation for considering market designs, we appeal for its recognition.

5.6 Concluding Remarks

Our study focuses on a structured analysis of BEM based on the ME framework (Weinhardt, Holtmann, et al., 2003; Gimpel et al., 2008) and is mainly concerned with a holistic market perspective. While not all research disciplines may consider this approach comprehensive (e.g., rather technical researchers might feel misunderstood), we identify a breadth of open questions and indicate that current research rarely goes beyond the use of blockchain for BEM scenarios, neglecting a structured approach. We exhibit an intense concentration of extant works focus, methodological variety, and specific issues addressed. To take the lead in this emerging research area, we encourage scholars to shift their focus more on a BEM perspective that respects its multidimensional nature instead of following a *blockchain-fits-all* strategy. Towards this endeavor, we propose synergistic efforts and interdisciplinary research approaches such as ME (Weinhardt, Holtmann, et al., 2003; Gimpel et al., 2008), or DSR (Hevner, March, et al., 2004). These different perspectives might lead to meaningful insights for both theory development and practical problem solving and inspire RQs beyond the focus of contemporary work. In terms of the domains, we identify a clear focus on manufacturing (n=18). However, some researchers also deal with logistics (n=5), while isolated articles exist in the realms of aircraft (n=1) and chemistry (n=1). In addition, a small number of publications (n=4) do not focus on a specific domain but approach data sharing through BEM as a generic issue. Finally, five publications appear too general to be categorized in a particular field.

Following, we analyze our literature corpus using concept matrix dimensions guided by the ME Framework[5]. It consists of interdependent structures and protocols (micro-structure for marketplace mediation, business structure, IT infrastructure), auxiliary services, agent behavior, market outcomes and performance, which all relate to a transaction object embedded in a market environment (Gimpel et al., 2008). Moving forward, these dimensions are clustered as structural guidelines to analyze BEM in institutional settings.

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[5] Since our categorization is not disjunctive, each publication may be assigned towards more than one dimension.

6

Requirements & Design Principles for Decentralized Marketplaces

This chapter is based on a peer-reviewed article titled "Requirements and Design Principles for Blockchain-enabled Matchmaking-Marketplaces in Additive Manufacturing". The article was co-authored by Marcel Linkenheil and Christof Weinhardt and is published in the 56th Annual Hawaii International Conference on System Sciences (HICSS) Proceedings. The tables, figures, and appendices were systematically renamed, reformatted, and appropriately referenced to align with the overall structure of the thesis. To further enhance clarity and consistency, formatting, and reference style were adapted and references were updated.

Publication details: *Kölbel, T., Linkenheil, M., & Weinhardt, C., Requirements and Design Principles for Blockchain-enabled Matchmaking-Marketplaces in Additive Manufacturing, 56th Annual Hawaii International Conference on System Sciences Proceedings, 2023.*

Abstract: Blockchain-enabled marketplaces offer considerable potential for cross-company networks. The area of additive manufacturing appears particularly promising. However, the practical impact of business-to-business marketplaces in today's organizations are still scarce, and academic literature contains limited design guidelines. Synthesizing knowledge from literature, practice, and qualitative expert interviews, our study explores 27 mandatory requirements, six optional requirements, and 12 design principles.

Keywords: B2B, Marketplace, Blockchain, Manufacturing, Design Science Research.

6.1 Introduction

A proliferation of IT-driven digitization presents new business opportunities and marks a shift toward a more technology-driven instead of an industry-driven economy (Weinhardt, Peukert, et al., 2021). Over the past decade, sub-economies such as platform economy, sharing economy, gig economy, or blockchain economy have emerged (Weinhardt, Peukert, et al., 2021). They yield great successes and quickly disrupt industries. Affected areas include lodging (e.g., Airbnb), transportation (e.g., Uber), and shopping (e.g., Amazon), to name a few.

The impact of these new sub-economies slowly extends to the B2B sector (European Commission, 2020; Cusumano, 2015), which is challenged by megatrends like Industry 4.0 and Cyber-Physical Systems (Wee et al., 2015). Manufacturers face a business environment characterized by complex market dynamics and uncertainty for future demands, while modern production strives for maximum efficiency and cost reduction along the supply chain (Lund et al., 2020). To respond flexibly and adaptively to changing conditions, manufacturers alter their monolithic production concepts towards dynamically defined value networks (Wee et al., 2015; Woods, 2015). One option here is the intra- and inter-organizational sharing of production capacities via marketplaces (European Commission, 2020), an approach that is predicted to proliferate (Mourtzis et al., 2020). Xometry, a company that operates a marketplace for efficiently matching supply (capacities) and demand (service requests), is a prime example of that paradigm shift. Its recent valuation of around $3 billion (Taulli, 2021) indicates the relevance of this application domain. However, researchers, regulators, and practitioners recognize downsides of centralized marketplaces controlled by dominant firms that hinder B2B adoption. These range from trust issues, to transparency of business-relevant data, and manipulations by matching orchestrators (De Bas et al., 2017; Kölbel, Dann, et al., 2022).

With blockchain technologies aiming to prevent intermediaries (Nakamoto, 2008), a stream of research has emerged that seeks to overcome these concerns. Relying on cryptographic methods and open protocols, blockchain networks are governed by communities and operate across distributed networks. The IS community explores this avenue with publications on BEM that aim to strengthen self-determined, privacy-preserving, and trusted B2B interaction (Hofmann et al., 2021; Dann et al., 2020; Notheisen, Hawlitschek, et al., 2017). Yet – in contrast to research on centralized marketplaces, which relies on concepts based on previously identified requirements (Freichel, Hofmann, Fischer, et al., 2019) – a literature review on BEM notes a paucity of structured approaches, including principles for designing BEMs (Kölbel, Dann, et al., 2022).

Against this backdrop, we set out to address three research appeals: First, we respond to a more general proposition to explore the interconnections between novel sub-economies (Weinhardt, Peukert, et al., 2021) by linking facets of marketplace sharing with the blockchain economy. Second, we concentrate on the blockchain infrastructure of electronic markets (Alt, 2020a) and specifically study requirements and principles for the structured design of BEMs, that represents a striking research gap (Kölbel, Dann, et al., 2022). Third, we focus on the use case of AM, as it allows for more flexibility than traditional mass production, is an innovative and fast-growing industry (Wohlers Associates, 2019), and thus represents an optimal starting point for this research endeavor (Freichel, Hofmann, Fischer, et al., 2019). Collectively, this study is driven by the following RQ:

Research Question: *Which requirements and principles should be considered when designing BEM for matching AM supply and demand?*

Our paper proceeds as follows. Section 6.2 presents foundations and related work on BEM in AM. Section 6.3 introduces our methodology. Section 6.4 reports our research results by proposing requirements and DPs. Section 6.5 concludes with contributions, limitations, and future research opportunities.

6.2 Foundations & Related Work

We position our RQs at the intersection of three topics in IS: capacity sharing in production networks, AM marketplaces, and BEM in business.

Following the spirit of the sharing economy, the inter- and intra-organizational **sharing of production resources** via marketplaces combines digital markets with production networks. Marketplaces act as logical central points (Kölbel and Kunz, 2020) and 'Matchmakers' (Evans and Schmalensee, 2016) between two (or more) customer segments, usually represented by a supply and demand side (Cusumano, 2015). They coordinate the interaction of these two sides and strive for optimal resource allocation. Previously underutilized resources can effectively be shared among users, dynamizing production networks. This multilateral connectivity of business partners leads to improved performances and lower costs, as machines do not remain idle (Stein et al., 2019; Hofmann et al., 2021). At the center of this ecosystem is the digital infrastructure of a marketplace, which is typically operated and controlled by a dominant company. Their role is to provide transparency about the market situation and orchestrate market participants' interactions. From a generic perspective, different marketplace mechanisms can be distinguished. These include the matchmaking function as a control mechanism (Kölbel and Kunz, 2020) and the distinction of marketplace interaction phases – information and approach, intention and agreement, and clearing and settlement (Veit, 2003).

While there are concepts for matching manufacturing resources at the machine level, we concentrate on the higher-level matching of supply (manufacturing capacity) and demand (service requests) at an organizational level. Specifically, we focus on **AM marketplaces** as a real-world use case that enables the transformation of 3D digital models into products (Weller et al., 2015). While this process may not substitute for mass production methods in all industries (Holweg, 2015), it enables well-known applications such as rapid prototyping, small-batch, or spare parts manufacturing (Ben-Ner and Siemsen, 2017) and has widely been studied in research on manufacturing marketplaces. Examples include Rayna et al. (2015), who provide an overview of AM service providers; Stein et al. (2019), who developed a market mechanism for efficient resource optimization; and Freichel, Hofmann, Fischer, et al. (2019), who propose requirements and a metamodel for a centralized marketplace that facilitates AM capacity trading between companies.

Alongside concepts for centralized marketplaces, numerous publications exploit novel technologies like blockchain and pursue **decentralized marketplace concepts**. Similarly, they connect consumers who want to print 3D models with a network of manufacturers who offer printing capacities. However, through cryptographically secured mechanisms, these decentralized concepts eliminate centralized intermediaries, thus strengthening the individual sovereignty of consumers (Kölbel, Dann, et al., 2022). In line with the perspective of Notheisen, Hawlitschek, et al. (2017), BEMs may be defined as a multi-layered construct with four dimensions: The first describes external market constraints, the second an infrastructure layer with blockchain-specific protocols, the third involves economic value creation, and the fourth an agent layer characterizing economic actors' behavior. In this context, Herm and Janiesch (2021) study requirements for blockchain-based collaboration platforms. In addition, we encounter publications with technical frameworks for BEM in manufacturing (Hofmann et al., 2021; Rožman, Diaci, et al., 2021; Hasan and Starly, 2020), although previously identified requirements do not substantiate these. For a more detailed overview of publications on BEMs in business ecosystems, we refer to a literature review by Kölbel, Dann, et al. (2022). Overall, they regard research to be at an early stage, noting the paucity that, in the context of using BEMs for AM, a structured deduction of requirements and DPs, the fundamental basis of any marketplace design (Gimpel et al., 2008), represents a striking research gap.

6.3 Methodological Approach

Our paper employs DSR methods to explore requirements and articulate principles for BEMs in AM. We argue that this approach is particularly suitable as it combines practical relevance with scientific rigor (Hevner, 2007) and allows to design and rigorously evaluate our artifacts iteratively. As illustrated in Figure 6.1, we fall back on Hevner's three-stage approach: the rigor cycle, the relevance cycle, and the design cycle (Hevner, 2007).

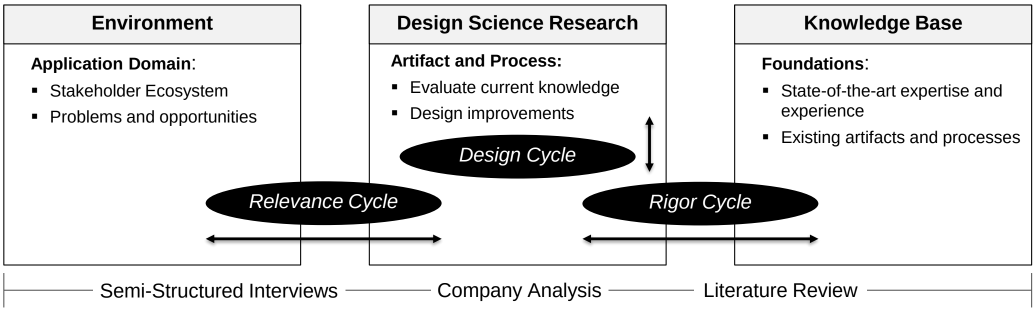

Fig. 6.1.: Hevner (2007)'s Three-Staged DSR Approach and Applied Research Methods.

The **rigor cycle** focuses on the existing knowledge base and ensures that state-of-the-art research is reflected in our endeavour. With a **structured literature review** following the methodological approaches suggested by Webster and Watson (2002), we collect and review the existent body of research. Our initial literature base builds on querying a wide range of interdisciplinary databases[1] concerning several topic-related key terminologies[2]. We conducted the first database search in October 2021 and repeated the process in January 2022. To ensure that only high-quality and topic-relevant literature is considered, we applied the following criteria: First, we concentrate on peer-reviewed publications available in English. Second, we include literature that concentrates on BEM and explicitly or implicitly addresses requirements. This comprises frameworks and prototypical concepts, and simulations that provide insights regarding mediating supply and demand through blockchain and other Web3 technologies. Third, we focus on literature in the field of AM. Consequently, we exclude studies that consider blockchain as a database (i.e.,

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[1] ScienceDirect, EBSCOHost, ACM DL, Emerald Insight, IEEEXplore DL, AIS eLibrary

[2] (Decentral* OR Web3 OR Blockchain) AND (Additive Manufacturing OR 3D-printing) AND (Platform OR Marketplace)

Tab. 6.1.: Analyzed Companies.

ID	*Name*	*Website*
C1	Xometry	https://www.xometry.com/
C2	Shapeways	https://www.shapeways.com/
C3	Essentium	https://www.essentium.com/
C4	LINK3D	https://www.link3d.co/
C5	Inkbit	https://www.inkbit3d.com/
C6	3YOURMIND	https://www.3yourmind.com/
C7	Origin	https://www.origin.io/
C8	Jiga	https://www.jiga.io/
C9	AstroPrint	https://www.astroprint.com/

for traceability along supply chains) and do not conceptualize a marketplace in terms of resource allocation between supply and demand. The search returned a total of 705 hits. Screening all papers' titles and abstracts results in 39 articles that meet our inclusion criteria, including five removed duplicates. By analyzing main texts, we exclude six publications from the analysis corpus. An iterative backward and forward search with the remaining 29 publications yield seven additional articles, resulting in a final set of 36 articles.

For the **relevance cycle**, which links design activities to real-world problems and enhances the practical relevance of artifacts, we opted for a twofold approach: Firstly, we analyzed companies that provide marketplace solutions in AM, and secondly, we conducted qualitative expert interviews.

The dataset for the **company analysis** relies on CrunchBase, the world's largest database for young companies. We first considered all companies listed for the keywords "Blockchain; Marketplace; Additive Manufacturing" in the "3D Printing (Manufacturing)" industry and identified 319 companies. To ensure that our sample includes only relevant companies, we applied the following selection criteria. First, companies are relevant if they had already been mentioned in our literature review (i.e., Xometry, Shapeways, 3YOURMIND). Second, to consider potentially successful companies, we only selected firms that already received funding. Companies that went bankrupt or did not have an English homepage were excluded. In addition, we only considered companies that operate a marketplace for AM. Startups that do not provide a matchmaking marketplace but represent 3D printing manufacturers were excluded. Finally, we excluded companies that did not provide information on the aforementioned criteria. Considering all criteria, the final set of analyzed companies covered nine cases (see Table 6.1).

Tab. 6.2.: Details on Expert Interviews.

ID	*Job title*	*Job tenure*	*Interview duration*
E1	Head of CIO	31 years	74 min
E2	CEO & Founder	23 years	56 min
E3	Managing Director	27 years	58 min
E4	Research Engineer	17 years	53 min
E5	Project Director	30 years	65 min
E6	Product Development	4 years	47 min
E7	Innovation Manager	18 years	49 min
E8	Head of Blockchain Research	11 years	59 min

To collect data for the second iteration of the rigor cycle, we followed a qualitative approach conducting **semi-structured interviews**. This approach aimed to complement requirements derived from literature and company analysis and identify further necessities through exploratory interviews with experts and practitioners (Paré, 2004). We selected the interviewees (Table 6.2) with focus on ensuring that all experts have experience in the field of interest, represent different job tenure, and cover a diverse group of industries, research institutions, and company sizes. The time frame for conducting eight interviews spanned from January 2022 to February 2022, lasting on average 58 minutes, with a total of 461 interview minutes included in the analysis. Characteristics of the interviewees and the duration of the interviews are listed in Table 6.2.

We started the interviews by briefly presenting the research team and project and asked the interviewees to introduce their professional backgrounds. For the subsequent interview process, we developed an interview guideline and based our questions on preliminary considerations (Mayring, 2014). First, they align with inductive dimensions identified during the structured literature review (Corbin and Strauss, 2008). Second, we integrate deductive information (Mayring, 2014) and align our questions with the model of Veit (2003), that structures marketplace interactions (see Section 6.4). Due to the semi-structured nature, experts could also add novel ideas (Paré, 2004), and we were able to ask follow-up questions when interviewees mentioned interesting and unexpected insights (Paré, 2004). For data collection and analysis, we followed an iterative process (Corbin and Strauss, 2008). First, after conducting the interviews and obtaining informed consent, we transcribed the recorded interviews, presented them to the interviewees for approval (Brink, 1993), and analyzed the interview transcripts as we continued interviewing. Second, we analyzed the data and classified important aspects using codes (Corbin and Strauss, 2008) based on the qualitative content analysis guideline by Mayring

(2014). As data collection and analysis progressed, we continuously reconciled and modified our codes and dimensionalized codes and concepts (Corbin and Strauss, 2008). In total, we derived 302 open-ended codes, which we group into seven categories with 55 sub-codes. For interview transcription and analysis, we used 'MAXQDA 2020'.

Hevner's third step is the **design cycle**. It builds on the rigor and relevance cycles and is at the heart of any DSR project. Here, all previously identified findings are iterated as input to the design of an artifact. In our case, the artifact consists of synthesizing requirements and then articulating principles for BEM designs in AM. We gather the required input for this endeavour through the methodological steps above and describe core aspects as design rationales in the following section.

6.4 Design Rationales for Blockchain-enabled Marketplaces

Next, we focus on design rationales for BEMs in AM that emerge from our literature review, company analysis, and expert interviews (see Figure 6.2). We derive 27 mandatory requirements (MR), six optional requirements (OR) and formulate 12 DPs using the structure proposed by Chandra, Seidel, and Gregor (2015). To capture and communicate our design knowledge, we align our propositions with Veit's model, which structures marketplace interactions along the following phases (Veit, 2003): information and approach, intention and agreement, clearing and settlement, and add suggestions for BEM governance.

6.4.1 Information & Approach Phase

The first phase involves approaching potential transactions and identifying agents who share information on offered or demanded services (Veit, 2003). Participating agents include organizations, their employees, and machines (Angrish et al., 2018). To interact with each other and be identifiable, BEM agents require **digital IDs**. In AM scenarios, ID attributes **(MR1)** include both company IDs **(MR1.1)** (Al-Jaroodi and Mohamed, 2019) and 3D printer machine IDs **(MR1.2)** (Hofmann et al., 2021; Angrish et al., 2018). To track product histories (e.g., origin, process parameters), product identities **(MR1.3)** are also required (Ghimire et al., 2021, E2). They may be linked to digital twins **(OR1)** (Ghimire et al., 2021; Rožman, Diaci, et al., 2021; Li, Fu, et al., 2021, E2, E4, E8). "I think there are many cases where a real-time connection is not crucial and an implementation would cost you a lot of money. I do look at finished products and in hindsight on the manufacturing parameters but I don't need the data from the last four milliseconds. You should carefully assess whether you need a real-time synchronization or if a discrete or sporadic synchronization is enough" (E8). Consequently, we identified several ID features **(MR2)** that are particularly important for BEMs in B2B contexts. First, IDs should be able to map possible affiliation constructs (e.g., subsidiaries) and hierarchy levels (e.g., procuration levels) **(MR2.1)** (E2-4). Second, the level of stakeholder anonymity is essential. Although it should not be transparent to every market participant who interacts with whom or how market participants' supplier relationships are structured **(MR2.2)** (E2-7), firms should know direct business partners (Herm and Janiesch, 2021, E6, E7). In addition, independent third parties (e.g., auditors) should be able to trace relationships in a rule-based process **(MR2.3)** (E1, E2, E4). Potentially, an identifiable company brand also represents a certain value as it conveys trust **(OR2)** (E5, E7). Consequently, experts [E1, E4-7] suggest pseudonymous and sovereign identities by means of SSI to be viable for BEMs. By applying this concept, companies could independently and seamlessly be represented by SSI wallets holding ID credentials and certificates (Engelmann et al., 2018; Kaynak et al., 2020). In addition, wallets may be linked to a commercial registry record to enable ID authentications (E5).

DP1: *Design BEMs that allow each actor to manage their sovereign and pseudonymous IDs.*

DP2: *Design BEMs that support sovereign wallets that may hold certificates and other ID credentials to qualitatively and quantitatively describe actors.*

Another vital element involve the **data exchange**, where security (Lu, Xu, Liu, and Zhang, 2018) and integrity (Barenji, Li, et al., 2018) are crucial **(MR3)**. Especially in AM scenarios, sensitive and competition-relevant data (e.g., Computer Aided Design (CAD) product designs) are shared (E1-5) and must reach their destination without tampering **(MR3.1)** (Li, Barenji, et al., 2018; Ghimire et al., 2021, E3-8). Consequently, data storage and exchange design should ensure that only the most necessary data – depending on individual requirements or use case (Herm and Janiesch, 2021) – are stored on-chain (E1, E4-7) **(MR3.2)**. This approach may also circumvent transaction costs (E5) and limited storage capacity issues of blockchain protocols (Lu, Xu, Liu, Weber, et al., 2019; Kurpjuweit et al., 2021).

DP3: *Design BEMs to prevent unauthorized access to sensitive business data and store only a necessary minimum as a persistent blockchain trust anchor.*

Status updates of production processes and visualizations of real-time data **(OR2)**, as proposed by several researchers (Ghimire et al., 2021; Engelmann et al., 2018) and applied in cloud manufacturing projects (C1, C2, C4, C8, C9), represent a helpful feature that mainly brings convenience in BEMs (E4, E5, E7). Examples include better-estimated delivery dates (E3) and allowing supply chain actors to access product-specific information (E7). Several interviewees further mention **traceability (MR4)** requirements and note that ex-post transparency about production parameters **(MR4.1)** such as temperatures during printing processes and humidity in pressure chambers are essential for quality assurance (E1, E4, E5, E8). Consequently, they must be documented persistently and be accessible to authorized actors (e.g., customers, producers, auditors, regulators) (E2, E7).

DP4: *Design BEMs that require manufacturers to persistently log manufacturing data.*

6.4.2 Intention & Agreement Phase

This phase concerns offer and request coordination and terms and conditions negotiation (Veit, 2003).

The **supply side** shall provide information about their materials and processes to manufacture a product **(MR5)** (Freichel, Hofmann, and Winkelmann, 2021, E2, E4, E5), thereby accounting for DP3. This includes material origin (C3, C7), material properties (C5, C7), printer-specific information like run time, maintenance status, and service performance (E1, E4-6), and if used materials and processes are certified **(MR5.1)** (E1, E2, E4-6). General information on corporate certifications **(MR5.2)** might also be of interest (C1-3, E5). Additionally, suppliers could specify which complementary post-processing procedures they offer to refine a product **(OR4)** (E2). Depending on the BEM target customer group, producers need to be able to bid on requests (i.e., supplier-centric marketplaces) or indicate their available production capacities and processes (i.e., demand-centric marketplaces) (Stein et al., 2019; Freichel, Hofmann, and Winkelmann, 2021) and index possible delivery dates **(MR5.3)** (E6).

DP5: *Design BEMs that require manufacturers to provide information about their service offerings and specify their individual preferences.*

The **demand side** must specify its request **(MR6)** to match it with possible suppliers. Product and production specifications **(MR6.1)** include desired material properties

(Stein et al., 2019) and post-processing methods (Freichel, Hofmann, and Winkelmann, 2021), product quality, certification, and delivery date (Hofmann et al., 2021; Freichel, Hofmann, and Winkelmann, 2021), maximum dimensions (Stein et al., 2019), and an indication of the highest price (Hofmann et al., 2021, E2, E3, E5, E6) consumers are willing to pay **(MR6.2)**. Having an optional ability to filter by geographic location **(OR4)** allows producers to specify their preferred venue (Zhu et al., 2020, E4, E6).

DP6: *Design BEMs that enable consumers to specify their service requests.*

Given that BEMs purpose is to enable cross-company and multilateral cooperation, they should be designed with customizable functionalities and a UI **(MR7)**. To ensure a customer-centric approach for supplier matching, experts suggest filter options (e.g., lot size, production location) **(MR7.1)** (E6, E7). Furthermore, BEMs should have UIs with visualized information on offers, requests, manufacturing metrics, and transactions (Barenji, Guo, et al., 2021). Here, users should be able to enter data manually (via a human-machine interface HMI) or monitor automated processes (via a machine-to-machine interface) **(MR7.2)** (E1, E5).

DP7: *Design BEMs with ambidextrous user interfaces and functionality to screen marketplace data.*

Another element of BEMs include non-discriminating and transparent **reputation systems (MR8)** for customer relationship management (Leng et al., 2020; Zhu et al., 2020, E3, E4, E6, E7). As E6 notes, "you need a very sophisticated rating system to ensure that the necessary quality is provided across the platform." Demand-side customers might utilize reputation metrics as a filter option and selection aid for potential suppliers in terms of trustworthiness and reliability (E3, E4, E6, E7). Besides a company's reputation on quality, delivery time, communication behavior, and general user satisfaction (E6, E7), the rating of individual printers (E1, E2, E4, E6) and the option to individually prioritize specific reputation criteria are regarded relevant (E7). In the case of an automated reputation mechanism using smart contracts, updateable real-time data is required (Leng et al., 2020).

DP8: *Design BEMs with a reputation system where consumers can filter different criteria according to their individual preferences.*

Supply and demand matchmaking (MR9) can be designed in different configurations depending on a market design, the complexity of requests, and the technical knowledge of demanders (E5). Either consumers specify their requests according to DP4 and producers submit offers related to these service requests (E6, E7), or producers present their offerings (e.g., available machines with specifications and prices per utilization period), and consumers select a service provider according to their preference (Baumung and Fomin, 2019; Liao et al., 2020). In both supply-centric and demand-centric marketplaces, it is necessary to comply with DP2 by not disclosing sensitive data until the matchmaking process is complete **(MR9.1)** (Hofmann et al., 2021, E5, E7). Here, the process's degree of automation through IS depends on a product's manufacturing complexity (E1) and the customer's production knowledge (E5). In principle, fully automated matching seems technically possible (C1, C2, C6); however, experts consider it rather critically in B2B (E4, E6). Therefore, they advocate designing BEMs as demand-side marketplaces with partially automated processes, where consumers receive suitable matches for their requested services, but they manually select the final producer **(MR9.2)** (Hofmann et al., 2021, E1-7).

DP9: *Design BEMs as demand-driven marketplaces with semi-automated matchmaking functions where consumers receive suggestions for matching producers and choose to select the final producer based on their individual preferences without disclosing sensitive data.*

To reach a **transaction agreement (MR10)** in the matchmaking process, BEMs should further be capable of hybrid pricing and negotiation mechanisms such as bulk pricing **(MR10.1)** (E3-5, E7, C2). In addition, artificial intelligence-based instant bidding mechanisms, where service requests are first checked for feasibility followed by the calculation of an indicative price for service requests, may also be a feature of AM marketplaces (E2, E4-7, C1, C2, C6). However, experts adhere that – depending on users' security needs and trust in the B2B context – fully automated instant bidding should be an optional feature that does not represent an essential part of BEMs **(OR6)** (E5, E7).

DP10: *Design agreements in BEMs as hybrid systems that support individual pricing and negotiation.*

6.4.3 Clearing & Settlement Phase

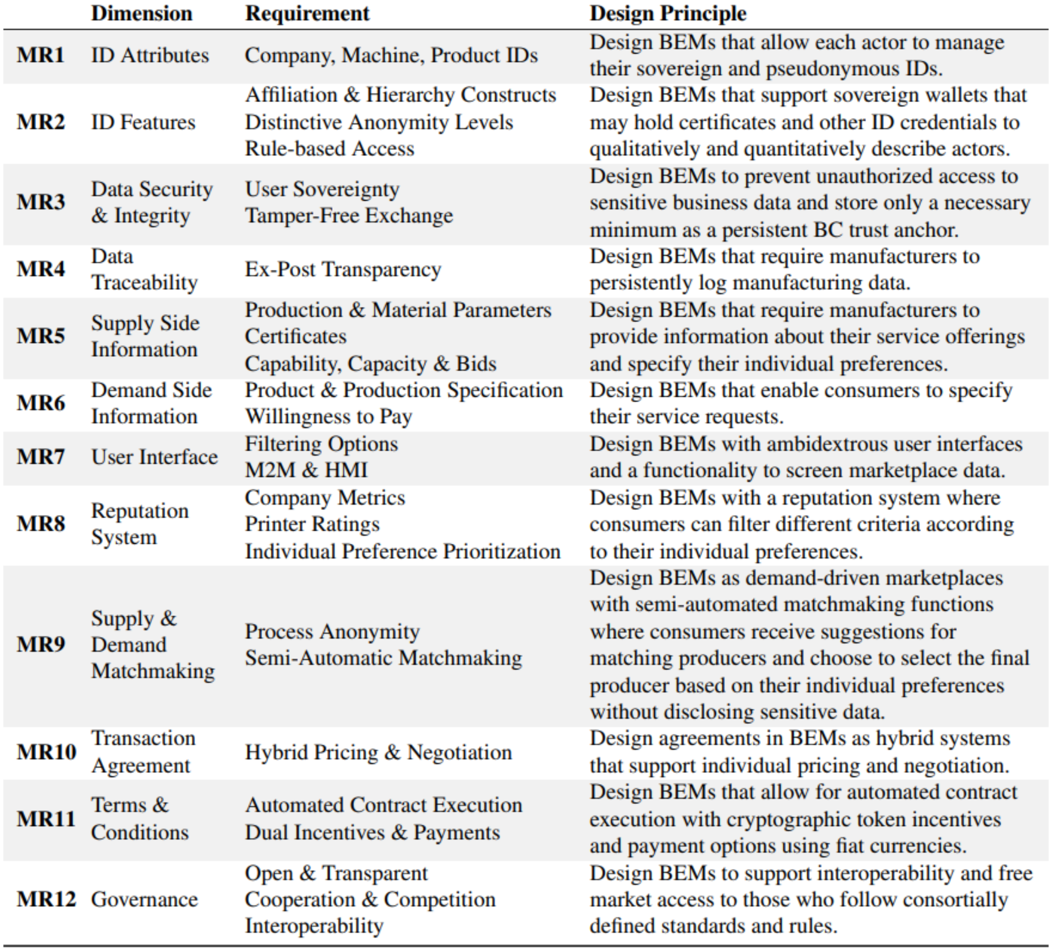
This phase involves the execution of consented agreements and the process of payment (Veit, 2003). BEMs are supposed to ensure the execution of terms and conditions **(MR11)** via smart contracts that are automatically and reliably triggered when predefined conditions are met **(MR11.1)** (Kaynak et al., 2020; Leng et al., 2020; Hasan and Starly, 2020, E2, E3). In terms of payment methods, different options prevail, that need to be considered in bidirectional and multilateral business interactions **(MR11.2)**. On the one hand, tokens and cryptocurrencies such as Ether can be used to provide both payments and incentive mechanisms (Kaynak et al., 2020; Angrish et al., 2018). On the other hand, some experts doubt the maturity of token systems for current B2B applications (E2, E4, E5) and, therefore, suggest that BEMs should offer classic payment options with fiat currency, especially at the very first stages of a BEM (E1-5, E8, C1, C2). As [E8] states: "At least, these are the questions we face. It's not either 'or', but often an 'and', especially in the early days." As an evolutionary step between fiat systems and cryptocurrencies, it might be helpful to use stable coins pegged to currencies such as the dollar, thus increasing exchange rate stability (Hofmann et al., 2021, E3-5).

DP11: *Design BEMs that allow for automated contract execution with cryptographic token incentives and payment options using fiat currencies.*

6.4.4 Suggestions on Governance

Shaping the governance openly and transparently **(MR12)** – along with the design of the marketplace interaction phases – has a critical importance for the success of BEMs in B2B contexts (E1, E2, E6). Particularly relevant are open standards that enable interoperability **(MR12.1)** with other marketplaces and avoid user lock-in (E2, E8). "If BEMs use common standards to identify users and enable interactions among them, the marketplace is fully interoperable with others. If a A-language and a B-language exist, users get locked-in. This is exactly what we want to prevent. It's a K.O. criterion for decentralized marketplaces. If this happens, we could use a centralized marketplace. But nobody (or at least not our company) wants that in business relationships. Sovereignty is king" (E8). Similar to researchers in blockchain-based B2B logistics (Beck, Kildetoft, et al., 2020), experts (E2, E5) argue that BEM governance and interoperability should be provided and observed by a consortium of industry leaders that creates a legally binding framework for interaction and monitors compliance **(MR12.2)**. This would include standards and rules that are jointly established with the participation of all interested stakeholders (E1, E2, E6). Companies would need to be able to pursue their interests within these boundaries and compete based on the jointly established infrastructure **(MR12.3)** (Kölbel and Kunz, 2020, E5). Having consortial structures at the organizational level would reflect the idea of decentralization as realized at the technological level through the operation of distributed nodes (E5).

DP12: *Design BEMs to support interoperability and free market access to those who follow consortially defined standards and rules.*



	Dimension	Requirement	Design Principle
MR1	ID Attributes	Company, Machine, Product IDs	Design BEMs that allow each actor to manage their sovereign and pseudonymous IDs.
MR2	ID Features	Affiliation & Hierarchy Constructs Distinctive Anonymity Levels Rule-based Access	Design BEMs that support sovereign wallets that may hold certificates and other ID credentials to qualitatively and quantitatively describe actors.
MR3	Data Security & Integrity	User Sovereignty Tamper-Free Exchange	Design BEMs to prevent unauthorized access to sensitive business data and store only a necessary minimum as a persistent BC trust anchor.
MR4	Data Traceability	Ex-Post Transparency	Design BEMs that require manufacturers to persistently log manufacturing data.
MR5	Supply Side Information	Production & Material Parameters Certificates Capability, Capacity & Bids	Design BEMs that require manufacturers to provide information about their service offerings and specify their individual preferences.
MR6	Demand Side Information	Product & Production Specification Willingness to Pay	Design BEMs that enable consumers to specify their service requests.
MR7	User Interface	Filtering Options M2M & HMI	Design BEMs with ambidextrous user interfaces and a functionality to screen marketplace data.
MR8	Reputation System	Company Metrics Printer Ratings Individual Preference Prioritization	Design BEMs with a reputation system where consumers can filter different criteria according to their individual preferences.
MR9	Supply & Demand Matchmaking	Process Anonymity Semi-Automatic Matchmaking	Design BEMs as demand-driven marketplaces with semi-automated matchmaking functions where consumers receive suggestions for matching producers and choose to select the final producer based on their individual preferences without disclosing sensitive data.
MR10	Transaction Agreement	Hybrid Pricing & Negotiation	Design agreements in BEMs as hybrid systems that support individual pricing and negotiation.
MR11	Terms & Conditions	Automated Contract Execution Dual Incentives & Payments	Design BEMs that allow for automated contract execution with cryptographic token incentives and payment options using fiat currencies.
MR12	Governance	Open & Transparent Cooperation & Competition Interoperability	Design BEMs to support interoperability and free market access to those who follow consortially defined standards and rules.

Fig. 6.2.: Synthesizing Description of Design Rationales.

6.5 Discussion & Conclusion

The decentralization of marketplace models through blockchain-enabled peer-to-peer networks is expected to have disruptive potential, especially in cross-company applications (Mourtzis et al., 2020). Given its five times higher volume compared to the B2C industry, the B2B context is particularly interesting (Ziegler et al., 2022), but requires specific structures in implementation. We identify these requirements and translate them into tangible DPs. To this end, our DSR methodology combines insights from a structured literature review with an analysis of practical projects and interviews with domain experts. In this context, Veit's (2013) marketplace interaction phases serve as a model and classification guideline.

Our three-fold research approach, incorporating both theoretical and practical knowledge, results in numerous managerial and scientific **contributions**. They reflect in 12 DPs, 27 MRs, and six ORs that describe identified factors for collaborative BEM networks and embody the core contribution of our work. We extend current approaches to designing BEMs that are largely not based on pre-structured requirements (Stein et al., 2019; Hofmann et al., 2021). Thereby, we follow the call for a more nuanced approach to this topic (Kölbel, Dann, et al., 2022), which focuses on the blockchain infrastructure of electronic markets (Alt, 2020a) and links the sub-economies of marketplace sharing with blockchain economies (Weinhardt, Peukert, et al., 2021). By developing a schema to describe, classify, and structure this complex topic, we contribute to exploring this novel research domain and lay a foundation for future research. With our DPs, we enable BEM practitioners to design technical constraints independently. For example, our expert interviews and startup analysis suggested that a demand-only market can be considered for BEMs in AM, where consumers of 3D printing capabilities communicate their specifications in return for a quote with individual preferences. This would imply that the respective companies' semantically ambiguous and historically entrenched production systems would not need to be connected to the market, thus considerably reducing complexity. Moreover, we argue that our proposed DPs can be applied to similar BEM use cases. Transferring the principles might require adjustments to certain features (e.g., information provided in the intention and agreement phase). However, we provide a baseline for researchers and developers of inter-organizational IS to draw upon.

When interpreting our results, we acknowledge inherent **limitations** to our study, which at the same time open avenues for **future research**. First, we encountered the challenge of keeping DPs generic so that they apply to a class of artifacts rather than just one instance. Here, we focused on technical aspects. However, we note that BEMs need to be considered from different perspectives. Relevant aspects include, for example, business models, incentive mechanisms, and legal and organizational aspects. Governance, which we briefly address in DP12, should also be considered in more detail. Similarly, it is worth investigating BEMs from an ecosystem and value co-creation perspective (e.g., through service-dominant logic). Second, our work needs to be regarded in its context, as designing marketplaces depends on individual use cases. Experts see the potential of BEMs in AM mainly in on-demand production for customer-specific requests and small batch sizes (e.g., prototypes, spare parts) rather than mass production (E3, E4). Our results can serve as a foundation for research that evaluates our DPs in, for instance, focus groups or workshops to confirm or iteratively revise them. Third, we identify subsequent topics for future research. These include auxiliary services (e.g., quality checks, certification services; E1-4, E7, C1), SSI utilization (E2, E5, E8), UI design (E6, E8), or chatbots (C2, C4) complementing BEM ecosystems. While previous BEM concepts (Freichel, Hofmann, and Winkelmann, 2021; Kurpjuweit et al., 2021) mainly propose automated payments via crypto tokens, our interviewees point to various issues when using tokens in B2B contexts (e.g., legal obstacles) and propose a hybrid system with fiat currencies (E1-5). Accordingly, further research should investigate the acceptance of tokens in business transactions. Naturally, another research avenue involves instantiating a BEM using our design rationales, which contributes to narrowing the chasm between promised business and the actual value of blockchain for organizations.

7

Interface Design of Decentralized Marketplaces

This chapter is based on a submitted article titled "Developing Blockchain-enabled Marketplace Interfaces: A Design Science Research Study". The article was co-authored by Ahmed Zekri and Christof Weinhardt and is currently under review at the 44th International Conference on Information Systems (ICIS). The tables, figures, and appendices were systematically renamed, reformatted, and appropriately referenced to align with the overall structure of the thesis. To further enhance clarity and consistency, formatting, and reference style were adapted and references were updated.

Publication details: *Kölbel, T., Zekri, A., & Weinhardt, C., Developing Blockchain-enabled Marketplace Interfaces: A Design Science Research Study, 44th International Conference on Information Systems (Under Review).*

Abstract: Digital transformation's scope evolves from being limited to the organizational level to inter-organizational collaboration in supply chain networks and business ecosystems. BEM have the potential to transform business networks by eliminating intermediaries. To investigate the interface design and visualization of BEMs, we employed a design science methodology and synthesized knowledge from literature, practice, and qualitative expert interviews. Our research provides (1) theoretically grounded and prescriptive knowledge expressed in meta-requirements and design principles inspired by effective use theory, and (2) presents concrete design features and an expository prototype instantiation. The prototype is evaluated through focus group workshops and interviews with experts and potential users. Our work contributes to recent calls to investigate the design and visualization of blockchain-enabled marketplaces, advances research on blockchain applications in B2B contexts, and expands the literature on information system design for marketplace-oriented transformations.

Keywords: Blockchain, B2B, Interface, Design Science Research, Theory of Effective Use.

7.1 Introduction

Digital transformation has become a boundary-spanning phenomenon that extends beyond the organizational level and requires organizations to not only adapt internally but also focus on inter-organizational collaboration in supply chain networks and business ecosystems (Beverungen et al., 2022; Hanelt et al., 2021). Initiatives span from cross-sectoral efforts like 'Gaia-X' to industry-specific projects such as 'Catena-X' in automotive and 'Manufacturing-X' in production. As a result, organizations no longer act in isolation but shape their business ecosystem and vice versa. Beyond transforming internally (e.g., adapting production sites to changing market conditions), they must reform their business relationships (e.g., altering monolithic production concepts toward dynamic ecosystems) and address political and socio-economic developments (e.g., push for digital sovereignty). Furthermore, from a production planning perspective, organizations must evaluate platform and marketplace concepts for sharing intra- and inter-organizational production capacities (Mourtzis et al., 2021; Veronesi et al., 2021) to respond flexibly to overcapacity or capacity bottlenecks caused by demand volatility and machine availability. The sharing economy for B2B is also deemed increasingly important (Große, 2022; Ocicka and Wieteska, 2017); however, organizations are still hesitant to share their data across organizational boundaries and participate in ecosystems (Prieëlle et al., 2022; Kaiser et al., 2019).

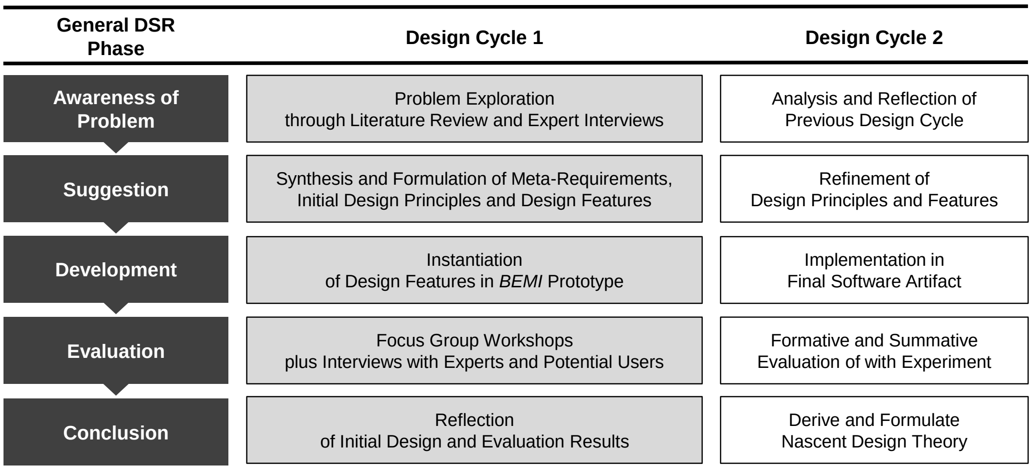
To support the adoption of business ecosystems, researchers, practitioners, and regulators advocate for digital sovereignty and note that ecosystems orchestrated by intermediaries lead to trust issues among complementors that hinder B2B adoption (Hoess et al., 2021; Kölbel and Kunz, 2020; European Commission, 2018; Hawlitschek, Teubner, et al., 2016). This paradigm shift is reflected in legislative initiatives such as the European 'DGA' and 'DMA', as well as in alternative concepts on decentralized markets powered by blockchain technology (Kölbel, Dann, et al., 2022; Dann et al., 2020; Notheisen, Hawlitschek, et al., 2017). Although blockchain technologies have yet to prove their supremacy over competing approaches, they have garnered attention for their potential to eliminate intermediaries and prompted research into various instruments that enable disintermediation (Beck and Müller-Bloch, 2017). This potential is particularly relevant in ecosystem contexts where the orchestrator role is not cast in an exclusive, non-adversarial position but instead embraces a competitive and dynamic role that fosters cross-organizational collaboration (Jovanovic et al., 2022; Hoess et al., 2021; Kölbel and Kunz, 2020; Zavolokina et al., 2020; Jensen et al., 2019). An emerging research area in the field of IS that follows this notion are BEMs. Studies explore BEMs potential for equal value creation (Kollmann et al., 2020), requirements for their design (Kölbel, Linkenheil, et al., 2023; Große, 2022), and concepts and technical implementations (Hofmann et al., 2021). However, an interface between the system and its users is essential to efficiently implement BEMs in practice, as it provides the main point of functionality connecting human objectives and computing resources. Moreover, an appealing design enhances marketplace traffic and positively affects user repurchase intentions (Matthew et al., 2021; Pee et al., 2018). Despite this, studies on interface design for BEM applications are nascent, albeit having a rich tradition in marketplace research. To bridge this gap, this study aims to investigate the design of a BEM interface (BEMI) in the context of collaborative additive manufacturing (CAM). CAM is a rapidly growing and innovative industry that offers more flexibility than traditional mass production (Wohlers Associates, 2019) and has been found to improve the sustainability of supply chains, especially in decentralized approaches with leased production capacities (Manco et al., 2023). Therefore, we pose the RQ:

Research Question: *How can BEMIs be designed that effectively support supply and demand matching in CAM?*

We conduct a DSR study (Kuechler and Vaishnavi, 2008) to provide prescriptive knowledge both of theoretical interest and practical importance for developers. It includes two main components: (1) design knowledge and (2) a prototype – particularly for web-based BEMIs in CAM that facilitate the matching of supply and demand. We obtain our design knowledge from a preliminary literature review and interviews with domain experts. This leads to theory-driven Meta-Requirements (Meta-REQ) and DPs inspired by the theory of effective use (TEU) (Burton-Jones and Grange, 2013). We then derive tangible design features (DF)s and implement them in a design prototype. To evaluate our prototype, we conduct two focus group workshops and further interviews with experts and potential users. Thus, we respond to recent calls to study the design and visualization of BEMs, advance the research field on blockchain applications in B2B contexts, and expand the literature on IS design for marketplace-oriented transformations. We focus primarily on the development perspective for informed design decisions and aim to balance simplicity and complexity. Nonetheless, we believe that providing comprehensible interfaces is also relevant for users to analyze make informed purchase decisions.

7.2 Research Design

We follow the DSR process to design a BEMI that enhances user interaction and access to CAM-related information to explore, extract, and aggregate knowledge about supply and demand. DSR is well-suited to guide our research, as it aims to create design knowledge through innovative solutions to practical problems (Hevner, March, et al., 2004). In this section, we outline our design process and elaborate on intermediate steps that led to design outcomes discussed later. The primary focus of this paper is on the activities and results of the first design cycle, as depicted by grey boxes in Figure 7.1.



General DSR Phase	Design Cycle 1	Design Cycle 2
Awareness of Problem	Problem Exploration through Literature Review and Expert Interviews	Analysis and Reflection of Previous Design Cycle
Suggestion	Synthesis and Formulation of Meta-Requirements, Initial Design Principles and Design Features	Refinement of Design Principles and Features
Development	Instantiation of Design Features in *BEMI* Prototype	Implementation in Final Software Artifact
Evaluation	Focus Group Workshops plus Interviews with Experts and Potential Users	Formative and Summative Evaluation of with Experiment
Conclusion	Reflection of Initial Design and Evaluation Results	Derive and Formulate Nascent Design Theory

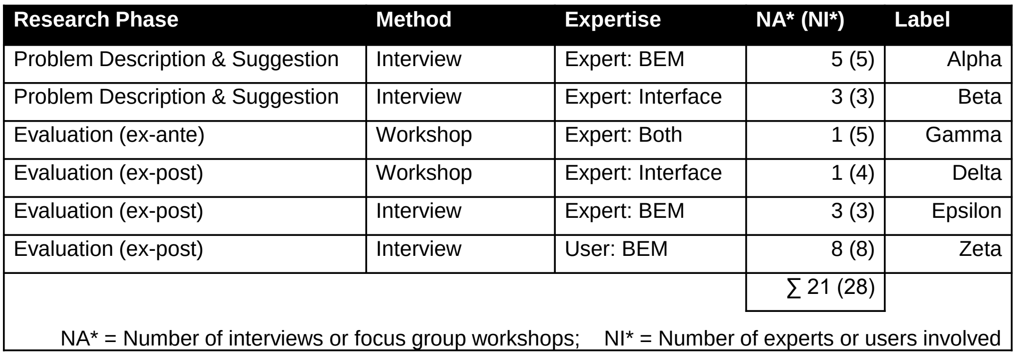
Fig. 7.1.: Design Science Research Methodology based on Kuechler and Vaishnavi (2008).

Problem Description & Suggestion. We started the first cycle by aiming for a comprehensive understanding of both obstacles faced by companies in interacting with marketplace interfaces and foundational capabilities of interface design. To ensure rigor and relevance, we adopted a twofold approach. First, we conducted a structured literature review on the design of interfaces in marketplaces (rigor). Since literature on BEMIs is unavailable, we focused on the existing knowledge on marketplace interfaces at large. To supplement what we found in the literature and check the applicability for BEMIs, we subsequently conducted interviews with experts that practically inform our design (relevance). Inspired by Gregory and Muntermann (2014)´s work, we adopted mechanisms for abstraction (i.e., extract relevant knowledge from the general design of marketplace interfaces and apply it to the specific context of BEMIs) and de-abstraction (i.e., transfer abstract theoretical knowledge to our specific design instantiation).

The structured literature review followed the methodological suggestions by Webster and Watson (2002). We queried six databases (ACM Digital Library, AIS Library, Taylor & Francis Online, Scopus, Web of Science, and ProQuest) for the keywords "Marketplace OR Platform AND User Interface OR UI OR Interface Design OR Website Design" and obtained 1866 studies. We then removed duplicates and analyzed each article's title and abstract, yielding 34 articles. To ensure the relevance of the selected studies, we reviewed the full texts using three inclusion criteria; (1) the study must focus on the design of marketplaces, (2) it must be in English, and (3) it must be peer-reviewed. This resulted in 16 relevant articles. Further forward and backward searches yielded nine additional articles, resulting in a total of 25 papers.

To refine and validate our findings, we conducted exploratory interviews with eight domain experts with diverse backgrounds (see Table 7.1). We aimed to gather insights from experts familiar with BEMs but not regularly involved in interface development and design-savvy participants. The semi-structured interviews consisted of open-ended questions aimed at assessing the applicability of our structured literature review findings to BEMIs and identifying obstacles that the experts anticipate in the design process. All interviews were recorded, transcribed, and coded using MAXQDA software (Corbin and Strauss, 2008) and a qualitative content analysis approach following Mayring (2014). The interviews and structured literature review supported the practical relevance of our research before artifact development (Sonnenberg and vom Brocke, 2012) and revealed that transparent interaction with BEMIs is vital for effective use but achieving it can be more complex than expected.

Tab. 7.1.: Interview and Focus Group Overview.



Research Phase	Method	Expertise	NA* (NI*)	Label
Problem Description & Suggestion	Interview	Expert: BEM	5 (5)	Alpha
Problem Description & Suggestion	Interview	Expert: Interface	3 (3)	Beta
Evaluation (ex-ante)	Workshop	Expert: Both	1 (5)	Gamma
Evaluation (ex-post)	Workshop	Expert: Interface	1 (4)	Delta
Evaluation (ex-post)	Interview	Expert: BEM	3 (3)	Epsilon
Evaluation (ex-post)	Interview	User: BEM	8 (8)	Zeta
			∑ 21 (28)	

NA* = Number of interviews or focus group workshops; NI* = Number of experts or users involved

Development & Evaluation. Drawing on the TEU (Burton-Jones and Grange, 2013) as our overarching kernel theory, we derived Meta-REQs to inform the design of our BEMI. The authors' framework thereby informs our approach for designing IS that enables users to interact effectively with the system by considering three dimensions: (1) unimpeded access to the system's representations through *transparent interaction;*

(2) improvement of *representational fidelity*, or the ability to obtain representations that accurately reflect the domain; and (3) *informed action*, or the ability to act on accurate representations and make informed decisions to improve one's state in the market. In the context of our study, the demand side of a CAM marketplace, for instance, requires access to accurate demand information through transparent interaction, a representative overview of the supply of 3D printers through improved representational fidelity, and the ability to make informed decisions to optimize purchasing behavior such as selecting the right transaction partner, ordering services, or invoicing through informed action. Building on our Meta-REQ, we then proposed initial DP following Gregor, Chandra, et al. (2020) and translated these DPs into tangible DF to support artifact development (Meth et al., 2015). Finally, we instantiated our design suggestions in a prototype using 'AdobeXD software', a valuable tool for prototyping and communicating design concepts (Rae, 2020).

To evaluate our initial prototype, we employed a two-step strategy. The first step was a formative ex-ante evaluation conducted through an exploratory focus group workshop (Tremblay et al., 2010), with five participants (2 females, 3 males) of varying job tenure and expertise levels (BEM experts and interface designers). We encouraged participants to interact with our interface and then asked them about the challenges they faced during the interaction. This initial demonstration allowed us to discuss completeness, consistency, and applicability (Venable et al., 2016) and gather feedback for further improvements. For instance, we collected feedback regarding individual features' design, order, or arrangement. Then, after implementing the changes, we applied summative ex-post evaluation episodes through a focus group workshop and semi-structured interviews with both experts (3 males) and potential users (4 females, 4 males) of BEMs (see Table 7.1). In this step, we demonstrated the instantiated artifact by a click-through and asked for feedback on effectiveness, efficiency, and consistency.

7.3 Designing Interfaces for Blockchain-enabled Marketplaces

7.3.1 Problem Description

Our research addresses the intersection of three research streams in IS: production resource sharing via marketplaces, BEM concepts, and interface design and development. We build on previous studies that focus on the efficient allocation of production resources in networks (Freitag et al., 2015), market mechanisms in CAM platforms (Stein et al., 2019), and BEMs for cooperative production in AM (Kölbel, Linkenheil, et al., 2023; Hofmann et al., 2021). Ming et al. (2008) further provide insights into interfaces for cooperative networks in product development. Islam et al. (2016) illustrate the implementation of an industrial visualization model that provides its users with cloud-based interfaces in cooperative manufacturing.

Despite these advances, previous research tends to examine these areas in isolation, and there is a recognized need to study the transferability between contexts to design BEMIs (Kölbel, Linkenheil, et al., 2023). This challenge is further compounded by practice-oriented experts and less tech-savvy individuals, who have reported difficulties of B2B users in interacting with interface concepts used in decentralized settings today. For example, one interviewee mentioned their experience with the marketplace for NFTs *OpenSea*, stating that she had to "search the interface extensively before even knowing how to get to the needed information" (Beta 3). Another interviewee expressed their concern that "interfaces that we know from decentralized finance are far too playful, which definitely leads to trust issues in business contexts" (Alpha 2). To address these challenges, our study is guided by the TEU and employs a two-fold research approach. We conduct a structured literature review to synthesize and refine the theoretical foundations for designing marketplace interfaces in general, and expert interviews to discuss concrete instantiations in the context of BEMIs. We provide an overview of the requirements identified in the literature, summarized in Table 7.2, and separated into general requirements for UIs, web application-specific requirements, and marketplace-specific requirements. Black dots indicate that the respective characteristics or attributes are explicitly named in the analyzed studies. White dots indicate that the characteristics are named, but the authors do not specify further, while blanks indicate that the characteristics are not mentioned in the paper. Drawing on both theoretical underpinnings and supplementary expert opinions, we outline Meta-REQs, DPs, and DFs for designing BEMIs below and discuss challenges that companies face in the design process.

7.3.2 Suggestion

Given our emphasis on **transparent interaction** as the first category of effective use, our design propositions for BEMIs are centered on two crucial actions that can enhance users' ability to interact with the system, namely adapting and learning the interface structure (Burton-Jones and Grange, 2013). Users' participation in adapting a system's interface structure is typically facilitated through personalization of the UI or by providing suggestions for improvement to system designers. These suggestions

Tab. 7.2.: Synthesis of Literature Review Findings on Interface Design.

	Dimensions	**Usability**					**Aesthetics**		**User orientation**		**Technical concepts**			
	Characteristics	Efficiency	Simplicity	Recognition value	Intuitiveness	Error prevention	Layout	Coloring	Target group orientation	Requirements gathering	Resilience	Interoperability	Safety	Scalability
General Requirements on User Interfaces	Briones et al., 2021	●				●		○	●	○				
	Chiu and Wu, 2020	●	●	●	●	●	○	○	○			○		
	Ferre et al., 2001	●	●			●	●	○						
	Ferris and Zhang, 2016	●					●	●	●					
	Mahfouz, 2000	○						○		●				
	Molich and Nielsen, 1990	●	●	○	●	●								
	Nielsen, 2005	●	○	●	○	●	●	○						
	Roth, 2017						●							
Web Application-specific Requirements	Adams and Reynolds, 2006									●		●		
	Arnold et al., 2003				○		●		●	●				
	Barbosa et al., 2020												●	
	Battig, 2003	●	●		○	○				●				
	Garett et al., 2016		●	○	○		●			○				
	Johnston and Warkentin, 2004												●	
	Lavie and Tractinsky, 2003		●	○			●	○						
	Mazumder and Das, 2014	●	●	●	○	●		○	○	○				
	Nguyen, 2012	●	○		○									
	Yang and Xu, 2022						●	●						
Marketplace-specific Requirements	Bakos, 1998	●								●			○	
	Lampinen and Brown, 2017											○	●	
	Martins et al., 2020	●	○			○	●	●		●				
	Matthew et al., 2021	○		○	●	○	●	○						
	Meyliana et al., 2017		○							●				
	Usländer et al., 2021										●	●	●	●
	Walia and Zahedi, 2008							○					●	

can then be used to modify the interface to meet users' needs (Barki et al., 2007). Furthermore, organizations that introduce new IS usually provide training sessions and system manuals to aid users in learning the structure of the system (Lauterbach et al., 2020). However, these strategies are more challenging in the context of BEMIs due to the decentralized nature of these marketplaces. Unlike a traditional marketplace that is operated by a single entity, there is no apparent intermediary to provide training and support. Instead, BEMIs are operated by a network of actors and rely on community engagement to drive the system. Consequently, our initial approach to improving users' transparent interaction and access to information in BEMIs centers on adapting the interface's structure (Burton-Jones and Grange, 2013). Emphasizing an operational perspective, the design of BEMIs should prioritize simplicity and user-focused information (Ferris and Zhang, 2016, Alpha 3-5), with a navigational landing page that serves as the first point of contact and overview of the platform's functionalities and features (Alpha 3; Beta 1-3). The landing page should provide quick redirection to different pages and parts of the marketplace (i.e., supply or demand side), enhancing the transparency and intuitiveness of the user experience and allowing audience-specific content and access to general as well as supply and demand-specific data (Gamma 1). The design should integrate clear and recognizable icons for each action or function to simplify the interaction process between users and the interface (Alpha 2, 5; Beta 1, 2). Using neutral colors, such as gray or white for the background, and a mixture of primary, secondary, and accent colors for further controls will increase user satisfaction and reduce the risk of user frustration or confusion (Ferris and Zhang, 2016, Alpha 3-5). However, finding a balance between simplicity and trustworthiness **(Meta-REQ1)** is challenging for BEMIs (Alpha 2). The interface should be accessible to individuals with different technical knowledge and abilities, ensuring usability for both tech-savvy and non-tech-savvy individuals despite an overall technical complexity (Alpha 1, 2; Beta 2). BEMIs should simplify navigation by allowing users to formulate their information needs naturally using established patterns like in traditional marketplaces (Nguyen, 2012, Alpha 2, Beta 1-3). As one interviewee suggested, "The decentralization leads to an unprecedented complexity in the marketplace backend. A major challenge is designing interfaces and bringing individual components together so that the front-end user does not notice decentralized technologies being used. In terms of use, there should be no discernible difference between traditional, centralized, and decentralized marketplace interfaces. As a designer, find the sweet spot" (Alpha 1). Following this line of thought, we propose our first DP1.

DP1: *"Design BEMIs that prioritize simplicity and intuitiveness while balancing trustworthiness and usability to ensure a user experience that resembles traditional marketplaces."*

As a complementary approach to improve users' transparent interaction, BEMIs should support users' learning (Burton-Jones and Grange, 2013) by providing concise and audience-specific explanations of complex concepts **(Meta-REQ2)**, thereby fostering intuitive and user-friendly interfaces. This can be achieved through comprehensive documentation (Garett et al., 2016; Mazumder and Das, 2014; Molich and Nielsen, 1990) on how the marketplace works, including functional, technical, and non-technical aspects (Alpha 3-5; Beta 1). This is especially important in BEMI contexts, as blockchain technology is often complex, and users need to understand key concepts such as digital signatures, consensus algorithms, and SCs. Another subpage should explicitly focus on community engagement (Gamma 1). As blockchain projects are governed not by an intermediary but by on-chain voting processes, BEMI users should be able to quickly access these mechanisms and provide opportunities for users to connect, communicate, and collaborate (Gamma 1). To further account for the decentralized nature of blockchain communities and foster innovation, BEMIs should enable users to experiment and explore new ideas by integrating tools and resources that support the development and deployment of new applications and services (Gamma 1). Access to technical documentation of the marketplace and open-source code further fosters trust by transparency and enables forking (Alpha 3-5; Beta 1). As one expert notes, "decentralized marketplaces are all about trust. Trust in the technology, trust in the network behind it, and trust in the community. Without trust, a decentralized marketplace cannot succeed. Providing users with a clear and concise explanation of the system's details is essential to promote user adoption" (Beta 3). Based on these considerations, we propose our second DP.

DP2: *"Design BEMIs that support users' learning and engagement by providing comprehensive documentation to foster trust by transparency and stimulate innovation in decentralized communities."*

IDM plays a critical and strategic role in the design of BEMIs, as it serves as the "gateway and doorkeeper to the marketplace" (Beta 1). To ensure trust and efficiency in marketplace transactions, BEMIs must implement clear and intuitive mechanisms for IDM that enable users to establish their reputation within the community, thereby increasing trust and credibility among market participants (Große, 2022; Usländer et al., 2021; Barbosa et al., 2020; Lampinen and Brown, 2017). Self-sovereign authentication methods are emphasized by experts as vital instantiations, as they enable users to manage and verify their digital IDs without relying on central authorities (Kölbel, Linkenheil, et al., 2023, Alpha 1, 3). The identities should be designed for interoperability, easily accessible, and manageable by users across different platforms **(Meta-REQ3)**. As one expert stated, "decentralization thrives primarily upon our ability to ensure persistence and value across different networks" (Alpha 3). The challenge in this context is providing role profiles that can map the variability and dynamics of user roles (Gamma 1). Additionally, to ensure secure and private data transfer between market participants, BEMIs must provide encrypted methods of transmitting and storing data, preventing unauthorized access to sensitive information, and enabling users to make informed decisions about how their information is used (Kölbel, Linkenheil, et al., 2023). To protect user privacy and control, BEMIs must have an interface that connects digital identity wallets to the marketplace (Alpha 1-5). To ensure that users can trust the information exchanged on the marketplace (Lampinen and Brown, 2017), only verified participants should be able to interact with each other (Alpha 2). As such, a fair, transparent and interoperable reputation system **(Meta-REQ4)** should be implemented. This system should differentiate between actor-specific trust and trust in marketplace processes (Alpha 3). To avoid fake ratings, only ratings where it can be verified that the actors were in a transactional relationship should be allowed (Alpha 1,2). By following the spirit of ”recognition is better than recall” (Alpha 2), we propose as our third DP.

DP3: *“Design BEMIs with an interoperable identity management and reputation infrastructure to increase trust between transaction partners and enable user-empowerment with sovereign authentication methods.”*

Intending to achieve **representational fidelity** in the design of BEMIs, users must be able to obtain transparent and reliable representations of a particular domain (operational perspective) in order to make informed decisions based on trustworthy data (strategic perspective). This requires considering humans’ limited information-processing capacity, which makes it challenging for them to consider all perspectives and information at once (Chun et al., 2011). To adapt the interface structure and enable a more natural way of interaction, we draw on the concept of affordances (Gibson, 1977) that provides a solid theoretical grounding for next DPs. Affordances help users to directly interact and change interface visualizations. For example, interactive features such as menus, sliders, and filters allow users to translate their information needs into a series of actions within the interface (e.g., setting filters). By operationally dividing complex and multidimensional concepts – such as the use case of CAM – into smaller parts and allow for adjustable visualizations **(Meta-REQ5)** providing filters on BEMIs, users can start with one particular perspective and successively take additional perspectives into account (Martins et al., 2020; Alpha 1). To improve efficiency and reduce search effort, BEMIs should provide both supply and demand-side filtering capabilities that are adjustable to accommodate user preferences (Martins et al., 2020, Gamma 1). The filtering options should include information about organizations as potential transaction partners, transaction process information, and specifications of the product or service (Alpha 1). Representational fidelity is enabled by displaying only data items that match the defined criteria. For example, filtering for and comparing certificates on the demand side helps identify those potential transaction partners with specific qualifications for a particular production process (Alpha 1, Beta 2), thus creating qualitative comparability and consistency (Freichel, Hofmann, and Winkelmann, 2021). To further increase recognition among users and enhance the overall user experience, BEMIs should allow for consistent graphical representation of service operations (i.e., orders) and available hardware resources (i.e., 3D printers) **(Meta-REQ6)** (Garett et al., 2016; Mazumder and Das, 2014; Nielsen, 1994, Alpha 1, 4, 5, Beta 1). Considering this, we argue implementing our fourth DP.

DP4: *"Design BEMIs with graphical representations and functions for CAM-specific perspectives in order for users to seamlessly navigate its multidimensionality and incorporate stakeholders' points of view."*

Our next DP focuses on supporting users in independently interacting with BEMIs. Given the relative novelty of the topic, the design should facilitate the opportunity for users to interact with the interface and receive feedback when something goes wrong. To minimize the rate of errors and increase the efficiency of the system, it is crucial to ensure that inputs are validated and users are alerted to any potential errors (Briones et al., 2021; Ferris and Zhang, 2016; Molich and Nielsen, 1990, Alpha 1). A high error rate can negatively impact the system's usability, reducing both efficiency and user satisfaction (Mazumder and Das, 2014; Ferre et al., 2001; Nielsen, 1994). Therefore, functions should be implemented that instantly validate inputs and alert users to any errors **(Meta-REQ7).** Additionally, error-prone operations should be checked, and users should be offered a confirmation option before executing the operation (Nielsen, 1994). It is important to note that the principle of reversible errors is more complicated which applied in BEMs in comparison to centralized marketplaces as transactions once finalized cannot be altered and the stored information becomes irreversible (Alpha 2-4). Hence, we propose our fifth DP.

DP5: *"Design BEMIs with real-time input plausibility checks to reduce the risk of errors and allow for time-limited corrections."*

The design of BEMIs requires a strategic balance between preserving the integrity of marketplace data and safeguarding the privacy and confidentiality of sensitive information (Kölbel, Linkenheil, et al., 2023, Delta 1). Designers must ensure that the interface can provide a secure and trustworthy environment for users to interact and conduct transactions by incorporating functionalities that allow for selective data transmission **(Meta-REQ8).** This balance is essential in CAM, where sensitive and competition-relevant data (e.g., CAD product designs, business relationships) are shared between organizations (Alpha 5, Gamma 1). Maintaining the confidentiality of such data protects against unauthorized access and exploitation by competitors, as well as preserving valuable intellectual property (Alpha 4). However, using blockchain technology raises concerns over the potential exposure of confidential information if it is stored publicly on the blockchain (Kölbel, Dann, et al., 2022). To address these concerns, BEMIs should feature functionalities that allow for secure off-chain storage of confidential information in P2P databases instead of transparently on the blockchain (Kölbel, Linkenheil, et al., 2023, Alpha 5). This approach mitigates blockchain protocol limitations (Herm and Janiesch, 2021), such as limited storage capacity and high transaction costs, and provides organizations with greater control over the data they share. In the context of CAM, BEMIs should provide references to the storage location of, for example, product data instead of directly storing it on the platform (Alpha 5). To enhance the security and privacy of such data, they should include functionalities for encrypting the information before storing it in off-chain P2P databases (Gamma 1). This involves the implementation of client-side encryption to ensure the secure transmission and storage of data on a decentralized network. Organizations can regulate data access through role-based access controls and encryption mechanisms, thus preventing any unauthorized access to sensitive information (Gamma 1). By incorporating functionalities that allow for off-chain storage of confidential information, BEMIs can increase the trust of organizations in BEMs and encourage their participation in the marketplace, promoting growth and competitiveness against centralized marketplaces. Hence, we propose our sixth DP.

DP6: *"Design BEMIs with external storage connectivity to mitigate blockchain scalability issues and enable privacy-preserving data storage."*

BEMs involve complex mechanisms like SCs, which can be difficult for users to understand and navigate. To mitigate these challenges and turn transparent interactions into **informed actions**, interface designers must develop interfaces that are user-centric, clear, and concise in presenting the information. Accordingly, BEMIs must provide tabular overviews of all user-specific information in dashboards that must be specialized to supply-side and demand-side market participants (Alpha 1,2) **(Meta-REQ9).** Dashboards visually represent essential information on a single screen, offering relevant information to various stakeholders in a marketplace at a glance (Few, 2006). This enables stakeholders to monitor and analyze key performance indicator (KPI) and quickly understand the market to make informed and data-driven decisions about buying and selling products and services. Given its tailored nature, it addresses the specific needs of each user and allows them to easily find and focus on relevant information, reducing the time and effort required to make informed decisions. Thus, dashboards empower users with the information they need to optimize processes and improve their state in the domain. For example, comparing sales metrics helps identify potential growth opportunities, provides cost transparency, and enables decision-making to optimize purchasing processes. In CAM, suppliers may want to track key metrics such as the number of transactions, average order value, and customer satisfaction, while customers may be more interested in monitoring their expenses and analyzing their favorite transaction partners. To promote transparency in the marketplace, dashboards should also provide users with a clear visualization of the transaction history, including the time, date, and parties involved (Gamma 1). The ability to save preferred settings and views is also crucial in enhancing the user experience and ensuring efficient decision-making (Gamma 1). Considering this, we argue implementing our seventh DP.

DP7: *"Design BEMIs with user-specific dashboards that enable customized information and reports on essential KPIs across variable levels of granularity."*

To provide users with actionable insights that facilitate decision-making and reflect industry-specific processes, we further argue that BEMIs implement two domain-specific functions **(Meta-REQ10)**. First, according to several experts (Alpha 1, 2, 4, 5; Beta 1, 3), a direct communication channel between buyers and sellers should be implemented. This channel should facilitate marketplace interactions and provide users with a sense of security and confidence in their transactions. As noted by the interviewees, direct contact in BEMs is crucial to ensure transparency in the marketplace while eliminating the need for third-party mediation. Second, the BEMI should enable demanders to reserve suppliers' manufacturing capacities (Alpha 2, 4). As one interviewee noted, "Even in decentralized marketplaces, there is a process behind ordering manufacturing capacity. In other words, the decision-making to buy something takes quite some time, while you also need the certainty that the capacity you desire is still available" (Alpha 2). However, to prevent the exploitation of this function, experts argue that it should be associated with additional costs (Alpha 2, 4, 5). The reservation costs should depend on the product's price as a percentage and increase over time (Alpha 5). As expert Alpha 5 explains, "The longer I block a capacity, the more I should have to pay." Taken together, we formulate our last DP as follows.

DP8: *"Design BEMIs that reflect industry-specific processes to guide users with actionable insights that facilitate decision making."*

To implement our DPs in an artifact (i.e., BEMI prototype), ensure replicability, and provide practitioners with actionable guidance to instantiate the design knowledge, we translated our DPs into appropriate DFs. Figure 7.2 illustrates the overall process with ten Meta-REQ, eight DPs, and 16 DFs.To implement our DPs in an artifact (i.e., BEMI prototype), ensure replicability, and provide practitioners with actionable guidance to instantiate the design knowledge, we translated our DPs into appropriate DFs. Figure 7.2 illustrates the overall process with ten Meta-REQ, eight DPs, and 16 DFs.

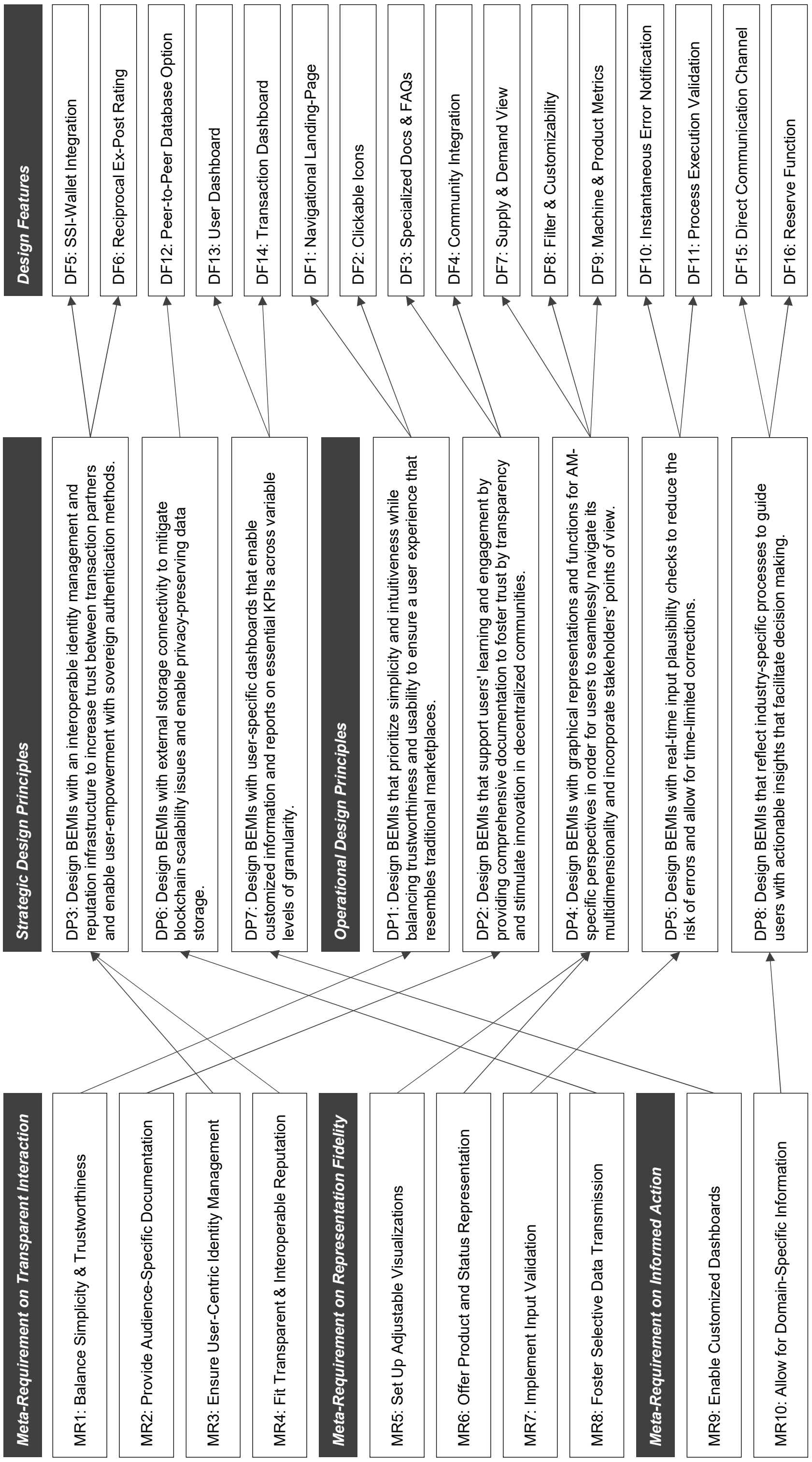


Fig. 7.2.: Mapping of Meta-Requirements, Design Principles and Design Features.

7.3.3 Development

Expository instantiation. To illustrate the generalized design knowledge with a concrete example, we mapped our DPs to DFs and implemented them using 'AdobeXD'. Below, we present our prototype, "*Open3D* marketplace" (Figure 7.3), that instantiates the proposed design solution.

To instantiate DP1, we applied an onboarding process that enables users to familiarize with BEMIs. Upon first accessing the *Open3D* marketplace, users are directed to a landing page (DF1), which serves as the artifact's central point of contact. This landing page provides users with essential information about the system, such as BEM values, terms of use, and a help center, as well as clickable icons (DF2) that allow for interface customization, including language selection and settings. Users can learn about the BEMI and gradually engage with its functionalities by utilizing these features. Consistent with DP2, we integrate community engagement mechanisms into the BEMI to support decentralized governance, transparency, and user learning, which are fundamental characteristics of Web3 communities. We believe that allowing users to participate in the marketplace's governance makes them more likely to feel a sense of ownership, co-determination, and commitment to the system, which increases the chances of sustained adoption and growth. To promote transparency and provide users with detailed information about the system, we implement icons that redirect users to the technical documentation and whitepaper of the marketplace (DF3). Furthermore, we foster community engagement (DF4) by offering users the opportunity to participate in the marketplace's governance via 'Get Involved in DAO', access a software development kit (SDK) to create their own marketplace via 'Start Building Your Own Marketplace', or join an existing BEM's Discord community. DAOs allow the community to decide on the direction of the marketplace, while the SDKs encourages innovation and experimentation by enabling users to develop new modules for or fork BEMIs.

The system architecture of *Open3D* is designed to provide access to further subsystems of the marketplace from the landing page, but it requires authentication before entering market-specific subpages. The authentication process is facilitated by the 'Connect Wallet' function (DF5), which integrates an interoperable IDM and reputation infrastructure through Self-Sovereign Identity (SSI) wallets. This feature is designed to promote trust between transaction partners and enable users to verify their identity using sovereign authentication methods (DP3). Successful authentication displays the Decentralized Identifier (DID) of the logged-in user, which is a unique identifier that enables secure and decentralized IDM with verifiable credential (VC), enabling certified interaction while preserving privacy. The use of

SSI wallets in *Open3D* allows users to maintain control over their data and provides secure access to services while integrating reputation mechanisms that are crucial for building trust in decentralized marketplaces (DF6). Once users connect their SSI wallet and complete authentication, they can access the supplier and demand subsystems through specific dashboards (DF7). These dashboards are customizable, allowing for the use of interactive features (e.g., drilldown, filters; DF8) and visual features (e.g., diagrams, images; DF9), which can be used depending on the intended purpose (e.g., planning, monitoring) and the users' characteristics (e.g., knowledge level) (Yigitbasioglu and Velcu, 2012). To enhance the user experience and enable effective decision-making, *Open3D* allows users to filter the data displayed in a visualization, roll-up (abstract), and drill-down (elaborate) the data at the level of individual processes. This helps users to easily navigate the system and identify potential transaction partners, increasing the efficiency and effectiveness of the marketplace. The 'Become a Supplier' and "'Order Your Parts' buttons are unlocked after authentication, allowing users to access different interaction points. Clicking the 'Order Your Parts' button takes users to the demand side while clicking the 'Become a Supplier' button takes users to the supplier side. On the supplier side, users can filter published offerings based on company-related information (e.g., company size, industry, location, rating, supplier certificates), product-related information (e.g., printing material, production technology, machine type, availability period, minimum capacity, finishing method), and process-related information (e.g., delivery time, price indications). Similarly, the demand side provides information about requests for 3D printing capacities. The "Issue a New Request" button triggers a smart contract through which demanders can post orders. Users can filter by the industry, willingness to pay, location of potential customers, and the due date, volume, and desired filament of the part to be printed.

To help users input information and instantiate DP5, *Open3D* implements instantaneous error notification (DF10). This feature informs users of any possible errors in their interactions with the BEMI, such as assigning null entities to the filter or drilldown intent or entering incorrect input values. If an error is detected, users are notified that their desired action cannot be performed and provided with guidance on what input data is valid. To prevent users from triggering incorrect data and ensure that users have confirmed their actions, process execution validation is also employed (DF11). Given that blockchain-based systems do not allow for changes to transactions once they are completed and stored information is irreversible, *Open3D* provides a confirmation function via a pop-up window to ensure users have confirmed the initial action before execution. Additionally, a percentage progress bar appears in a pop-up window, and the action is executed with a time delay, allowing users to still click ’Cancel’ and reverse their decision in the short term if needed. Furthermore, sensitive data and information that should not be stored on the blockchain due to scalability limitations are integrated into BEMIs through P2P database linking (DF12). For example, images and technical specifications on 3D printers are integrated externally via the IPFS. This linking ensures that all relevant information is readily available to users without compromising the security and scalability of the blockchain-based system.

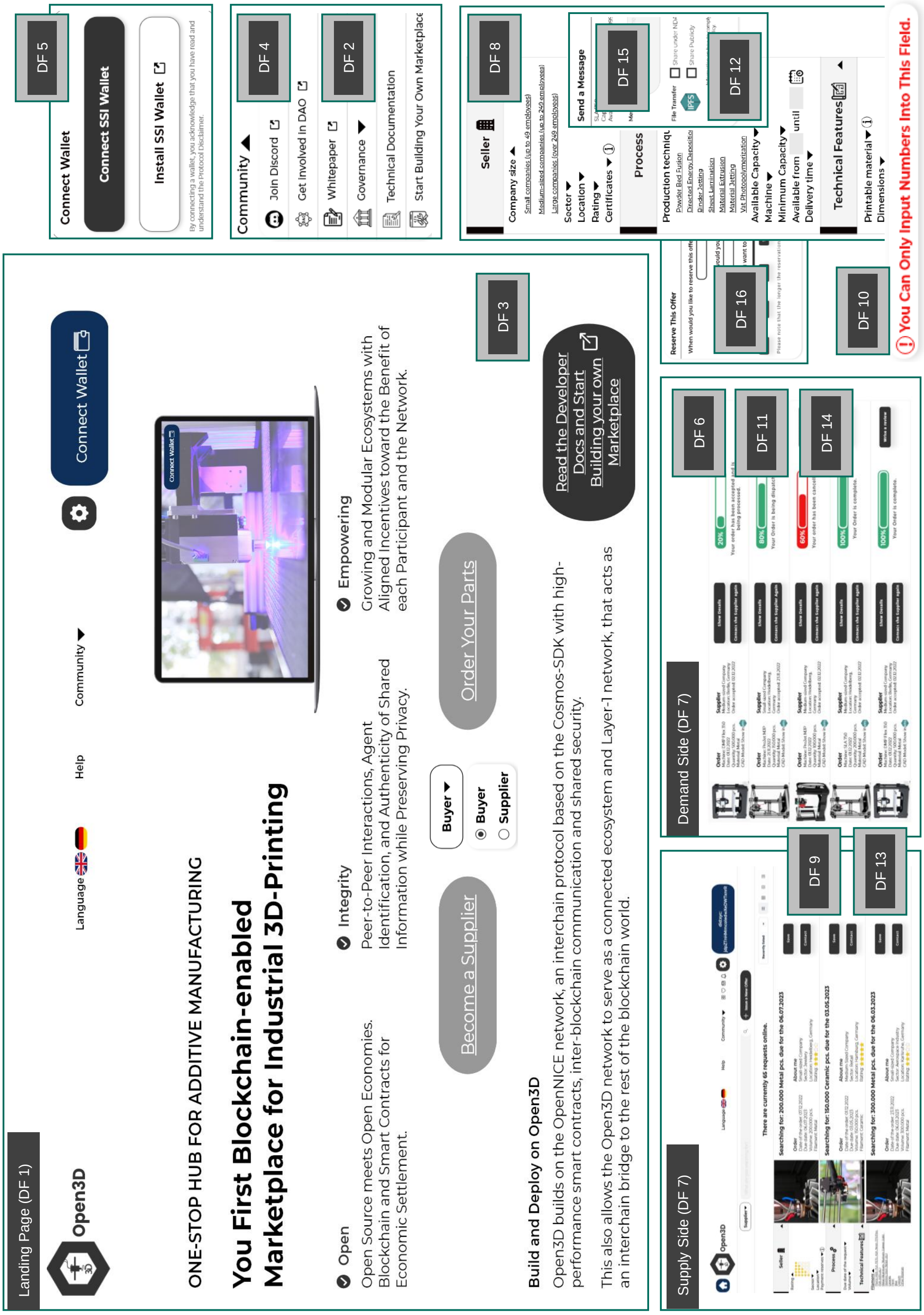
The marketplace’s supply and demand side are complemented by specific dashboards that function as information subsystems connecting the marketplace backend and blockchain ecosystem to provide users with customized and trustworthy information, including transaction history (DF14). The supplier dashboard provides an overview that visualizes the connected wallet, displaying saved searches, recent transactions, and recent reviews. The ’Your Sales’ overview presents suppliers with information on their number of sales, revenue, and monthly revenue growth. Similarly, the demand side dashboard also has an overview of the connected wallet, and demanders can see their recent transactions and spending. The dashboard also displays saved favorites, which users can access by clicking the ’My Orders’ button. This button provides users with a summary of their orders that have been accepted, presenting users with the most crucial information about their order and the corresponding service provider. Additional details can be accessed by clicking the ’Show Details’ button. The ’Contact Supplier’ button allows users to contact the supplier in case of queries and feedback. Each order’s processing status is represented by a percentage progress bar that displays on-time deliveries in green and delays and canceled orders in red. This feature offers users a quick overview of their orders’ progress and helps them track their transactions with ease.

To facilitate direct communication (DF15) between transaction partners in the B2B environment, *Open3D* offers the ’Contact’ button, which allows users to establish an off-chain communication channel with the respective other market side. Users can compose messages through a free text field via a popup window. Additionally, users can share relevant files to the order (e.g., CAD product details) with transaction partners using the ’File Transfer’ feature. When uploading files, users can choose to share their files publicly (i.e., ’Share Publicly’) or under a non-disclosure agreement (i.e., ’Share under NDA’). Furthermore, users can reserve available capacity through the ’Reserve’ button (DF16). After clicking the button, a new popup ’Reserve This Offer’ appears, allowing users to specify the start date and duration of the reservation period, as well as the number of monthly hours they wish to reserve. A slider is provided to help users select the duration of the reservation, with a note indicating that the reservation fee varies according to the duration of the reservation. Finally, users can confirm the reservation request by clicking the ’Confirm’ button. We thereby enable users to interact with opposed market sides directly, clarify details, and reserve capacity more efficiently, enhancing the BEMIs overall user experience.

7.3.4 Evaluation

Ex-post Evaluation Episodes. In DSR, the literature recommends conducting multiple evaluation episodes during and after the design process (Venable et al., 2016; Sonnenberg and vom Brocke, 2012). Therefore, in this study, we performed four evaluation episodes, including ex-ante and ex-post evaluations, in different settings (see Section 7.2). Our main objective was to validate the practical relevance of our design solution in resolving business problems and to assess its applicability in real-world contexts.

Overall, the feedback received from the participants indicates that our BEMI design was positively received. The interactive features were particularly appreciated by less tech-savvy participants, allowing them to navigate and directly express their information needs. They noted that the interface design reduces the complexity of decentralized systems; as one participant stated, “the interface is simple and intuitive, which is a plus for users who are not very familiar with blockchain technology” (Zeta 3). Conversely, more tech-savvy participants found that the design improved their efficiency and recognized that the feasibility of our prototype provided a solid foundation for designing BEMIs. An expert remarked, “I appreciate the feasibility of the prototype and the fact that it takes into account not only the technological aspects - as in most research approaches to design decentralized marketplaces - but also business considerations” (Epsilon 2). Nonetheless, participants raised concerns that the DFs presented may only be suitable for some B2B contexts as other use cases may require more complex and specific functionalities (Gamma 1). They also mentioned that they would prefer BEMs as an addition to, rather than a replacement of, traditional purchasing processes (Gamma 1). Some participants regard a need for more familiarity with and confidence in using marketplaces to interact with business peers as a critical challenge (Delta 1; Zeta 4, 5). Moreover, experts and potential users praised the interface’s comprehensiveness and user-friendliness, enabling easy navigation and information sharing between transaction partners (Delta 1; Epsilon 3; Zeta 2, 7, 8). In the words of a domain expert, “the design is well-thought-out, reflects a deep understanding of the needs, and addresses significant challenges faced in CAM industries” (Epsilon 1). Additionally, users appreciated the landing page (DF1) that provided essential information about the system, helping them understand the value proposition of the marketplace and



Landing Page (DF 1)

Open3D

ONE-STOP HUB FOR ADDITIVE MANUFACTURING

You First Blockchain-enabled Marketplace for Industrial 3D-Printing

Open
Open Source meets Open Economies. Blockchain and Smart Contracts for Economic Settlement.

Integrity
Peer-to-Peer Interactions, Agent Identification, and Authenticity of Shared Information while Preserving Privacy.

Empowering
Growing and Modular Ecosystems with Aligned Incentives toward the Benefit of each Participant and the Network.

Buyer ▾
● Buyer
○ Supplier

Build and Deploy on Open3D

Open3D builds on the OpenNICE network, an interchain protocol based on the Cosmos-SDK with high-performance smart contracts, inter-blockchain communication and shared security.

This also allows the Open3D network to serve as a connected ecosystem and Layer-1 network, that acts as an interchain bridge to the rest of the blockchain world.

Connect Wallet

By connecting a wallet, you acknowledge that you have read and understand the Protocol Disclaimer.

Company size ▴
Small companies (up to 49 employees)
Medium-sized companies (up to 249 employees)
Large companies (over 249 employees)

Production techniq
Powder Bed Fusion
Directed Energy Deposition
Binder Jetting
Sheet Lamination
Material Extrusion
Material Jetting
Vat Photopolymerization

Reserve This Offer

You Can Only Input Numbers Into This Field.

Fig. 7.3.: BEMI Prototype ‘Open3D Marketplace’ and Design Features.

what to expect from the system (Zeta 2, 4, 6). Transparent documentation and community integration were also regarded as significant in balancing simplicity and trustworthiness. The use of icons (DF2) to redirect users to technical documentation and whitepapers (DF3) was seen as promoting transparency (Delta 1; Epsilon 2, 3), while the ability to join a BEM's Discord community (DF4) was considered a means of fostering community engagement (Zeta 1, 4). An expert commented on integrating community engagement mechanisms, "I appreciate the effort to involve users in governance as it creates a sense of commitment to the system and the option to access the SDK to create my own marketplace" (Epsilon 1). However, potential users expressed concerns about the complexity of the governance mechanisms and suggested that the BEMI could benefit from more guidance and support in this area. One participant stated, "while I appreciate the opportunity to participate in the marketplace's governance, I found it a bit overwhelming. It would be helpful to have more support in this area. I would appreciate more guidance on how to get involved" (Zeta 6). Another participant noted, "while the community engagement features are a step in the right direction, more should be done to incentivize users to participate in the governance process" (Epsilon 3). *Open3D*'s system architecture has further received recognition for its secure and self-sovereign IDM (DF5) and reputation mechanisms (DF6) that promote trust and enable users to verify their identity using sovereign authentication methods. One expert commended, "the SSI wallet integration promotes trust and enables secure access to services while preserving privacy, which is crucial for building trust in decentralized marketplaces" (Epsilon 1). However, participants also expressed concerns about the authentication process being a barrier to entry (Delta 1). One potential user noted, "while the authentication process is necessary for security, it may be a bit cumbersome for new users who are not familiar with SSI wallets" (Zeta 7). Additionally, requiring authentication before entering market-specific subpages may discourage potential users from exploring the marketplace and limit its accessibility (Gamma 1; Delta 1). Regarding supply and demand views (DF7), both experts and potential users have praised the clear and transparent presentation of the dashboard. The marketplace's supply and demand dashboards were well-designed and catered to the needs of both market sides (Gamma 1; Zeta 3, 7, 8). Users appreciated the ability to access a customized and trusted view (DF13), including the transaction history (DF14), with one expert noting that "the ability to access transaction history is essential to building trust between users and ensuring the marketplace's transparency" (7). Similarly, a demander appreciated the machine and product metrics (DF9), stating, "the progress bar is very helpful. It gives me a quick overview of where my order stands" (4). Despite these positive sentiments, experts suggest that some DFs could be improved. For instance, one expert noted that "the progress bar could be enhanced to include more detailed information on the current processing phase of the order, such as the estimated time of completion"

(Epsilon 1). Additionally, a potential user suggested that the filtering options (DF8) could be more user-friendly, saying, “filters are great, but I think they could be better organized and easier to use. It would be helpful if there were some preset filters for common search criteria” (Zeta 2). Moreover, potential users found technical details overwhelming, suggesting less complex filtering options, saying, “it would be helpful to have simpler filtering options for users who are not familiar with the technical aspects of 3D printing” (Zeta 5). The implementation of *Open3D* to support users in inputting information and instantiating DP5 is overall well-received by both experts and potential users. One workshop participant noted that the instantaneous error notification (DF10) is “a great help in preventing users – especially novice users who may not be familiar with the system – from making mistakes that could lead to irreversible actions” (Delta 1). This sentiment is echoed by a potential user, who remarks, “I really like how the system guides me in providing valid input data. It saves me a lot of time and frustration” (Zeta 6). Another expert adds, “especially with blockchain technologies, it is essential to avoid errors. I believe that this is well implemented here and that process-critical errors can be significantly reduced” (Epsilon 2). However, some users have identified an area of improvement in the process execution validation (DF11). They note that the time delay during process execution validation can be frustrating in situations where they need to execute a process quickly. One potential user provided feedback on this by stating, “I understand the need for the time delay, but in some cases, it feels like it’s just slowing me down” (Zeta 3). This implies that the implementation of the DF may need further refinement to reduce the time delay and improve the overall user experience. Regarding DP6 and DP8, experts emphasized that Open3D combines the decentralized approach of BEMs with industry-specific features, such as direct communication (DF15), to improve transparency and enhance B2B relationships (Epsilon 2, 3). Direct communication (DF15) was perceived as an effective way to enhance transparency and foster stronger relationships with transaction partners. One expert stated that communicating and sharing data directly with partners can help prevent miscommunications, resolve issues, and clarify details quickly (Epsilon 3), while others noted that a more structured communication channel with predefined fields could be more effective (Delta 1). However, the direct communication feature was also seen as a double-edged sword that could slow down the process and prevent scaling (Delta 1). For data exchange, P2P database linking (DF12) was seen as necessary for ensuring the accessibility of all relevant information without compromising the security and scalability of the blockchain-based system. Experts appreciate that sensitive data is kept off the blockchain and is only accessible through external linking (Epsilon 1, 3). One potential user stated that “sharing files such as CAD drawings is critical in CAM, and off-chain file transfer can help ensure that the right information is shared securely" (Zeta 4). Regarding the IPFS implementation, experts see "[...] a scalable solution to handle large files without compromising the integrity of the blockchain. It's a clever way to handle limitations" (Epsilon 3). Experts noted that the 'Share under NDA' feature is crucial for B2B transactions, where confidentiality is paramount, but users want to get pre-bids, enabling transaction partners to share sensitive information without compromising their intellectual property rights (Epsilon 2, 3). Although the reserve functionality (DF16) was highly practical and applicable in real-world contexts, experts suggested that improvements could be made to the design. They noted that the slider provided to help users select the reservation duration could be confusing and suggested that the system provide more information on the reservation fee and how it is calculated (Epsilon 1). One expert stated that "the 'Reserve' button is a useful feature, but the reservation fee calculation is not transparent enough, and users may feel that they are being charged unfairly" (Epsilon 2).

In conclusion, the BEMI design was well-received by experts and potential users in artificial and naturalistic settings, emphasizing the applicability of the design solution. While there were suggestions for improvement, the overall sentiment towards the design was positive.

7.4 Discussion & Conclusion

The potential disruptive effects of blockchain-enabled networks and marketplace models have been recognized in literature, particularly in cross-company scenarios (Kölbel, Linkenheil, et al., 2023; Mourtzis et al., 2021). This article complements previous research on the blockchain infrastructure of electronic markets (Alt, 2020) by addressing the nascently researched topic of interfaces for BEMs. Furthermore, it links the sub-economies of marketplace sharing with blockchain economies (Weinhardt, Peukert, et al., 2021), as it proposes prescriptions for the development of BEMIs that support CAM-oriented supply and demand matchmaking. Our approach integrates both theoretical and practical knowledge and complements other facets of the boundary-spanning and ecosystem-driven transformation with BEMs. These facets include, for instance, the potential of BEMs for equal value creation (Kollmann et al., 2020), overall designs (Kölbel, Linkenheil, et al., 2023; Große, 2022), and technical implementations (Hofmann et al., 2021). Building on this foundation and following the DSR paradigm we report the first cycle outcomes of a larger DSR project that aims to address recent calls to study the interface design and visualization of BEMs (Kölbel, Linkenheil, et al., 2023). To the authors' knowledge, this is the first study to do so. We provide (1) theoretically grounded and prescriptive knowledge and (2) an expository instantiation for designing an innovative artifact in the form of a BEMI prototype, namely the *Open3D* Marketplace. We evaluate the prototype through a focus group workshop and interviews with both experts and potential users that highlight functions that we plan to incorporate in a second DSR cycle.

From a **theoretical perspective**, our work provides a new and effective solution to a known problem by offering prescriptive knowledge and a prototypical interface for designing BEMIs, thereby representing a Level 1 contribution and an improvement in the DSR knowledge contribution framework (Gregor and Hevner, 2013). As such, we have taken initial steps in developing a nascent design theory by formulating Meta-REQ and DPs that draw inspiration from the TEU (Burton-Jones and Grange, 2013) and instantiating our prototype. While this study is anchored in the context of CAM and thus develops knowledge for a specific class of artifacts, it might also be transferable to other solution spaces, opening avenues for designing a broader class of BEMIs that can be adapted to different contexts (Chandra, Seidel, and Purao, 2016). Thus, it is fruitful to investigate the applicability of (a subset of) the proposed principles in additional domains with potential results extending or verifying our design knowledge. In terms of **practical contribution**, we propose a user-centric solution that supports marketplace tasks and assists businesses to engage in BEMs and collaborate in CAM, thereby boosting economic performance and process efficiency. From a strategic perspective, our interface design allows users to engage with an interoperable IDM and reputation infrastructure, which enhances trust, user empowerment, and digital sovereignty and avoids dependencies and lock-in effects. Additionally, the design fosters privacy-preserving interactions and strategic decision-making by offering user-specific dashboards that allow customized information and reports on essential KPIs across varying levels of granularity. From an operational standpoint, our BEMI provides an overview of available resources and their essential metrics. It allows for a detailed display of specific resources based on user-defined criteria and facilitates the analysis of the CAM market, thereby improving users' informed decision-making in informed purchase decisions. Furthermore, our study provides valuable insights for developers seeking to implement BEMIs. The prescriptive knowledge derived from both theoretical and practical sources, along with the subsequent implementation and evaluation of the prototype, may further serve as a foundation to enhance BEMI prototyping tools and systems, particularly in the context of CAM. We allow professionals to design technical constraints independently and develop a schema to describe, classify, and structure this complex and novel topic.

However, the exploratory nature of our study and the nascent stage of research on BEMs give rise to **limitations** that, vice versa, point to **future research opportunities**. One major challenge pertains to transferring design knowledge to prototypes based on personal decisions. Although we draw upon expert feedback and literature to inform design decisions, some principles might be instantiated through other functions. For instance, while we are confident that our twofold approach ensures both rigor and relevance in data collection, alternative opinions, such as those of purchasing department experts, may result in different conclusions. We plan to involve a broader range of experts in the second design cycle to address this. A second challenge relates to the selection of the underpinning theory. While we believe that focusing on the TEU is most appropriate for creating design knowledge for BEMIs, utilizing another theoretical lens might yield a different set of DPs. Furthermore, our study aims to provide design knowledge and a prototype for a class of artifacts (i.e., BEMIs) that focuses on one particular instance, namely the context of CAM. While visualizing interfaces for other production technologies, such as compression molding or CNC machining, may require variations, we argue that many BEMIs share the same underlying technology and require similar interfaces. Therefore, further research could generalize our findings and test the design in other BEM contexts. Finally, our evaluation aimed to obtain qualitative insights into the artifact's applicability and usefulness. By doing so, we adhere to common evaluation approaches, such as the 'prototyping pattern', where researchers "demonstrate that the artifact design and its corresponding prototype are suitable to address the specific business problem" (Sonnenberg and vom Brocke, 2012, p. 381). However, it must be noted that our evaluation is limited to qualitative data. Hence, future research can utilize our results to verify or revise our design solution. Researchers may determine appropriate variables to measure effective use, formulate testable propositions, and conduct experiments. They may also investigate the direction and strength of the individual effect for each DP and explore interaction effects. In our second design cycle, we plan to refine our tentative design knowledge based on evaluation results before implementing them into a software artifact. Overall, our study offers valuable insights for designing BEMIs in CAM and contributes to the growing body of knowledge in this field.

Part IV

Business Model

8

Cooperative Business Models in Self-Sovereign Identity Ecosystems

This chapter is based on a peer-reviewed article titled "Shaping Governance in Self-Sovereign Identity Ecosystems: Towards a Cooperative Business Model". The article was co-authored by Tobias Gawlitza and Christof Weinhardt and is published in the 17th International Conference on Wirtschaftsinformatik (WI) Proceedings. The tables, figures, and appendices were systematically renamed, reformatted, and appropriately referenced to align with the overall structure of the thesis. To further enhance clarity and consistency, formatting, and reference style were adapted and references were updated.

Publication details: *Kölbel, T., Gawlitza, T., & Weinhardt, C., Shaping Governance in Self-Sovereign Identity Ecosystems: Towards a Cooperative Business Model, 17th International Conference on Wirtschaftsinformatik Proceedings, 2022.*

Abstract: The Internet has created great opportunities for consumers. With the digitalization wave breaking, Single Sign-On services emerged that satisfy the desire for seamless online journeys and provide users with their digital identities. On a global scale, oligopoly structures evolved where 'Tech Giants' primarily manage identities and personal data. Conversely, recent developments stemmed from the desire for data privacy, digital sovereignty, and self-determination, both from the user perspective and legislature. In line with recent discussions, this study focuses on Self-Sovereign Identity, a new paradigm that promises independence from intermediary identity providers. We follow an appeal for further research on business aspects and strategic alliances and adopt an exploratory research approach with semi-structured interviews. We identify cooperatives as suitable to govern Self-Sovereign Identity Ecosystems, shape their business model along Al-Debei and Avison's V^4Business Model dimensions, and outline paths for future inquiries.

Keywords: Self-Sovereign Identity, Cooperative, Business Model, Governance.

8.1 Introduction

Today, we live in a world where our digital footprint is rapidly growing. Digital services become increasingly available as digitization progresses. Recently, the Corona pandemic accelerated this development and strengthened the desire for seamless online journeys (European Commission, 2021). This trend has spawned interest in and increased the importance of digital IDs, which are used to identify people, organizations and things in the digital world. Organizations like Apple, Amazon, Google, or Facebook quickly recognized the importance of identification on the Internet (Birch, 2020) and created single sign-on (SSO) services that allow users to have one ID across systems. Tied to this convenience is a shift from multiple to a few accounts, where users do not need a separate username and password for each website but rely on the ID service provided by SSO operators. As long as they use this service, users can have a trusted ID and build a reputation. Meanwhile, companies with SSO solutions position themselves as de facto ID gatekeepers, as they have their own isolated data storage, as well as trust and reputation systems that are beyond users' control (European Commission, 2021). By analyzing user data, they further obtain valuable information about individual user behavior, interests, purchases, and locations (Allen, 2016). However, users often do not know how their data is being processed (Cinnamon, 2017). As a result, they relinquish control over their data and become transparent and traceable across multiple services (Allen, 2016; Cinnamon, 2017; Zuboff, 2015; Morley et al., 2020).

Consequently, addressing identification in the digital space, what data is collected about users, where that data is stored, and who owns and controls the data is a complex, timely, and important matter (Laatikainen et al., 2021). As the desire for data privacy, digital sovereignty, and self-determination has increased in recent years, the independence from intermediary ID providers becomes more and more prominent (European Commission, 2021). An initiative by the European Union, increasing its focus on digital IDs as a strategic asset, also illustrates this development (European Commission, 2021): *"We want rules that puts people at the center. This includes control over our personal data, which we still have far too rarely today. Whenever an app or website asks us to create a new ID or easily log on via a big platform, we have no idea what happens to our data. That is why the Commission will propose a secure European e-identity."*

A new idea for digital IDs that various initiatives devote their attention to (Mühle et al., 2018) is a technical concept called SSI. In contrast to centralized ID systems, the SSI paradigm builds on decentralized technologies like blockchain (Zwitter et al., 2020; Zachariadis et al., 2019) and allows users to manage their credentials (e.g., a person's age, organizations' master data, or a machine certificate) independently in self-determined contexts (Allen, 2016; Mühle et al., 2018). Without user tracking and with a high degree of interoperability (Naik and Jenkins, 2020), SSI-based ecosystems aim to be user-friendly and economically beneficial[1]. Academic publications on SSI to date examine technological aspects (Mühle et al., 2018), different SSI solutions (Naik and Jenkins, 2020), the user's perspective (Ostern and Cabinakova, 2019), trust requirements (Kubach and Sellung, 2021; Grüner et al., 2020), legal prospects (Zwitter et al., 2020; Kondova and Erbguth, 2020) and the real-world adoption of SSI (Wang and De Filippi, 2020; Lockwood, 2021). Some authors further emphasize considering SSI as an ecosystem in which technology and governance are intertwined (Zwitter et al., 2020; Trust Over IP Foundation, 2021). This perspective sparks interest in research that conceptualizes SSI ecosystems as strategic alliances (Zachariadis et al., 2019; Wang and De Filippi, 2020).

The secure digital identities (SDI) initiative, a project funded by the German government with more than €40 million, pursues this idea as several consortia develop SSI infrastructures for secure exchanges of digital ID attributes (Bundesregierung, 2021a; Bundesregierung, 2021b). Referring to SSI ecosystem collaboration, Laatikainen et al. (2021) emphasize the need for further research on business aspects that provide fair value to each actor (Laatikainen et al., 2021). We follow this appeal by addressing business models in strategic alliances governing SSI ecosystems. Studying business model concepts is not a fairly new endeavor. It has garnered attention in several research disciplines (e.g., strategic management, entrepreneurship, and IS), but - today - it remains largely unexplored in the SSI domain. In light of its increasing importance, this seems all the more surprising. This study presents the results of an inductive, qualitative approach with expert interviews conducted in collaboration with an SDI project and aims to answer the following RQ:

Research Question: *What are business model design considerations in strategic alliances governing SSI ecosystems?*

The remainder of the paper is structured as follows. First, we introduce SSI and business model fundamentals (Section 8.2) and describe our methodological approach (Section 8.3). Then, we analyze the qualitative expert interviews and outline business model design considerations along Al-Debei and Avison (2010)'s V^{4}business model dimensions (Section 8.4). Finally, we discuss our findings and conclude with an appeal for further research on business models in SSI (Section 8.5).

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[1] The McKinsey Global Institute estimates the economic value of digital ID programs that aim to strengthen civic and social empowerment at 3 to 13 percent of GDP in 2030 (White et al., 2019).

8.2 Fundamentals

8.2.1 Self-Sovereign Identities & their Ecosystem

In essence, the novel topic of SSI may be considered from three different angles, as there is no consensus in the current literature (Laatikainen et al., 2021). First, SSI is an ID management system that centers on users in digital environments. It enables them to manage their IDs and associated data in a secure manner without the need for a trusted intermediary to provide or validate information (Allen, 2016; Mühle et al., 2018; Wang and De Filippi, 2020). Second, SSI is a human-centric data management paradigm (Laatikainen et al., 2021), where self-determined users share their data, either stored locally on their devices or managed decentrally on a (blockchain-based) network (Naik and Jenkins, 2020). Third, the SSI concept is tied to an ID protocol that, as an infrastructure component, enables private, secure, and trustworthy communication in the digital space (Zwitter et al., 2020).

From a technological perspective, SSI's key components and standards are primarily developed by open source communities and non-profit organizations (e.g., TrustOverIP Foundation) as well as standard-setting institutions and regulatory authorities (e.g., eIDAS, GDPR). At the core of SSI are decentralized identifier (DID) and VC designed by the World Wide Web Consortium (W3C) and the Decentralized Identity Foundation (DIF). In addition, the encryption-based communication protocol DIDcomm enables secure and private communication.

From an ecosystem perspective, SSI thrives on the symbiosis of technological and organizational interrelation of three actors (Zwitter et al., 2020; Laatikainen et al., 2021): issuers, holders, and verifiers. Technically, issuers represent the origin of a credential, determine its creation and meaning, and define the means of verifying associated information. Holders may be individuals, organizations, or other entities that hold a credential in their wallets. They request it from issuers and present it to verifiers upon request. Finally, verifiers are ecosystem actors that may require certain parts of a holder's ID. For example, an e-commerce service may request a user's credit card information. Organizationally, the *"digital trust triangle"* (Trust Over IP Foundation, 2021; Davie et al., 2019) of issuer, holder, and verifier is managed by strategic alliances that can be organized in various shapes (e.g., a consortia). The alliance organizes the ecosystem regarding business, legal, and technical concerns by publishing a governance framework.

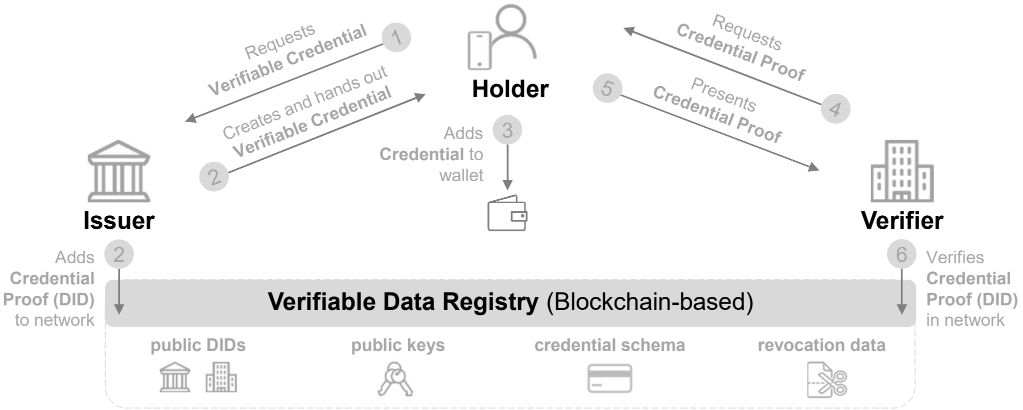

Fig. 8.1.: Schematic Representation of the SSI Concept.

8.2.2 Business Models & Representation Techniques

In the late 1990s, the Internet boom triggered research on the construct of business models. Since then, the research stream gained momentum and is still growing (Zott et al., 2011). Despite numerous publications, a clear definition of the term itself is still missing (Osterwalder, Pigneur, and Tucci, 2005; Al-Debei and Avison, 2010). In general, business models can be seen as a blueprint or framework that elucidates basic principles of how value is created, delivered, and captured by organizations and their network partners (Chesbrough and Rosenbloom, 2002; Osterwalder, Pigneur, and Tucci, 2005; Osterwalder and Pigneur, 2010; Al-Debei and Avison, 2010).

Business model representations, as a specific tool to analyze, design, and compare different value-creation and value-capturing approaches, support practitioners in shaping coherent conceptualizations of business models (Veit et al., 2014). Since conceptualization can pursue different goals, various representations exist that differ in their goals and structures (Veit et al., 2014). For this research, we build upon the Unified Business Model Framework proposed by Al-Debei and Avison (2010) and apply it as meta-characteristics. Essentially, the framework contains the V^4business model dimensions of ’value architecture’, ’value network’, ’value finance’, and ’value proposition’.

8.3 Research Methodology

Our research aims to apply extant knowledge about business models representations to the emerging phenomenon of governance in SSI networks. We follow an exploratory, design-oriented approach to explore this previously uncharted phenomenon inductively with rich contextual insights (Paré, 2004). Accordingly, we adopt a qualitative empirical research design and conduct semi-structured interviews (Rubin and Rubin, 2011) with experts at the intersection of SSI and business models.

Following the recommendations of Rubin and Rubin (2011), we conducted ten interviews (see Table 8.1) during the period from May to July 2021. By involving multiple experts with substantial experience in the area of interest, the overarching goal was to collect empirical data from various organizational contexts and explore a broad range of affordances. Consequently, we selected a diverse group of interviewees from a wide range of industries, governmental organizations, and company sizes.

Tab. 8.1.: List of expert interviews (#E1 to #E10) with details on interview partners.

ID	*Interviewee job position*	*Organizational context*
E1	Business Architect Blockchain	IoT Solutions & Services
E2	Head of Communication & Deputy Project Manager	Banking Services
E3	Project Manager & Cooperative Lead	Banking Services
E4	Portfolio Manager Blockchain	Transportation
E5	Senior Manager & Project Lead SSI	Connected Industry & Ecosystems
E6	Chief Innovation Officer	SSI Solutions & Services
E7	Research Associate in SSI	Governmental Institution
E8	Senior Information Security Consultant	SSI Solutions & Services
E9	Manager Identity & Access Management	Standard-Setting Institution
E10	Expert Innovation	Connected Industry & Ecosystems

All interviewees were recruited through the authors' personal network. To avoid an overemphasis of one occupation's expertise and respect the interdisciplinary nature of our research endeavour, we selected about the same number of interviewees with and without knowledge in business models. The interview process was conducted virtually and lasted between 32-60 minutes, with an average of 44 minutes. After informed consent, interviews were recorded and transcribed before being returned to respondents for approval to increase the validity of our findings (Brink, 1993). We conducted the interviews either in German or English to prevent misunderstandings and enhance informative value, depending on the interviewees' native languages. In general, interviews were based on a questionnaire and separated into three parts. The respondents were first asked to describe their experience in the area of interest (e.g., job position and tasks). Then, we asked questions relating SSI value propositions, customer relationships, and network finances. Finally, we moved from key activities and key partners towards questions that address challenges for successfully shaping business models in SSI ecosystems. Due to the semi-structured nature, we were able to dig deeper when the interviewees mentioned interesting and unexpected insights (Paré, 2004). In addition, open-ended questions offered the opportunity to describe actual experiences without being limited to a narrow, predefined structure.

As part of a qualitative, cross-sectional analysis (Wilde and Hess, 2007), we analyzed and coded (Corbin and Strauss, 2008) the interview content using 'MAXQDA' software (Mayring, 2014). In doing so, codes (e.g., 'data privacy' and 'trafficking user data') were combined into inductive dimensions (e.g., 'pains') that relate to deductive categories following V^4business model axioms (Al-Debei and Avison, 2010). This approach allowed us to identify shared perspectives in the experts' perceptions rigorously. We present the results of our analysis below.

8.4 Qualitative Insights for Business Model Designs

This section presents the results of our qualitative expert interviews (parencited with interview ID), serving as input toward shaping business model designs in strategic alliances governing SSI ecosystems. We introduce why the interviewed experts consider cooperatives the most appropriate legal form to govern the ecosystem and what specific issues they perceive related to business model design (i.e., cross-category remarks). The presentation of findings in subsequent sections follows the V^4business model dimensions We choose this framework because it is parsimonious and includes all business model dimensions mentioned in previous representations (Al-Debei and Avison, 2010). Moreover, its multidimensionality appears appropriate and sufficiently comprehensive to capture all relevant aspects while avoiding conceptual ambiguity. Figure 8.2 provides a synthesized illustration for the dimensions further described below.

8.4.1 Cross-Category Remarks

First, experts believe that a **cooperative legal form** is particularly suitable to govern SSI ecosystems through strategic alliances and shape their business model (further referred to as cooperative business model (CBM). On the one hand, cooperatives would create a legally binding framework, allowing companies to pursue their interests within these boundaries (E9). Nonetheless, a bilateral exchange would promote and strengthen ties between involved actors, resulting in two key benefits:

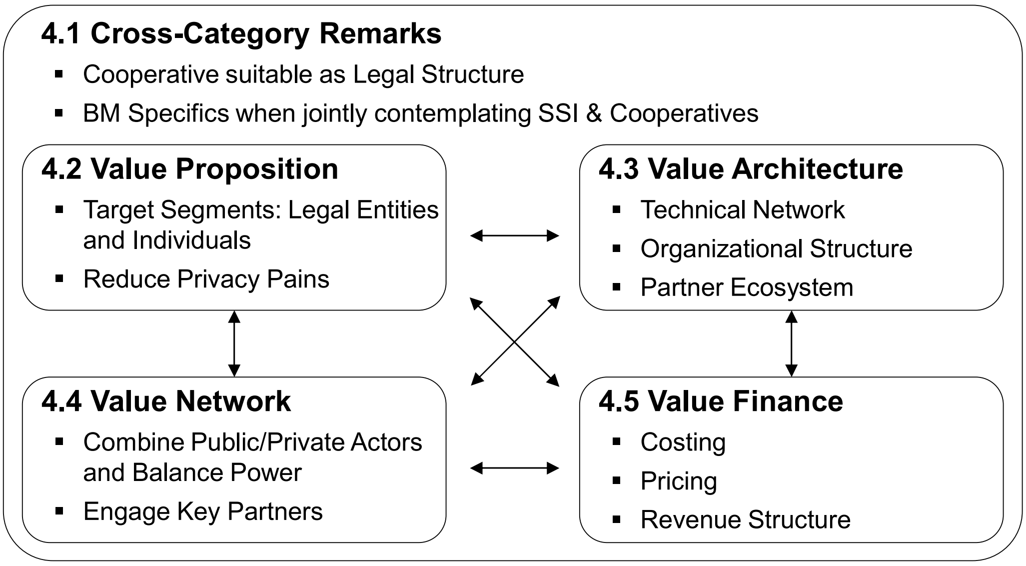

Fig. 8.2.: Business Model Design Dimensions.

First, it would create a mutually beneficial innovation ecosystem around SSI that could leverage synergies between companies within an industry or even across domains (E3-5). Second, cooperation between several actors along the entire value chain is essential for decentralized technologies in general to meet both user needs (i.e., seamless online journeys) and the technological requirements of a decentralized network with distributed node operation (E2, E10). On the other hand, the legal form of a cooperative is in line with SSI principles. From a technological point of view, operating nodes in distributed networks would be decentralized; structuring governance as a cooperative would reflect that idea on an organizational level. Some experts also emphasize the de-commercialized nature of cooperatives, which pursue not-for-profit purposes and act on behalf of their users (E1, E5).

Second, experts believe **business model design specifics** needs to be respected when jointly contemplating SSI and cooperatives. They argue for the distinction of business models in SSI ecosystems on two levels: infrastructure and application (E1-2). The infrastructure level deals with the network operation, while the application level refers to actors who use a given SSI network and build their business model on top. As two experts point out, different requirements have to be considered in this context, yet they are closely related (E1, E3). For example, transaction costs set at the infrastructure level influence the feasibility of different services at the user level. Accordingly, experts consider three addressees for business models: (1) companies that want to build up their own business based on a SSI network, (2) the perspective of individuals who are primarily interested in user-friendly processes and SSO-alike solutions, and (at some point in time) (3) things that need to interact automatically with the system (E5, E7, E10). Related to this is the financing of the network (E3-4, E10). Current models in ID management (i.e., SSO solutions) rely on earning money from user data to provide a service to users for free (E9). However, SSI creates a basic infrastructure where traditional data monetization without user consent should no longer be possible. As a result, the costs incurred for building and operating the ID infrastructure could no longer be cross-financed via data monetization. Accordingly, other forms of financial means have to be identified. This transformation could also impact existing business models and services offered by companies since data monetization as a traditionally attractive source of revenue would no longer be available. As a result, companies would have to find other solutions to cover their costs for service offerings. Conversely, this could also mean that services that were previously free of charge would have to be paid for by users. In terms of business models at the infrastructure level, experts pointed out that cooperatives do not maximize profits but rather have an obligation to the community while primarily aiming to cover their operating costs and make sustainable reinvestments (E2, E6, E8). One author commented that cooperatives do not have a real business model in this context but rather a "sustainability model" (E3). Another issue stemming from the technological design of SSI is that data verifiers receive a significant benefit from the network but cannot be asked to pay for it as the system is designed for privacy. For example, an e-commerce service that wants to verify user data would benefit from an SSI network. However, costs in SSI networks are caused mainly by writing operations (i.e., issuer’s expense) and not by presenting (i.e., holder’s expense) or verifying (i.e., verifier’s expense). Accordingly, adequate solutions have to be developed that reflect both benefits and incentives of each actor (E1, E3, E9-10). Other challenges mentioned in the interviews were the incentivization of cooperative members (E1), the coordination of cooperative members (E3), and the initial agreement on governance rules (E3). One expert also noted that SSI is a greenfield where efforts and benefits are difficult to assess (E8).

8.4.2 Value Proposition

As part of the value proposition dimension, representing offer and customer segments (Al-Debei and Avison, 2010), the interviewed experts believe it is essential to address both issues related to current ID management systems (pains), and the benefits users derive from SSI (gains).

An essential **pain**, which also reflects in the public discourse on digital ID (European Commission, 2021), is data management by third parties and associated concerns about data privacy and data security. Here, the interviewed experts perceive a particular risk if users do not control their data but rather rely on ID service providers they have to trust. Both the substantial leverage of SSO providers (E2-3, E4-5, E7-9), their ability to block user IDs, which could result in the loss of access to services (E7, E9), and trafficking user data without their consent (E1, E6, E8-10) are perceived to be related aspects. A further issue describes the topological design of traditional ID management systems and a perceived lack of trustworthiness in interactions. On the one hand, central databases would be vulnerable to hacker attacks (E3-5, E7, E9). On the other hand, when a holder presents data to a third party (i.e., a verifying service), they might not be able to verify whether the data truly belongs to the claimant or if it was deceived (E10). Furthermore, it would also be challenging to determine issuer IDs and the validity of the data. On the contrary, users might be confronted with phishing attacks, exposing their data based on false information presented by their counterparts, which they cannot verify unequivocally (E5). Ultimately, another criticized aspect is the lack of interoperability between different SSO providers, which leads to lock-in effects and switching costs (E4).

Identified **gains** arising from SSI-based ID networks may be divided into two groups, both considered being target segments of CBMs: legal entities (i.e., companies and institutions) and individuals (i.e., private persons).

Experts suggest that *legal entities* particularly benefit from process improvements (E1-2, E4, E6). For example, master data and certificates that companies need for interactions along the value chain are (today) usually maintained manually, requiring simultaneous data updates in several databases (push principle). As a result, the effort scales linearly to the product of customers and suppliers (n*m relationship) or is handled by service providers. As experts see it, this process might be transformed into a pull-based system by using SSI, which would reduce not only costs for redundant data maintenance but also create a single point of truth that would increase data quality (E1-2, E5). At the same time, organizations would retain end-to-end control over their data. For authorities that mainly perform certification activities and frequently have to verify data, digital verifications through VCs would both be a considerable simplification and increase security (E7-9). Furthermore, intermediaries who charge service fees could be prevented, and interoperability between different SSI networks could avoid switching costs by allowing users to own their data and migrate their wallets as desired. Ultimately, improving processes would enhance customer experience and increase security in handling customer data (E9-10).

Individuals would significantly benefit from regaining control over their data and having better access to digital services while at the same time avoiding lock-in effects (E3-5). Transparency about who shares what data with whom adds another advantage (E8). SSI further allows for the selective disclosure of information. If, for example, only one attribute (e.g., a person's age) of a credential of several attributes (e.g., an ID card) is requested by a verifier, SSI allows to present only this attribute selectively (E3). Consequently, a service provider only receives data it needs to provide a service. If users do not want traceable profiles, SSI enables them to work with a separate identifier for each service (E9). This could prevent data correlations and brings advantages in terms of privacy and data protection. Furthermore, independence from third parties and flexibility in wallet software choice and data storage are also emphasized positively (E7, E9). In addition, actor authentication in SSI networks (e.g., via VCs) could impede phishing attempts (E3, E5). For example, users who want to register a bank account or initiate a wire transfer should be able to identify their transaction partners (E2-3).

8.4.3 Value Architecture

The value architecture perspective focuses on a holistic structural design. It encompasses both technological infrastructure and organizational architecture with their respective configurations as well as assets, resources, and core competencies (Al-Debei and Avison, 2010). Experts consider a balanced equilibrium of a technologically trustworthy infrastructure and a transparent model of organizational cooperation to be particularly important in SSI (E1, E5).

The **technical network** forms the first pillar and core of the ecosystem, providing integrity and trust through decentralized technologies that operate on multiple servers (i.e., nodes). In principle, experts propose a hybrid approach where read access to the network's distributed database (i.e., ledger) is unrestricted to facilitate the scaling of applications (E2-3, E10). However, node operation (i.e., stewards), write permissions (i.e., endorsers), and transaction initiations (i.e., transaction author) should be limited to known entities and governed by a cooperative (E3, E5). In addition, to be compliant with regulations on data protection, a suggestion is that the ledger should not hold contextual data (e.g., personal data), but only "reference data" (e.g., via the public key of the issuer of credentials) (E10). However, interoperability between SSI networks and alignment with worldwide standards (i.e., VCs, DIDs, DIDComm) is crucial. Based on these standards, further network and technology development constitutes a cooperative key activity (E2). Alongside monetary resources, this requires necessary competencies such as human capital (E1, E6, E10). Monitoring technical parameters such as node operation is also considered essential (E4-5). Thus, the cooperative's tasks would include incident management, network maintenance, and bug-fixing to avoid technical malfunctions.

The holistic designs' second pillar consists of the cooperative's **organizational structure**. Experts anticipate rules and regulations for the interaction between ecosystem cooperative members - defined in statutes, rules of procedure, and other contracts, that describe the rights and obligations of actors involved - to be crucial for a successful project (E2-3, E7). As long as they sign relevant contracts, it should be possible for any interested legal entity to participate in the network without being cooperative member (E5). These agreements would include stewards, endorsers, and transaction authors. Moreover, structuring the cooperative in several committees and working groups with operational representation by a *Management Board* appears to be a viable strategy (E2-3). Management leads the cooperative's business following committee resolutions and existing contracts (E3). A *Supervisory Board,* elected by cooperative members (according to the principle of one actor, one vote) and acting as a trustee, appoints and dismiss the management board members. Experts also suggest that the supervisory board should determine preliminary rules of the network at the time of its establishment (E2-3, E5, E10). However, cooperative member should be able to change these rules per prescriptive voting rules (E10). As the third building block, a *Technical Steering Committee* should deliberate and decide on the network's technical issues and advancements (e.g., development resource allocation) while coordinating with the international developer community (E2-3, E10). The fourth building block might consists of *Specific Topics Committees*. These include public relations or legal aspects, IP protection, and compliance with current regulations such as GDPR, eIDAS, and the Money Laundering Act (E2). According to experts, a key competence and potential competitive advantage involve the successful coordination between working groups and committees (E1, E6). Another goal of governance should be to remain efficient in decision-making and maintain trustworthy and non-monopolistic structures as the number of cooperative members increases. Three experts (E2-3, E5) propose the legal form of the European cooperative (Sociedad Cooperativa Europea, SCE). This would align with European values, be scalable, and allow a high degree of digitization (E2-3).

The third pillar involves building and developing a **partner ecosystem**. This constitutes the support of cross-company collaboration, for example, by offering use case matching between cooperative partners (E1, E6). Public relations and the availability of public resources might also be necessary (E3). On the one hand, it would help promote awareness regarding SSI technology and the network and attract new members. On the other hand, transparency might foster trust (E7-8).

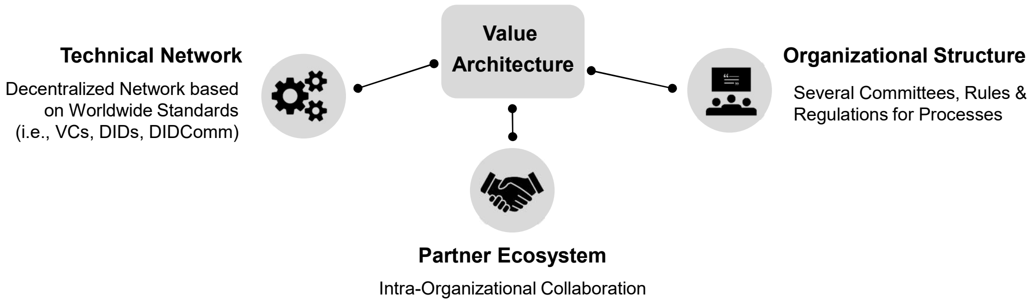

Fig. 8.3.: Cooperative Value Architecture Pillars.

8.4.4 Value Network

The value network construct represents an inter-organizational perspective and describes how transactions are enabled through coordination and collaboration among ecosystem actors (Al-Debei and Avison, 2010). With respect to the CBM, experts distinguish between the organizational structure of network actors and technology-based characteristics that deserve attention.

As for the **actors** of an SSI ecosystem, several interviewees suggest a combination of public and private actors (E2, E4, E7, E10). They argue a balanced mix of cooperative members would be decisive. This would allow different perspectives and would exploit potential synergies between cooperative members. Considering a fair value for each cooperative member, a balanced distribution of power is considered vital. Therefore, experts suggest a clear delineation between actor roles and the need to prevent that any actor dominates the ecosystem (E5, E10).

Key partners in SSI-based systems would be wallet service providers, as they provide the primary interface between the SSI network and its customers (E6, E8). To avoid lock-in effects, wallets should be network agnostic and allow a certain degree of interoperability (E4, E7). Other partners include standards-setting institutions, as close collaboration is critical to develop solutions that comply with applicable law and enable interoperability among SSI networks (E9-10). If SSI networks handle regulatory use cases such as digital ID cards, governments and public authorities would be another key partner group (E5, E7). Further, the cooperative should foster a dialog with industry associations to ensure that it is informed about specific issues in certain domains (E2-3).

8.4.5 Value Finance

Business models appear to be strongly related to the economic and financial design of organizations. Therefore, the value finance dimension considers how organizations generate revenue (Al-Debei and Avison, 2010). It includes information on costing, pricing methods, and revenue structure (Osterwalder, Pigneur, and Tucci, 2005), that affect each of the other three dimensions, especially the value proposition (Al-Debei and Avison, 2010).

Concerning cooperatives, experts unanimously emphasized that the CBM's primary goal should not be to maximize profits but to cover all expenses of the cooperative. Corresponding **costs** would arise through the network's further development. This includes costs for personnel in marketing to increase the network's visibility (E2, E5), the coordination with standard-setting institutions and communities (E2, E9), as well as technical development and maintenance costs for operating the network (E4). In addition, node operation incurs costs (E2-3, E5, E10). According to an expert's estimate, these could amount from €150,000 to €200,000 per year and 25 node operators (E5). Yet, these costs would not have to be borne by the cooperative but by institutions that operate a network node (E3, E5). However, since node operators are essential for network operation, governance has to incentivize them (E1). Several possibilities were discussed during the interviews. One involves a minimum wage for node operation, paid at a fixed rate (E4). Another possibility would be to compensate node operators based on their actual expenses, distributing the average amount to each operator (E4). Incentivizing nodes indirectly would be another possibility (E3, E10). For example, if node operators would have lower costs for writing operations on the ledger, they could build their own business model that refinances node operations. Non-monetary approaches and intrinsic motivation to operate nodes might also be feasible (E3, E5). One expert refers to this as "skin in the game" (E5), meaning that companies with many use cases based on the ID network would be interested in its stability, and therefore, want to operate their own node.

To **cover expenses**, experts consider that a CBM can draw on three sources of income. First, membership fees that are collected via annual fees and depend on the size of an organization (E3, E7). While noting that network utilization should, in principle, be open to all, participation in and influence on the network's governance (e.g., in committees) might be conditional on memberships (E2, E5). Second, various security services could provide revenue (E10). For example, a cooperative's certification of trusted wallet software and the issuance of certificates to wallet providers could increase users' trust in a particular service. The third revenue stream might be endorser write permissions, which are required for network transactions. An option for this would be volume packages that allow a certain amount of writes at a fixed price (E3-5). Then, if more writes are needed than a corresponding package contains, companies might automatically switch to a different category (E3). However, this solution entails a problem: mainly issuers perform write operations on the ledger - hence, their costs would be high while having relatively low value (see Section 8.4.2). For a sustainable CBM, most consulted experts advocate that the cooperative's cost recovery should be based on quantity-based pricing derived from the previous year's costs (E2-5, E7-8). Stewards may receive a fixed amount for operating nodes, factored into the cooperative's costs. The costs incurred could then be divided among endorsers on a source-by-cause basis. Experts suggest not charging for each write operation individually but introducing a consumption index consisting of the write operations of a respective cooperative member divided by the total number of write operations (reference: previous year). To calculate the contribution of each cooperative member, the consumption index could then be multiplied by a cost estimate for the cooperative's following year (E3-4). This process may be governed and monitored by the cooperative's committees and contracts (E3, E5).

8.5 Discussion & Research Opportunities

In line with recent discussions, this study focuses on SSI ecosystems, as this new paradigm promises independence from intermediary ID providers. Following the appeal for further research on business aspects and collaborative efforts (Laatikainen et al., 2021), we address business model design considerations in strategic alliances governing SSI ecosystems. To answer our RQ, we follow an exploratory and design-oriented approach. Through a qualitative research design featuring semi-structured expert interviews, we derive rich contextual insights that are fruitful for practitioners and researchers.

The presentation of findings follows Al-Debei and Avison (2010)'s established V^{4}BM dimensions and provides cross-category remarks. Stakeholders seeking to develop SSI ecosystems can draw on our insights to guide their design. We discuss why cooperatives seem particularly for governance and indicate considerable aspects related to their business model. Considering both the user perspective of legal entities (i.e., companies, institutions) and individuals (i.e., private persons), our value proposition dimension specifies pains of classic ID management (e.g., SSO systems) and gains arising from SSI-based ID networks. With respect to the value architecture, we identify three crucial pillars that ecosystem orchestrators must consider: Technical network, organizational structure, and partner ecosystem. Experts believe a balanced equilibrium of a technologically trustworthy infrastructure and a transparent organizational cooperation model is essential. Referring to SSI value networks, we propose a combination of public and private actors and identify key partners. The value finance dimension further addresses network costs and suggests possible revenue streams. Experts propose to cover the consortium's costs as primary rationale, as it does not operate for profit but in its users' interest. For essential ecosystem stakeholders, we further outline basic business models. We highlight that SSI networks' core values are user-centricity and secure data sharing, and CBM design must align with these objectives. Our findings increase transparency in SSI network governance by providing insight into the business model layer and, therefore, set to foster user adoption and trust in SSI ecosystems. Moreover, we enhance the understanding and extend the applicability of the V^4BM Framework (Al-Debei and Avison, 2010) to CBMs in an SSI context. We demonstrate that it provides an interdisciplinary framework to strategically structure, analyze, and design novel initiatives. Researchers and practitioners may draw on our findings to communicate business model dimensions and characteristics or add additional elements. This is particularly useful as studies in SSI are a fairly new and rapidly evolving area of research.

Although we took a first step toward shaping governance in SSI ecosystems, there are limitations and numerous areas for future research. We discuss some of these avenues in our work and add three additional directions below. First, our qualitative interviews with experts working in an SDI project may only tell one side of the story. While their assessments are based upon day-to-day experience, all hold strong convictions about SSI's potential. In order to neutrally assess CBM concepts, further research should also embrace the customer perspective. This might entail the understanding and acceptance of SSI systems from a user perspective and other aspects such as SSI's impact on perceived privacy. Evaluating our findings with experts who do not represent an SDI project might also be helpful. Second, SSI is a new paradigm for data management that is dependent on widespread adoption. Our experts point out that SSI could also disrupt existing services offered by cooperative members (see Section 8.4.2). Therefore, future research might either (1) investigate the impact of SSI on existing business models, (2) explore new business model designs based on SSI, or (3) analyze how to leverage SSI and legacy business models together. Third, our results represent the first draft of a CBM. It can be argued that the concept is still fuzzy and insufficiently defined. We suggest that researchers extend our study to evaluate and, if necessary, revise the findings following an iterative process. For example, surveys with individuals and institutions might provide in-depth insights into anticipated problems and the magnitude of outlined benefits to test hypotheses about value propositions. Further inquiries could also examine the organizational structure and the partner ecosystem of the value architecture in more detail. In addition, studies on optimal value network structures of SSI ecosystems as well as assessments of costs and revenue streams of the value finance dimension might be worthwhile. In general, drawing on the iteration loops' knowledge, we propose to explore CBMs based on prototypes or real-world applications.

9

Enterprise Business Models in Self-Sovereign Identity Ecosystems

This chapter is based on a peer-reviewed article titled "Enterprise Business Models Leveraging Self-Sovereign Identity: Towards a User-Empowering Me2X Economy". The article was co-authored by Mahia-Cara Härdtner and Christof Weinhardt and is published in the 56th Annual Hawaii Conference on System Sciences (HICSS) Proceedings. The tables, figures, and appendices were systematically renamed, reformatted, and appropriately referenced to align with the overall structure of the thesis. To further enhance clarity and consistency, formatting, and reference style were adapted and references were updated.

Publication details: *Kölbel, T., Härdtner, M.-C., & Weinhardt, C., Enterprise Business Models Leveraging Self-Sovereign Identity: Towards a User-Empowering Me2X Economy, 56th Annual Hawaii Conference on System Sciences Proceedings, 2023.*

Abstract: The Self-Sovereign Identity (SSI) paradigm aims to transition online identity silos exhibiting privacy issues to user-controlled sharing mechanisms. While various governments back and promote its development, business models often play a subordinate role in these efforts. Building on academic literature and practical projects, our study addresses this and contributes a taxonomy of business enabled by SSI with 12 dimensions, 9 sub-dimensions, and 51 characteristics.

Keywords: Self-Sovereign Identity, Blockchain, Business Model, Privacy, Taxonomy.

9.1 Introduction

Digital ID is something we rarely think about in our day-to-day lives, but it affects humans and businesses alike. Every time users open an online account, make a purchase, interact with social media, or browse the web, they leave a data trail. SSO services operated by private companies such as Apple, Amazon, and Google collect, analyze, and store this data, creating digital footprints that they feed into profiles to sell data-driven business models like targeted advertising (Human and Cech, 2021; Richter and Anke, 2021). Interactions in regulated contexts (e.g., finance) further require user verification through effortful KYC processes (Schlatt et al., 2021). Overall, technological progress is outpacing security (Boysen, 2021), with our web having no built-in ID protocol (Richter and Anke, 2021). Users are dependent on ID providers acting as pivotal ecosystem entities (Toth and Anderson-Priddy, 2019). They operate isolated data silos and integrate trust and reputation mechanisms that are beyond the users' control, entailing inherent security, economic, and ethical risks (Sartor et al., 2022; Sedlmeir, Smethurst, et al., 2021).

Recently, the increased prevalence of data breaches, cybersecurity incidents, and detriments of data silos have fueled a public discourse and a strong push for user-empowering data control, autonomy, and sovereignty (European Commission, 2021; Human, Gsenger, et al., 2020; Sedlmeir, Smethurst, et al., 2021). Particularly in the European Union, this altruistic shift manifests in regulatory initiatives such as the DGA, which could pave the way for a user-centric IDM (European Commission, 2022a) that embraces the social notion of sustainability (Alt, 2020b). The DGA argues that users should have self-determined and trusted digital interactions while maintaining privacy. Instead of ID brokers managing data indirectly on a user's behalf, they store their IDs in digital wallets (European Commission, 2021). An emerging technology that overlaps the intensions of this new data strategy has been labeled as *SSI*. It describes a trusted network approach for authentic, verifiable, and seamless identification (Tobin and Reed, 2017). Users receive a master copy of their data, issued once by accredited entities, authenticated with digital signatures, and cryptographically secured using distributed structures like blockchain. With SSI, users can independently and selectively share their ID credentials and prove the trustworthiness of their information (Allen, 2016). Once issued and accredited, SSI credentials are interoperable and portable (Richter and Anke, 2021; Sedlmeir, Smethurst, et al., 2021), enabling cross-service KYC and a user-empowering 'Me2X' economy, what we define as an SSI-driven movement from a B2C world where intermediary third parties provide IDs to a user-centric world where users can bring their IDs to any service.

National governments like Germany ('Secure ID program') and Canada ('VON'), European Union initiatives ('ESSIF'), the World Economic Forum ('KTDI'), firms (e.g., Microsoft), and research institutions (MIT's 'DCC') actively explore the IDM based on the SSI paradigm. Academic publications on SSI to date focus primarily on technical design (Mühle et al., 2018), user experiences in wallet software (Sartor et al., 2022), SSI use cases (Schlatt et al., 2021; Bartolomeu et al., 2019), and SSI network design (Kölbel, Gawlitza, et al., 2022; Kubach and Roßnagel, 2021). Some authors further emphasize an intertwined SSI perspective of technical and business aspects (Kölbel, Gawlitza, et al., 2022; Laatikainen et al., 2021). While technical maturity, design, and user acceptance are prerequisites for the adoption of 'Me2X' IDM, scholars argue that studying business models in SSI is essential for economic success and requires a distinct analysis (Kölbel, Gawlitza, et al., 2022). However, to the best of our knowledge, there is no empirically-based research on how SSI can serve as the basis for business models in IDM. To avoid this pitfall, our work focuses on the following RQ:

Research Question: *What business model characteristics distinguish enterprises leveraging SSI ecosystems?*

To contribute a tangible analysis relevant to academic and practitioner communities, we develop a taxonomy of business enabled by SSI (BESSI) following Nickerson et al. (2013). Here, we consider business models that rely on SSI ecosystems as an integral part of their offering. Our analysis is guided by Al-Debei and Avison's (2010) business model dimensions and incorporates data from literature and real-world projects. For practitioners, we identify business models in SSI to reduce complexity and assist in selecting and developing viable BESSI. From a theoretical perspective, we develop a tool for researchers to model and systematically compare enterprise business models leveraging SSI ecosystems to achieve comparable results and scientific rigor.

The article proceeds as follows. Section 9.2 presents SSI fundamentals, and Section 9.3 explains our research design. Section 9.4 discusses results and presents the BESSI taxonomy. Section 9.5 highlights contributions, states limitations, and suggests further research avenues.

9.2 SSI Fundamentals

The SSI paradigm places users at the center of ID ecosystems (Richter and Anke, 2021), enables direct control over pertaining data, and ensures that users must explicitly consent to the sharing, use, and processing of their data (Toth and Anderson-Priddy, 2019). It aims to create a trusted data economy that allows users to verify, control, and trust the people they interact with, both in physical and digital realms (Kronfellner et al., 2021).

From an ecosystem perspective, SSI revolves around three specific actors: the issuer, the holder, and the verifier, who communicate P2P with each other (Richter and Anke, 2021; Kubach and Roßnagel, 2021). Together, these three actors form the so-called *trust triangle* (Davie et al., 2019), which facilitates data collection, resolution, updating, and revocation without the need for centralized ID intermediaries (Mühle et al., 2018). An **issuer** is an entity capable of issuing trusted data as VCs. VCs refer to a tamper-proof data file that contains a set of statements ('claims') about a holder that can be cryptographically verified. Several types of VCs offer advantages such as privacy protection (e.g., selective disclosure). Issuers can come in many shapes and sizes (e.g., governments, financial service providers). They verify and attest to a fact or attribute about another entity. The degree of reliance on this attestation is at the discretion of the verifier. A **holder** can be a person, organization, or object with a set of attributes attested by an issuer. The holder may hold these attributes in the form of VCs and manage them through software clients ('wallets'). Upon request, holders can bundle VCs into a verifiable presentation (VP) to self-prove attributes to third parties. A **verifier** is an entity that can check the authenticity and validity of a VC against a presented VP. It can verify that the data presented was issued by the correct, legitimate issuer and that the VC has not been tampered with or revoked. As such, the trust triangle allows the verifier to trust the data it receives directly from a holder without the need for direct interaction or relationship with the issuer (Davie et al., 2019; Kölbel, Gawlitza, et al., 2022). This decentralized trust, which extends beyond the validity of VCs, is enabled by cryptographic signatures and DIDs that are anchored in **immutable data registries** (Tobin and Reed, 2017). The W3C, seeking to standardize the technological basis of SSI amid other open source communities and non-profit organizations (e.g., TrustOverIP and Decentralized Identity Foundation), describe DIDs as *"a globally unique identifier that does not require a centralized registration authority because it is registered with distributed ledger technology or other form of decentralized network"* (Reed et al., 2019).

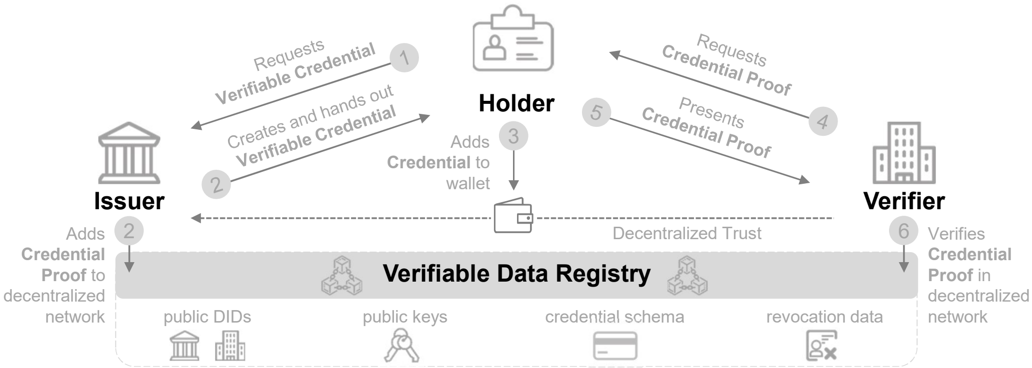

Fig. 9.1.: SSI Trust Triangle (Kölbel, Gawlitza, et al., 2022; Davie et al., 2019).

9.3 Methodological Approach

To develop the BESSI taxonomy of enterprise business models leveraging SSI ecosystems, we adopted Nickerson et al. (2013)'s methodology. We argue that this approach is particularly suitable as it applies across disciplines and combines practical relevance with scientific rigor. Moreover, it assists researchers and practitioners in understanding a complex domain by providing a well-documented and systematic process for defining dimensions and characteristics (Nickerson et al., 2013). Our taxonomy development process consists of an iterative approach with seven steps (see Figure 9.2). First, we defined meta-characteristics that reflect the purpose of our taxonomy and serve as guidance throughout the process (Step 1). We then defined ending conditions that determine when the iterative development process is complete (Step 2). In total, Nickerson et al. (2013) propose eight objective and five subjective ending conditions, which we borrowed for our research design. Subsequently, we started the iterative process of taxonomy development, choosing between inductive and deductive reasoning (Steps 3-6). While the conceptual-empirical approach is guided by empirical evidence, the empirical-conceptual approach focuses on extracting dimensions and characteristics from the scientific knowledge base (Nickerson et al., 2013). Our research process considers both options with a conceptual-empirical literature review and the analysis of real-world SSI projects as part of the empirical-conceptual approach. We iterated the process until the ending conditions were met (Step 7) and evaluated our results with three individual raters classifying five evaluation cases. We ensured that most of the required information was available on the companies' websites in selecting the cases. To compare the rater results and measure the level of agreement, we used Fleiss kappa (Fleiss, 1971). The analysis yielded a value of 63% that corresponds to a *"substantial agreement"* (Landis and Koch, 1977) and thus indicates that our taxonomy is suitable for a consistent classification and concise description of BESSI.

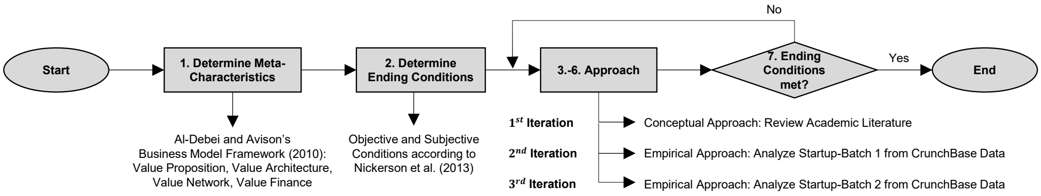

Fig. 9.2.: Applied Methodology following Nickerson et al. (2013).

Meta-characteristic. As a first step, we define the Unified business model framework by Al-Debei and Avison (2010) as meta-characteristics that reflect the purpose of our taxonomy and serve as guidance throughout the process. Accordingly, each of our taxonomy dimensions must relate to one of their **Value**[4]**business model dimensions**, namely value proposition, architecture, network, and finance (further described in Section 9.4). We argue that this guidance is particularly appropriate for our endeavor as it first explicitly addresses digital business models and, second, covers the multidimensionality of business models.

Conceptional-to-empirical. The starting point of our taxonomy development process forms a **structured literature review**. With this procedure, we build a knowledge base on business models in SSI, incorporate state-of-the-art research and strive to increase scientific rigor. The structured literature review follows the methodological suggestions of Webster and Watson (2002) and builds on querying a wide range of interdisciplinary databases[1] concerning several topic-related key terminologies[2]. To ensure that only high-quality and topic-relevant literature is considered, we applied the following criteria: First, we concentrate on peer-reviewed publications available in English and published between 2016 and 2022. Second, we review literature that concentrates on SSIs and explicitly or implicitly addresses business models. This comprises papers relating to specific business models in SSI as well as ecosystem initiatives and projects that consider SSI an integral part of their business activity. Consequently, we excluded studies that focus on SSI fundamentals and technological aspects, especially blockchain-related specifications such as asymmetric encryption (Fan et al., 2020; Rana et al., 2019). The search returned a total of 295 hits. Screening all papers' titles and abstracts resulted in 56 articles that met our inclusion criteria, including 12 removed duplicates. By analyzing the main texts, 35 additional publications were excluded from the analysis corpus. An iterative backward and forward search with the remaining nine publications yielded five additional relevant articles. In sum, we identified a total of 14 articles that provide the basis for our initial taxonomy.

Empirical-to-conceptional. Given the novelty of SSI and the moderate number of scientific publications related to business models, our second and third iteration phase incorporates projects that engage in SSI ecosystems. With this empirical data, we aim to address the topic's recency and improve the practical relevance of our taxonomy. The dataset for the **project analysis** relies on the CrunchBase new venture database and our structured literature review. We first considered all CrunchBase-listed projects for the keyword "self-sovereign identity" and identified 32 ventures. To ensure that our sample includes only relevant projects, we applied the following selection criteria. First, projects are relevant if they have already

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[1] ACM, AISeL, EBSCOHost, Emerald Insight, IEEEXplore, ProQuest, ScienceDirect, Taylor & Francis, Web of Science

[2] (Self-Sovereign Identit* OR Self Sovereign Identit* OR SSI)

Tab. 9.1.: List of Companies.

Iter.	*ID*	*Name*	*Website*
2	P1	Passbase	passbase.com
2	P2	Evernym	evernym.com
2	P3	Cheqd	cheqd.io
2	P4	Tykn	tykn.tech
2	P5	Liquid Avatar	liquidavatarech.com
2	P6	Finema	finema.com
2	P7	iGrant	igrant.io
2	P8	Vereign	vereign.com
2	P9	Trinsic	trinsic.id
3	P10	Blockpass	blockpass.org
3	P11	Metadium	metadium.com
3	P12	uPort	uport.me
3	P13	EarthID	myearth.id
3	P14	CoR	corinc.io
3	P15	Equideum	equideum.health
3	P16	Esatus	esatus.com
3	P17	Spherity	spherity.com
3	P18	Kiva	kivaprotocol.com

been mentioned in our structured literature review (e.g., Evernym, uPort/now Serto and Veramo, Trinsic, Spherity, Esatus, Kiva). Furthermore, to consider potentially successful projects, we only selected those firms that had already received funding. Projects that were not active anymore (Learning Machine Technologies, Space Elephant) or did not have an English homepage were excluded. In addition, we only considered projects that introduce SSI as an integral part of their business model, thereby excluding five enterprises (Synacts, Yat Labs, Coinplug, Ohanae, life.io). Finally, we excluded projects that did not provide sufficient information on the aforementioned criteria (Konsent, Cultu.re, Avila Security, Spidchain, Object Tech, Mooti). After considering all factors, the final set of analyzed enterprises covered 18 cases (see Table 9.1). For the taxonomy development, we considered the first nine projects in iteration two, and analyzed the remaining nine projects in iteration three.

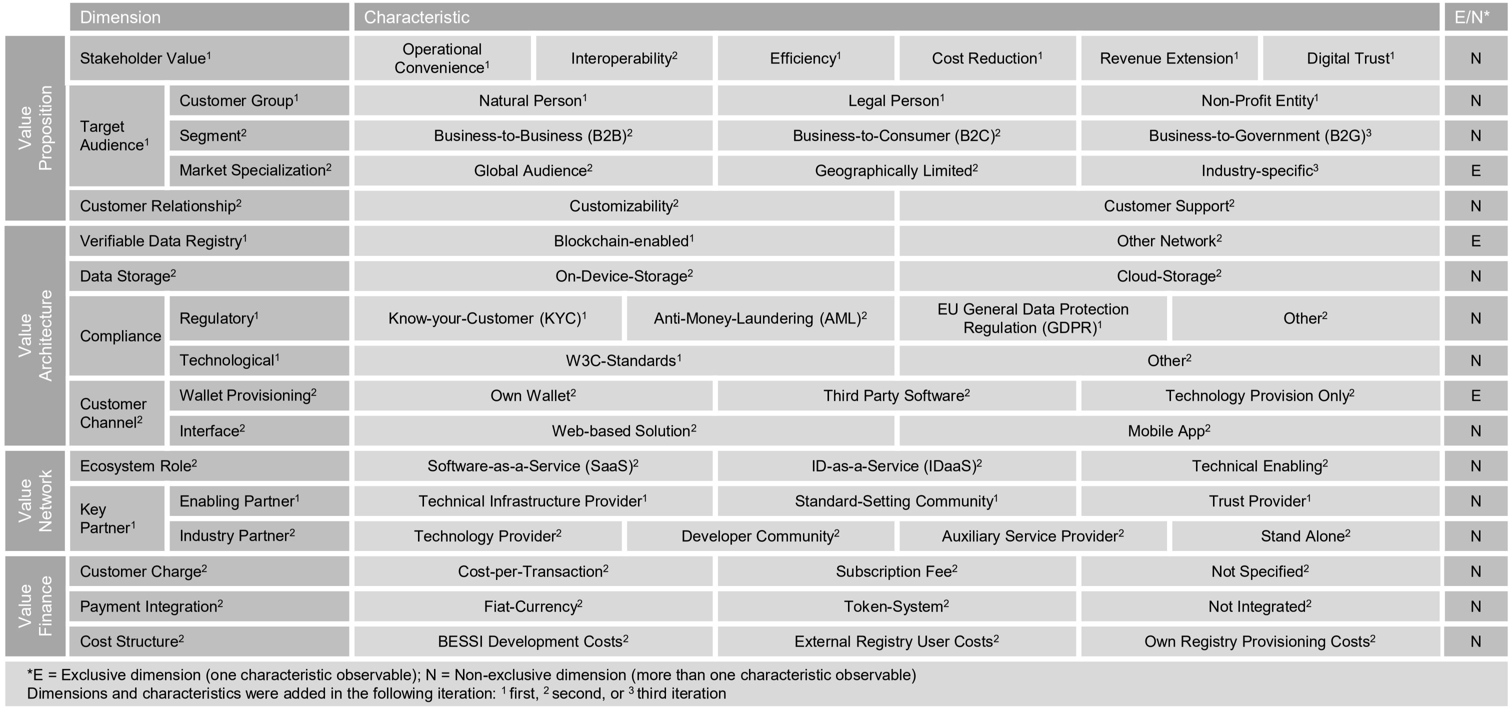
9.4 Taxonomy of Businesses enabled by Self-Sovereign Identity (BESSI)

This section presents our BESSI taxonomy. Figure 9.3 illustrates 12 dimensions and nine sub-dimensions, while two to six characteristics further describe each (sub) dimension. The right column of Figure 9.3 indicates whether an element is exclusive (E) or non-exclusive (N). Exclusive elements imply that a business model can solely be described by one characteristic per dimension. Conversely, non-exclusive elements suggest that one or more attributes characterize a business model. In addition, the superscripted numbers in Figure 9.3 indicate the iteration in which a dimension or characteristic was added. We present the taxonomy elements in detail below and structure our findings along the Value^{4}business model dimensions of Al-Debei and Avison (2010). We choose this framework because its multidimensionality appears appropriate and sufficiently comprehensive to capture all aspects of BESSI while avoiding conceptual ambiguity (Kölbel, Gawlitza, et al., 2022).

9.4.1 Value Proposition

The first perspective addresses mechanisms of BESSI to satisfy diverse customer needs. It comprises three dimensions, namely stakeholder value, target audience, and customer relationship.

Stakeholder value deals with the benefit of a specific business idea (product or service) that BESSI implies. It is a non-exclusive dimension since an enterprise can provide more than one value for its customers and leveraging SSI may have multiple benefits for enterprises. The first of six characteristics introduces *operational convenience*, which involves augmenting traditional business models with SSI attributes. Examples include ID verification and exchange (Kubach and Roßnagel, 2021; Bernabe et al., 2019), digitization of physical ID documents and access management through wallet solutions (Stockburger et al., 2021; Shuaib et al., 2021, P6, P16), portability of digital IDs across multiple services (Richter and Anke, 2021), and the elimination of passwords through biometric SSI authentication solutions (Wang and De Filippi, 2020, P4), thereby reducing administrative burden and improving customer experience. In addition, *interoperability* addresses the ability of a BESSI to communicate and exchange information with other SSI networks. Besides adhering to technical standards and communication protocols such as DIDcomm, BESSI offerings also differentiate based on the verifiable data registry used. For example, Cheqd (P3) supports multiple networks with a Cosmos-based system that promotes



<table>
<tr><th></th><th colspan="2">Dimension</th><th colspan="12">Characteristic</th><th>E/N*</th></tr>
<tr><td rowspan="5">Value Proposition</td><td colspan="2">Stakeholder Value^1</td><td colspan="2">Operational Convenience^1</td><td colspan="2">Interoperability^2</td><td colspan="2">Efficiency^1</td><td colspan="2">Cost Reduction^1</td><td colspan="2">Revenue Extension^1</td><td colspan="2">Digital Trust^1</td><td>N</td></tr>
<tr><td rowspan="3">Target Audience^1</td><td>Customer Group^1</td><td colspan="4">Natural Person^1</td><td colspan="4">Legal Person^1</td><td colspan="4">Non-Profit Entity^1</td><td>N</td></tr>
<tr><td>Segment^2</td><td colspan="4">Business-to-Business (B2B)^2</td><td colspan="4">Business-to-Consumer (B2C)^2</td><td colspan="4">Business-to-Government (B2G)^3</td><td>N</td></tr>
<tr><td>Market Specialization^2</td><td colspan="4">Global Audience^2</td><td colspan="4">Geographically Limited^2</td><td colspan="4">Industry-specific^3</td><td>E</td></tr>
<tr><td colspan="2">Customer Relationship^2</td><td colspan="6">Customizability^2</td><td colspan="6">Customer Support^2</td><td>N</td></tr>
<tr><td rowspan="6">Value Architecture</td><td colspan="2">Verifiable Data Registry^1</td><td colspan="6">Blockchain-enabled^1</td><td colspan="6">Other Network^2</td><td>E</td></tr>
<tr><td colspan="2">Data Storage^2</td><td colspan="6">On-Device-Storage^2</td><td colspan="6">Cloud-Storage^2</td><td>N</td></tr>
<tr><td rowspan="2">Compliance</td><td>Regulatory^1</td><td colspan="3">Know-your-Customer (KYC)^1</td><td colspan="3">Anti-Money-Laundering (AML)^2</td><td colspan="3">EU General Data Protection Regulation (GDPR)^1</td><td colspan="3">Other^2</td><td>N</td></tr>
<tr><td>Technological^1</td><td colspan="6">W3C-Standards^1</td><td colspan="6">Other^2</td><td>N</td></tr>
<tr><td rowspan="2">Customer Channel^2</td><td>Wallet Provisioning^2</td><td colspan="4">Own Wallet^2</td><td colspan="4">Third Party Software^2</td><td colspan="4">Technology Provision Only^2</td><td>E</td></tr>
<tr><td>Interface^2</td><td colspan="6">Web-based Solution^2</td><td colspan="6">Mobile App^2</td><td>N</td></tr>
<tr><td rowspan="3">Value Network</td><td colspan="2">Ecosystem Role^2</td><td colspan="4">Software-as-a-Service (SaaS)^2</td><td colspan="4">ID-as-a-Service (IDaaS)^2</td><td colspan="4">Technical Enabling^2</td><td>N</td></tr>
<tr><td rowspan="2">Key Partner^1</td><td>Enabling Partner^1</td><td colspan="4">Technical Infrastructure Provider^1</td><td colspan="4">Standard-Setting Community^1</td><td colspan="4">Trust Provider^1</td><td>N</td></tr>
<tr><td>Industry Partner^2</td><td colspan="3">Technology Provider^2</td><td colspan="3">Developer Community^2</td><td colspan="3">Auxiliary Service Provider^2</td><td colspan="3">Stand Alone^2</td><td>N</td></tr>
<tr><td rowspan="3">Value Finance</td><td colspan="2">Customer Charge^2</td><td colspan="4">Cost-per-Transaction^2</td><td colspan="4">Subscription Fee^2</td><td colspan="4">Not Specified^2</td><td>N</td></tr>
<tr><td colspan="2">Payment Integration^2</td><td colspan="4">Fiat-Currency^2</td><td colspan="4">Token-System^2</td><td colspan="4">Not Integrated^2</td><td>N</td></tr>
<tr><td colspan="2">Cost Structure^2</td><td colspan="4">BESSI Development Costs^2</td><td colspan="4">External Registry User Costs^2</td><td colspan="4">Own Registry Provisioning Costs^2</td><td>N</td></tr>
<tr><td colspan="16">*E = Exclusive dimension (one characteristic observable); N = Non-exclusive dimension (more than one characteristic observable)
Dimensions and characteristics were added in the following iteration: ^{1} first, ^{2} second, or ^{3} third iteration</td></tr>
</table>

Fig. 9.3.: Taxonomy of business enabled by Self-Sovereign Identity (BESSI).

communication between blockchains, while other projects rely on single-network solutions with limited interoperability (e.g., P4, P6, P14). More characteristics include *efficiency gains* through SSI-based automation of processes (Naik and Jenkins, 2020; Ertemel, 2018; Gebresilassie et al., 2020, P1, P9, P10, P12) and *cost reductions* through simplification of costly and cumbersome compliance regulations (Schlatt et al., 2021, P3, P11), which are particularly important when the cost and speed of verifying information is an essential business activity. While cost-saving measures and improved customer experience are potentially the quickest wins for businesses leveraging SSI ecosystems, SSI further unlocks *revenue extensions*, empowering companies to generate new business models and seamlessly engage (new) customers faster with customer-direct data (P2). Examples include cross-service KYC and due diligence processes (Schlatt et al., 2021, P10, P17, P18), platforms for self-determined data exchange and monetization (e.g., for health data, Stockburger et al., 2021; Thomason, 2021), SSI-based IDs and avatars in the metaverse (e.g., P5, P10), and all-in-one SSI enterprise suites (e.g., P12, P16). In addition, SSI also enables credentialing-as-a-service offerings and role-based, privacy-preserving access to lifecycle credentials of objects and machines along value chains of complex B2B supply chain structures (e.g., P17). Empowering the characteristic of *digital trust*, which describes user self-determination and secure data exchange through cryptographically secured SSI ecosystems, BESSI allows users to exchange data quickly, efficiently, and respectfully. In this context, real-world projects (e.g., P2, P4, P11) indicate that SSI also minimizes risk and complicates ID theft by keeping individual data in the hands of users and allowing companies to securely and independently validate their customers via the verifiable data registry. For example, Evernym's value proposition that their products are carefully designed to protect privacy (P2) is exemplified by cryptography and zero-knowledge proofs for data minimization. Similarly, Finema aims to reduce fraud-related costs by offering an automated, document-centric ID verification service that checks any document using artificial intelligence and computer vision (P6).

The second dimension of **target audience** involves three characteristics. The first is the *customer group* addressed by a BESSI. Following research on the stakeholder landscape in SSI ecosystems (Kubach and Roßnagel, 2021; Laatikainen et al., 2021), we distinguish between natural persons, legal entities, and non-profit entities. The second characteristic of *customer segment* differentiates B2B, B2C, and Business-to-Government (B2G). BESSI can also address multiple audiences (i.e., Me2X). For example, an offering may include a B2C wallet app (e.g., P9, P16) or SSI-secured email signatures (e.g., P8). Other options comprise SDKs sold as white-label products that can be customized and rebranded for B2B (e.g., P1, P6, P12, P14) or standards-based authentication platforms to connect government ID systems with financial services and payment infrastructures (e.g., P18). The *market specialization* additionally describes whether a BESSI is available to a global audience and thus does not target a focus market (e.g., P2, P3, P14) or whether availability is geographically limited to a specific country (e.g., P13) or region (e.g., P6) (e.g., to comply with specific legislation), or is industry-specific (e.g., P1, P13, P15).

Next, **customer relationship** classifies the connection between a BESSI and its customers. We distinguish two characteristics: First, *customizability* characterizes a customer's involvement and the flexibility of a BESSI. Here, our project analysis identifies the provisioning of different service packages that vary in functionality and price (e.g., P1, P8, P16). Second, *customer support* specifies the support mechanisms and responsiveness of employees working for a BESSI regarding assistance. Here, the level of support can vary. For example, Passbase (P1) offers its customers 24-hour assistance via email, chat, or phone at no additional cost, while Evernym (P2) conditions this service on the package size purchased by customers.

9.4.2 Value Architecture

The second perspective describes the architecture and structural design of business models, including the technological and organizational infrastructure that facilitate BESSI to create and deliver value. It comprises four dimensions, namely verifiable data registry, data storage, customer channel, and compliance.

Verifiable data registry describes the technical infrastructure a BESSI relies on to establish trust. Our taxonomy distinguishes between *blockchain-based* (e.g., P2-13) and *other networks* (e.g., P1, P16). In the first case, we identify different blockchain types, differing between public chains (e.g., P2-4, P10-13) and consortium chains (e.g., P5, P6, P9). In terms of blockchain networks, we observe the utilization of Ethereum (Stockburger et al., 2021, P10, P12, P15), Hyperledger projects (e.g., P2, P4, P8, P9), and other networks (e.g., P3, P7, P11). We further acknowledge different consensus mechanisms. These include, for example, PoW (e.g., P10), PoS (e.g., P3, P6), PoA (e.g., P11), Proof-of-Elapsed-Time (PoET) (e.g., P8), and self-created mechanisms (e.g., P2, P14).

The **data storage** dimension specifies a BESSIs data retention. We distinguish *on-device-storage*, where users self-host and locally store their data (e.g., P2, P11, P14), and *cloud-storage* (e.g., P1, P7, P12), where users store data in a self-hosted cloud or the environment of a contracted service provider. A combination of both storage types is also feasible (e.g. P4).

With the **compliance** dimension, we further indicate whether a BESSI complies with regulatory and/or technical standards. *Regulatory standards* involve, for example, KYC and AML legislation in regulated industries (e.g., financial sector). It also extends to compliance with the European Union's GDPR, a data protection law endorsed by the European Commission that governs the third-party processing of personal data and addresses the so-called 'CIA triad' (confidentiality, integrity, and availability) of data protection (Almeida et al., 2022). In this regard, researchers indicate that GDPR compliance could be operationalized by SSI (Davie et al., 2019; Kronfellner et al., 2021). Weigl, Barbereau, Rieger, et al. (2022) note that user-centric data management and privacy-enhancing characteristics of SSI systems (e.g., selective disclosure) support privacy compliance. In addition, our taxonomies *technical standards* dimension indexes whether a BESSI follows W3C-defined standards for DIDs and VCs, which Richter and Anke (2021) describe as the *"most notable"* initiatives in terms of the technical standardization and interoperability of SSI. Beyond, the 'other' category includes any other standards adopted by a BESSI (e.g., Aries Interoperability Standard; P2).

The **customer channel** describes how a BESSI connects with its target audience. *Wallet provisioning* distinguishes businesses that offer their wallet software (e.g., P2, P13, P16), offerings reliant on access to third-party software (e.g., P7, P11), and technology provisioning only (e.g., P3). Concerning BESSI *interfaces*, we differentiate web-based solutions (e.g., P4, P9, P13) and mobile apps (e.g., P4, P9, P13). In this context, Evernym (P2) offers a mobile SDK to embed the company's proprietary wallet functionality into apps of B2B customers. In addition, customers can build a customized, new app according to their needs and requirements. Cheqd, on the other hand, works with a technology partner that offers an interchain wallet that can be used for both web and mobile applications (P3).

9.4.3 Value Network

The third perspective refers to inter-organizational actors that form SSI ecosystems and describes how they collaboratively create value. We distinguish two dimensions, namely ecosystem role and key partner.

Ecosystem role describes the type and vertically integrated value proposition by a BESSI. *Software-as-a-Service (SaaS)* vendors provide B2B software that other ecosystem participants use for their SSI offerings. These include, for example, function-specific (e.g., P3) or all-in-one SSI suites (e.g., P16). *ID-as-a-Service (IDaaS)* offerings, on the other hand, have a direct customer interface and aim to enable users to interact in SSI ecosystems. They offer an array of applications that can range from issuing DIDs (e.g., P2, P9) and verifying VCs (e.g., P1, P6, P12) to providing a metaverse where users can leverage their SSI-enabled ID (P5). In addition, *technical enabling partner* provide services such as APIs that allow, for example, to transfer verifiable data between ID wallets (e.g., P9). This category also includes SDKs that enable the plug-and-play integration of VCs into mobile applications (e.g., P2, P12, P17). In this context, we see a variety of programming languages being offered. For example, Passbase (P1) provides solutions in JavaScript, Python, Java, and Ruby, while Evernym (P2) focuses on Java, Node.Js, Python, and .NET.

The **key partner** dimension characterizes complementary actors involved in a BESSI provision. In general, this refers to the issuer, holder, and verifier of the SSI trust triangle (see Section 9.2), which Davie et al. (2019) consider universal stakeholder roles in SSI ecosystems. Schlatt et al. (2021) further describe these actors in the context of KYC processes as a service-providing bank (i.e., verifier) that validates a service-seeking customer's (i.e., holder's) claim issued by a TTP (i.e., issuer). Beyond, our taxonomy considers more fine-grained partner relationships. By *enabling partner*, we first mean infrastructure providers that support various technical aspects (e.g., node services, consensus mechanisms) and act as active stakeholders of SSI ecosystems (Kubach and Roßnagel, 2021, P10). Second, we consider standard-setting communities (e.g., TrustOverIP Foundation, Decentralized Identity Foundation) that support and evolve SSI's technological foundations and establish standards that active stakeholders build upon (Kubach and Roßnagel, 2021). In addition, we consider trust providers such as government institutions and non-profit organizations to be BESSI partners, acting, for example, as TTPs and issuers of VCs (Laatikainen et al., 2021, P1). Similarly, we categorize companies that are directly or indirectly involved in the creation of a BESSI as *industry partners*. Here we distinguish between technology providers and developer communities involved in developing a service, auxiliary service providers (e.g., consulting firms), and the stand-alone provision of a BESSI. In this context, Evernym (P2), for example, considers consulting firms, insurance companies, telecommunication technology companies, and service-related development service providers as their BESSI partners.

9.4.4 Value Finance

The fourth dimension represents monetization strategies and costs associated with a BESSI. We distinguish three dimensions, namely customer charge, payment integration, and cost structure.

Customer charge indicates how a consumer pays for a BESSI (Kuperberg, 2020). First, we distinguish *cost-per-transaction* models, where, for example, consumers pay a fee for each issue, verification, and storage operation (e.g., P3, P9, P11). Second, BESSI projects adopt *subscription* models where consumers pay a monthly or annual fee (e.g., P16). Furthermore, we identify combinations within business models where, for example, using a wallet app is free. At the same time, services (e.g., document authentication, APIs, SDKs) cost a monthly subscription fee, and auxiliary services (e.g., AML and KYC compliance verification) get charged on a per-transaction basis (e.g., P1, P5).

The **payment integration** dimension further describes whether payment transactions are offered as part of a BESSI. Here, we distinguish between *fiat-currency* integrations (e.g., P2, P4), *token systems* (e.g., P3), and a *not-integrated* option where a business model does not provide monetary transactions (e.g., P5, P7).

Lastly, the **cost structure** dimension describes expenses related to a BESSI. First, we distinguish *BESSI development costs* incurred for the implementation of a business model (e.g., personnel costs). Second, *external registry user costs* indicate whether a BESSI provider relies on third-party cooperation and has no direct impact on, for example, transaction costs when using a blockchain network as a verifiable data registry (e.g., P2, P6, P7). In contrast, the characteristic *own registry provisioning costs* allows to include expenses if a provider, for example, operates its own network whose governance and financial design are subject to its influence (e.g., P3).

9.5 Discussion & Conclusion

The SSI paradigm is a rapidly evolving topic (Sedlmeir, Smethurst, et al., 2021). It embodies a user-centric sharing mechanism to present trusted and verified data (Boysen, 2021), that offers humans, businesses, and smart devices a convenient and privacy-oriented alternative to both physical means of identification and centralized ID platforms (Kölbel, Gawlitza, et al., 2022). Several researchers suggest that SSI, by virtue of its decentralized approach, changes the underlying principles of established services' business models that rely on collecting, analyzing, and selling user data, traffic, or advertisements (Sedlmeir, Smethurst, et al., 2021; Laatikainen et al., 2021). However, while the technical benefits of SSI to end-users are clear, we argue that business benefits remain rather ambiguous. We address this matter by adopting a multilayered research approach that incorporates both academic sources and real-world projects. Our main contribution is the theoretically grounded and empirically validated BESSI taxonomy, which follows the methodological guidelines of Nickerson et al. (2013). Structured along the Value[4]business model dimensions of Al-Debei and Avison (2010), we present a market overview, analyze and abstract individual business models, and highlight variations.

Our analysis shows that BESSI address several user groups, ranging from natural and legal persons to non-profit entities, spanning multiple segments (B2B, B2C, B2G). Besides a customizable offering and sophisticated customer support, vendors differ in value propositions. Examples include SSI networks' operational convenience and interoperability, where users profit from improved customer experience and reduced administrative complexity. Furthermore, BESSI promote efficiency gains and cost reductions and transform how customers are treated, enabling businesses to 'level-up' on digital trust while serving users and services (Boysen, 2021). Beyond influencing traditional business models in IDM, SSI facilitates the exploration of new revenue. This includes platforms for secure exchange and private data sales, along with innovative ideas such as IDs for the metaverse. Although platforms in SSI can't sell any data they want, researchers indicate a potential for fair monetization through SSI-based systems (Stockburger et al., 2021; Thomason, 2021). However, we note a gap between theory and practice, as incentive mechanisms in SSI are being pursued by only one real-world project (P3). Concerning value architectures, we observe a widespread use of blockchain-based verifiable data registries as trust anchors, whereas user data is stored in wallets or cloud services following the SSI principle of control (Allen, 2016). Businesses can develop their own (web or mobile) wallets, rely on open source from third parties, or act as technology providers. BESSI is influenced by growing regulatory efforts like DGA, GDPR, and KYC - especially regarding data collection and usage - and compliance with technical standards. We support Richter and Anke (2021)'s thesis that W3C standards for DIDs and VCs are the "most notable" technical initiatives related to SSI as they are being followed by most of our projects. For value networks, we consider SaaS-focused BESSI for B2B, IDaaS vendors targeting B2C, and offerings limited to technical support. As key partners, we identify enabling partners and industry-specific partners. In value finance, we observe that many BESSI rely on subscription or cost-per-transaction models. We notice an indifferent structure concerning payment integration, as BESSI come with payments in fiat currency and cryptocurrencies or without payment. Finally, as costs to consider, we identify offer-related development costs and costs related to the operation of a BESSI.

Our study contributes to the descriptive knowledge of the SSI phenomenon by exploring the poorly grasped area of BESSI. From a theoretical perspective, we add to the SSI ecosystem literature by providing the BESSI taxonomy that identifies tangible dimensions and characteristics to help understand how SSI affects business models. It serves as a basis for analyzing, designing, and configuring offerings, as well as analyzing antecedents. We contribute a common understanding of this complex topic and propose a tool for future research. In doing so, we follow the call for an economic perspective on SSI that examines business model aspects besides technological features (Kölbel, Gawlitza, et al., 2022; Sedlmeir, Smethurst, et al., 2021; Laatikainen et al., 2021). Practitioners may use the BESSI taxonomy and related case studies within ideation phases to identify options for business model innovation toward SSI and assess its impact on their current business. As a technology-specific tool, it assists decision-makers in evaluating and implementing business ideas in an enterprise context, such as building their own SSI solution or integrating and extending their current business model with an external SSI solution. We provide executives with an overview of existing business models that can be used to systematically analyze niches of not yet offered services, identify potential market entry opportunities, and rank relevant startups.

In interpreting our results, we acknowledge **limitations** that inherently constrain our study. First, Nickerson et al. (2013) notes that taxonomies are never perfect nor exhaustive. While we describe the current state, SSI ecosystems are subject to rapid technological evolution, which means that concepts and business models constantly evolve. Therefore, our taxonomy is a contemporary snapshot that requires periodic updating. However, we designed our taxonomy to be revisable and extensible so that new perspectives, characteristics, and dimensions can be added (Nickerson et al., 2013). Second, we were unable to evaluate analyzed BESSI concerning firm performance, and third, we cannot ensure that all businesses exploring SSI are part of our sample. We aim to address this issue by relying on projects cited in the literature and incorporating new ventures from the CrunchBase database. However, we note that our sample does not include SSI projects from incumbents (e.g., those funded by the German government's 'Secure Digital ID' program, such as Bosch, Commerzbank, and Deutsche Bahn).

Besides the limitations, which vice versa present **research opportunities**, the business potential of SSI is still in its infancy and will evolve further, thereby indicating avenues for future research. For example, scholars could reexamine the same projects we analyzed later to explore potential transformations in their business models. Future research could also adopt our taxonomy's dimensions and characteristics as constructs for further empirical studies, qualitative or quantitative. Qualitative interviews with representatives from research and practice, for example, could evaluate our findings to confirm further or iteratively revise them. This review for completeness and applicability would improve the validity of our results.

In addition, researchers can build on our taxonomy and explore archetypes that describe recurring patterns in BESSI offerings. These patterns could serve as a starting point to understand superordinate configurations, anticipate comparative trends, and identify key BESSI success factors. We argue that SSI infrastructures require close collaboration between business peers and competitors, exemplifying the coopetition model. Like blockchain solutions, SSI works best in contexts where different entities collaborate in a decentralized and distributed network, thereby turning SSI implementations toward business rather than technology challenges. In this context, we see a need for research on governance and collaboration models that ensure networks are reliable, secure, and provide adequate data protection. As SSI progresses in real-world applications, researchers can also extend our taxonomy toward a maturity model for BESSI. In addition, studying Me2X economies foci and SSI ecosystems from a service-dominant logic perspective or developing an artifact using DSR represent attractive research avenues. Given our observation that in current BESSI, network benefits appear to accrue predominantly to holders and verifiers, we suggest that future research could also analyze whether current SSI systems face bootstrapping and chicken-and-egg problems familiar from research on multi-sided markets that impact the adoption of SSI-based IDM. We argue that SSI ecosystems could benefit from self-reinforcing network effects when a critical mass of actors of the SSI trust triangle are interconnected and propose studies that focus on BESSI revenue streams as a function of their respective values. In this context, we note that current monetization strategies depend primarily on issuers bearing the costs of key operations in SSI ecosystems (e.g., DID document creation, VC signing, verification). However, we argue that they are not the primary beneficiaries of these operations and suggest exploring the extent to which holders and verifiers should bear these costs or whether, for example, governments could subsidize network operations. Here, attention could also be given if fees for each transaction add value or if SSI systems should ideally be able to distinguish SSI operations and charge only for value-adding processes.

10

Business Model Archetypes in Self-Sovereign Identity Ecosystems

This chapter is based on a submitted article titled "Empowering Users in Digital Identity Management: A Taxonomy and Archetypal Patterns of Business Models Leveraging Self-Sovereign Identity Ecosystems". The article was co-authored by Matthias Schradi and Christof Weinhardt and is currently under review in the Electronic Markets Journal. The authors' submitted manuscript's supplementary material can be found in Appendix A.3. The tables, figures, and appendices were systematically renamed, reformatted, and appropriately referenced to align with the overall structure of the thesis. To further enhance clarity and consistency, formatting, and reference style were adapted and references were updated.

Publication details: *Kölbel, T., Schradi, M., & Weinhardt, C., Empowering Users in Digital Identity Management: A Taxonomy and Archetypal Patterns of Business Models Leveraging Self-Sovereign Identity Ecosystems, Electronic Markets (Under Review).*

Abstract: As the world moves towards a more digital future, novel identity concepts like Self-Sovereign Identity (SSI) are gaining traction. Yet, conceptual and empirical evidence on the specifics of the SSI phenomenon remains scarce, and literature misses providing foundational insights and actionable knowledge on the potential business value of SSI-enabled identity management. To address this gap, we conduct a design science research project and develop an empirically and theoretically grounded taxonomy of SSI business models. Drawing on a dataset of 66 real-world projects and employing an established clustering procedure, we derive six distinct archetypes of business models leveraging SSI: Platform-as-a-Service, Cross-Layer Service, SSI-enabled Service, (SS)ID-as-a-Service, Infrastructure-as-a-Service, and Network-as-a-Service. We further introduce a multi-layer framework that disentangles distinct characteristics of interconnected and pivotal elements of SSI ecosystems. Our findings augment the theoretical understanding of SSI business models and empower decision-makers to identify strategic opportunities for leveraging SSI to enhance their business portfolios.

Keywords: Business Models, Self-Sovereign Identity (SSI), Ecosystem, Taxonomy, Archetypes, Cluster Analysis.

10.1 Introduction

Digital IDs are pivotal to today's online presence, allowing individuals and businesses to access services and connect with others. Traditional methods for authentication are mainly account- and password-based methods; however, managing passwords can be challenging. Such challenges include periodically resetting passwords, data breaches in password managers, using simple and insecure passwords, or repeating the same or similar passwords that leave users vulnerable to phishing attacks (Sartor et al., 2022; Bonneau et al., 2012; Herley, 2009). To address this issue, private organizations such as Google, Apple, and Amazon, along with government-operated identity platforms (IdPs), have developed SSO services (Kölbel, Gawlitza, et al., 2022; Maler and Reed, 2008). These services can provide convenience, yet they also present risks to user privacy and security that entail economic and ethical concerns (Sedlmeir, Smethurst, et al., 2021). For instance, when IdPs act as ecosystem intermediaries (Kölbel, Härdtner, et al., 2023; Toth and Anderson-Priddy, 2019) and implement trust and reputation mechanisms beyond users' control (Sartor et al., 2022; Sedlmeir, Smethurst, et al., 2021), the collection and analysis of cross-domain data can create digital footprints that are used to generate user profiles for data-driven business models such as targeted advertising (Human, Gsenger, et al., 2020; Richter and Anke, 2021). As a result, users are increasingly dependent on intermediaries (Kölbel, Härdtner, et al., 2023) while seeking more convenient IDM. This situation is particularly daunting in light of the rapid pace of the digital transformation, where technological advances outpace security (Boysen, 2021) and siloed IDM systems dominate the web in absence of a built-in ID protocol (Kölbel, Härdtner, et al., 2023; Richter and Anke, 2021).

Consequently, addressing identification in the digital sphere, from what data is collected to where it is stored and who owns and controls it, is a complex but timely and utmost important matter (Kölbel, Gawlitza, et al., 2022; Laatikainen et al., 2021). The current discourse on this subject is driven by a growing demand for data privacy and digital sovereignty, which led to a strong push for user-centric and decentralized IDM that empowers users with control, autonomy, and self-determination, and reduces the reliance on intermediary IdPs (European Commission, 2018; Sedlmeir, Smethurst, et al., 2021; Human, Gsenger, et al., 2020). Especially in the European Union, the desire for a *"[. . .] digital identity ecosystem that gives citizens full control over data and companies the opportunity to improve their product and service offerings"* (Kronfellner et al., 2021) leads to initiative like the 'DGA', which promotes secure digital interactions while protecting privacy (European Commission, 2022a). The DGA advocates using digital wallets instead of ID brokers, thereby paving the way for a user-centric and privacy-oriented IDM (Kölbel, Härdtner, et al., 2023) that embraces the social notion of sustainability (Alt, 2020a).

Recently, a technical concept referred to as SSI has gained momentum and emerged as a new paradigm in digital IDM that aligns with users' preferences for data control. SSI empowers users to self-manage and fully own their ID through digital wallets, providing both convenience and control over their data (Sedlmeir, Smethurst, et al., 2021; Kölbel, Gawlitza, et al., 2022). It builds on a user-centric and trusted network approach for authentic, verifiable, and seamless identification (Tobin and Reed, 2017) that reshapes IDM and drives business innovation. Identity attributes are attested through digital certificates carrying electronic signatures by accredited issuers. Upon request, individuals can choose to reveal selected identity attributes to relying parties in a cryptographically verifiable way using distributed structures like blockchain (Kölbel, Härdtner, et al., 2023). Once issued and accredited, SSI credentials are interoperable and portable between services (Richter and Anke, 2021; Sedlmeir, Smethurst, et al., 2021). Governments are increasingly supportive of SSI, with the 'European Self-Sovereign Identity Framework' (ESSIF) and large-scale projects like Canada's 'Verifiable Organizations Network' (VON), or Germany's 'IDunion' consortium exploring the approach (Sedlmeir, Barbereau, et al., 2022). Furthermore, leading consultancies argue that IDM is currently at an inflection point (Kronfellner et al., 2021) and estimate economic value of digital ID programs that aim to strengthen civic and social empowerment at 3-13 percent of GDP in 2030 (White et al., 2019).

Despite the relevance of emerging IDM concepts and SSIs potential to disrupt incumbent IdPs (Sedlmeir, Smethurst, et al., 2021), conceptual and empirical evidence on the specifics of the SSI phenomenon remain limited. Current research predominantly focuses on technological aspects (Mühle et al., 2018), user perspectives on wallet software (Sartor et al., 2022; Ostern and Cabinakova, 2019), and SSI network design (Kölbel, Gawlitza, et al., 2022; Kubach and Roßnagel, 2021). Some authors further emphasize an intertwined perspective of technical and business aspects, spotting a need for research related to the characteristics of SSI ecosystems (Kölbel, Gawlitza, et al., 2022; Laatikainen et al., 2021). Others illustrate SSI's transformational impact and how it can potentially alter processes and service provision within different industries (Kölbel, Härdtner, et al., 2023; Feulner et al., 2022; Schlatt et al., 2021; Bartolomeu et al., 2019). However, to the best of our knowledge, no empirical-based research exists on how SSI can serve as the basis for business models in IDM, change existing and build the foundation for new ones (Bock and Wiener, 2017). Furthermore, current literature lacks a structural analysis that explicitly examines the anatomy, such as stereotypical patterns (i.e., archetypes) of business models leveraging SSI ecosystems (Kölbel, Härdtner, et al., 2023). Moreover, in practice, there is a gap between the potential business value of SSI-enabled IDM and the actual value delivered. Building on those shortcomings, this paper focuses on the following RQs:

Research Question 1: *What are conceptually and empirically grounded characteristics of business models in SSI ecosystems?*

Research Question 2: *What are the archetypal patterns of business models leveraging the SSI paradigm?*

We address these questions by conducting a DSR project (Hevner, 2007) that includes two iterative phases. The first iteration builds on the study of Kölbel, Härdtner, et al. (2023) and employs Nickerson et al. (2013)'s taxonomy development process. After conducting a literature review on SSI business models, we analyze 66 real-world examples of projects that utilize SSI. To ensure both rigor and relevance, we qualitatively and quantitatively verify and revise our findings by conducting ten expert interviews and having three raters classify a subset of the cases to compare their ratings. The resulting taxonomy is structured along the four business model perspectives proposed by Al-Debei and Avison (2010) (i.e., value proposition, value architecture, value network, and value finance) and comprises 21 dimensions and 98 corresponding characteristics. The second iteration utilizes the taxonomy to re-classify the set of 66 real-world business models and applies cluster analysis to derive six groups of business models that share similar characteristics across the taxonomy dimensions. By comparing the individual cases within each cluster, we derive archetypes as qualitative interpretations that describe and distinguish configurations of business models leveraging SSI. Finally, we evaluate the differentiation among the six patterns across each dimension with statistical analyses.

The contribution of our work is threefold. First, we provide a systematically analyzed dataset of business models that employ SSI technology, providing an overview of how organizations use this emerging technology for IDM. Secondly, our taxonomy and archetypes complement existing literature on business models by establishing a common language for the analysis, classification, and configuration of SSI-based business models. This approach leads to a better understanding of higher-level business model configurations. Finally, practitioners can employ our taxonomy and archetypes as strategic management tools for developing novel SSI-based business models and for benchmarking existing ones. Both artifacts and our ecosystem framework pave the way for future research, including upcoming DSR projects in this highly relevant domain.

The following article is organized as follows: In Section 10.2, we elaborate on the evolution of digital identity models and their transition towards user-centricity and define SSIs technical foundations. Subsequently, we describe the methodological approach of our DSR project (Section 10.3). Section 10.4 presents our taxonomy and corresponding archetypes for business models in the SSI domain. In Section 10.5, we discuss our findings and elaborate the SSI concept from an ecosystem perspective. Finally, we provide a summary of implications, limitations, and potential future research directions of our study.

10.2 Background

In this study, we analyze business models that utilize SSI for a user-centric IDM approach. Prior to discussing the empirical findings, we provide the theoretical basis for this inquiry by addressing (1) digital identity models and their transition path, and (2) the foundational characteristics of SSIs.

10.2.1 Digital Identity Models & Their Transition Path Towards User-Centricity

A *digital identity* could be defined as a digital reference to a human, a legal entity, or a device (Kölbel, Gawlitza, et al., 2022; Sedlmeir, Smethurst, et al., 2021). It consists of a set of claims made by one subject (i.e., a user) about itself or another subject in response to requests for identification, authentication, or authorization in the digital world (Sedlmeir, Smethurst, et al., 2021; Toth and Anderson-Priddy, 2019; Cameron, 2005). These claims contain temporary or permanent attributes that are revocable, transferable, or exchangeable, such as citizenship, institutional affiliations, and ownership proofs (Preukschat and Reed, 2021; Sedlmeir, Smethurst, et al., 2021). Identity attributes are typically linked to a subject through a unique identifier, which distinguishes a single identity from other datasets of the same type within a system (ISO/IEC 24760-1, 2019). Subjects can prove their identity attributes using credentials, and multiple methods can be selected for both credentials and authentication depending on convenience, security needs, and regulatory requirements (Kölbel, Härdtner, et al., 2023; Toth and Anderson-Priddy, 2019). For example, a credential can be a password demonstrating ownership of a particular identifier like an email address or a verifiable document issued by a third party like a government-issued ID card (Sedlmeir, Smethurst, et al., 2021). Authentication methods can also vary, with one-time passwords or Two-Factor Authentication (2FA)/ Multi-Factor Authentication (MFA) being common used to that define the trust level and quality of identity data (Preukschat and Reed, 2021; Sedlmeir, Smethurst, et al., 2021). By setting such factors, a third party can determine how much trust they can place in the presented ID data.

In the current web environment, digital IDM models are regarded as socio-technical constructs that are in a constant state of innovation (Sedlmeir, Barbereau, et al., 2022; Smith and McKeen, 2011; Seltsikas and O'Keefe, 2010). Various factors, such as the emergence of new technologies, changes in regulatory policies, and the evolving needs of users, drive the innovation process of these models. We distinguish three fundamental models of identity innovation that differ in terms of storage location, the scope of validity, privacy protection, and users' power to dispose of their data (see Table 10.1): *Isolated identities*, *federated identities*, and *SSI*.

Tab. 10.1.: Perspectives on Digital Identity Models.

Digital Identity Model	Description	Trade-off for Users
Isolated Identities	• Discrete identities for every service • Cumbersome processes where users may fall victim to password theft	Balancing the amount of growing digital identities and ease of use.
Federated Identities	• Company-provided identities entail convenience • Questionable data monitoring, data sharing and privacy ethics	Balancing the ease of use vs. dependency on gatekeeping ID providers.
Self-Sovereign Identities	• Identity data stored at user's discretion • Users independently manage and selectively share their identity data	Balancing convenience of centralized services and decentralized properties.

Isolated identities are characterized by centralized models, where discrete identities are created within individual online services, such as social media accounts (Preukschat and Reed, 2021). These identities typically consist of a set of credentials, such as a combination of username and password, that users use to access and utilize various platforms, services, and software (Boysen, 2021). While this approach has its advantages, such as the ability to compartmentalize data, it also results in a fragmented identity experience. Service-specific user accounts require different credentials for each platform, leading to a rapidly growing number of digital identities in the isolated model (Preukschat and Reed, 2021). This growing number of digital identities becomes cumbersome for users to manage as a large number of passwords needs to be kept secure, and user data is distributed across multiple places on the internet (Kölbel, Härdtner, et al., 2023; Boysen, 2021). As a result, users may fall victim to password theft, such as phishing, key logging, viruses, and malware (Sedlmeir, Smethurst, et al., 2021; Herley, 2009). Additionally, users cannot easily transfer identity-related information from one account to another, which necessitates repeating lengthy registration processes, in which users often disclose and share more identity information than is necessary for a given operation to fulfill a service request (Kölbel, Härdtner, et al., 2023; Boysen, 2021).

Federated identities are designed to alleviate some of the challenges by providing IDM platforms that connect information on multiple instances (Preukschat and Reed, 2021; Sedlmeir, Smethurst, et al., 2021). Such platforms include SSO services and social login features, which major technology companies like Apple, Amazon, Google, and Facebook offer (Kölbel, Gawlitza, et al., 2022). The centralized silos created by these IdPs store identity data and facilitate the exchange of identity-related information between services connected to the platform (Sedlmeir, Smethurst, et al., 2021; Maler and Reed, 2008). When a user logs in with a federated identity, they are redirected to the IdP for authentication. Users no longer need to create separate usernames and passwords for each website they access, thereby having a process that is easy to use and convenient. However, tied to this convenience and shift from multiple to a few accounts are drawbacks, including the user's dependence on the IdP for authentication and the provider's ability to dictate the terms of use as de facto gatekeepers (Kölbel, Gawlitza, et al., 2022). By consenting to the IdP's data collection practices, users cede control over their data (e.g., individual behavior, preferences, purchases, and locations), leading to transparency and traceability across multiple services (Kölbel, Gawlitza, et al., 2022; Zuboff, 2015). These security vulnerabilities, questionable data sharing and monitoring ethics, and compromised privacy rights in centralized IDM platforms were extensively addressed by various scholars in prior research (e.g., Kölbel, Gawlitza, et al., 2022; Sedlmeir, Smethurst, et al., 2021; Zuboff, 2015).

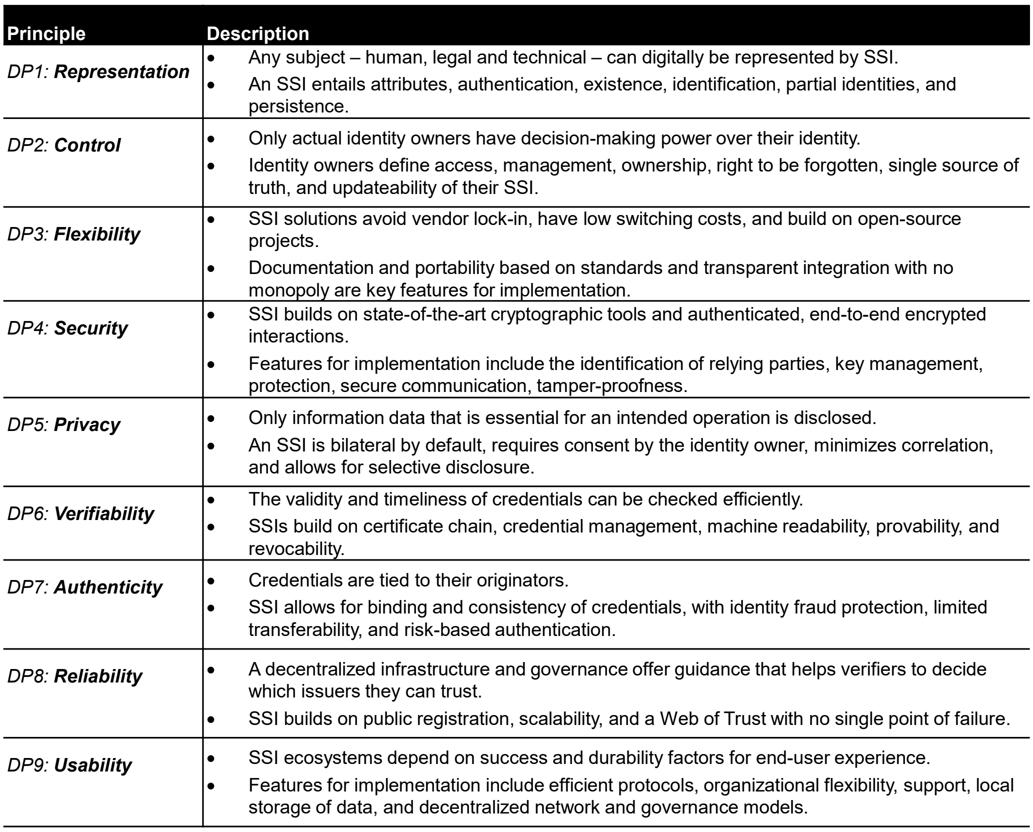
Consequently, approaches for handling *user-centric identities* have gained favor (Toth and Anderson-Priddy, 2019) and increased interest among scholars in recent years (e.g., Kölbel, Gawlitza, et al., 2022; Sartor et al., 2022; Sedlmeir, Barbereau, et al., 2022; Laatikainen et al., 2021; Richter and Anke, 2021). Such approaches address the so-called identity crisis and empower individuals to better manage and control their privacy when accessing digital services (Preukschat and Reed, 2021; Toth and

Anderson-Priddy, 2019). One of the latest approaches is a principle-based framework for user-centric identities called SSI. It was introduced and popularized by Allen (2016) and is widely regarded as a paradigm shift in digital IDM (Kölbel, Härdtner, et al., 2023; Feulner et al., 2022). It is a rapidly evolving topic that enables users to use and control their identity across multiple digital services with a password-less login and digital representations of verifiable documents (Sedlmeir, Smethurst, et al., 2021). SSI allows users to independently manage and selectively share their identity data without being limited to a single domain or use case (Kubach, Schunck, et al., 2020; Wang and De Filippi, 2020). Unlike other IDM systems, it eliminates the need for an intermediary to store and transfer information, ensuring confidential and verifiable IDs in bilateral interactions (Schlatt et al., 2021; Kubach, Schunck, et al., 2020). Subsequently, we briefly elaborate on SSIs' characteristics.

10.2.2 Fundamentals of Self-Sovereign Identity

The concept of SSI is a novel technological innovation that is often interrelated and regarded as a synonym with the general paradigm and movement of decentralized digital identities (Laatikainen et al., 2021; Preukschat and Reed, 2021; Sedlmeir, Smethurst, et al., 2021). The definition of SSI is broad and loosely defined in the current literature (Laatikainen et al., 2021; Mühle et al., 2018), and it can be approached from various angles. While there is a general consensus among scholars, practitioners, and community enthusiasts that SSI (1) places users at the center of IDM systems in digital environments (Kölbel, Gawlitza, et al., 2022; Preukschat and Reed, 2021; Wang and De Filippi, 2020), and (2) ensures that self-determined users must explicitly consent to the sharing, use, and processing of their data (Sedlmeir, Barbereau, et al., 2022; Weigl, Barbereau, Rieger, et al., 2022; Kubach, Schunck, et al., 2020; Toth and Anderson-Priddy, 2019), there is no overall consensus on the explicit definition of SSI. Various attempts have proposed 'principles of SSI' to define the broad term and focal topic. Movement incubators such as Allen (2016) focus on a techno-centric and libertarian definition (Sedlmeir, Barbereau, et al., 2022), while early scholars emphasized blockchain's essential role as a technological building block (Mühle et al., 2018). However, more recent research suggests a smaller role for blockchain (Schlatt et al., 2021) and more focus on SSI applications (Feulner et al., 2022; Sartor et al., 2022). In this study, we adopt the perspective of Sedlmeir, Barbereau, et al. (2022), which proposes a multi-level approach with nine DPs for SSI that build on current research, industry applications, and regulatory aspects, thereby incorporating both practitioners' and researchers' perspectives with technical, regulatory, and business requirements (Table 10.2).

Tab. 10.2.: Principles of Self-Sovereign Identities modified after Sedlmeir, Barbereau, et al. (2022).



Principle	Description
DP1: ***Representation***	• Any subject – human, legal and technical – can digitally be represented by SSI. • An SSI entails attributes, authentication, existence, identification, partial identities, and persistence.
DP2: ***Control***	• Only actual identity owners have decision-making power over their identity. • Identity owners define access, management, ownership, right to be forgotten, single source of truth, and updateability of their SSI.
DP3: ***Flexibility***	• SSI solutions avoid vendor lock-in, have low switching costs, and build on open-source projects. • Documentation and portability based on standards and transparent integration with no monopoly are key features for implementation.
DP4: ***Security***	• SSI builds on state-of-the-art cryptographic tools and authenticated, end-to-end encrypted interactions. • Features for implementation include the identification of relying parties, key management, protection, secure communication, tamper-proofness.
DP5: ***Privacy***	• Only information data that is essential for an intended operation is disclosed. • An SSI is bilateral by default, requires consent by the identity owner, minimizes correlation, and allows for selective disclosure.
DP6: ***Verifiability***	• The validity and timeliness of credentials can be checked efficiently. • SSIs build on certificate chain, credential management, machine readability, provability, and revocability.
DP7: ***Authenticity***	• Credentials are tied to their originators. • SSI allows for binding and consistency of credentials, with identity fraud protection, limited transferability, and risk-based authentication.
DP8: ***Reliability***	• A decentralized infrastructure and governance offer guidance that helps verifiers to decide which issuers they can trust. • SSI builds on public registration, scalability, and a Web of Trust with no single point of failure.
DP9: ***Usability***	• SSI ecosystems depend on success and durability factors for end-user experience. • Features for implementation include efficient protocols, organizational flexibility, support, local storage of data, and decentralized network and governance models.

The overall concept of SSI is fundamentally distinct from traditional user accounts, as it establishes direct connections between subjects using asymmetric cryptography with private and public key pairs (i.e., digital signatures) and a trusted registry for verification purposes (Preukschat and Reed, 2021; Davie et al., 2019). The claims associated with a subject, such as attributes (e.g., name, age) or relationships between subjects (e.g., institutional affiliations), are represented through digitally signed data objects known as VCs (Babel and Sedlmeir, 2023; Kubach and Roßnagel, 2021; Preukschat and Reed, 2021). These VCs have flexible semantics and can be automatically and cryptographically verified. To present identity attributes for identification or authorization, SSI networks rely on the collaborative efforts of three actors that form an ecosystem: *holders*, *issuers*, and *verifiers*. These roles are symbiotically interrelated and form what is known as the digital *trust triangle* of SSI (Kölbel, Gawlitza, et al., 2022; Laatikainen et al., 2021; Preukschat and Reed, 2021). Holders represent actors who own their identity and store digital attestations (i.e., credentials) in self-managed edge devices (e.g., mobile phones) in digital wallets (Laatikainen et al., 2021; Sedlmeir, Smethurst, et al., 2021). Issuers are responsible for issuing credentials and can be any entity with a good reputation, including public sector institutions, banks, individuals, or even machines (Babel and Sedlmeir, 2023). To disclose identity attributes to relying parties (i.e., verifiers), holders request credentials from issuers. As an example, an e-commerce service in the role of a verifier may request a user's credit card information as part of a KYC process, including several attributes of a holder's ID such as name, date, and address. In this scenario, a verifier typically establishes a connection to a holder's endpoint – typically their wallet – and sends a 'proof request' that seeks the disclosure of specific attributes stated in the holder's credential. The holder then transmits a VP to a verifier's endpoint. When the request is received, the holder's digital wallet automatically searches for stored credentials that include the requested attributes and – subject to the holder's consent - generates a cryptographic proof about the correctness of the holder's claim that is being sent as proof to the verifier (Babel and Sedlmeir, 2023). The verifier can cryptographically evaluate the VP's integrity based on the issuer's digital signature (Babel and Sedlmeir, 2023). If the verifying party trusts the issuer, they can rely on the attested attributes for their service (Sedlmeir, Barbereau, et al., 2022).

We identify distinguishing commonalities that SSI collectively combines to form an ecosystem (Autio and Thomas, 2020): First, SSI encompasses a heterogeneous group of participants transcending industry sectors and the boundary between public and private sectors, each individually fulfilling unique roles and responsibilities in the SSI trust triangle to collectively create a coherent system-level output. Second, the nature of interdependence among ecosystem participants and the nature of ecosystem governance in SSI. Relying on DIDs that contain public keys enriched with metadata, SSI ecosystems facilitate communication among actors using agents and direct P2P connections (Sedlmeir, Barbereau, et al., 2022; Kubach and Roßnagel, 2021; Preukschat and Reed, 2021). This architecture ensures that neither party has exclusive control over the connection. By encrypting data with the recipient's public key and signing data with the sender's private key, as well as incorporating mechanisms like 'zero-knowledge proof' for selective attribute disclosure, the network can improve confidentiality, data minimization, and privacy (Babel and Sedlmeir, 2023; Kölbel, Härdtner, et al., 2023). In an SSI ecosystem, each actor privately stores their private key, while their public keys can be obtained from a trusted register known as the *Verifiable Data Registry* by resolving the respective DIDs. This registry constitutes a distributed database that services as a physically decentralized but logically centralized source of truth for identity-related information. It can be instantiated in end-users' digital wallets or made publicly available through infrastructures like blockchain, which manage trust relationships by recording actors' public keys and storing public revocation registries (Preukschat and Reed, 2021; Schlatt et al., 2021; Mühle et al., 2018). With SSI, verifiers can automatically verify received data's validity, authenticity, and origin without he need to contact the issuer. The trust among actors in SSI is established through (1) standardized technologies suggested by organizations such as the W3C and the DIF and (2) network-specific governance frameworks comprising technical, business, and legal regulations and policies determined by a governance authority that may represent any set of issuers organized in different forms such as consortia, cooperatives, or governments (Laatikainen et al., 2021; Preukschat and Reed, 2021; Davie et al., 2019). Hence, SSI solutions necessitate not only technological solutions but also governance frameworks, and these two building blocks are intertwined (Kölbel, Gawlitza, et al., 2022; Zwitter et al., 2020).

10.3 Research Design

Our research follows the DSR approach, as outlined by Hevner (2007), to present a taxonomy and archetypal patterns of business models that capitalize on the SSI paradigm. Consistent with Hevner (2007)'s framework, our DSR project comprises three iterative cycles, namely rigor, relevance, and design, that ensure both practical relevance and scientific rigor (Baskerville et al., 2018). The rigor cycle integrates existing knowledge and research into the artifacts, the relevance cycle connects design activities to real-world phenomena, and the design cycle enhances and iteratively evaluates artifacts. Our DSR project comprises two sequential iterations, each with three phases. In the first iteration, we construct a taxonomy by combining DSR with the taxonomy development method proposed by Nickerson et al. (2013) and supplementary evaluation guidelines (Kundisch et al., 2022; Szopinski et al., 2019). The second iteration builds and evaluates archetypal business model patterns for SSI by conducting a cross-case cluster analysis (Yin, 2009; Punj and Stewart, 1983) and interpreting the results. Figure 10.1 summarizes the iterations. The following sections provide a detailed description of both iterations.

10.3.1 Iteration 1: Taxonomy Development

The first iteration of our DSR project focuses on developing a taxonomy of business models leveraging SSI ecosystems by adopting the methodology presented by Nickerson et al. (2013). We argue that this approach is well-suited to business model research, as it enables researchers to identify and classify the various components

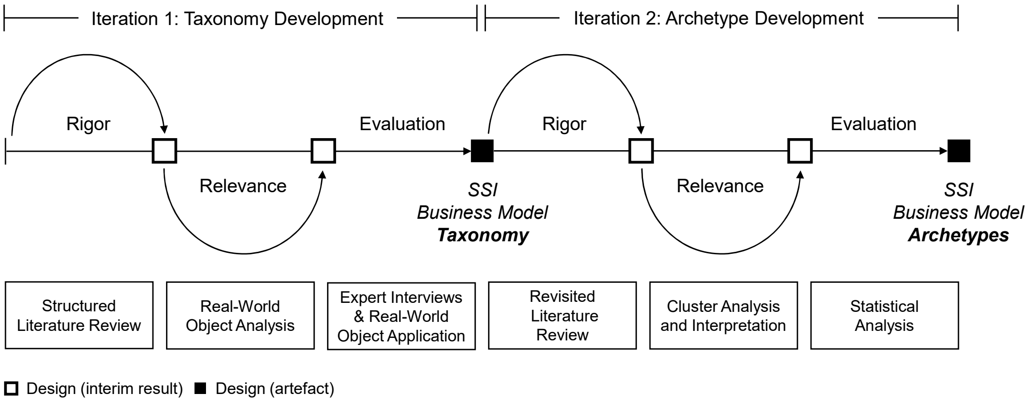


Fig. 10.1.: Research Design of our DSR Project.

that constitute a business model based on similarities and characteristic properties. Taxonomies have emerged as a prominent methodological tool in information systems research, aimed at combining practical applicability and scientific rigor, thereby providing a systematic process for defining dimensions and characteristics that assists both researchers and practitioners in understanding a complex domain (Nickerson et al., 2013). By structuring and organizing these components with taxonomies, researchers can develop a more nuanced and rigorous understanding of the relationships between different business model elements, identify gaps, overlaps, and areas for changes or improvements to enhance the overall effectiveness of the model. The taxonomy development process consists of an iterative approach with seven steps, as illustrated in Figure 10.2. Initially, we set meta-characteristics that serve as guidance throughout the process (Step 1). Subsequently, we defined ending conditions for the iterative method (Step 2), where we followed the conditions according to the authors (Nickerson et al., 2013). After setting the foundations of taxonomy development, we conducted the first design cycle, choosing between inductive and deductive reasoning (Steps 3-6). The conceptual-empirical approach is guided by empirical evidence, whereas the empirical-conceptual approach focuses on extracting dimensions and characteristics from the scientific knowledge base (Nickerson et al., 2013). Our research considers both options, which comprise a conceptual-empirical literature review and the analysis of real-world SSI projects as part of the empirical-conceptual approach. We iterated the process until the ending conditions were met (Step 7) and evaluated our results through qualitative expert interviews and quantitative real-world object classification. We elaborate on the detailed process below.

Meta-Characteristic. As a first step, we define the Unified Business Model Framework introduced by Al-Debei and Avison (2010) as kernel theory and meta-characteristics

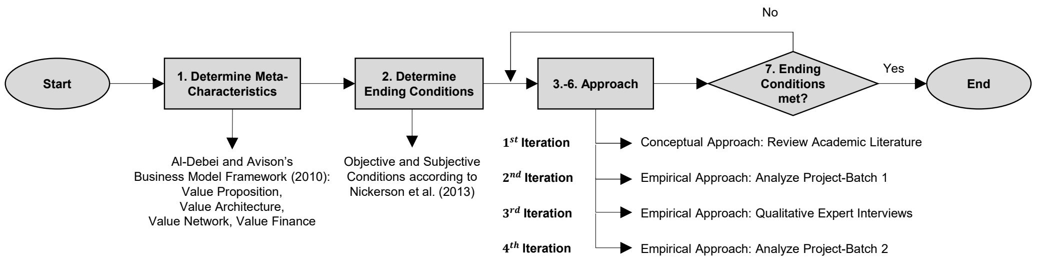


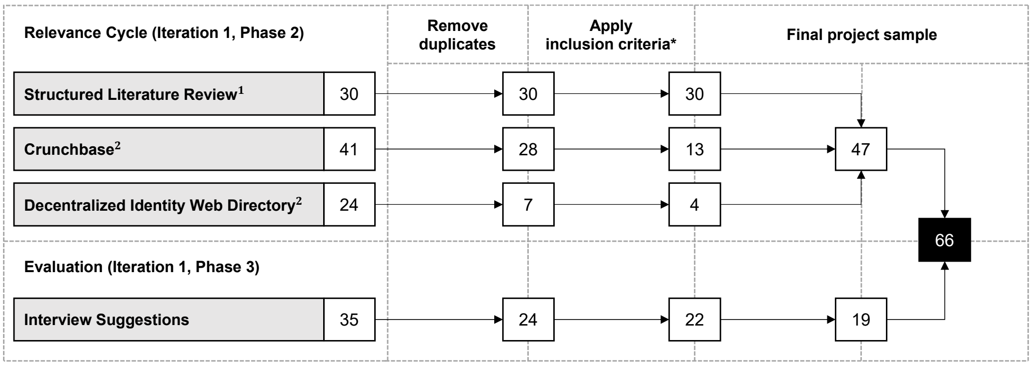
Fig. 10.2.: Applied Taxonomy Development Process following Nickerson et al. (2013).

that encapsulate the objective of our taxonomy throughout the design process. To this end, each of the taxonomy's dimensions must align with one of the frameworks business model dimensions, namely value proposition, value architecture, value network, and value finance. We argue that this guidance is particularly suited to our endeavor since it explicitly addresses digital business models and encompasses their multidimensionality.

Conceptional-to-Empirical. We started the taxonomy development process with a structured literature review in the rigor cycle. This procedure aimed to establish a knowledge base on SSI business models, incorporate state-of-the-art research, and increase scientific rigor. Our structured literature review followed the methodological suggestions of Webster and Watson (2002) and involved querying the interdisciplinary databases EBSCOHost, Emerald Insight, IEEEXplore, ScienceDirect, Wiley, and Taylor & Francis. We searched by using the string "Self-Sovereign Identity" or "SSI" AND ("Business Model" OR "Business Value" OR "Application") to identify articles in the title, abstract, or keywords. To further increase the topicality and completeness of our review, we included papers from the AIS Electronic Library matching the keyword "Self-Sovereign Identity" or "SSI." To ensure that only high-quality and topic-relevant literature is considered, we applied the following criteria: First, we focused on peer-reviewed publications in English. Second, we reviewed papers that deal with SSI and explicitly or implicitly address at least one of the four business model dimensions represented by the taxonomy's meta-characteristics. This includes papers related to specific business models in SSI, as well as ecosystem initiatives and projects that consider SSI an integral part of their business activity. Consequently, we excluded studies focusing on SSI fundamentals and technological aspects (Naik, Grace, et al., 2022). The search returned a total of 369 hits. We screened the abstracts and eliminated irrelevant papers by applying the abovementioned criteria and duplicates, resulting in 54 remaining articles. After conducting a full-text screening, we excluded an additional 29 papers. The remaining 25 documents formed the basis for the forward and backward search, which resulted in 14 additional papers. In sum, we identified a total of 42 articles that provide the basis for our initial taxonomy.

Empirical-to-Conceptional. Given the novelty of SSI and the moderate number of scholarly publications relating to business models, our second and third iterations of the relevance cycle integrate projects that leverage SSI ecosystems. With this empirical data, we aim to address the topic's recency, improve the practical relevance of our taxonomy and establish links between our theoretical insights and real-world phenomena. To construct an exhaustive and representative dataset of SSI business models, we gathered data from multiple sources and analyzed the sample sequentially and analytically. For our initial dataset, we relied on CrunchBase, where we analyzed all projects listed for the keyword "self-sovereign identity," resulting in 41 ventures. To ensure that our sample includes only relevant projects, we applied the following selection criteria: First, projects were considered relevant if they had already been mentioned in our structured literature review (e.g., ION.foundation, Evernym, Trinsic, Spherity, Esatus). Furthermore, we only selected firms already receiving funding to consider potentially successful projects. Projects that were not active anymore (Tykn, Learning Machine Technologies, Mooti) or did not have an English homepage were excluded. In addition, we only considered projects that introduce SSI as an integral part of their business model. Finally, we disregarded projects that did not offer sufficient information on the aforementioned criteria (e.g., Cultu.re, Object Tech). Subsequently, we expanded our sample using an SSI-specific database called 'Decentralized Identity Web Directory', which helped us identify four additional relevant projects that supplement our dataset (ont.io, hylandscredentials.com, mattr.global, veres.io). After considering all factors, our final set covered 47 cases. To analyze the projects SSI business models, we obtained information from various sources that were deemed reliable and business-oriented, such as company websites, CrunchBase, LinkedIn, and news articles. The data gathered from project websites provided insights into the project's operations, products, and services. CrunchBase and LinkedIn were used to gather information on funding, key personnel, and organizational structure. Lastly, we collected information from news articles that focused on business-related topics, which provided insights into the project's recent developments, partnerships, and strategic decisions. The overall process is illustrated in Figure 10.3, and the final business model sample is presented in Appendix Table A.6.

Evaluation. To evaluate our taxonomy, we extended Nickerson et al. (2013)'s original development process (Kundisch et al., 2022; Szopinski et al., 2019) and adopted the idea that it is crucial to evaluate preliminary artifacts in DSR projects (Venable et al., 2016). To this end, in the final phase of the first iteration, we utilized



[1] Databases: EBSCOHost, Emerald Insight, IEEEXplore, ScienceDirect, Wiley, Taylor & Francis, AIS Electronic Library
Search Term: "Self-Sovereign Identity" OR "SSI" AND ("Business Model" OR "Business Value" OR "Application")
[2] Search Term: „Self-Sovereign Identity"
* Inclusion criteria: Project must (1) still be active, (2) provide an English website, and (3) fucus on the SSI domain

Fig. 10.3.: Company and business model selection process in Phase 2 and 3 of the first iteration.

Szopinski et al. (2019)'s taxonomy evaluation framework to assess our taxonomy. Our evaluation process consists of two episodes, utilizing both qualitative and quantitative methods. In the first episode, we conducted ten expert interviews using a semi-structured approach based on the recommendations of Myers and Newman (2007). Six interviews were with practitioners, and four were with academic researchers with extensive experience in the SSI domain, business models, and/or taxonomy building (see Table 10.3 for details). We asked questions regarding the adequacy, completeness, and relevance of the taxonomy while also encouraging an open discussion. Additionally, we invited suggestions for modifying the taxonomy, such as adding, renaming, or removing dimensions or characteristics based on Kundisch et al. (2022). All interviews were conducted by two authors, lasted on average 57 minutes, and were recorded, transcribed, and then analyzed using MAXQDA software. Through this process, we qualitatively evaluated the taxonomy on the criteria of comprehensibility, completeness, perceived usefulness, and the level of abstraction of its characteristics and dimensions.

In the subsequent phase of the *design cycle*, we employed Mayring (2014)'s qualitative content analysis as a flexible research technique to analyze and interpret the qualitative interview data. To conduct the analysis, we adopted a deductive coding approach, utilizing the previously defined meta-characteristics and tentative taxonomy dimensions and characteristics as our coding scheme to analyze the interview data in a structured manner. Based on the resulting codes, we added, renamed, swapped, splitted, or deleted dimensions or characteristics of the taxonomy (Kundisch et al., 2022, see Appendix Table A.12). To ensure the validity and reliability of the coding process, the data was independently analyzed by one author,

Tab. 10.3.: Overview of interviewees with background, role, expertise, and interview duration.

Background	Role	Expertise	Duration
Corporate	Project Director	SSI	73 min
	Chief Executive Officer	SSI, Business Models	51 min
	Lead Software Developer	SSI	60 min
	Product Owner	SSI, Business Models	32 min
	Business Developer	SSI, Business Models	66 min
	Digitalization Officer	SSI, Business Models	40 min
Academia	Assistant Professor	SSI, Taxonomies	50 min
	Research Scientist	SSI, Taxonomies	58 min
	Postdoctoral Researcher	SSI, Taxonomies	77 min
	Doctoral Candidate	SSI, Taxonomies	64 min

and the findings were reviewed and discussed with the other two authors. Finally, we compared the identified codes with the initial version of the taxonomy and modified our artifact, resulting in the final version of the taxonomy (see Figure 10.5).

Following the modifications to the taxonomy, we conducted a second evaluation episode to assess its practical applicability and usefulness in classifying and comparing real-world objects. To avoid limiting the evaluation to objects used in the previous development process in Phase 2 (n =47), we expanded our sample by including additional projects leveraging SSI ecosystems that were not previously involved. To expand the dataset, interviewees were asked to suggest interesting projects from the SSI domain. After removing duplicates and comparing the mentioned projects to those included in Phase 2, a total of 35 additional projects were identified. Subsequently, the inclusion criteria utilized during the previous phase were applied while reviewing the projects' websites, leading to a final set of 66 relevant projects for the second evaluation episode (see Appendix Table A.6).

The identified set of objects was then classified based on the dimensions and characteristics of the taxonomy. Here, a single author classified the 66 business models according to the definitions provided in Appendix Table A.7, Table A.8, Table A.9, Table A.10, and Table A.11, which served as a codebook for provisional coding (Hunke et al., 2021; Saldaña, 2017). To verify the quality of the classification, a random sample of business models (n = 10) was coded individually by three independent raters. Fleiss (1971)'s Kappa was used to measure the degree of agreement, which resulted in a value of 61%, indicating *"substantial agreement"* according to Landis and Koch (1977). Based on these results, it can be assumed that our taxonomy meets our evaluation criteria and is suitable for a coherent classification and concise description of SSI business models.

10.3.2 Iteration 2: Archetypal Pattern Development

To better understand different SSI business models and verify our taxonomy's applicability, we employed a mixed-methods approach to identify archetypes as primordial patterns in the second iteration of the study. We ensure rigor and relevance by incorporating input from literature and real-world objects in two primary design activities: a quantitative cluster analysis (Punj and Stewart, 1983) to identify groups of similar real-world objects; and a qualitative cross-table analysis of the clustering solution (Hambrick, 1984) to interpret the clusters and derive meaningful archetype descriptions. Lastly, we evaluated the results through statistical analyses to confirm that the patterns significantly differ in each dimension.

The second iteration of our research commenced with a *rigorous review cycle* of the literature to incorporate its findings into our interpretation of the cluster analysis' quantitative outcomes and appropriately label, define, and describe the identified archetypes. In the subsequent *relevance cycle*, we performed cluster analysis (Punj and Stewart, 1983) using the R statistical package on a sample of 66 projects and the underlying business model taxonomy to identify groups of similar objects. To measure distances, we converted the dataset of 66 firms and 21 dimensions of the taxonomy into dichotomous dummy variables for each characteristic of each dimension, resulting in a binary vector for each project.

In the *design cycle*, we utilized hierarchical, agglomerative clustering using the Ward method (Kaufman and Rousseeuw, 1990; Ward, 1963) as a data analysis technique. Unlike other clustering techniques, agglomerative hierarchical clustering algorithms do not require a priori decision on the final number of clusters. Instead, it follows a bottom-up strategy by initially considering each observation as a separate cluster and then merging the two most similar clusters at each step. The merging process is based on a linkage criterion, which defines the distance between two clusters. The selection of an appropriate distance or dissimilarity measure, which defines how the similarity of two objects is measured, is a crucial step in this and any other clustering algorithm, as it defines the effectiveness of these algorithms (Finch, 2021). For our study, we opted for the Lin similarity measure in conjunction with complete linking for the hierarchical clustering of datasets with a higher number of variables (Šulc and Řezanková, 2019). This measurement gives more weight to matches on frequent values and less weight to mismatches on infrequent values (Boriah et al., 2008), which appears suitable for our context as it is less susceptible to outliers in singular dimensions. To assess the quality of the clustering structure and compare different clustering algorithms, we compared different linkage approaches, such as simple, complete, and Ward, to determine the appropriate number of clusters, as the a priori definition of the number of clusters is a well-known issue in cluster analyses (Anderberg, 2014). As each algorithm applied resulted in a different number of suggested clusters, we followed recent recommendations (e.g., Nahr and Heikkilä, 2022) and conducted a qualitative analysis of the suggested clusters to ensure that the clusters are separable (inter-heterogeneity) and that single clusters share common characteristics (intra-homogeneity). We found that the number of six clusters was fitting, as it represented a balance between the manageability of the overall cluster solution and homogeneity within each cluster (Milligan and Cooper, 1985), resulting in easily distinguishable and explainable archetypes. Figure 10.4 presents the dendrogram highlighting the final set of six cluster groups.

Next, based on the cluster analysis results, we performed two qualitative interpretive steps to label and describe the business model archetypes. First, we conducted a within-cluster analysis by re-reading all the collected data on the business models assigned to each cluster. Second, we conducted a cross-table analysis (see Appendix Table A.13), examining the frequency distributions of each cluster's characteristics to identify the most pronounced ones (Hambrick, 1984). Based on this bipartite analysis, we derived archetype labels for the six clusters, namely Platform-as-a-Service (A1), Cross-Layer Service (A2), SSI-enabled Service (A3), (SS)ID-as-a-Service (A4), Infrastructure-as-a-Service (A5), and Network-as-a-Service (A6).

To *evaluate* the clustered archetypes, we opted for a twofold approach First, we conducted statistical analyses using Pearson's chi-squared test of independence (Delucchi, 1983). This involved constructing contingency tables with the clustering allocation as one vector and each dimension of our taxonomy as the other. We calculated Cramér's V (Cramér, 1946) and a corrected version (Bergsma, 2013) to assess the strength of the relationship between the dimensions and overcome potential biases in finite samples. To identify the distinguishing dimensions for each group, we tested the independence or dependence of the dimensions within each of the groups, utilizing the respective dichotomized clustering allocation vector. Second, considering the presence of small values in some contingency tables, we employed Fisher's exact test to validate the differentiation among the six patterns across each dimension (Fisher, 1990). This analysis examined whether the clusters exhibited significant differences across the 22 dimensions of the taxonomy. Detailed results can be found in Table 10.4. Overall, these results affirm the validity and applicability of both the number of clusters and the clusters themselves.

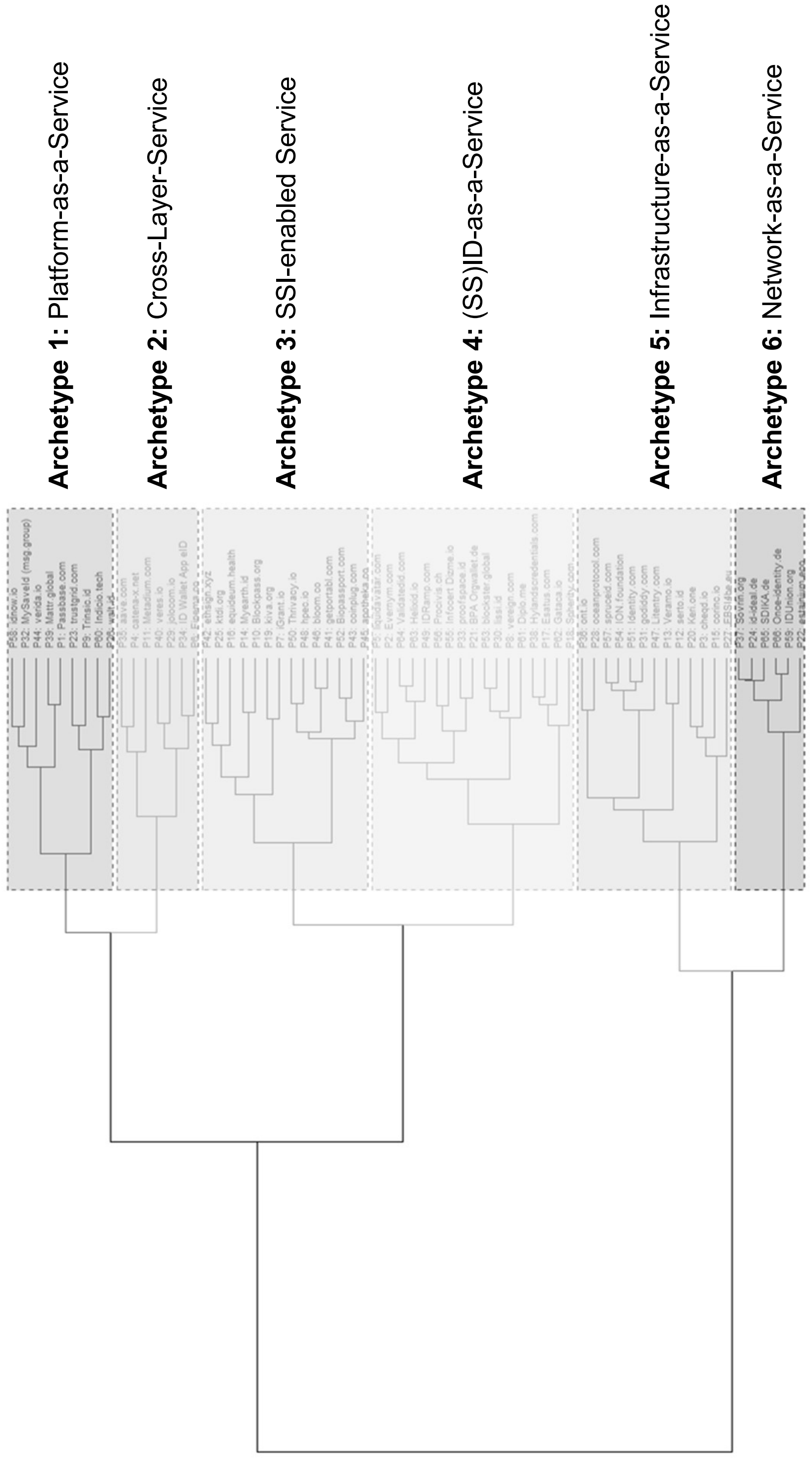


Fig. 10.4.: Results of Ward Clustering Visualized by a Dendrogram with Six Cluster Groups.

Tab. 10.4.: Contingency Table Analysis Results for Cluster Analysis.

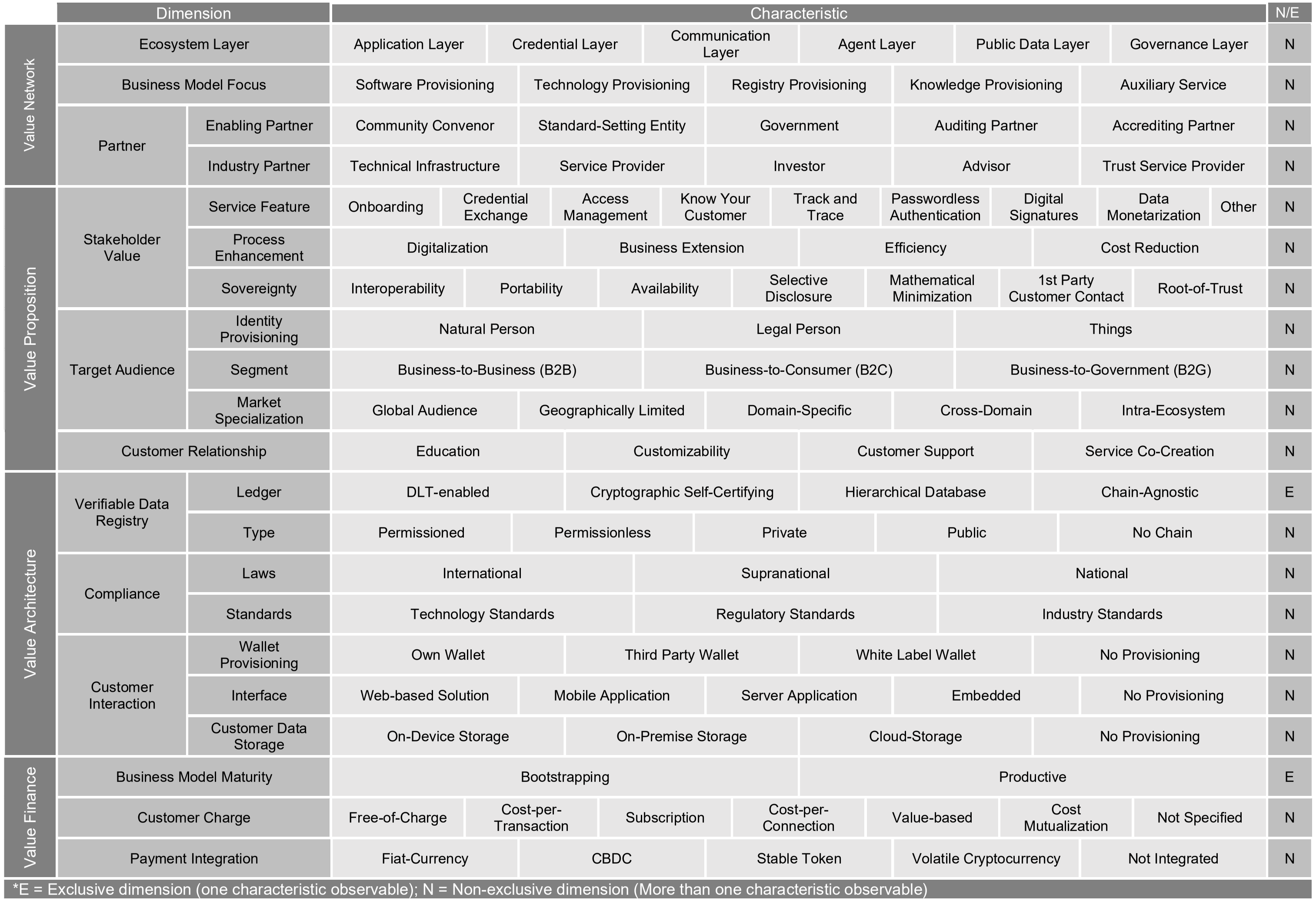
Contingency Table Dimensions	Chi-Sq	p-Value Chi-Sq	Cramer´s V	Corrected Cramer´s V	Fisher Exact Test
Clustering ↔ Ecosystem Layer	133.67	2,20E-16****	0.4001	0.3661	5,00E-04****
Clustering ↔ Business Model Focus	72.769	6,39E-05****	0.3741	0.3231	5,72E-04****
Clustering ↔ Enabling Partner	13.921	8,35E-01	0.1452	0	8,74E-01
Clustering ↔ Industry Partner	15.131	1,27E-01	0.248	0.1444	1,21E-01
Clustering ↔ Service Feature	73.806	9,02E-04****	0.2528	0.1725	4,00E-03***
Clustering ↔ Process Enhancement	11.259	7,34E-01	0.1343	0	7,79E-01
Clustering ↔ Sovereignty	18.674	9,47E-01	0.1101	0	9,70E-01
Clustering ↔ Identity Provisioning	15.131	1,27E-01	0.248	0.1444	1,19E-01
Clustering ↔ Segment	7.287	6,98E-01	0.1613	0	7,22E-01
Clustering ↔ Market Specialization	60.329	6,33E-03***	0.3203	0.2651	5,00E-04****
Clustering ↔ Customer Relationship	19.178	2,06E-01	0.2665	0.124	1,79E-01
Clustering ↔ Ledger	27.24	2,68E-02**	0.3628	0.2465	1,70E-02**
Clustering ↔ Type	39.821	5,26E-03***	0.293	0.2094	3,50E-03***
Clustering ↔ Standards	5.345	8,67E-01	0.1348	0	8,40E-01
Clustering ↔ Wallet Provisioning	48.566	2,06E-05****	0.4527	0.3827	5,00E-04****
Clustering ↔ Interface	59.184	9,52E-03***	0.3361	0.2772	1,10E-02**
Clustering ↔ Customer Data Storage	40.748	3,49E-04****	0.3283	0.2636	6,00E-03***
Clustering ↔ Business Model Maturity	11.373	4,45E-02**	0.4183	0.3136	5,45E-02*
Clustering ↔ Customer Charge	30.827	4,24E-01	0.2662	0.03418	3,57E-01
Clustering ↔ Payment Integration	24.684	2,14E-01	0.2888	0.1255	2,56E-01

*p < 0.1; **p < 0.05; ***p < 0.01; ****p < 0,001

10.4 Results

10.4.1 Taxonomy of Self-Sovereign Identity Business Models

In this section, we present the final version of our SSI business model taxonomy as the first artifact of our DSR project. The taxonomy is structured as a morphological box, where a specific combination of characteristics describes a business model. The taxonomy comprises 21 dimensions that encompass 98 characteristics. To ensure comprehensibility and real-world applicability and improve clarity and consistency, we organized the taxonomy using the pre-specified meta-characteristic of value network, value proposition, value architecture, and value finance. The final version of the taxonomy is illustrated in Figure 10.5, while the dimensions and characteristics are detailed in Appendix Table A.7, Table A.8, Table A.9, Table A.10, and Table A.11. The last column of Figure 10.5 indicates whether a particular element is exclusive (E) or non-exclusive (N). If an element is exclusive, it implies that a business model can be characterized by only one characteristic per dimension. Conversely, if an element is non-exclusive, it suggests that one or more attributes can characterize a business model.



	Dimension		Characteristic									N/E
Value Network	Ecosystem Layer		Application Layer	Credential Layer	Communication Layer	Agent Layer	Public Data Layer	Governance Layer				N
	Business Model Focus		Software Provisioning	Technology Provisioning	Registry Provisioning	Knowledge Provisioning	Auxiliary Service					N
	Partner	Enabling Partner	Community Convenor	Standard-Setting Entity	Government	Auditing Partner	Accrediting Partner					N
		Industry Partner	Technical Infrastructure	Service Provider	Investor	Advisor	Trust Service Provider					N
Value Proposition	Stakeholder Value	Service Feature	Onboarding	Credential Exchange	Access Management	Know Your Customer	Track and Trace	Passwordless Authentication	Digital Signatures	Data Monetarization	Other	N
		Process Enhancement	Digitalization	Business Extension	Efficiency	Cost Reduction						N
		Sovereignty	Interoperability	Portability	Availability	Selective Disclosure	Mathematical Minimization	1st Party Customer Contact	Root-of-Trust			N
	Target Audience	Identity Provisioning	Natural Person	Legal Person	Things							N
		Segment	Business-to-Business (B2B)	Business-to-Consumer (B2C)	Business-to-Government (B2G)							N
		Market Specialization	Global Audience	Geographically Limited	Domain-Specific	Cross-Domain	Intra-Ecosystem					N
	Customer Relationship		Education	Customizability	Customer Support	Service Co-Creation						N
Value Architecture	Verifiable Data Registry	Ledger	DLT-enabled	Cryptographic Self-Certifying	Hierarchical Database	Chain-Agnostic						E
		Type	Permissioned	Permissionless	Private	Public	No Chain					N
	Compliance	Laws	International	Supranational	National							N
		Standards	Technology Standards	Regulatory Standards	Industry Standards							N
	Customer Interaction	Wallet Provisioning	Own Wallet	Third Party Wallet	White Label Wallet	No Provisioning						N
		Interface	Web-based Solution	Mobile Application	Server Application	Embedded	No Provisioning					N
		Customer Data Storage	On-Device Storage	On-Premise Storage	Cloud-Storage	No Provisioning						N
Value Finance	Business Model Maturity		Bootstrapping	Productive								E
	Customer Charge		Free-of-Charge	Cost-per-Transaction	Subscription	Cost-per-Connection	Value-based	Cost Mutualization	Not Specified			N
	Payment Integration		Fiat-Currency	CBDC	Stable Token	Volatile Cryptocurrency	Not Integrated					N

*E = Exclusive dimension (one characteristic observable); N = Non-exclusive dimension (More than one characteristic observable)

Fig. 10.5.: Self-Sovereign Identity Business Model Taxonomy.

10.4.2 Archetypes of Self-Sovereign Identity Business Models

As a second outcome of our DSR project, we have identified six archetypes that represent different configurations of real-world business models that market-pioneers pursue in SSI. These archetypes correspond to clusters of six to seventeen cases, centered along different characteristics of the taxonomy, representing intra-homogeneity and inter-heterogeneity. To provide an overview of the frequency distribution of the taxonomy characteristics for each archetype, we present the cross-table results from the cluster analysis in Appendix Table A.13. This allows to characterize the respective cluster groups vertically and delimit them from each other horizontally. Table 10.5 summarizes the six archetypes we identified during our analysis along their separating characteristics.

We have developed the following interpretive labels for the six archetypes: Platform-as-a-Service (A1), Cross-Layer Service (A2), SSI-enabled Service (A3), (SS)ID-as-a-Service (A4), Infrastructure-as-a-Service (A5), and Network-as-a-Service (A6). We indicate the differentiating characteristics of each archetype based on a relative value of the frequency of a particular characteristic within one archetype to the overall frequency. This approach allows to identify characteristics that make an archetype unique and different from others. We acknowledge that not all projects of one archetype have precisely the same combination of characteristics, as one archetype may cover more than one characteristic in some dimensions. Therefore, we provide detailed explanations of each archetype below, focusing on the most differentiating dimensions and characteristics for each pattern.

Archetype 1: Platform-as-a-Service

The first archetype is defined by the provision of technology offerings in the form of platform software for the upper layers (Application, Credential, Communication, and Agent) of the SSI tech stack. Providers in this archetype offer APIs, SDKs, and webhooks that allow their customers to build their own identity products, thereby enhancing their process efficiency and reducing time-to-market. Unlike other patterns, providers in this archetype offer a software product for SSI without specifying the business models that will be built on top of it. The primary value proposition of this isolated business model is to act as an *SSI enabler* by offering various implementations that are independent of the application domain, do not mediate between existing value chains, and primarily provide the basis for business models built on top of it. Projects in this archetype provide harmonized solutions that enable independent service providers to integrate and leverage their technology stack without having to deal with multiple relationships to different SSI infrastructures and individual data formats. This easy access to SSI indirectly adds value to ecosystem complementors, as customers of this business model, by incentivizing the development of third-party services. At the same time, complementors retain control over how they design their service. Consequently, the customer base of this business model primarily comprises legal entities operating within the B2B segment, with only 44% of providers also offering wallets catering to the B2C segment. Typically, software solutions are domain- and region-independent, and adhere to technology and industry standards for interoperability. Projects within this archetype often partner with standard-setting entities to ensure compliance with SSI standards. Some also collaborate with auditing and accreditation partners to accredit their software and meet compliance requirements of specific domains (e.g., financial industry KYC requirements) to increase customer confidence. Providers distinguish their SSI solutions through customization that addresses specific business requirements, such as mathematical data minimization. This cluster group offers the highest level of customizability and white-labelling, emphasizing service co-creation. Additionally, most solutions are chain-agnostic and do not rely on a single DLT or hierarchical database. Finally, most projects within this archetype are in the productive phase and follow a subscription-based payment model.

This archetype is exemplified by nine projects, including Trinsic[1] and Walt.id[2], which provide SDKs for cloud-based identity wallets for VC onboarding and exchange. In addition, Passbase[3] provides document- and dashboard-based user verification services, relying on trust services and extensive data registers to prevent financial crimes such as AML. Trustgrid[4] and Walt.id prioritize zero-knowledge network security, while IDnow[5] and Passbase embrace the openness of this archetype regarding the Verifiable Data Registry Type. The MATTR Pi[6] solution is also notable for its ability to respond flexibly to customer requirements and allows for seamless integration into existing IT landscapes.

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[1] https://trinsic.id/

[2] https://walt.id/

[3] https://passbase.com/

[4] https://trustgrid.com/

[5] https://www.idnow.io/products/identity-wallet/

[6] https://mattr.global/resources/articles/introducing-mattr-pi/

Archetype 2: Cross-Layer Service

The second archetype is characterized by its wide-ranging and dynamic offerings, spanning all SSI technology stack layers. The primary value proposition of these business models is to act as *SSI enabler* by supplying credential exchange and digital access management products that enhance efficiency for both B2B and B2C customer segments. Additionally, this archetype caters to individual providers who maintain their data on self-managed on-device storage. In contrast to other patterns, 86% of projects in this archetype have a regional focus, and many partner with governments, considering trust registries as an essential part of their business model. To enhance customer experience, providers emphasize education, customizability, and value co-creation. They often work with standard-setting entities to ensure technology and industry standards adherence. All projects in this archetype use DLT with varying write and read permissions. An additional pattern is that one-third of the projects in this cluster also offer chain-agnostic solutions and white-label wallets, with 71% operating their own wallet. However, it is notable that none of the analyzed projects transparently specifies its cost model.

This archetype is exemplified by seven projects, including Finema[7] and Veres One[8] that operate their own data registry in addition to offering SSI solutions on the top four layers of the SSI technology stack. Other projects like Catena-X[9] and Metadium[10] do not operate their own chain. Instead, they focus on governance and knowledge sharing within their respective ecosystems. Catena-X mandates SSI solutions in its governance statutes and maintains a “golden record” for business partners that should facilitate use cases such as tracking CO2 emission levels. Projects like Metadium[11] focus on digital access management, providing SSO mechanisms for access to NFT marketplaces.

Archetype 3: SSI-enabled Service

The third archetype represents business models leveraging SSI to enhance value networks and digital IDM. Providers offer SSI solutions that digitize processes, reduce costs, and increase efficiency while providing value in terms of user sovereignty and trusted interactions for all participants within an ecosystem. This pattern mainly focuses on software provisioning from ecosystem players at the Application and

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[7] https://finema.co/
[8] https://veres.one/
[9] https://catena-x.net/en/
[10] https://metadium.com/
[11] https://metadium.com/

Credential Layers of the SSI technology stack, particularly in the B2C space. Unlike other patterns, providers in this archetype offer domain-specific and geographically limited solutions to customers, following a one-size-fits-all approach that is often accredited by partners, with limited customer interaction and service co-creation. These solutions are developed independently by providers or are based on code components and resources provided by other ecosystem members. They rely on the technical infrastructure and trust anchors that other players in the SSI ecosystem provide. The primary value proposition of these business models is to act as *SSI integrator* and transaction authors, using SSI as a medium to operate and provide tangible products and services that consumers can use directly. These models are primarily based on public-permissioned blockchains, where customers can store their data on mobile devices or use web-based solutions. Notably, solutions of this archetype are optimized around a specific ecosystem and lack interoperability and portability. Furthermore, most projects are still in the bootstrapping phase and aim to offer various solutions for revenue and payment.

This archetype is exemplified by 14 projects, including MyEarthID[12], Blockpass[13], and Kiva[14], which offer services for KYC processes and due diligence, for example. Other projects in this cluster group offer services for digital signatures, such as ethsign[15], or classical credential exchange platforms like Bloom[16]. Furthermore, some projects, such as Bio Passport[17], introduce incentive programs that allow customers to sell their data to public health institutions and research institutes, providing an opportunity to monetize their data.

Archetype 4: (SS)ID-as-a-Service

The fourth archetype of business models in the SSI space comprises more than a quarter of the projects in our dataset and involves ecosystem actors on the SSI technology stack's application and credential layers. Unlike other archetypes, providers of this archetype use SSI as a medium to offer customized solutions for VC onboarding and exchange. Their business model also relies on network infrastructure provided by other players in the SSI ecosystem, including the necessary technical infrastructure and the trust anchor. Their primary value proposition is to act as an *SSI integrator* by offering tangible products and services that consumers can use directly. Their

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[12] https://www.myearth.id/
[13] https://www.blockpass.org/
[14] https://kivaprotocol.com/
[15] https://www.ethsign.xyz/
[16] https://bloom.co/
[17] https://www.biopassport.io/

offerings aim to fulfill the value propositions of the SSI paradigm through process enhancement and user sovereignty, allowing users to retain control over their data sharing and storage options (e.g., on-device or on-premise). The projects are generally domain-independent and use SSI networks as writing endorsers. Their customer base includes individuals and legal entities in both B2B and B2C segments. This pattern is characterized by a close contact and connection between the SSI solutions provider and its customers, which may involve the provision of own wallet software for web and mobile applications and customer support. Notably, three-quarters of the projects within this cluster use DLT with public read and private write capabilities. Another key differentiator is the customer charge, where more than half of the projects have the pattern of already being productive but offering their services free of charge, depending on time or volume.

This archetype is exemplified by 17 projects, including Esatus[18], Blockster[19], ProofSpace[20], and Gataca[21], that offer web-based solutions for issuing credentials and providing wallets for end-users, for example. Other projects, such as Liquid Avatars[22], Diplome[23], and Hyland[24], specialize in providing decentralized identities to individuals in the B2C segment. Finally, the Business Partner Agent[25] is a B2B-focused project that provides a platform for legal entities to securely exchange company data, such as addresses, bank accounts, and certificates.

Archetype 5: Infrastructure-as-a-Service

The fifth archetype of SSI business models involves the development and maintenance of the SSI technology stack's technical backbone. This cluster of projects includes the bootstrapping and operation of Verifiable Data Registries as node operators or stewards, as well as the ongoing development of technical protocols and agents. Unlike other archetypes, providers of this archetype do not focus on user-centric business models but instead offer the technical infrastructure as an *SSI facilitator* for other business models to build upon. Their customer base primarily consists of legal entities operating in B2B contexts, such as developers and application builders. Providers of the infrastructure archetype are typically dependent on only a few partnerships and do not specify a particular channel, as their offering

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[18] https://esatus.com/index.html%3Flang=en.html
[19] https://blockster.com/
[20] https://www.proofspace.id/
[21] https://www.gataca.io/
[22] https://liquidavatartechnologies.com/self-sovereign-identity-services/
[23] https://www.diplo-me.eu/index.html
[24] https://www.hylandcredentials.com/
[25] https://orgwallet.de/en/

is often provided as open-source software. They offer minimal service features to the end-user and provide limited interfaces or data storage options. Most providers operate globally and are domain-independent. Solutions offered by these providers are usually chain-dependent and rely on a single DLT or hierarchical database. Infrastructure providers differentiate themselves by modifying existing networks, such as altering the underlying consensus mechanism or incorporating privacy-preserving mechanisms, to target specific business requirements or incorporate general developments related to digital IDM. Depending on the mechanism design, providers may benefit from cost-per-transaction payment models. They can further benefit from direct and indirect revenues if they rely on a DLT-based solution with token issuance.

This archetype is exemplified by 13 diverse projects, including Cheqd.io[26], EBSI[27], and KERI[28], which exhibit varying degrees of blockchain integration. While Cheqd.io follows a DLT-based token model, KERI, for instance, does not follow a blockchain-based business model. The archetype also includes protocol developers, such as Identity.com's[29] gateway protocol and ION[30], which enable the connection of dApps to the network. Other protocols, such as those provided by Litentry[31] and Ocean Protocol[32], facilitate token transactions or the monetization of data on marketplaces. Furthermore, providers like SpruceID[33] and Godiddy[34] offer libraries to facilitate the resolution of DIDs and public keys.

Archetype 6: Network-as-a-Service

The sixth and final archetype of SSI business models centers around governing activities within SSI ecosystems. These projects establish trust by setting rules for interaction protocols, defining roles within the network, creating incentive mechanisms, and monitoring compliance. Unlike other archetypes, they do not provide technology building blocks nor focus on user-centric business models but instead offer the governmental infrastructure as an *SSI facilitator* for other business models to build upon. The main objective of these projects is to ensure interoperability within the ecosystem. They focus on providing trust registries, auxiliary services,

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[26] https://cheqd.io/
[27] https://ec.europa.eu/digital-building-blocks/wikis/display/EBSI/Home
[28] https://keri.one/
[29] https://www.identity.com/
[30] https://github.com/decentralized-identity/ion
[31] https://www.litentry.com/
[32] https://oceanprotocol.com/
[33] https://www.spruceid.com/
[34] https://godiddy.com/

and communication of SSI knowledge. These projects typically consider standards and collaborate with industry and enabling partners at the center of SSI ecosystems. Partnerships are often formed bilaterally, such as advising other members on SSI integration, or multilaterally, such as working groups on SSI development. Unlike other archetypes, the target audience of SSI governing projects is not limited to one consumer group. However, due to the fragmentation of legislative jurisdictions, they are often geographically limited and specialized to one ecosystem. As a trusted entity, projects following this pattern often assume the role of accrediting partners for products and services of other ecosystem complementors. All of the projects examined in the dataset are DLT-based and are public-permissioned. Organizationally, projects of in this pattern are often organized consortially in non-profit organizations, are financed by membership fees, make information available open source, and do not integrate payment methods. Six projects exemplify this cluster, including Sovrin[35], and IDunion[36].

10.5 Discussion

Decentralized digital identity at scale, particularly the user-centric paradigm of SSI, is a rapidly evolving topic in IS research (Sedlmeir et al., 2021). SSI leverages emerging technologies that have the potential to provide a foundation for trustworthy digital interactions and shape the movement toward an *identity in everyone's pocket*. Its widespread adoption could lead to fundamental changes in incumbent processes, new business models, and new strategic alliances aimed at disrupting the oligopoly structure of today's internet, where digital identities and data are primarily managed by 'Tech Giants' (Kölbel, Gawlitza, et al., 2022; Sedlmeir, Smethurst, et al., 2021; Laatikainen et al., 2021). Yet, despite the vast potential of SSI applications, mainstream adoption has been limited, with a significant gap between the promised business value and the actual value in a market environment characterized by high volatility, fast changes, and manifold characteristics.

To explore business aspects of SSI, we follow a DSR approach and develop a taxonomy of business models leveraging SSI ecosystems that depicts key characteristics. The taxonomy is theoretically rooted in both SSI and business model literature and is empirically supported by the analysis of 66 real-world projects that use SSI as an integral technology of their business model. Building on the taxonomy, we conducted a cluster analysis of the 66 projects to develop a systematic understanding

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[35] https://sovrin.org/

[36] https://idunion.org/?lang=en

Tab. 10.5.: Overview of identified Business Model Archetypes.

ID	Archetype	Distinguishing Characteristics
A1	*Platform-as-a-Service*	• SSI enablers with technology offerings for upper layers of the SSI tech stack, offering APIs and SDKs that enable customers to build their own products. • Domain- and region-independent solutions, customization, and chain-agnostic white-labelling with a primary focus on the B2B segment and a subscription-based payment model.
A2	*Cross-Layer-Service*	• Wide-ranging and dynamic offerings covering all SSI tech stack layers. • Regional focus with emphasis on government partnerships and trust registries. • Providers prioritize education and customizability and use DLT with varying write and read permissions but do not state a transparent cost model.
A3	*SSI-enabled Service*	• Focus on tangible products at the application and credential layers of the SSI tech stack, primarily in the B2C space. • Domain-specific and geographically limited solutions, often accredited by partners, with limited customer interaction and service co-creation. • Providers depend on complementors infrastructure and offer optimized solutions for a specific ecosystem that lack interoperability and portability.
A4	*(SS)ID-as-a-Service*	• Offerings on the SSI tech stack's Application and Credential Layers with tangible products and services for both B2B and B2C customers. • Providers use SSI networks as writing endorsers and rely on network infrastructure provided by complementors. • Providers use DLT with public read and private write capabilities, have a close connection with their customers, often providing their own wallet and customer support. Many offer their services free of charge depending on time or volume.
A5	*Infrastructure-as-a-Service*	• Providers act as node operators and stewards, developing and maintaining the SSI tech stack's technical backbone for other business models to build upon. • B2B-focused customer base, such as developers and application builders, with minimal service features to the end-user. • Providers are typically chain-dependent and only have a few partnerships. Their open-source offering can benefit from cost-per-transaction models and token revenues.
A6	*Network-as-a-Service*	• Projects provide the governmental infrastructure as an SSI enabler, ensuring interoperability within an ecosystem by operating trust registries, auxiliary services and communicating SSI knowledge. • They are often geographically limited and specialized to one network, collaborate with various partners, assume the role of accrediting partners for complementors, and are often organized consortially in non-profit organizations financed by membership fees.

of business model configurations. This analysis derived six archetypes illustrating how SSI can change existing and trigger new business models.

Both our business model taxonomy and archetypes depict the collaborative efforts of multiple actors in SSI ecosystems towards innovation. These actors include infrastructure providers, complementing partners, and end-users. Infrastructure providers deliver technology or a governance framework, while partner projects and end-users provide products, services, demands, and capabilities. Overall, we identify three overarching categories of business model archetypes. Category 1 consists of cross-contextual and industry-agnostic business models, where *SSI facilitators* (A5-A6) enable further business models by offering the necessary infrastructure and protocols for SSI networks to operate smoothly and securely on both technological and governance levels. In contrast, categories 2 and 3 represent context-specific business models that offer direct value by providing innovative services either to business partners (Category 2, A1-A2) or end-customers (Category 3, A3-A4). Category 2 archetypes (A1-A2) are *SSI enablers* that build upon and add value to existing SSI infrastructure by creating software solutions and tools for SSI applications. These enablers offer greater functionality and user experiences, thereby promoting adoption and driving innovation in the ecosystem. They overcome restrictions on what can be offered by whom, hence, enabling new business models by complementing service providers. Category 3 archetypes (A3-A4) are *SSI integrators* that create innovative solutions using existing SSI offerings that address real-world problems and provide tangible benefits to end-users. They integrate SSI-driven benefits into their products and services to improve security, privacy, and user control.

10.5.1 Towards a Self-Sovereign Identity Ecosystem Framework

Building upon our taxonomy and archetypal patterns of SSI business models, we extend our analysis to SSI-based ecosystems at both micro and macro levels. In addition to the classification schemes from our DSR project, we subsequently present the *SSI Ecosystem Framework* (see Figure 10.6), which provides an integrated, holistic view of interconnected and pivotal elements of SSI ecosystems and surrounding factors. The framework uses a multi-layer perspective to structure and understand the characteristics of SSI-based ecosystems and accommodate the openness of the technology. Inspired by the SSI trust triangle (Kölbel, Gawlitza, et al., 2022; Preukschat and Reed, 2021) and the ME Framework (Weinhardt and Gimpel, 2007), the *SSI Ecosystem Framework* comprises three layers: the *Environment Layer*, *Infrastructure Layer*, and *Application Layer*, each with multiple sub-structures.

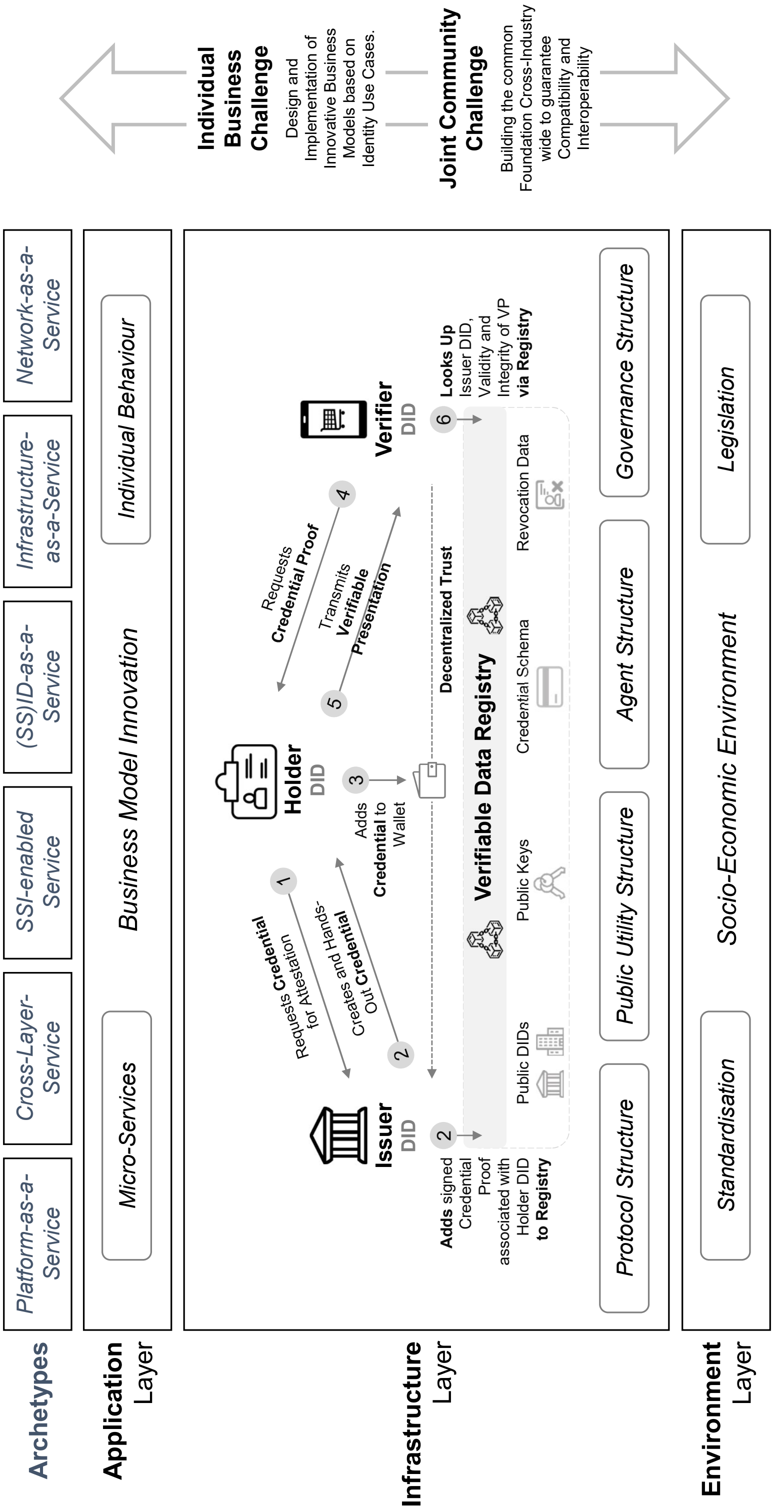

Fig. 10.6.: SSI Ecosystem Framework with Pivotal Elements, Layers and Business Model Archetypes.

The **Environment Layer** is the fundamental macro layer of SSI ecosystems, serving as the ambient foundation that captures the social, legal, and economic context of the

SSI domain as the field of application. It serves as the socio-economic environment that constraints the action space available within the other layers and builds the foundation for a resilient, competitive, and sovereign ecosystem that embraces the social notion of sustainability (Alt, 2020a). Accelerating digital innovations with increased flexibility and independence of cross-sectoral value networks, this layer consists of two key components: legislative laws and regulations related to digital identification, data exchange, and protection[37], and organizations and initiatives that aim to define, standardize, and provide tools for common SSI architectures. These organizations and initiatives include open-source communities, standard-setting organizations, and non-profit organizations[38], as well as public authorities[39].

The technological backbone of SSI ecosystems is formed by the shared **Infrastructure Layer**, which builds on the Environment Layer. It implements the basic infrastructure to deploy a decentralized ecosystem and sets-up a shared service infrastructures to scale the ecosystem dynamically as a joint challenge of the SSI community. The *Public Utility Structure* (e.g., DIDs, DID methods, credential types, and Verifiable Data Registry types) provides essential tools for implementing the core elements of SSI, as introduced in the background section (see Section 10.2) and the value architecture of our taxonomy. The *Protocol Structure* enables P2P data exchange and encryption-based communication protocols such as DIDComm, which connects the heterogeneous actors in the SSI trust triangle with a specific application context. The *Agent Structure* encompasses the virtual representations of human or computer agents in SSI systems, including key management services, agent messaging interfaces, ledger interfaces, and controllers. Key management services, such as SSI wallets, are responsible for managing digital IDs and VCs, while agent messaging interfaces establish and manage connections with other agents, allowing the exchange of messages between them. The ledger interface resolves DIDs, reads and writes data to the ledger, and handles VCs. Finally, the controller determines the business rules for the agent, such as the actions it will initiate and how it will respond to events. The *Governance Structure* of an SSI network plays a vital role in ensuring trust among all participants in the ecosystem. For example, the structure defines the roles and responsibilities of various participants in the network, such as Stewards, Endorsers, Transaction Authors, and Observers in Hyperledger Indy SSI networks. It also ensures the security and integrity of the public utilities, enables holders to establish trust with verifiers, and certifies agent software, such as data

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[37] Examples include eIDAS 2.0, GDPR, DGA, and the Pan-Canadian Trust Framework.

[38] Examples include the W3C Consortium, DIF, TrustOverIP Foundation, Linux's Foundation Hyperledger Aries

[39] Examples include Canada's VON, the European Union's ESSIF, which utilizes the European Blockchain Service Infrastructure (EBSI), the European IDunion consortium, and the Spanish Alastria Network.

wallets, based on compliance with environmental factors. Moreover, the governance structure also facilitates the development and implementation of standards, policies, and procedures that govern the operation and evolution of the SSI network.

To foster business model innovation and individual value creation at the micro-level of SSI ecosystems, the **Application Layer** must offer value propositions in digital products and services that facilitate human interactions with SSI while enabling computer agents to interact with the underlying layers of our framework. It is worth noting that in SSI, agents, not humans, perform interactions. Therefore, the individual behaviour of real-world actors, which serves as the analogue component of digital IDM, must be translated into the Infrastructure Layer of an SSI ecosystem. Here, the individual strategic goal of each actor involved and varying requirements for different applications and industries drive the activities as individual entrepreneurial challenges on the Application Layer. They lead to the development of entrepreneurial business models, which we have analyzed and visualized through our archetypes. In line with research on blockchain systems (e.g., Notheisen, Hawlitschek, et al., 2017), we see a challenge in reliably transferring information about real-world interactions to the virtual representations within the SSI system. However, we argue that SSI ecosystems could pave the way to overcome the trust frontier between the virtual and analogue parts in ‘trust-free’ P2P systems, provided that actors on the Application Layer adhere and align to the structure provided by the Infrastructure and Environment Layer. By doing so, SSI ecosystems can promote trust and security in P2P interactions.

10.5.2 Implications for Research & Practice

The application of SSI technologies in various market settings has garnered attention in both the public press and business context (Kronfellner et al., 2021; White et al., 2019). However, research on decentralized economic systems in the IS field is limited and actual scenarios as to how the potential of SSI might form entrepreneurial competitive advantages are nascent. Therefore, our research complements this discourse and adds to the descriptive knowledge of SSI and associated business models. We contribute to the broader stream of IS research that explores the business opportunities, managerial implications, and societal questions related to identification technologies (Sedlmeir, Smethurst, et al., 2021; Whitley et al., 2014). Furthermore, we extend innovation research by emphasizing the importance of digital IDM in designing and managing business processes (Sedlmeir, Smethurst, et al., 2021; Mendling et al., 2020). In contrast to other SSI researchers focusing primarily on technological aspects, we propose a theoretical foundation for SSI as an

IT artifact in economic applications. By doing so, we provide yet required empirical insights that show how projects translate SSI into business opportunities and contribute to identifying applications and areas where SSI-based economic systems offer effective and efficient solutions. To ensure both relevance and rigor, we adopted a DSR approach and followed best practices in IS research. The outcome of our study is a theoretically sound and empirically validated taxonomy that summarizes the characteristics of SSI business models, along with six archetypes representing recurring patterns across all characteristics and the *SSI Ecosystem Framework*. Our contributions enhance the understanding of the SSI domain and provide theoretical, empirical, and methodological implications for future research.

First, in the current literature on disruptive technologies such as SSI, a central issue is the ambiguous use of key terms (Kölbel, Härdtner, et al., 2023; Sedlmeir, Barbereau, et al., 2022; Sedlmeir, Smethurst, et al., 2021). To address this issue, our research introduces a taxonomy that provides theoretical insights to establish a common language and structure for analyzing, classifying, and configuring various conceptualizations of SSI-based business models. This taxonomy enhances the understanding of how SSI impacts business models and can serve as a vocabulary in business model research, enabling a systematic description of SSI business models. Additionally, the taxonomy illustrates opportunities for business model innovations while acknowledging their inherent complexity. The corresponding archetypes can serve as a starting point for understanding superordinate business model configurations in SSI ecosystems. Moreover, our empirical findings contribute to the understanding of economic applications by presenting six predominant configurations of SSI business models. These archetypal patterns, combined with the underlying taxonomy, describe the technical prerequisites (i.e., *value architecture*) required by ecosystem actors in their potential roles (i.e., *value network*) to offer products and services (i.e., *value proposition*) with different economic models (i.e., *value finance*). Hence, our research addresses recent calls for a better understanding of the business aspects related to SSI (Kölbel, Härdtner, et al., 2023; Laatikainen et al., 2021; Sedlmeir, Smethurst, et al., 2021), analyzes business model patterns in a disruptive environment (Remané, Hanelt, et al., 2019), and investigates the understudied topic of how new technologies, such as SSI, influence traditional business models (Bock and Wiener, 2017). In sum, this study opens up a business perspective on the technology-driven body of literature on SSI.

Second, our research design demonstrates the process of deriving a technology-specific business model taxonomy and archetypal patterns through a DSR project (Hevner, 2007). To ensure both rigor and relevance, we draw inputs from the existing literature corpus and industry-specific real-world objects with 66 SSI projects.

In doing so, we contribute to the business model literature in the emerging field of enterprise classifications based on business models (Weking et al., 2020). Our approach encompasses all three levels of business model research, including real-world instances (cases), business model elements (taxonomy), and archetypes (Osterwalder, Pigneur, and Tucci, 2005). By leveraging these methods, we demonstrate how to systematically derive a specific business model taxonomy that integrates the existing knowledge base while ensuring practical relevance (Weking et al., 2020).

Third, in response to calls for research on SSI ecosystems (e.g., Laatikainen et al., 2021), we propose a framework that actively supports the interplay between individual SSI applications and a joint development of basic SSI infrastructure at both the micro and macro levels. With our *SSI Ecosystem Framework*, we (1) provide a distinction between the concept of SSI ecosystems and related organizational constellations; (2) offer an analytical starting point for the under-researched phenomenon of SSI ecosystems; and (3) propose a concept that informs managerial action (Autio and Thomas, 2020). We thereby contribute a *"theory for explaining"* (Gregor, 2006) that does not claim to generate testable propositions but provides a theoretical conceptualization to guide the design and analysis of SSI-based applications and support research on developing SSI-based markets that account for the complexity and multidimensional nature of SSI ecosystems.

Fourth, we contribute to the understanding of digital innovation in the IDM sector by presenting a systematically analyzed dataset of SSI business models. Our data collection process relied on publicly available sources such as project websites and industry-specific business reports, ensuring the reproducibility and extendibility of the dataset for future expansion. As such, the dataset is a valuable resource that can inform future studies in the SSI domain.

Fifth, our study provides a comprehensive market overview that contributes to the understanding of business model design aspects in the SSI space. Practitioners can utilize the taxonomy and archetypes to assess opportunities and barriers to integrating SSI into their existing IDM systems. The six archetypes identified in our study can guide the transformation process by specifying the relevant dimensions for business model innovation. During the ideation phase, these archetypes and associated cases can provide inspiration for innovating business models toward SSI. The taxonomy and archetypes may also function as decision-support tools for evaluating and implementing SSI solutions, whether through internal development or external partnerships. Furthermore, our findings enable managers to identify potential business opportunities and market entry points within the SSI ecosystem. By highlighting unexplored areas in the market, our results facilitate decision-making regarding the adoption and implementation of SSI concepts. One such unexplored area pertains to the development of technology-driven products and services that prioritize identity provisioning for objects, thus supporting the realization of an *Economy of Things*. Another area of interest involves harmonizing regional SSI networks characterized by diverse policies, standards, and laws. The taxonomy, archetypes, and framework can be further employed as strategic management tools, allowing practitioners to communicate their current business model to stakeholders, focus on improving specific operational aspects, or develop new business models in alignment with corporate strategy (Spieth et al., 2014). Moreover, they can be used to systematically analyze competitors and identify unique combinations of features that have yet to be explored in the market. In sum, our business model taxonomy, archetypes, framework, and related cases provide valuable resources for identifying established innovation paths and offer technology-specific support for business model innovation.

10.5.3 Limitations & Research Opportunities

In interpreting our results, we acknowledge limitations that inherently constrain our study and, vice versa, present avenues for future research. First, it should be noted that taxonomy-based research is a dynamic process that captures a snapshot of a specific point in time (Nickerson et al., 2013), and our taxonomy and archetypes only represent the current state of SSI business models. However, future developments, such as legislation mandating digital wallets instead of ID brokers (European Commission, 2022a), may drive innovation and lead to new archetypes. Additionally, the evolving nature of SSI may lead to the emergence of innovative business models and new markets related to digital identity, such as identity insurance (Wang and De Filippi, 2020). As existing real-world business models empirically inform our findings, they may only partially capture these future trends. As the field continues to evolve, it would be valuable for future research to evaluate our findings to ensure their relevance and applicability continuously. Our taxonomy has been designed to be revisable and extensible, allowing for the inclusion of new perspectives, characteristics, and dimensions (Nickerson et al., 2013). Conducting a longitudinal study would provide further valuable insights into the long-term success and failure of SSI-enabled business models. Additionally, future research could focus on developing trajectories and a strategy positioning map for SSI-enabled business models, aiding in identifying critical factors for decision-making during development and for managing SSI. This would enable strategic transitions between SSI archetypes to enhance customer value.

Second, our research focuses on developing a taxonomy and associated archetypes within the manifold domain of SSI. As a result, our findings have a broad scope, encompassing various business models with different emphases, such as end-user applications, technology provision, and infrastructure-based models that enable novel services. To delve deeper into the subject, future studies should explore specific archetypes by creating more specific taxonomies and sub-archetypes for these business models. This exploration should involve examining horizontal interoperability among different ecosystems, delineating architectural dependencies and requirements, and identifying specific inner and joint governmental processes needed for interaction. Here, it remains to be seen how the governance of SSI systems differs from today's centralized alternatives, and how governance can be harmonized across different systems and national borders. As we have identified a strong customer relationship as a prerequisite for value co-creating SSI, exploring how SSI providers can deliberately design desirable interactions and touchpoints with their customers would further be worthwhile. Additionally, studying the success factors of existing business models that harness specific potentials could offer practical insights for building sustainable businesses. Future research could also investigate the causal effects of SSI-enhanced portfolios of IDM incumbents. For example, examining the varied business capabilities organizations require depending on the archetype they aim to offer would be an interesting avenue of exploration. Considering the differing technical skill sets associated with each archetype, this topic presents promising opportunities for investigation.

Third, to ensure the validity of our dataset, we constructed the taxonomy and conducted the coding process by leveraging publicly available information. Our data collection employed a triangulation approach, drawing from diverse sources such as project websites, CrunchBase, LinkedIn, news articles, and the Decentralized Identity Web Directory. While our dataset primarily consists of start-up use cases, we contend that these are a valuable source for identifying SSI offerings that reflects our studies exploratory endeavour. However, we acknowledge that this focus limits the generalizability of our findings. Future analyses should analyze more diverse sample of cases, including SSI use cases from larger organizations, to enhance the robustness and applicability of our results.

Fourth, our evaluation of the taxonomy encompassed both quantitative and qualitative analyses. However, the evaluation of the archetypes primarily focused on quantitative measures, specifically employing Pearson's chi-squared test and Fisher's exact test to validate the differentiation among the six patterns across each dimension. Future research could complement our work by qualitatively evaluating the archetypes through expert interviews. Such qualitative investigations could uncover interdependencies between different business model archetypes and shed light on the strategic decision factors that organizations consider when adopting different archetypes in their business model innovation processes. This would provide a more holistic understanding of the relationships between the archetypes and the business strategies adopted by organizations.

Fifth, we see a promising avenue in investigating the conceptual constructs of SSI in the context of digital trust. Specifically, we propose exploring the impact of SSI on digital trust and its associated concepts, such as trusted interaction, trust requirements, implicit trust, trusted processes, trust enablement, and chain of trust. Moreover, we see potential in examining the role of SSI within the context of trust-free economic systems (Notheisen, Hawlitschek, et al., 2017), where SSI facilitates a transition from trust in traditional institutions to trust in algorithms by leveraging SSI as an IT artifact.

Part V

Finale

Conclusion & Outlook

11

> *We always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten years.*
>
> — **Bill Gates**
> (Co-Founder and former CEO of Microsoft)

Bill Gates' statement captures the challenge of accurately predicting the trajectory of technological advancements and their profound societal impact, often leading to overestimating short-term changes and underestimating the transformative power of long-term shifts. In line with this thought, last decades' technological landscape has witnessed a surge in innovation, with Web3 paradigms and blockchain technology emerging as influential forces driving aspirations for radical transformation across various industries. Speculation about their potential to revolutionize traditional business models and reshape economic interactions has fueled excitement and hype. However, like many disruptive technologies, the trajectory of Web3 and blockchain follows the pattern described by the Gartner Hype Cycle, characterized by a peak of inflated expectations followed by a trough of disillusionment, where the reality of implementing these technologies falls short of the initial hype. To reach the plateau of productivity, where these technologies deliver substantial real-world utility, it is essential to navigate the current state of skepticism and address the underlying complexities and challenges. At this critical juncture, it is essential to shift the focus from hype and excessive optimism to a more balanced and nuanced perspective.

This thesis contributes to the engineering of next-generation business ecosystems by embracing new approaches and perspectives that go beyond the prevailing blockchain-fits-all mentality. Recognizing that blockchain alone cannot be regarded as a panacea or a one-size-fits-all solution, this research advocates for a holistic understanding of the Web3 landscape. It acknowledges that the true potential and impact of Web3 technologies lie not in short-term fads or speculative frenzy but in their long-term utility and transformative capacity within digital ecosystems.

Addressing the challenges and complexities of business ecosystems, this thesis argues that viewing blockchain as the sole driver of Web3 transformation is no longer sufficient. Instead, a comprehensive approach is needed, considering multiple technologies within the Web3 space. By adopting this multi-dimensional lens, this research challenges the prevailing blockchain-centric mindset that has dominated much of the existing research. Moreover, this thesis acknowledges that technology alone is not sufficient to create thriving business ecosystems. It aims to examine the interplay between technological innovations, governance structures, and economic incentives, thereby extending beyond the narrow scope of blockchain and recognizing the synergistic potential of multiple technologies within an ecosystem. This holistic approach allows for a more robust and realistic understanding of the Web3 paradigm and its transformative potential that acknowledges the complex dynamics that drive the evolution of next-generation business ecosystems.

11.1 Contributions & Implications

This dissertation investigates the emerging field of engineering next-generation business ecosystems, emphasizing the importance of integrating technical design, economic models, governance choices, and socio-technical dynamics. By exploring the implications of Web3 on digital innovation and transformation paths, nine embedded publications contribute to our comprehension of this evolving field. Through a combination of qualitative and quantitative research methodologies, this thesis presents three primary contributions at the conceptual, design, and business model levels. The RQs, introduced and motivated in PART I, are subsequently addressed based on the findings presented in embedded studies.

First, on the conceptual level, PART II provides a **perspective on 'tokenization'** in markets, clarifying its ambiguity and providing a unified understanding of its role in ecosystems. This perspective includes frameworks on: (a) technological, (b) economic, and (c) governance aspects of tokenization. In particular, it addresses RQ1: *Which conceptually and empirically grounded characteristics shape blockchain-enabled tokenization?*

Conceptualizing Blockchain-enabled Tokenization. The first two studies conceptualize and synthesize 'tokenization' as a potentially disruptive blockchain-enabled innovation (van Gysegem, 2021). Both perspectives adhere to the taxonomy development process of Nickerson et al. (2013) and utilize qualitative and quantitative research methods to classify tokenization across different levels while identifying commonalities and differences crucial for engineering next-generation ecosystems.

Both studies contribute to the expanding body of research on blockchain in IS and related disciplines, addressing the need for empirical research in this area (Treiblmaier, 2019; Risius and Spohrer, 2017). By organizing the elements of tokenized systems within a market context, the developed taxonomies establish a common language essential for researchers and practitioners as prerequisites for understanding a domain (Szopinski et al., 2019). Furthermore, these taxonomies have practical implications, as they enable organizations to effectively communicate their current business models to stakeholders, identify areas for operational improvement, and even develop new business models that align with their corporate strategies (Spieth et al., 2014). In addition to their descriptive value, the morphological analysis conducted in these studies offers a systematic approach that can stimulate innovative thinking and assist organizations in their creative processes (Geum et al., 2016).

The first study adopts a **technological lens** and focuses on the five-stage token lifecycle of NFTs (P1, see Chapter 2). This study employs an iterative approach to develop a taxonomy that captures 20 dimensions and 77 characteristics associated with NFTs. The taxonomy is constructed based on a thorough review of literature, analyses of startups, consulting reports, and incumbent companies operating in the NFT space. It captures the stages of origination, distribution, transfer, trade, and redeem, providing a descriptive understanding of NFTs by synthesizing insights from both academia and practice. This approach goes beyond existing non-peer-reviewed classifications by providing a more widely applicable framework and exploring previously unmentioned characteristics. These include distribution channels, exclusiveness, price formation, wallets, and copyright considerations. Moreover, it emphasizes the technical foundations of NFTs, including their composability, blockchain infrastructure, and network. The taxonomy also encompasses a domain-independent categorization of NFTs based on their purpose, which covers various aspects such as investment, display, access, engagement, and burn mechanisms. To validate the usefulness and practicality of this multi-layered taxonomy, preliminary expert interviews were conducted, and a sample of NFT projects was classified according to the taxonomy's framework.

The second study adds an **economic lens** to existing taxonomies and focuses on asset tokenization services (P2, see Chapter 3). By considering the influence of business models, this study aims to deepen our understanding of the value creation potential of tokens within blockchain-based markets (van Gysegem, 2021). To provide a comprehensive understanding of the economic aspects of tokenization, we draw on a range of sources, such as academic literature, practitioner publications, consulting reports, and real-world projects. It analyzes asset tokenization across the dimensions of value proposition, value creation and delivery, and value capture. These findings further highlight the similarities between tokenization and classical platform ecosystems, emphasizing the prevalence of two-sided markets and the influence of a single controlling organization. These intermediaries shape the trust structure and integrate code-based trust through smart contracts. When it comes to integrating users into the tokenized world, our findings illustrate how intermediaries integrate actors in the ecosystem with varying degrees of autonomy. Notably, our analysis demonstrates that service providers assume control over the ecosystem through tight coupling. This, in turn, strengthens the cross-side network externalities between loosely coupled and highly autonomous complementors and consumers. Despite the aspirations for market decentralization in Web3, asset tokenization services' primary customer value proposition, whether involving tangible or intangible assets, lies in the increased market liquidity facilitated by the tokenization process rather than a fully decentralized ecosystem.

Conceptualizing Tokenized Governance. The third study puts a special focus on the design objective of 'decentralization' in Web3-enabled ecosystems, exploring the concept of **tokenized governance** in blockchain-based systems (P3, see Chapter 4). This study contributes to a critical sub-field of IS research that focuses on power concentration in Web3 (Feulner et al., 2022; Gochhayat et al., 2020; Schneider, 2019; Werner, Freudiger, et al., 2022; Aramonte et al., 2021). It conceptually elaborates and differentiates the notion of 'decentralization' into technical and socio-political-economic. Drawing on the findings of a literature review and responding to calls for research on blockchain decision rights (Beck, Müller-Bloch, and King, 2018; Liu, Lu, Zhu, et al., 2023), we conducted exploratory case studies and developed a framework to analyze tokenized decision-making, the influence of various parameters on project decentralization, and the role of venture capital investors in the governance process. The framework specifically focuses on the governance of the blockchain itself rather than governance through the blockchain. It considers both project-based and community-based characteristics and recognizes the interplay between social and technical factors by examining network-internal and ecosystem-specific factors that impact governance decisions. To validate the framework's applicability, we conducted a study involving four Web3 projects and investigated the impact of venture capital investments on governance decision-making. By exploring the dynamics of tokenized governance in Web3 ecosystems, this study enhances our understanding of power distribution and concentration, shedding light on the challenges and opportunities associated with decentralized decision-making processes. It contributes to the theoretical understanding of decentralized system governance by providing a conceptual perspective on the dual nature of blockchain governance as both an object of decision-making and an instrument for executing governance.

Second, on the design level, PART III provides a **perspective on 'decentralized marketplaces'**, linking facets of marketplace sharing with the blockchain economy (Weinhardt, Peukert, et al., 2021) and highlighting the need for an integrated understanding of micro-structures, business structures, and IT infrastructures in blockchain-enabled marketplaces. This perspective includes: (a) an explorative literature review on design factors; (b) case studies and insights from practitioners to develop requirements and design principles; and (c) a design science project with an interface design prototype of blockchain-enabled marketplaces. In particular, it addresses RQ2: *Which pivotal elements guide the design of decentralized marketplaces for value co-creating business ecosystems?*

Synthesizing Research on Decentralized Marketplaces. The first study is an initial **literature review** (P4, see Chapter 5) structured along the interdisciplinary market engineering framework proposed by Weinhardt, Holtmann, et al. (2003) and Gimpel et al. (2008). This review reveals that scholars in the field employ the concept of 'decentralization' ambiguously and at varying levels of analysis. For instance, blockchain-enabled infrastructures can be described based on technical, ecosystem, or a combination of both configurations. Each of these perspectives emphasizes different characteristics of blockchain-enabled infrastructures and their corresponding ecosystems. The technology-oriented perspective focuses on the infrastructure as an IT artifact that can be enhanced by complementary services, while the market-oriented perspective highlights the role of blockchains as facilitators in two-sided markets. Given that Web3 ecosystems are typically based on an extensible blockchain infrastructure while also exhibiting market characteristics, it is crucial to consider both perspectives jointly. However, existing publications tend to prioritize conceptual models that advocate for a blockchain-fits-all strategy, neglecting crucial dimensions of markets such as business structures, agent behavior, and desired market outcomes. We analyze that a holistic view of decentralized marketplaces with requirement analysis and structured approaches is largely absent in the literature. Many scholars focus on identifying potential blockchain applications instead of evaluating how specific marketplace functionalities could be decentralized. We see the limitations of these approaches, including technical challenges and concerns about privacy in business ecosystem interactions, where the confidentiality of sensitive and competition-relevant information is paramount (Narang, 2019; Gelhaar and Otto, 2020). Recognizing these limitations, our study offers a critical perspective on the current state of research and outlines future directions for developing decentralized marketplaces in the B2B context. It suggests examining specific micro-structures within decentralized marketplaces, such as identity management and emphasizes the importance of developing governance structures that align with business needs, such as consortia. We encourage scholars in this emerging research area to shift their focus towards approaches that acknowledge markets' multidimensional nature and consider their diverse requirements rather than adhering to a one-size-fits-all strategy centered solely on blockchain.

Designing Decentralized Marketplaces. Drawing on the insights gained from the literature review, the second study employs DSR methods to conduct an in-depth analysis of the **requirements and design principles** for decentralized marketplaces in the context of additive manufacturing (P5, see Chapter 6). By integrating knowledge from academic literature, industry practices, and qualitative expert interviews, this study identifies and explores a total of 27 mandatory requirements, six optional requirements, and 12 design principles. To organize and present our findings in a coherent manner that provides a structured understanding of the complex interactions within decentralized marketplaces, we adopt Veit's model of marketplace interactions (Veit, 2003), which encompasses the stages of information and approach, intention and agreement, as well as clearing and settlement. Within each stage, we outline the specific requirements and design principles that are crucial for the successful establishment and functioning of decentralized marketplaces in AM, including identity management, information sharing, transaction mechanisms, supply and demand matching, privacy, and interoperability. Additionally, we provide suggestions for the governance of these marketplaces, recognizing the importance of establishing effective mechanisms to ensure fairness, digital trust, and accountability. To comprehensively explore this complex topic, we develop a schema that enables the description, classification, and structuring of the requirements and design principles. This contribution enables practitioners to independently design technical constraints that effectively address the unique challenges of decentralized marketplaces in next-generation business ecosystems.

Building upon the knowledge derived in previous studies and tackling the IS research gap in designing decentralized marketplaces, the third study focuses on a design science project that centers on **interface designs** for decentralized markets (P6, see Chapter 7). It serves as a crucial link between human objectives and computing resources, facilitating the efficient implementation of decentralized markets in practice and positively influencing marketplace traffic and user repurchase intentions (Matthew et al., 2021; Pee et al., 2018). We derive design requirements and principles from a preliminary literature review and interviews with domain experts, guided by the theory of effective use (Burton-Jones and Grange, 2013). These insights are translated into tangible design features and implemented in a prototype called the 'Open3D Marketplace' that represents a Level I contribution within the DSR knowledge contribution framework (Gregor and Hevner, 2013). The resulting IT artifact contributes to both the growing body of blockchain design literature and the interdisciplinary analysis of Web3-based economic systems. The project responds to recent calls for studying the design and visualization of decentralized marketplaces, advancing the research field on blockchain applications in B2B contexts, and expanding the literature on IS design for marketplace-oriented transformations. Strategically, the interface design enables users to interact with an interoperable identity management and reputation infrastructure, leveraging SSI as a complementary Web3 technology. This integration enhances trust, user empowerment, and digital sovereignty while mitigating dependencies, lock-in effects, and the one-size-fits-all approach often associated with blockchain implementations. Moreover, the design facilitates privacy-preserving interactions and supports strategic decision-making through user-specific dashboards providing customized information and reports on essential KPIs at various levels of granularity. Operationally, the prototype offers an overview of available resources and their essential metrics, allowing for a detailed display of specific resources based on user-defined criteria. This functionality enhances market analysis and empowers users to make well-informed purchase decisions. By adopting a design science research approach, this project contributes to the practical implementation and evaluation of decentralized marketplaces, offering tangible solutions to enhance trust, transparency, and efficiency within these markets. While our study is anchored in the context of collaborative additive manufacturing and, thus, focuses on a specific class of artifacts, there is potential for the transferability of the proposed principles to other solution spaces. This opens avenues for designing a broader class of interface designs that can be adapted to different contexts (Chandra, Seidel, and Purao, 2016).

Third, on the business model level, PART IV provides a **perspective on SSI business models** as micro-structural elements of decentralized markets. This perspective includes: (a) value creation mechanisms and business aspects of strategic alliances governing SSI ecosystems; (b) business model characteristics adopted by organizations leveraging SSI; and (c) business model archetypes and a framework for SSI ecosystem engineering efforts. It opens up a business perspective on the technology-driven literature on SSI, particularly addressing RQ3: *Which collaborative efforts and business models characterize ecosystems with self-sovereign identities that improve user control in digital interactions?*

Strategic Alliances Governing SSI Ecosystems. The first study sheds light on SSI ecosystem collaboration, specifically examining the business model aspects of strategic alliances governing SSI networks (P7, see Chapter 8). Using an inductive, qualitative approach that includes expert interviews and practical projects, it analyzes design considerations based on Al-Debei and Avison (2010)'s V^4 business model dimensions: value architecture, value network, value finance, and value proposition. We discuss the suitability of cooperatives for governance and specify the benefits of SSI-based networks compared to traditional identity management systems from both the user perspective of legal entities and individuals. In the value architecture dimension, we identify three crucial pillars for ecosystem orchestrators: technical network, organizational structure, and partner ecosystem, emphasizing the importance of a balanced equilibrium between technologically trustworthy infrastructure and transparent organizational cooperation models. Regarding value networks, we propose a combination of public and private actors as key partners. In the value finance dimension, we suggest potential revenue streams, highlighting that covering the consortium's costs should be the primary rationale, operating in the users' interest rather than for profit. Our findings contribute to transparency in SSI network governance by providing first insights into the business model layer, fostering user adoption and trust in SSI ecosystems. Furthermore, we extend the applicability of the V^4 business model framework to context-specific business models in the SSI domain.

Business Model Characteristics Adopted by Organizations Leveraging SSI. The second and third study shifts the focus from collaborative efforts to the specific actions taken by individual actors operating in SSI ecosystems. Building on a synthesis of scholarly literature and practical projects, the second study presents a theoretically grounded and empirically validated taxonomy of business models enabled by SSI (P8, see Chapter 9). While existing SSI research tends to emphasize technological aspects, our approach offers a theoretical foundation for understanding SSI as an IT artifact within economic applications. By doing so, we provide empirical insights that show how projects translate SSI into business opportunities. We focus again on the four central dimensions of Al-Debei and Avison (2010)'s V^4 business model classification to present a market overview, analyze and abstract individual business models, and highlight variations in characteristics. The value proposition dimension, for instance, highlights actor-specific attributes such as their role within the ecosystem, the target customer segment, and their motives for participating. Subsequent dimensions explore characteristics related to service offerings, governance mechanisms, value creation mechanisms, and the architecture of the digital infrastructure. In sum, the dimensions and underlying characteristics contribute to the broader stream of IS research that explores the business opportunities, managerial implications, and societal questions related to ID technologies (Sedlmeir, Smethurst, et al., 2021; Whitley et al., 2014). Drawing on Gregor (2006), our taxonomy can be classified as a Type I contribution, specifically a "theory for analyzing" that aims to describe and classify specific dimensions or characteristics by summarizing commonalities observed in discrete observations. Therefore, the artifact is a first step to provide a structural, reproducible framework to compare and design business models leveraging SSI in next-generation business ecosystems.

Business Model Archetypes and a Framework for SSI Ecosystem Engineering Efforts. The third study adopts a twofold DSR approach to build upon and evaluate the previously designed taxonomy to enhance our understanding of the impact of SSI on business models (P9, see Chapter 10). It serves as a vocabulary for business model research, enabling a systematic description of SSI business models and highlighting opportunities for business model innovations within their inherent complexity. Building on the taxonomy, we conduct a cluster analysis of 66 real-world SSI projects to develop a systematic understanding of business model configurations. We derive six distinct archetypes of business models leveraging SSI: Platform-as-a-Service, Cross-Layer Service, SSI-enabled Service, (SS)ID-as-a-Service, Infrastructure-as-a-Service, and Network-as-a-Service. These archetypal patterns, in conjunction with the underlying taxonomy, describe the technical prerequisites (i.e., value architecture) required by ecosystem actors in their potential roles (i.e., value network) to offer products and services (i.e., value proposition) with different economic models (i.e., value finance). While taxonomy research primarily focuses on descriptive aspects, our archetypes offer deeper insights into widely employed business model configurations. They serve as a reference point for further research and adaptation, facilitating the development of customized business models that align with specific goals and target markets. While our work does not propose a universally applicable solution, it offers a prescriptive component by providing actionable insights and guiding principles for practitioners in the field. By leveraging these findings, organizations can navigate the complex landscape of SSI ecosystems and make informed decisions regarding their business model design and implementation. Our archetypes provide a conceptual understanding of the underlying rationale behind different types of SSI-driven business models, contributing to a Type II mid-range theory of "theory for explaining" as outlined by Gregor (2006).

We further present the 'SSI Ecosystem Framework', which offers an integrated and holistic perspective on the interconnected elements of SSI ecosystems and their contextual factors. It facilitates the interaction between individual SSI applications and the collaborative development of foundational SSI infrastructure at both micro and macro levels. Drawing inspiration from the *SSI trust triangle* (Kölbel, Gawlitza, et al., 2022; Preukschat and Reed, 2021) and market engineering theory (Weinhardt and Gimpel, 2007), our framework adopts a multi-layer approach to delineate the characteristics of SSI-based ecosystems: the *Environment Layer*, *Infrastructure Layer*, and *Application Layer*. These layers and multiple sub-structures account for the inherent openness of the technology with social, legal, and economic constraints, a diverse hardware and software infrastructure, market structure, and agent behavior. In sum, our framework (1) provides a distinction between the concept of SSI ecosystems and related organizational constellations; (2) offers an analytical starting point for the under-researched phenomenon of SSI ecosystems; and (3) proposes a concept that informs managerial action (Autio and Thomas, 2020). We thereby contribute a 'theory for explaining' (Gregor, 2006) that does not claim to generate testable propositions. This theoretical conceptualization guides the design and analysis of SSI-based applications and supports research on developing SSI-based markets that consider the complexity and multidimensional nature of next-generation business ecosystems.

11.2 Limitations

The studies embedded in this thesis, and consequently the findings presented, are subject to certain limitations. These limitations arise from the chosen research approach, the selected data sources, and the nature of the thesis topic. While each individual publication in this cumulative dissertation provides a detailed discussion of its specific limitations, this section outlines some overarching shortcomings inherent in our research.

For most of our studies, we followed an interpretive, qualitative research approach, encompassing various methodologies such as literature review, taxonomy development, and DSR. While these approaches provide valuable insights and rich contextual understanding, it is essential to recognize their inherent subjectivity, context-dependency, and potential limitations in terms of biases and generalizability.

As part of the interpretivist research approach, researchers generally interpret observations within the phenomenon under investigation from their own viewpoints and perspectives, which introduces the potential for researcher bias. Literature reviews, for instance, have inherent limitations as they rely on the search process and identifying relevant papers. Despite employing comprehensive search techniques, such as forward and backward searches (Webster and Watson, 2002), we must acknowledge that not every pertinent paper may be captured by our approach. Additionally, the review process for scientific literature often spans several years, necessitating the inclusion of grey literature to incorporate recent developments and insights.

Furthermore, our analyses may be susceptible to coding biases that can influence conceptualization and interpretations. While the iterative taxonomy development method serves to organize and categorize concepts, variables, and relationships within the research domain, it is crucial to recognize that taxonomies, in general, cannot be exhaustive or perfect (Nickerson et al., 2013), as the phenomena being analyzed are subject to constant change and evolution. The taxonomies developed, therefore, provide a snapshot of the current situation, prioritizing pragmatism over perfection, and are designed to be extendable, providing a robust foundation for characterizing future innovations.

Acknowledging the inherent limitations of taxonomies based on real-world cases is also crucial. During the case study phase, we took precautions to address potential biases by employing constant comparison techniques to examine different data segments and compare them with existing theories (Corbin and Strauss, 2008). We furthermore collected several viewpoints on the phenomena we analyzed (Corbin and Strauss, 2008). For instance, when examining the requirements of decentralized marketplaces, we conducted interviews with experts at various levels of hierarchy. We further ensured that the interview transcripts were shared with the interviewees for their input and revision. The concept of inter-coder reliability should further ensure construct validity, although the validity of the developed construct remains to be tested through further quantitative research. We also engaged in data triangulation, involving the collection of data from various sources to better understand the phenomenon (Corbin and Strauss, 2008). For example, we enhanced our study on NFTs with comprehensive secondary data such as consulting reports. We further acknowledge that generalizability is a challenge inherent in qualitative research approaches such as case studies (Yin, 2009). The generalizability of the results in the embedded publications is particularly vulnerable to frequently changing conditions where uncertainty is high. For instance, the identified value co-creation practices in our studies on SSI ecosystems may be subject to modification as new technologies and standards emerge, whereas the individual business challenges in designing innovative business models based on SSI are more stable as they apply independent of technology to all value creation practices.

Limitations also arise from the selected data's nature, as the information quality can introduce biases. Data analysis techniques alone cannot rectify sparse or ambiguous case information. We employed data triangulation by incorporating secondary data sources to complement and validate the findings to address this. Moreover, the inclusion and exclusion criteria for cases may cause a selection bias. Cases were excluded if primary and secondary data did not provide sufficient information. Additionally, publication bias may exist in case surveys, as only published cases were considered, potentially resulting in a case sample with significant results and reducing the overall number of cases. To mitigate this limitation, we augmented the literature-based cases with secondary data and included cases based solely on secondary sources, ensuring careful attention to data triangulation. Lastly, it should be noted that underlying case studies typically focus on specific phenomena, and the uniqueness of individual cases may not always be fully considered due to the knowledge accumulation emphasis of the case study method (Yin, 2009).

With reference to the opening quote by Bill Gates, Web3 technologies, in general, and next-generation business ecosystems in particular, are still in their infancy, awaiting a breakthrough in the industry. This may – as the statement indicates – change over time. However, it is vital to acknowledge the inherent limitations and potential novelty effects of studying such an emerging field. The focus of this research is on the early phases of next-generation business ecosystems, recognizing that the long-term success of these Web3 projects is not guaranteed. It is plausible that some of the findings presented in this work may only be applicable in the short term. Numerous blockchain networks and decentralized markets have emerged and vanished throughout this dissertation, molding the broader Web3 ecosystem. While the studies discussed in this thesis offer a snapshot of this dynamic field, a longitudinal evaluation is necessary to establish more robust findings and determine the observed effects' persistence over extended periods. To achieve this, exploring IS continuance models and adapting them to the Web3 context would be valuable, e.g., following the approach by Bhattacherjee and Premkumar (2004) and Bhattacherjee (2001). Understanding the acceptance of Web3 systems is crucial for comprehending how the system changes impact user behavior from a theoretical perspective, as well as for guiding practitioners in developing new applications while considering the current state of technology.

11.3 Outlook on Future Research Avenues

This section identifies avenues for future research to build upon and expand the findings of this dissertation. As before each individual publication within this cumulative dissertation offers detailed insights into specific research opportunities, we outline overarching themes below.

Ecosystem Bootstrapping in the Absence of Intermediaries. When reviewing IS literature on ecosystems, the predominant part of research revolves around centralized ecosystems where a single platform owner plays a central role (e.g., Hein et al., 2019; Autio, 2022; Jacobides et al., 2018). However, in the context of blockchain-enabled Web3 environments, the concept of *decentralization* takes center stage, emphasizing the removal of intermediaries as a critical design objective (Chalmers, Matthews, et al., 2021; Werner, Frost, et al., 2020; Kölbel and Kunz, 2020). Consequently, the emergence and growth of next-generation business ecosystems in these environments depend on alternative mechanisms to ignite and facilitate positive network externalities among independent actors aligned around a shared value proposition. To comprehend the dynamics of these ecosystems and engineer their development, researchers should explore both the practical and theoretical aspects of value co-creating activities. Future research may delve into diverse forms of ecosystem engagement, analyzing how different forms influence governance mechanisms and shape the strategic trajectory of the ecosystem. Comparative studies examining ecosystems with central ownership, consortia, and peer-to-peer networks present intriguing avenues for exploration. Key considerations may include different degrees of autonomy, tight and loose coupling principles, and their impact on boundary resources and complementor capabilities. Moreover, comprehending the most effective approaches to managing intellectual properties and appropriating value in the context of open-source technologies poses interesting questions for IS research. Understanding how ecosystem participants can effectively collaborate while safeguarding their intellectual property rights and ensuring fair value distribution is a critical area that merits investigation. Future research can contribute to a deeper understanding of diverse engagement forms, governance mechanisms, potential cold-start problems in new networks, strategic trajectories, and value capture strategies by focusing on these aspects.

The Make or Join Decision in Ecosystem Emergence. Amidst the challenges organizations face in navigating the complex landscape of Web3 and the criticality of network effects for successful ecosystems, the question arises: Should every actor embark on creating a next-generation business ecosystem from scratch or consider joining an existing ecosystem as a partner? Consequently, exploring different paths of ecosystem emergence holds promise, as ecosystems can arise natively based on exogenous technological trajectories or through industry incumbents who recognize new possibilities and transition to an ecosystem strategy. We think it could be worthwhile to empirically compare organizations in a specific market or industry that have either created an ecosystem or joined an existing one. Such comparisons can enhance the understanding of the challenges involved in selecting and joining an existing ecosystem while also providing insights into the characteristics of incumbent companies that contribute to successful ecosystem creation or integration. These factors may include the competitive landscape, critical mass requirements, existing partner networks with complementary capabilities, and specific expertise in building technology-driven ecosystems. Further research can investigate the process of technological tinkering and assemblage in both successful and unsuccessful transformations, elucidating the antecedents and capabilities necessary for a successful strategic shift at the technology, governance, and market levels. By analyzing these aspects, practical strategies can be developed to guide organizations in launching and managing next-generation business ecosystems. Ultimately, these insights can enrich the existing literature on ecosystem dynamics and contribute to a more nuanced understanding of how to effectively build, grow, steer, and sustain different types of blockchain-enabled Web3 ecosystems.

Inter-Organizational Collaboration Driving Complexity. The design of next-generation business ecosystems leveraging Web3 requires engineers to consider a range of technologies and governance models that must align with diverse business requirements. Who makes the rules, how they are made, and what the underlying intentions are (i.e., governance) can be at least as important as how rules are enforced (i.e., decentralized technologies). Therefore, finding the right tools for a specific application becomes challenging, requiring an understanding of the fast-evolving Web3 landscape and the functional and organizational requirements of the stakeholders involved. Questions arise as to how, when, and which technology should be used, but also regarding the governance design, i.e., whether existing governance mechanisms are sufficient for replicating Web3 systems or if new concepts are necessary. While we have shed light on value co-creation practices from an isolated perspective within the different veins of tokenization, decentralized markets, and SSI, it remains to be understood how these different aspects interact to form thriving next-generation business ecosystems. Thus, future research should explore the interdependencies between technological capabilities, governance aspects, and value co-creation practices from the perspectives of various ecosystem actors. Our DSR studies on decentralized markets have partially addressed these solution spaces within the manufacturing industry, specifically the use case of CAM. To extend the applicability of our findings across industries, conducting multiple-case studies in diverse sectors would be valuable. Developing a more generalizable framework that defines the characteristics of next-generation business ecosystems would benefit scholars in the field. In this vein, we see further potential to evaluate which factors are sufficient to capture the complexity of real-world business domains, including the blurring of actor roles, the degree of transparency desired, and the existence of multiple ecosystem layers. These layers may encompass an internal core layer influencing data exchange mechanisms, a vertically integrated layer of third-party complementors, and a strategic partner layer. Understanding these characteristics can help determine successful ecosystems' attributes and identify failed ones' deficiencies. A generic framework for designing next-generation business ecosystems would enhance construct clarity, support theory building, and provide practitioners in various industries with insights into their transformation progress and potential design decisions to discover new solution spaces. An important first step in this endeavor is to explore optimal degrees of decentralization required to overcome the trust frontier between algorithmic and code-based trust in blockchain-based systems and the perceived trust in offline environments (Notheisen, Willrich, et al., 2019). Achieving this balance while eliminating the need for trusted third parties presents a major challenge for future work and may offer new business opportunities for intermediaries.

Examining Incentive Mechanisms for Collaboration. As next-generation business ecosystems continue to evolve, it becomes crucial to design and implement effective incentive structures that encourage actors to contribute their resources, knowledge, and expertise towards the shared goals of the ecosystem. Traditional models may not be directly applicable in these decentralized environments, necessitating the exploration of novel monetization strategies. One aspect to consider is the design of token-based incentive systems, which can align the interests of ecosystem participants, stimulate desired behaviors, and that foster innovation. Research in this domain can build on our research and delve into the different types of tokens, including utility tokens, security tokens, and governance tokens, and examine how these incentivize and align the interests of ecosystem participants, enabling them to contribute and extract value from the ecosystem. Further investigations could focus on token distribution mechanisms, token supply dynamics, and the impact of tokens on motivating collaboration and value creation. Understanding the functioning of token economies within these ecosystems, including aspects such as token utility, governance mechanisms, inflation/deflation mechanisms, and economic stability measures, may be crucial to ensure the long-term sustainability and resilience of the ecosystem. Potential avenues also include the challenges and opportunities associated with value distribution and ensuring fair and equitable monetization among ecosystem participants. By exploring the complexities of tokenomics, future research can provide valuable insights into the economic dynamics of next-generation business ecosystems. Understanding how these mechanisms enable value exchange, incentivize participation, and facilitate economic interactions can provide valuable insights into value creation and capture dynamics.

Exploring the Role of Trust. As blockchain technology plays a pivotal role in enabling decentralized and trustless interactions, future research could also delve into the dynamics of trust and security within next-generation business ecosystems.

Trust is a fundamental aspect of ecosystem participation, and it is further amplified in decentralized environments where traditional intermediaries are eliminated (Notheisen, Cholewa, et al., 2017; Hawlitschek, Notheisen, et al., 2018). Future research can investigate the mechanisms and factors influencing trust formation, maintenance, and erosion within these ecosystems. Another opportunity for future research is to examine the impact of non-financial incentives, such as reputation systems and governance participation, in driving value within the Web3 context. These systems and social incentives may be crucial in building trust and establishing credibility among ecosystem participants. Research can focus on the design and implementation of reputation models, the factors contributing to reputation scores, and the influence of reputation on collaboration and resource allocation. Understanding the dynamics of reputation formation, the impact of reputation on decision-making, and the strategies for managing reputation in Web3 can contribute to developing robust and trustworthy governance mechanisms. Moreover, research can explore the interplay between trust, security, and regulatory considerations in blockchain-enabled environments. As these networks operate in a decentralized and global context, understanding the legal and regulatory challenges they face, as well as the potential implications of compliance requirements, can provide valuable insights. Investigating the balance between maintaining trust and ensuring compliance with regulatory frameworks can contribute to developing effective governance models and legal frameworks for the blockchain-enabled Web3. By investigating these aspects, researchers can offer practical insights for ecosystem designers, policymakers, and practitioners to foster the growth of vibrant and sustainable next-generation business ecosystems that align the interests of participants and promote the broader adoption of Web3 technologies.

Varying Degrees of Decentralization with Transition Pathways. While the bright side of next-generation business ecosystems has received considerable attention, it is crucial to also acknowledge and investigate the potential dark side of their development. As we embark on our research journey, it is important to recognize that the landscape of Web3 paradigms is still evolving, and the full extent of their impact is yet to be realized. Drawing from the Gartner Hype Cycle, we understand that the emergence of next-generation ecosystems, particularly in complex business contexts, depends on lifecycle maturity and involves varying degrees of openness and collaboration, which influence value co-creation. Understanding the dynamics of governance, including the challenges of achieving effective decision-making, avoiding too much centralization, and mitigating governance-related risks, will contribute to developing robust governance frameworks that foster trust, transparency, and accountability. In our studies, we see that intermediating service providers often exert control over the ecosystem through tight coupling, particularly in the initial stages of initiation and expansion, hindering the goal of decentralization. Our research on blockchain governance (P3, see Chapter 4) suggests in line with other scholars (Pfister et al., 2022; Sunyaev et al., 2021) a potential trajectory towards decentralization. This trajectory begins with low decentralization during the project's creation phase and gradually moves towards the desired high decentralization during the operational phase. Projects adopt a more open strategy that emphasizes the increasing importance of engaging loosely coupled and autonomous actors in the more mature lifecycle phases. However, it is worth noting that achieving high decentralization may require a temporary 'founder dictatorship' to facilitate efficient decision-making and address code vulnerabilities (Beck, Müller-Bloch, and King, 2018; Buterin, 2017). It would be valuable to focus on these potential transition pathways to gain a comprehensive understanding of governance aspects and their impacts. Future research should explore how projects aiming for decentralization can best attract, promote, and achieve successful transitions. It will be important to start addressing these aspects at an early stage to intervene before potential issues become entrenched in the ecosystem.

11.4 Concluding Remarks

In this final part of the dissertation, we are reminded by Bill Gates' opening quote of the importance of adopting a long-term perspective when evaluating emerging technologies. Although the current state of Web3 and blockchain may not have lived up to the initial hype, it is crucial to acknowledge the underlying transformative power and explore new avenues for harnessing the full potential of decentralized markets, SSI, and tokenization. While blockchain technology undoubtedly offers unique features such as immutability, transparency, and decentralization, this thesis acknowledges its limitations and explores how other paradigms within Web3 can complement and enhance its capabilities. By embracing a holistic approach encompassing various technologies and dimensions, we may engineer next-generation business ecosystems that are not only technologically advanced but also sustainable, scalable, and impactful in the years to come. This thesis goes beyond a blockchain-centric mindset and ventures into new insights by employing empirical research, case studies, and theoretical analysis. We propose innovative frameworks and develop practical guidelines to help organizations navigate the complex landscape of Web3. By adopting this analytical lens, we contribute a first step to gain deeper insights into the potential and challenges of Web3 and develop strategies that leverage the strengths of both technology and market-oriented perspectives.

In closing this dissertation, I would like to share the words of two technology pioneers who emphasize the importance of developing technology with the aim of making the world a better place (Slater and Sanchez-Vives, 2016). Therefore, I hope this work will inspire readers to think as paradigm changers and advance next-generation business ecosystems that can positively impact both businesses and society. As we embark on this journey, we should embrace the complexity and interdisciplinary nature of Web3 technologies. Let us move beyond the hype and disillusionment and instead focus on building a solid foundation for a trust-enhancing future that drives meaningful change in the next decade and beyond.

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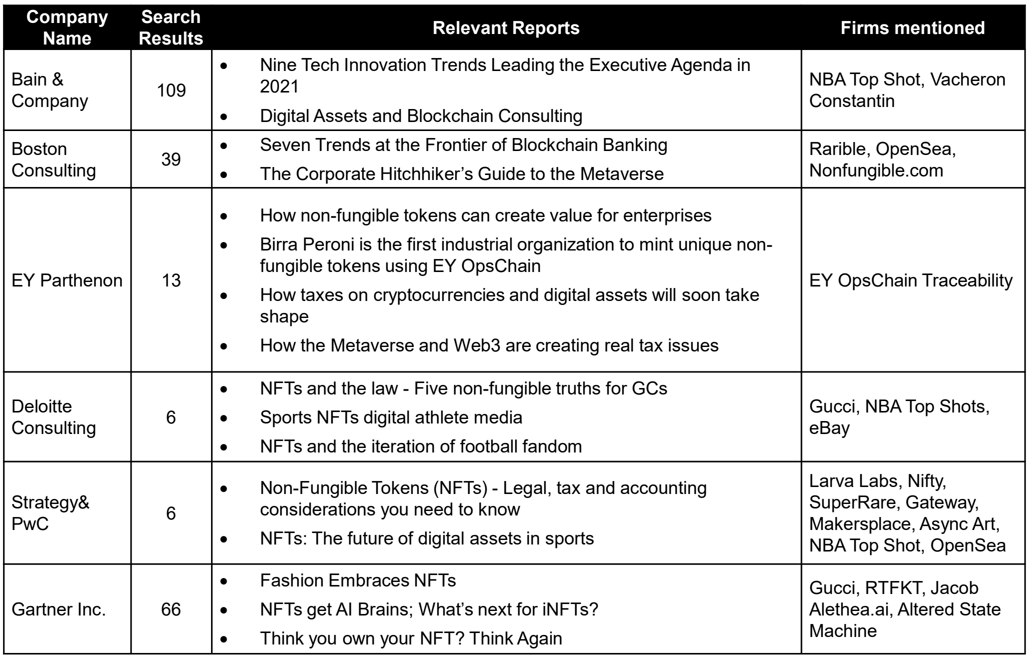
Appendix

A.1 Appendix A: Supplementary Material Chapter 2

Tab. A.1.: Analyzed Firms from Literature.

Art Blocks; Async Art; Atomic Hub; Audius; Axie Infinity; Bitsong; Blockparty; Catalog; Cent; Cryptovoxels; Dapper Labs; Decentraland; Digitalax; Emanate; eMusic; Epix; Foundation Labs; Gods Unchained; InfiNFT; Kalamint; KnownOrigin; MakersPlace; Mintable; Mintbase; MintyArt; NFT Showroom; Nifty Gateway; OpenSea; Opus; Pancakeswap; Paras; PolyientX; Portion; Rarible; SEEN HAUS; Somnium Space; Sorare; Sound; SuperRare; Virtua; The Sandbox; VIV3; Zora

Tab. A.2.: Analyzed Consultancy Reports.



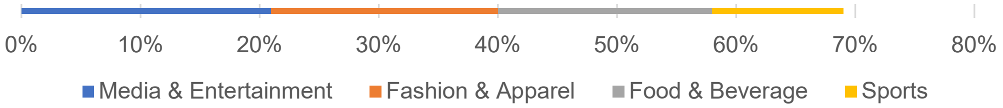
Company Name	Search Results	Relevant Reports	Firms mentioned
Bain & Company	109	• Nine Tech Innovation Trends Leading the Executive Agenda in 2021 • Digital Assets and Blockchain Consulting	NBA Top Shot, Vacheron Constantin
Boston Consulting	39	• Seven Trends at the Frontier of Blockchain Banking • The Corporate Hitchhiker's Guide to the Metaverse	Rarible, OpenSea, Nonfungible.com
EY Parthenon	13	• How non-fungible tokens can create value for enterprises • Birra Peroni is the first industrial organization to mint unique non-fungible tokens using EY OpsChain • How taxes on cryptocurrencies and digital assets will soon take shape • How the Metaverse and Web3 are creating real tax issues	EY OpsChain Traceability
Deloitte Consulting	6	• NFTs and the law - Five non-fungible truths for GCs • Sports NFTs digital athlete media • NFTs and the iteration of football fandom	Gucci, NBA Top Shots, eBay
Strategy& PwC	6	• Non-Fungible Tokens (NFTs) - Legal, tax and accounting considerations you need to know • NFTs: The future of digital assets in sports	Larva Labs, Nifty, SuperRare, Gateway, Makersplace, Async Art, NBA Top Shot, OpenSea
Gartner Inc.	66	• Fashion Embraces NFTs • NFTs get AI Brains; What's next for iNFTs? • Think you own your NFT? Think Again	Gucci, RTFKT, Jacob Alethea.ai, Altered State Machine

Tab. A.3.: Analyzed Firms from Crunchbase Data.

Afterparty; Autograph; Avocado Guild; Baller Mixed Relity; BAYZ; Boba Network; Boson Protocol; Burnt; Crypto Raiders; Crypto.com; DEIP; Dfns; Dogami; Double jump.tokyo; FanCraze; Fungyproof; Genopets; Horizon Games; IndiGG; Itheum; Lysto; Magic Eden; Meta Tenure; MetaLend; MetaStreet; Metaverse Group; Mojito; Nifty Island; Novel; OneOf; Palm NFT Studio; Pluto Digital; POAP; Project Galaxy; Proof of Learn; Recur; Royal; Space Runners; Spatial; Unstoppable Domains; Venly; White Sands; Wilder World; Zaiko

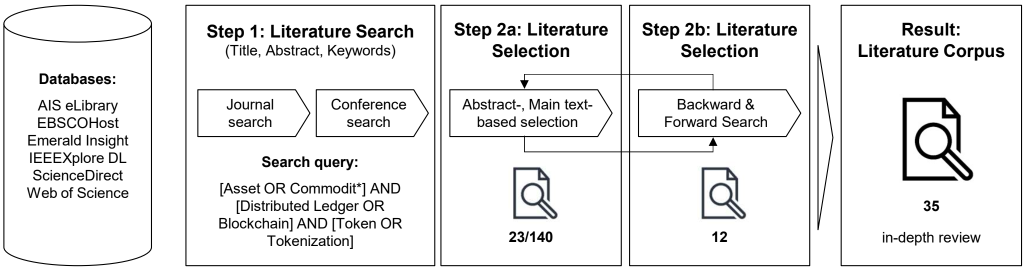
Fig. A.1.: Analyzed Incumbents that launched NFT Projects in 2021.

Fig. A.2.: Incumbents NFT launches in 2021 by Industry with a Market Share of at least 10%.



A.2 Appendix B: Supplementary Material Chapter 3

Fig. A.3.: Literature Search Strategy in Accordance with Webster & Watson (2002).



Tab. A.4.: Analyzed Consulting Reports related to Asset Tokenization.

Title	Author	Year
Advantages of security token offerings	Arner et al. (Deloitte)	2021
Navigation the Digital Asset Ecosystem	Burchardi et al. (BCG)	2020
Blockchain Gets Artsy	Cognizant Technology Solutions	2018
Taking the pulse of digital assets in financial services across EMEA	Dalton and Simpson (Deloitte)	2021
Are token assets the securities of tomorrow?	Deloitte	2019
Security Token Offering (STO) - A Snapshot of Switzerland	Ernst & Young	2021
Tokenization of Assets - Decentralized Finance (DeFi)	Ernst & Young	2020
Opportunity awaits - Crypto-assets in investment management	Flisgen et al. (Deloitte)	2021
Big Business Digs into Deep Tech	Gourévitch et al. (BCG)	2021
Digital Assets - Tokenized Revolution in Financial Services? - Current Developments & Outlook for Switzerland	Kobler und Dulay-Winkler (Accenture)	2019
Seven Trends at the Frontier of Blockchain Banking	Kronfeller et al. (BCG)	2021
The tokenization of assets is disrupting the financial industry. Are you ready?	Laurent et al. (Deloitte)	2019
Real Estate Tokenization	Pang et al. (KPMG)	2020
Tokenization – the future of the platform business model: Sustainable growth through blockchain-based incentives	Schaller et al. (Deloitte)	2020
The Tokenization of the Economy and its Impact on Capital Markets and Banks	Van Gysegem und De Patoul (Roland Berger)	2021
Blockchain for Trade Finance: Trade Asset Tokenization	Varghese und Goyal (Cognizant Technology Solutions)	2018

Tab. A.5.: Analyzed Projects Derived from Literature Review, Crunchbase and Medium.

Allinfra	Brickblock	Liquiditeam	Openfinance	Tokel
AlphaPoint	BrickMark	Look Lateral	OpenSea	Token City
ArtSquare	CODEX	Maecenas	Power Ledger	Tokeny
Aspen Digital	CurioInvest	Masterworks	Project Plutus	Tokenestate
AssetFi	Crowdlitoken	Maxima Horse	PRüF	tZERO
Atlant	Definder	micobo	RAAY Estate	UPRETS
Artpool	EnLedger	Modum	Rarible	Vertalo
Autograph	Everledger	MS Token	Scalable Solutions	
Bitbond	Fraxtor	Mt Pelerin	SPiCE VC	
Blockimmo	iCap Equity	NASDEX	Staxe	
BlockState	ImpactPPA	Ohanae	Templum	

Fig. A.4.: Distribution of Taxonomy Characteristics based on 20 Analyzed Projects.

	Dimension		Characteristic									E/N*
Value Proposition	Underlying Asset		Tangible-physical (65%)	Intangible-virtual (50%)								N
	Value for Customer		Intermediation Improvement (45%)	Increased Liquidity (95%)	Financial Inclusion (80%)	Digital Scarcity (70%)	Process Improvement (40%)	Security Enhancement (20%)	Tracability and Verification (35%)			N
	Trust Structure		Intermediary-based (85%)	Code-based (50%)	Reputation-based (10%)							N
	Value Classification	Service Provisioning	Intrinsic Stand-alone (40%)	Reference Add-on (70%)								N
		Customization	Full (15%)	Modular (45%)	Not Allowed (40%)							E
		Market Type	One-sided (10%)	Two-sided (90%)								N
		Token Function	Store of Value (65%)	Voting Rights (10%)	Right to Use (65%)	Dividend Right (85%)	Collectible (55%)	Speculation Object (80%)	Tracking (30%)			N
	Service Openess	Network Accessibility	Public (75%)	Private (25%)								E
		Geographic Targeting	Global (65%)	Selected Countries (35%)								E
		Verification Level	High Verification (65%)	Low Verification (20%)	No Verification (15%)							E
Value Creation and Delivery	Ecosystem Role		Service Provider (90%)	Infrastructure Provider (95%)								N
			Token Issuance (90%)	Brokerage (30%)	Clearing and Settlement (50%)	Safekeeping Custody (45%)	Assurance or Consultancy (50%)	Analytics (10%)	Hardware Producer (5%)	Software Producer (15%)	Platform Operator (100%)	N
	Customer Segment		B2B (80%)	B2C (100%)	C2C (25%)							N
	Key Partner		Minting Creator (Seller Side) (85%)	Technological Service Provider (100%)	Blockchain Network (100%)	Influencer (35%)						N
	Key Channel		Mobile Application (20%)	Desktop Website (100%)	Technology Provision without Channel (10%)							N
	Token Characteristic	Unit	Whole or One Token (30%)	Multiple Tokens Separable (55%)	Not Separable (15%)							E
		Properties	Portability (70%)	Fungibility (85%)	Destructibility (5%)	Tradeability (90%)						N
			Portable (60%)	Not Portable (10%)	Fungible (30%)	Non-fungible (50%)	Destructible (5%)	Not destructible (0%)	Tradable (90%)	Not Tradable (5%)		N
		Supply	Limited (45%)	Variable (25%)	Unlimited (25%)							E
		Creation	Singular (35%)	Conditional (25%)	Flexible (35%)							E
	Asset Governance	Asset Safekeeping	Self-administration (50%)	Third-party Management (65%)								N
		Private Key Custody	Self-administration (60%)	Third-party Management (50%)								N
		Interface	Qualitative (80%)	Quantitative (10%)	No Interface (10%)							E
Value Capture	Monetization		Upfront (20%)	Pay-as-you-go (60%)	Not specified (35%)							N
	Revenue Source		Minting Creator (Seller Side) (50%)	Customer (Buyer Side) (55%)	Third Party (10%)	Not specified (30%)						N
	Revenue Stream		Advertising (20%)	Fixed Service Fee (20%)	Transactional Fee (50%)	Value-based Fee (60%)	Second. Market Fee (35%)	Auction (20%)	Not specified (20%)			N
	Payment Channel		Own Token (40%)	Multiple Cryptocurrencies (65%)	Fiat Currency (50%)							N
	Network Costs		Use External Blockchain Network (90%)	Use Own Consensus Network (5%)								E

A.3 Appendix C: Supplementary Material Chapter 10

Tab. A.6.: Sample of Analyzed SSI Business Models.

Reference	Project Name		
Literature Review	• Passbase • Evernym • Cheqd.io • Catena-X • Liquid Avatar • Finema • iGrant • Vereign • Trinsic • Blockpass	• Metadium • Serto • Veramo • MyEarth • Corinc • Equideum • Esatus • Spherity • Kiva • Sovrin	• ION • Infocert Dizme • Procivis • Spruce ID • Diplome • Gataca • HelixID • Validatedid
CrunchBase	• Portabl • Ethsign • Coinplug • Verida • Apotheka	• Bloom • Litentry • Hpec • IDRamp	• Thrivacy • Identity.com • Bio Passport • Blockster
Interviews	• KERI • Business Partner Agent • Estanium • Trustgrid • IDideal • KTDI • Walt.id	• EBSI • Ocean Protocol • Jolocom • Lissi.id • Godiddy • MySaveID • ProofSpace	• ID Wallet App eID • IDnow • IDunion • Indico • SDIKA • Once-Identity
Decentralized Identity Web	• Aave • Hyland	• Mattr Global • Veres	

Tab. A.7.: Definition of Self-Sovereign Identity Business Model Taxonomy Dimensions.

Value Network	Ecosystem Layer		What position does the operator take within the SSI ecosystem value chain?
	Business Model Focus		What is the focal aspect of the business model?
	Partner	Enabling Partner	Which partners does the business model rely on as enablers?
		Industry Partner	Which industry partners are necessary for the business model?
Value Proposition	Stakeholder Value	Service Feature	What is the core business model feature?
		Process Enhancement	How does the business model improve processes?
		Sovereignty	How does the business model support user sovereignty?
	Target Audience	Identity Provisioning	Who is addressed by the value proposition?
		Segment	To whom does the operator provide its offerings?
		Market Specialization	Is the business model limited to market segments?
	Customer Relationship		To what extent are customers involved in the service provisioning?
Value Architecture	Verifiable Data Registry	Ledger	What kind of ledger does the business model incorporate?
		Type	How is access to the ledger restricted?
	Compliance	Laws	Which jurisdictions does the business model comply with?
		Standards	What standards are reflected in the business model?
	Customer Interaction	Wallet Provisioning	What is the vertical integration of the business model?
		Interface	What type of frontend is provided by the operator to interact with an SSI network?
		Customer Data Storage	Where is user data being stored?
Value Finance	Business Model Maturity		How developed is the business model?
	Customer Charge		What is the operator's charging model?
	Payment Integration		What payment methods does the operator allow in its offering?

Tab. A.8.: Definition of Value Network Characteristics.

Value Network	Ecosystem Layer		*Application Layer*	Business model focus on applications and customer value creation.
			Credential Layer	Business model focus on credential provisioning.
			Communication Layer	Business model focus on offerings for SSI network communication.
			Agent Layer	Business model focus on agent software.
			Public Data Layer	Business model focus on public hardware/software.
			Governance Layer	Business model focus on network governance.
	Business Model Focus		*Software Provisioning*	Business model focus on software.
			Technology Provisioning	Business model focus on technology offering.
			Registry Provisioning	Business model focus on (issuer) trust registries.
			Knowledge Provisioning	Business model focus on SSI knowledge dissemination.
			Auxiliary Service	Business model focuses on service with indirect SSI connection (e.g., custodians, insurance providers).
	Partner	Enabling Partner	*Community Convenor*	Business model focus on closed community (e.g., consortium) with dedicated governing entity.
			Standard-Setting Entity	Business model includes standardization partner.
			Government	Business model includes governmental partner.
			Auditing Partner	Business model builds on audited value creation.
			Accrediting Partner	Business model builds on accredited value creation.
		Industry Partner	*Technical Infrastructure*	Business model co-creation with infrastructure partner.
			Service Provider	Business model co-creation with service partner.
			Investor	Business model co-creation with investor.
			Advisor	Business model co-creation with advisors.
			Trust Service Provider	Business model co-creation with trust provider.

Tab. A.9.: Definition of Value Proposition Characteristics.

Value Proposition				
	Stakeholder Value	Service Feature	*Onboarding*	Actor integration to a network.
			Credential Exchange	Authentication solutions.
			Access Management	SSI-based access and check-out to digital and physical environments.
			Know Your Customer	Identity services and auditing.
			Track and Trace	SSI-enabled traceability (e.g. in supply chains)
			Passwordless Authentication	Enhancement of authentication process.
			Digital Signatures	Cryptographic signatures and attribute verification.
			Data Monetization	Incentivised sharing of data after customer consent.
			Other	Additional features.
		Process Enhancement	*Digitalization*	Transformation of analogue processes into digital space.
			Business Extension	Realization of business models that were previously not feasible.
			Efficiency	Economic viability through process automation.
			Cost Reduction	Direct savings on transaction costs.
		Sovereignty	*Interoperability*	Ability to migrate public identifiers such as DIDs across networks.
			Portability	Ability to transfer personal data between service providers (e.g., wallet operators).
			Availability	Identity self-determination and resilience.
			Selective Disclosure	No information is shared beyond what is necessary to provide a business model.
			Mathematical Minimization	Business model integrates mathematically verifiable zero knowledge proofs (ZKPs).
			1st Party Customer Contact	SSI enables direct contact between verifying service and customer.
			Root-of-Trust	SSI's Verifiable Data Registries serve as trust anchor in cryptographic system.
	Target Audience	Identity Provisioning	*Natural Person*	Customers are human beings.
			Legal Person	Customers are private or public organizations.
			Things	Customers are things like machines.
		Segment	*Business-to-Business (B2B)*	Offering provided to business partners.
			Business-to-Customer (B2C)	Offering provided to private customers.
			Business-to-Government (B2G)	Offering provided to public authorities.
		Market Specialization	*Global Audience*	Offering available worldwide.
			Geographically Limited	Offering limited to certain regions.
			Domain-Specific	Offering limited to certain domain.
			Cross-Domain	Offering open across domains.
			Intra-Ecosystem	Offering limited to horizontal SSI network participants.
	Customer Relationship		*Education*	Operator educates on SSI.
			Customizability	Adaptability to customer preferences (e.g., service packages).
			Customer Support	Operator offers/integrates support.
			Service Co-Creation	Operator facilitates prosumerism.

Tab. A.10.: Definition of Value Architecture Characteristics.

Value Architecture	Verifiable Data Registry	Ledger	*DLT-enabled*	Business model utilizes DLT network.
			Cryptographic Self-Certifying	Business model builds on cryptographic primitives to establish trust (e.g., KERI).
			Hierarchical Database	Business model utilizes centralized public key infrastructure (e.g., X509 PKI).
			Chain-Agnostic	Business model allows multiple trust anchors set by users.
		Type	*Permissioned*	Write access to network ledger restricted.
			Permissionless	Write access to network ledger open.
			Private	Read access to network ledger restricted.
			Public	Each network participant has read access to the ledger.
			No Chain	Business model does not use DLT.
	Compliance	Laws	*International*	Business model focuses on global market.
			Supranational	Business model limited to certain states.
			National	Business model limited to a national level.
		Standards	*Technology Standards*	Adherence with, e.g., W3C.
			Regulatory Standards	Adherence with, e.g., KYC, AML.
			Industry Standards	Adherence with, e.g., DIF, AIP.
	Customer Interaction	Wallet Provisioning	*Own Wallet*	Business model includes wallet offering.
			Third Party Wallet	Business model uses 3rd party wallet without changing its appearance.
			White Label Wallet	Business model builds on customized 3rd party wallet.
			No Provisioning	No provisioning within business model.
		Interface	*Web-based Solution*	Graphical User Interface (GUI) accessible via desktop application or Internet browser.
			Mobile Application	Distribution of offering to mobile device.
			Server Application	Offering with GUI, SDK, or API.
			Embedded	Integration of business model into embedded device via agent software.
			No Provisioning	No provisioning within business model.
		Customer Data Storage	*On-Device Storage*	Customer utilizes own storage (e.g., phone)
			On-Premise Storage	Customer utilizes self-hosted cloud application.
			Cloud Storage	Customer trusts third-party service.
			No Provisioning	No provisioning within business model.

Tab. A.11.: Definition of Value Finance Characteristics.

Value Finance	Business Model Maturity	*Bootstrapping*	Business model conceptualized and communicated.
		Productive	Business model productive and available for customer.
	Customer Charge	*Free-of-Charge*	Business model does not charge customers.
		Cost-per-Transaction	Fees are charged based on ledger transactions.
		Subscription	Customers pay a monthly or yearly subscription fee.
		Cost-per-Connection	Fees are charged per connection to SSI trust triangle participant (e.g., cost-per-DID, pay-per-wallet).
		Value-based	Pricing is tailored to the individual value of a specific customer.
		Cost Mutualization	Network costs are split among participants.
		Not Specified	Customer charge not specified within business model.
	Payment Integration	*Fiat-Currency*	Acceptance of fiat currencies.
		CBDC	Acceptance of Central Bank Digital Currency.
		Stable Token	Acceptance of stable token.
		Volatile Cryptocurrency	Acceptance of cryptocurrencies.
		Not Integrated	Payment not integrated into business model.

Tab. A.12.: Changes to Kölbel, Härdtner, et al. (2023)´s Taxonomy following our Evaluation.

Initial Taxonomy Element	Operation*	Our Element after Evaluation
Stakeholder Value	*split*	**Stakeholder Value – Service Feature** **Stakeholder Value – Process Enhancement** **Stakeholder Value – Sovereignty**
/	*add*	**Service Feature**
/	*add*	Onboarding
/	*add*	Credential Exchange
/	*add*	Access Management
/	*add*	Know Your Customer
/	*add*	Track and Trace
/	*add*	Passwordless Authentication
/	*add*	Digital Signatures
/	*add*	Data Monetization
/	*add*	Other
Operational Convenience	*rename*	**Process Enhancement**
/	*add*	Digitalization
Revenue Extension	*rename*	Revenue Extension
Efficiency	/	Efficiency
Cost Reduction	/	Cost Reduction
/	*add*	**Sovereignty**
Interoperability	/	Interoperability
/	*add*	Portability
/	*add*	Availability
Digital Trust	*split*	Selective Disclosure Mathematical Minimization 1st Party Customer Contact Root-of-Trust
Target Audience – Customer Group	*rename*	**Target Audience – Identity Provisioning**
Natural Person	/	Natural Person
Legal Person	/	Legal Person
Non-Profit Entity	*delete*	/
/	*add*	Things
Target Audience – Segment	/	**Target Audience – Segment**
Business-to-Business (B2B)	/	Business-to-Business (B2B)
Business-to-Consumer (B2C)	/	Business-to-Consumer (B2C)
Business-to-Government (B2G)	/	Business-to-Government (B2G)
Target Audience – Market Specialization	/	**Target Audience – Market Specialization**
Global Audience	/	Global Audience
Geographically Limited	/	Geographically Limited
Industry-specific	*split*	Domain-Specific Cross-Domain
/	*add*	Intra-Ecosystem
Customer Relationship	/	**Customer Relationship**
/	*add*	Education
Customizability	/	Customizability
Customer Support	/	Customer Support
/	*add*	Service Co-Creation
Verifiable Data Registry	*split*	**Verifiable Data Registry – Ledger** **Verifiable Data Registry – Type**

*Operations based on Kundisch et al. (2022): *add* (insert a new element), *rename* (change the name of an element), *swap* (change the order of two elements), *split* (divide an element into at least two elements), and *delete* (remove an existing element)

Initial Taxonomy Element	Operation*	Our Element after Evaluation
Blockchain-enabled	*rename*	DLT-enabled
Other Network	*split*	Cryptographic Self-Certifying
		Hierarchical Database
		Chain-Agnostic
/	*add*	Permissioned
/	*add*	Permissionless
/	*add*	Private
/	*add*	Public
/	*add*	No Chain
Data Storage	*rename*	**Customer Interaction – Customer Data Storage**
On-Device Storage	/	On-Device Storage
/	*add*	On-Premise Storage
Cloud-Storage	/	Cloud-Storage
/	*add*	No Provisioning
Compliance – Regulatory	*rename*	**Compliance – Laws**
Know-Your-Customer (KYC)	*delete*	/
Anti-Money-Laundering (AML)	*delete*	/
EU General Data Protection Regulation (GDPR)	*delete*	/
Other	*delete*	/
/	*add*	International
/	*add*	Supranational
/	*add*	National
Compliance – Technological	*rename*	**Compliance – Standards**
W3C-Standards	*delete*	/
Other	*delete*	/
/	*add*	Technology Standards
/	*add*	Regulatory Standards
/	*add*	Industry Standards
Customer Channel – Wallet Provisioning	/	**Customer Channel – Wallet Provisioning**
Own Wallet	/	Own Wallet
Third Party Wallet	/	Third Party Wallet
Technology Provision Only	*rename*	White Label Wallet
/	*add*	No Provisioning
Customer Channel – Interface	/	**Customer Channel – Interface**
Web-based Solution	/	Web-based Solution
Mobile App	/	Mobile App
/	*add*	Server Application
/	*add*	Embedded
/	*add*	No Provisioning
/	*add*	**Ecosystem Layer**
/	*add*	Application Layer
/	*add*	Credential Layer
/	*add*	Communication Layer
/	*add*	Agent Layer
/	*add*	Public Data Layer
/	*add*	Governance Layer

*Operations based on Kundisch et al. (2022): *add* (insert a new element), *rename* (change the name of an element), *swap* (change the order of two elements), *split* (divide an element into at least two elements), and *delete* (remove an existing element)

Initial Taxonomy Element	Operation*	Our Element after Evaluation
Ecosystem Role	*rename*	**Business Model Focus**
Software-as-a-Service (SaaS)	*rename*	Software Provisioning
ID-as-a-Service (IDaaS)	*delete*	
Technical Enabling	*rename*	Technology Provisioning
/	*add*	Registry Provisioning
/	*add*	Knowledge Provisioning
/	*add*	Auxiliary Service
Key Partner – Enabling Partner	/	**Key Partner – Enabling Partner**
Technical Infrastructure Provider	*swap*	Technical Infrastructure Provider
Standard-Setting Community	*split*	Community Convenor
		Standard-Setting entity
Trust Provider	*split*	Government
		Auditing Partner
		Accrediting Partner
Key Partner – Industry Partner	/	**Key Partner – Industry Partner**
Technology Provider	*delete*	/
Developer Community	*delete*	/
Auxiliary Service Provider	*rename*	Service Provider
Stand Alone	*delete*	/
/	*add*	Investor
/	*add*	Advisor
/	*add*	Trust Service Provider
/	*add*	**Business Model Maturity**
/	*add*	Bootstrapping
/	*add*	Productive
Customer Charge	/	**Customer Charge**
/	*add*	Free-of-Charge
Cost-per-Transaction	/	Cost-per-Transaction
Subscription Fee	*rename*	Subscription
/	*add*	Cost-per-Connection
/	*add*	Value-based
/	*add*	Cost Mutualization
Not Specified	/	Not Specified
Payment Integration	/	**Payment Integration**
Fiat Currency	/	Fiat Currency
/	*add*	CBDC
Token-System	*split*	Stable Token
		Volatile Cryptocurrency
Not Integrated	/	Not Integrated
Cost Structure	*delete*	/
BESSI Development Costs	*delete*	/
External Registry User Costs	*delete*	/
Own Registry Provisioning Costs	*delete*	/

*Operations based on Kundisch et al. (2022): *add* (insert a new element), *rename* (change the name of an element), *swap* (change the order of two elements), *split* (divide an element into at least two elements), and *delete* (remove an existing element)

Tab. A.13.: Characteristic Frequency Distribution across Archetypes.

Dimension			Characteristic	Archetype					
				Platform-as-a-Service	Cross-Layer-Service	SSI-enabled Service	(SS)ID-as-a-Service	Infrastructure-as-a-Service	Network-as-a-Service
Number of Cases per Cluster				9	7	14	17	13	6
Value Network	Ecosystem Layer		Application Layer	78%	100%	100%	100%	8%	0%
			Credential Layer	78%	100%	100%	100%	8%	0%
			Communication Layer	89%	100%	14%	0%	69%	0%
			Agent Layer	89%	100%	14%	0%	69%	0%
			Public Data Layer	0%	43%	0%	0%	31%	0%
			Governance Layer	11%	43%	21%	6%	15%	100%
	Business Model Focus		Software Provisioning	100%	86%	100%	100%	23%	0%
			Technology Provisioning	22%	100%	0%	0%	85%	0%
			Registry Provisioning	22%	71%	50%	35%	31%	100%
			Knowledge Provisioning	11%	71%	14%	6%	38%	100%
			Auxiliary Services	11%	14%	7%	0%	23%	83%
	Partner	Enabling Partner	Community Convenor	33%	29%	7%	35%	15%	33%
			Standard-Setting Entity	100%	100%	50%	100%	92%	100%
			Government	22%	57%	21%	24%	8%	67%
			Auditing Partner	78%	43%	43%	47%	23%	83%
			Accrediting Partner	67%	43%	79%	59%	38%	100%
		Industry Partner	Technical Infrastructure	67%	43%	93%	100%	69%	100%
			Service Provider	100%	71%	93%	59%	69%	100%
			Investor	22%	14%	0%	12%	15%	67%
			Advisor	33%	14%	21%	24%	23%	0%
			Trust Service Provider	89%	43%	36%	76%	15%	100%
Value Proposition	Stakeholder Value	Service Feature	Onboarding	78%	43%	57%	76%	15%	33%
			Credential Exchange	89%	100%	86%	100%	54%	50%
			Access Management	33%	71%	43%	35%	8%	33%
			Know Your Customer	89%	43%	50%	47%	31%	33%
			Track and Trace	44%	43%	29%	18%	8%	50%
			Passwordless Authentication	56%	29%	29%	41%	8%	0%
			Digital Signatures	44%	43%	14%	24%	0%	17%
			Data Monetarization	11%	0%	50%	6%	23%	0%
			Other	22%	57%	7%	0%	85%	100%
		Process Enhancement	Digitalization	89%	86%	100%	100%	92%	100%
			Business Extension	89%	43%	21%	35%	8%	100%
			Efficiency	100%	100%	86%	94%	69%	100%
			Cost Reduction	100%	86%	86%	94%	77%	100%
		Sovereignty	Interoperability	67%	86%	36%	100%	69%	100%
			Portability	67%	86%	29%	82%	54%	83%
			Availability	67%	71%	43%	94%	46%	100%
			Selective Disclosure	78%	86%	57%	88%	38%	100%
			Mathematical Minimization	67%	43%	14%	35%	8%	0%
			1st Party Customer Contact	56%	100%	79%	88%	46%	100%
			Root-of-Trust	67%	100%	100%	88%	69%	100%
	Target Audience	Identity Provisioning	Natural Person	100%	100%	100%	94%	100%	83%
			Legal Person	67%	57%	14%	24%	85%	100%
			Things	44%	57%	7%	18%	62%	100%
		Segment	B2B	100%	86%	71%	100%	92%	100%
			B2C	44%	71%	100%	88%	46%	83%
			B2G	67%	29%	29%	59%	31%	83%
		Market Specialization	Global Audience	78%	14%	64%	76%	92%	33%
			Geographically Limited	22%	86%	36%	24%	15%	67%
			Domain-Specific	11%	14%	79%	12%	0%	17%
			Cross-Domain	100%	71%	29%	88%	100%	83%
			Intra-Ecosystem	33%	29%	0%	18%	0%	83%
	Customer Relationship		Education	22%	57%	14%	24%	23%	100%
			Customizability	89%	43%	14%	35%	15%	67%
			Customer Support	56%	14%	36%	71%	15%	17%
			Service Co-Creation	44%	43%	0%	29%	8%	83%

Dimension			Characteristic	Archetype					
				Platform-as-a-Service	Cross-Layer-Service	SSI-enabled Service	(SS)ID-as-a-Service	Infrastructure-as-a-Service	Network-as-a-Service
Number of Cases per Cluster				9	7	14	17	13	6
Value Architecture	Verifiable Data Registry	Ledger	DLT-enabled	33%	100%	100%	76%	62%	100%
			Cryptographic Self-Certifying	0%	0%	0%	0%	8%	0%
			Hierarchical Database	22%	0%	0%	0%	0%	0%
			Chain-agnostic	44%	29%	0%	24%	31%	17%
		Type	Permissioned	22%	43%	64%	71%	15%	100%
			Permissionless	11%	43%	36%	6%	46%	0%
			Private	11%	29%	14%	6%	8%	0%
			Public	22%	57%	86%	71%	54%	100%
			No Chain	67%	14%	0%	24%	38%	0%
	Compliance	Laws	International	0%	0%	0%	0%	0%	16%
			Supranational	89%	57%	57%	88%	77%	83%
			National	44%	57%	79%	41%	31%	50%
		Standards	Technology Standards	100%	100%	79%	100%	92%	100%
			Industry Standards	100%	71%	93%	94%	69%	100%
			Regulatory Standards	33%	43%	57%	47%	8%	67%
	Customer Interaction	Wallet Provisioning	Own Wallet	56%	71%	57%	94%	8%	0%
			Third Party Wallet	22%	14%	36%	12%	23%	33%
			White Label Wallet	56%	29%	14%	18%	8%	0%
			No Provisioning	11%	14%	7%	0%	69%	67%
		Interface	Web-based Solution	56%	57%	57%	82%	31%	17%
			Mobile Application	78%	86%	93%	94%	23%	33%
			Server Application	89%	71%	29%	65%	85%	33%
			Embedded	0%	0%	7%	6%	0%	0%
			No Provisioning	0%	14%	0%	0%	0%	67%
		Customer Data Storage	On-Device Storage	56%	86%	100%	94%	38%	50%
			On-Premise Storage	78%	57%	64%	76%	46%	50%
			Cloud-Storage	89%	43%	29%	35%	23%	17%
			No Provisioning	0%	0%	0%	0%	54%	50%
Value Finance	Ecosystem Maturity		Bootstrapping	11%	57%	71%	24%	76%	33%
			Productive	89%	43%	29%	71%	62%	67%
	Customer Charge		Free-of-Charge	33%	29%	14%	53%	31%	0%
			Cost-per-Transaction	22%	0%	14%	18%	23%	17%
			Subscription	44%	0%	0%	18%	8%	17%
			Cost-per-Connection	22%	0%	7%	0%	8%	0%
			Value-based	0%	0%	7%	0%	0%	0%
			Cost Mutualization	0%	0%	0%	0%	8%	0%
			Not Specified	44%	86%	71%	53%	54%	83%
	Payment Integration		Fiat-Currency	11%	0%	21%	6%	8%	0%
			CBDC	11%	0%	0%	0%	0%	0%
			Stable Token	22%	14%	29%	6%	15%	0%
			Volatile Cryptocurrency	11%	0%	29%	0%	0%	0%
			Not Integrated	78%	86%	50%	88%	85%	100%