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Developing Blockchain-enabled Marketplace Interfaces: A Design Science Research Study

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Abstract

Digital transformation's scope evolves from being limited to the organizational level to inter-organizational collaboration in supply chain networks and business ecosystems. Blockchain-enabled marketplaces have the potential to transform business networks by eliminating intermediaries. To investigate the interface design and visualization of blockchain-enabled marketplaces, 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

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 (Beverunge 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 (European Commission, 2021; Mourtzis et al., 2021) to respond flexibly to overcapacity or capacity bottlenecks caused by demand volatility and machine availability. The sharing economy for business-to-business (B2B) is also deemed increasingly important (Große, 2022; Ocicka & Wieteska, 2017); however, organizations are still hesitant to share their data across organizational boundaries and participate in ecosystems (Prieëlle et al., 2020; 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 & Kunz, 2020; European Commission, 2018; Hawlitschek et al., 2016). This paradigm shift is reflected in legislative initiatives such as the European *Data Governance Act* and the *Digital Markets Act*, as well as in alternative concepts on decentralized markets powered by blockchain (BC) technology (Kölbel et al., 2022; Dann et al., 2020; Notheisen et al., 2017). Although BC 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 & 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 & Kunz, 2020; Zavolokina et al., 2020; Jensen et al., 2019). An emerging research area in the field of information systems (IS) that follows this notion is blockchain-enabled marketplaces (BEMs). Studies explore BEMs potential for equal value creation (Kollmann et al., 2020), requirements for their design (Kölbel 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 BEM interfaces (BEMIs) 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 **research question:** *How can BEMIs be designed that effectively support supply and demand matching in CAM?*

We conduct a Design Science Research (DSR) study (Kuechler & 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 and design principles inspired by the theory of effective use (TEU) (Burton-Jones & Grange, 2013). We then derive tangible design features 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 BC 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.

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 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 1.

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 (SLR) 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 & Muntermann's (2014) 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).

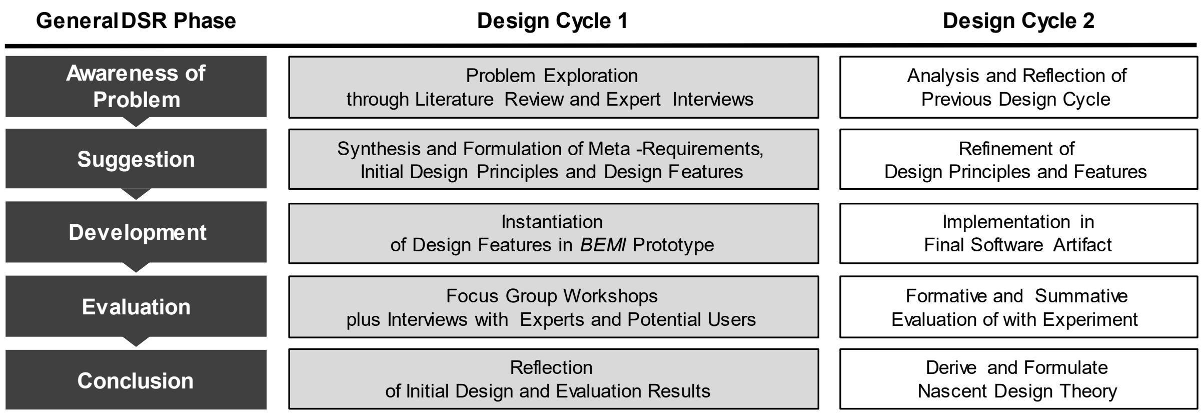

Figure 1. Design Science Research Methodology based on Kuechler & Vaishnavi (2008)

The SLR 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 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 SLR 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 & Strauss, 2008) and a qualitative content analysis approach following Mayring (2000). The interviews and SLR supported the practical relevance of our research before artifact development (Sonnenberg & Vom Brocke, 2012) and revealed that transparent interaction with BEMIs is vital for effective use but achieving it can be more complex than expected.

Development & Evaluation. Drawing on the TEU (Burton-Jones & Grange, 2013) as our overarching kernel theory, we derived Meta-Requirements (MRs) 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 MRs, we then proposed initial Design Principles (DPs) following Gregor et al. (2020) and translated these DPs into tangible Design Features (DFs) 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 (Step 1) 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 (Step 2) 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 1). In this step, we demonstrated the instantiated artifact by a click-through and asked for feedback on effectiveness, efficiency, and consistency.

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 unique experts or users involved

Table 1. Interview and Focus Group Overview

Designing Interfaces for Blockchain-enabled Marketplaces

Problem Description & Suggestion

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 additive manufacturing (Kölbel 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 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 non-fungible tokens *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 an SLR 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 2, and separated into general requirements for user interfaces, 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 MRs, DPs, and DFs for designing BEMIs below and discuss challenges that companies face in the design process.

	Dimensions	Usability					Aesthetics		User orientation		Technical concepts			
	Characteristics	Efficiency	Simplicity	Recognition value	Intuitiveness	Error prevention	Layout	Coloring	Target group	Requirements	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							○					●	

Table 2. Synthesis of Literature Review Findings on Interface Design

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 & Grange, 2013). Users' participation in adapting a system's interface structure is typically facilitated through personalization of the user interface or by providing suggestions for improvement to system designers. These suggestions 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 & Grange, 2013). Emphasizing an operational perspective, the design of BEMIs should prioritize simplicity and user-focused information (Ferris & 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 & Zhang, 2016; Alpha 3-5). However, finding a balance between simplicity and trustworthiness **(MR1)** 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:** “*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 & Grange, 2013) by providing concise and audience-specific explanations of complex concepts **(MR2)**, thereby fostering intuitive and user-friendly interfaces. This can be achieved through comprehensive documentation (Garett et al., 2016; Mazumder, 2014; Molich & 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 BC technology is often complex, and users need to understand key concepts such as digital signatures, consensus algorithms, and smart contracts. Another subpage should explicitly focus on community engagement (Gamma 1). As BC 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 BC 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 **DP2:** “*Design BEMIs that support users' learning and engagement by providing comprehensive documentation to foster trust by transparency and stimulate innovation in decentralized communities.*”

Identity management (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 & Brown, 2017). Self-sovereign authentication methods are emphasized by experts as vital instantiations, as they enable users to manage and verify their digital identities without relying on central authorities (Kölbel et al., 2023; Alpha 1, 3). The identities should be designed for interoperability, easily accessible, and manageable by users across different platforms **(MR3)**. 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 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 & Brown, 2017), only verified participants should be able to interact with each other (Alpha 2). As such, a fair, transparent and interoperable reputation system **(MR4)** 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 **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 **(MR5)** 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 et al., 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) **(MR6)** (Garett et al., 2016; Mazumder, 2014; Nielsen, 1994; Alpha 1, 4, 5; Beta 1). Considering this, we argue implementing our fourth **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 & Zhang, 2016; Molich & Nielsen, 1990; Alpha 1). A high error rate can negatively impact the system's usability, reducing both efficiency and user satisfaction (Mazumder, 2014; Ferre et al., 2001; Nielsen, 1994). Therefore, functions should be implemented that instantly validate inputs and alert users to any errors **(MR7)**. 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 **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 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 **(MR8)**. 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 BC technology raises concerns over the potential exposure of confidential information if it is stored publicly on the BC (Kölbel et al., 2022). To address these concerns, BEMIs should feature functionalities that allow for secure off-chain storage of confidential information in peer-to-peer databases instead of transparently on the BC (Kölbel et al., 2023; Alpha 5). This approach mitigates BC protocol limitations (Herm & 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 peer-to-peer 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 **DP6:** "*Design BEMIs with external storage connectivity to mitigate blockchain scalability issues and enable privacy-preserving data storage.*"

BEMs involve complex mechanisms like smart contracts, 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) **(MR9)**. 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 indicators (KPIs) 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 **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 **(MR10)**. 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 2 illustrates the overall process with ten MRs, eight DPs, and 16 DFs.

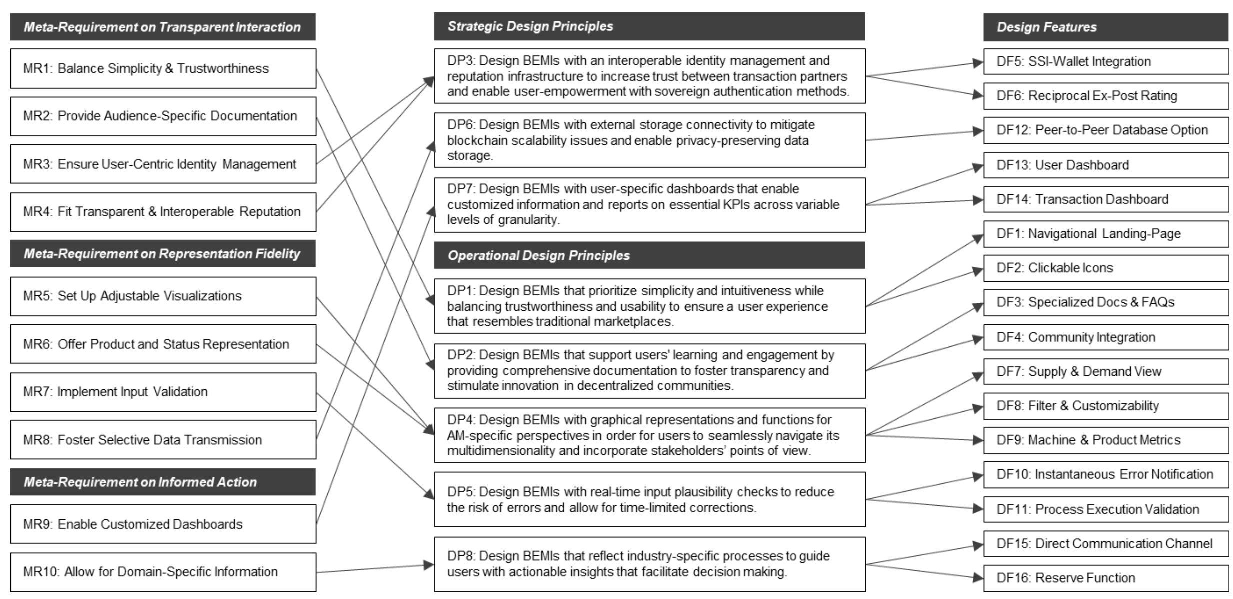

Figure 2. Mapping of Meta-Requirements, Design Principles and Design Features

Development & Evaluation

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 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 (decentralized autonomous organizations) allow the community to decide on the direction of the marketplace, while the SDK 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 credentials (VCs), 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 & 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 BC-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 BC due to scalability limitations are integrated into BEMIs through peer-to-peer database linking (DF12). For example, images and technical specifications on 3D printers are integrated externally via the InterPlanetary File System (IPFS). This linking ensures that all relevant information is readily available to users without compromising the security and scalability of the BC-based system.

The marketplace's supply and demand side are complemented by specific dashboards that function as information subsystems connecting the marketplace backend and BC 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.

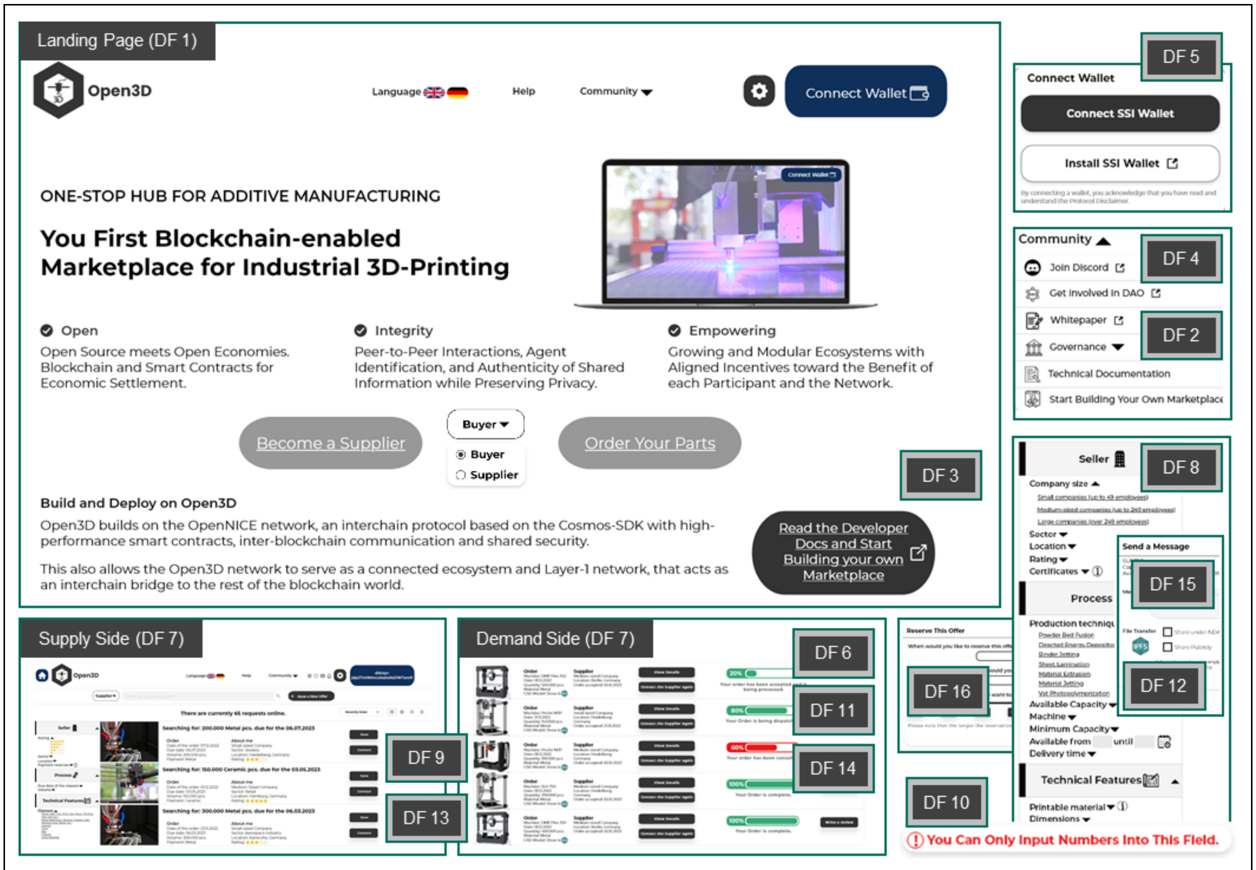

Figure 3. BEMI Prototype '*Open3D Marketplace*' and Design Features

Evaluation episodes. In DSR, the literature recommends conducting multiple evaluation episodes during and after the design process (Venable et al., 2016; Sonnenberg & Vom Brocke, 2012). Therefore, in this study, we performed four evaluation episodes, including ex-ante and ex-post evaluations, in different settings (see Method section). 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 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 BC 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, peer-to-peer database linking (DF12) was seen as necessary for ensuring the accessibility of all relevant information without compromising the security and scalability of the BC-based system. Experts appreciate that sensitive data is kept off the BC 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.

Discussion and Conclusion

The potential disruptive effects of BC-enabled networks and marketplace models have been recognized in literature, particularly in cross-company scenarios (Kölbel et al., 2023; Mourtzis et al., 2021). This article complements previous research on the BC 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 BC economies (Weinhardt 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 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 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 & Hevner, 2013). As such, we have taken initial steps in developing a nascent design theory by formulating MRs and DPs that draw inspiration from the TEU (Burton-Jones & 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 transferrable to other solution spaces, opening avenues for designing a broader class of BEMIs that can be adapted to different contexts (Chandra et al., 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 key performance indicators (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 & 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.

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