Proceedings of the 56th Hawaii International Conference on System Sciences | 2023

Requirements and Design Principles for Blockchain-enabled Matchmaking-Marketplaces in Additive Manufacturing

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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

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 et al., 2021). Over the past decade, sub-economies such as platform economy, sharing economy, gig economy, or blockchain (BC) economy have emerged (Weinhardt 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 business-to-business (B2B) sector (Cusumano, 2015; European Commission, 2020), 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 (European Commission, 2017; Kölbel et al., 2022).

With BC 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, BC networks are governed by communities and operate across distributed networks. The information systems (IS) community explores this avenue with publications on BC-enabled marketplaces (BEMs) that aim to strengthen self-determined, privacy-preserving, and trusted B2B interaction (Dann et al., 2020; Hofmann et al., 2021; Notheisen et al., 2017). Yet – in contrast to research on centralized marketplaces, which relies on concepts based on previously identified requirements (Freichel et al., 2019) – a literature review on BEMs notes a paucity of structured approaches, including principles for designing BEMs (Kölbel et al., 2022).

URI: https://hdl.handle.net/10125/103287
978-0-9981331-6-4

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 et al., 2021) by linking facets of marketplace sharing with the BC economy. Second, we concentrate on the BC infrastructure of electronic markets (Alt, 2020) and specifically study requirements and principles for the structured design of BEMs, that represents a striking research gap (Kölbel et al., 2022). Third, we focus on the use case of additive manufacturing (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 et al., 2019). Collectively, this study is driven by the following research question: *Which requirements and principles should be considered when designing BEMs for matching AM supply and demand?*

Our paper proceeds as follows. Section 2 presents foundations and related work on BEMs in AM. Section 3 introduces our methodology. Section 4 reports our research results by proposing requirements and design principles. Section 5 concludes with contributions, limitations, and future research opportunities.

2. Foundations and Related Work

We position our research question at the intersection of three topics in IS: capacity sharing in production networks, AM marketplaces, and BEMs 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 & Kunz, 2020) and *Matchmakers* (Evans & 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 (Hofmann et al., 2021; Stein et al., 2019). 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 & 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 & 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 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 BC 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 et al., 2022). In line with the perspective of Notheisen 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 BC-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 BC-based collaboration platforms. In addition, we encounter publications with technical frameworks for BEMs in manufacturing (Hasan & Starly, 2020; Hofmann et al., 2021; Rožman et al., 2021), 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 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 design principles, the fundamental basis of any marketplace design (Gimpel et al., 2008), represents a striking research gap.

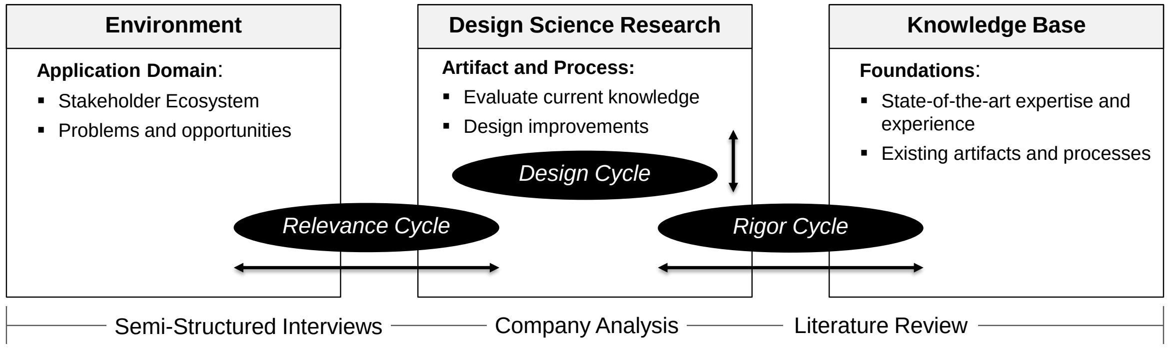

Figure 1. Hevner's three-staged DSR approach (Hevner, 2007) and applied research methods

3. Methodological Approach

Our paper employs Design Science Research (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 1, we fall back on Hevner's three-stage approach: the rigor cycle, the relevance cycle, and the design cycle (Hevner, 2007).

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 (SLR)** 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 BEMs and explicitly or implicitly addresses requirements. This comprises frameworks and prototypical concepts, and simulations that provide insights regarding mediating supply and demand through BC and other web3 technologies. Third, we focus on literature in the field of AM. Consequently, we exclude studies that consider BC as a database (i.e., 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 LR (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 1).

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

[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)

Table 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/

Table 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 BC Research	11 years	59 min

practitioners (Paré, 2004). We selected the interviewees (Table 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 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 SLR (Corbin & 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 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 & 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 & 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 & 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 (DRs) in the following section.

4. Design Rationales for Blockchain-enabled Marketplaces

Next, we focus on DRs for BEMs in AM that emerge from our LR, company analysis, and expert interviews (see Table 3). We derive 27 mandatory requirements (MRs), six optional requirements (ORs) and formulate 12 design principles (DPs) using the structure proposed by Chandra et al. (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.

4.1. Information and 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 identities (IDs)**. In AM scenarios, ID attributes **(MR1)** include both company IDs **(MR1.1)** (Al-Jaroodi & Mohamed, 2019) and 3D printer machine IDs **(MR1.2)** (Angrish et al., 2018; Hofmann et al., 2021). 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; M. Li et al., 2021; Rožman 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 & 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 Self-Sovereign Identities (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 et al., 2018) and integrity (Barenji et al., 2018) are crucial **(MR3)**. Especially in AM scenarios, sensitive and competition-relevant data (e.g., CAD product designs) are shared (E1-5) and must reach their destination without tampering **(MR3.1)** (Ghimire et al., 2021; Z. Li et al., 2018, E3-8). Consequently, data storage and exchange design should ensure that only the most necessary data – depending on individual requirements or use case (Herm & 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 BC protocols (Kurpjuweit et al., 2021; Lu et al., 2019).

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

Status updates of production processes and visualizations of real-time data **(OR2)**, as proposed by several researchers (Engelmann et al., 2018; Ghimire et al., 2021) 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.*

4.2. Intention and 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 et al., 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) (Freichel et al., 2021; Stein et al., 2019) 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 et al., 2021), product quality,

Table 3. Synthesizing Description of Design Rationales

	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.

certification, and delivery date (Freichel et al., 2021; Hofmann et al., 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 user interface (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 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 M2M 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 [6] 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 & 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.*

4.3. Clearing and 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)** (Hasan & Starly, 2020; Kaynak et al., 2020; Leng et al., 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 (Angrish et al., 2018; Kaynak et al., 2020). 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.*

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 BC-based B2B logistics (Beck 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 & 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.*

5. Discussion and Conclusion

The decentralization of marketplace models through BC-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 SLR 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 (Hofmann et al., 2021; Stein et al., 2019). Thereby, we follow the call for a more nuanced approach to this topic (Kölbel et al., 2022), which focuses on the BC infrastructure of electronic markets (Alt, 2020) and links the sub-economies of marketplace sharing with BC economies (Weinhardt 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 et al., 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 DRs, which contributes to narrowing the chasm between promised business and the actual value of BC for organizations.

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