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Striking a balance: Designing a blockchain-based solution to navigate coopetition dynamics in supply chain management

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Abstract

Coopetition dynamics, which refer to the simultaneous competition and cooperation, increasingly affect the management of digital supply chains. Current research profoundly explores the benefits and drawbacks of using blockchain systems in coopetition strategies to boost cooperation and automation in supply chains. However, these systems often do not adequately address how to manage competition dependencies, which practitioners need to address when considering adopting a blockchain solution that contains excessive disclosure of sensitive information during the data exchange within a transparent network. This paper examines how to protect such sensitive information essential for maintaining competitive dynamics. Following a design science research approach, we suggest a blockchain architecture specifically tailored to the construction industry. We focus on components that manage competition and privacy-enhancing technologies that address the trade-off between cooperation benefits and the need to protect sensitive business data, which is especially crucial in supply chain automation. This study contributes to the current scientific discourse by designing and deriving implementation guidelines for a solution that incorporates the benefits while addressing the potential drawbacks of blockchain technology through coopetitive data exchange to diffuse blockchain solutions into practice successfully.

Keywords Coopetition · Blockchain technology · Data transparency · Delivery invoices · Construction industry · Supply chain automation

JEL Classification O14

Abbreviations

API Application programming interface
BIM Building information management
ERP Enterprise resource planning

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CRM	Customer relationship management
DLT	Distributed ledger technology
DP	Design principle
DO	Design objective
EC	Exclusion criteria
EDI	Electronic data interchange
EDM	Electronic document management
EU	European Union
GDPR	General data protection regulation
IC	Inclusion criteria
IS	Information systems
PKI	Public key infrastructure
ZKP	Zero-knowledge proof
DSR	Design science research
SLR	Systematic literature review
SME	Small and medium-sized enterprise
ICT	Information and communication technology
B2B	Business-to-business
B2C	Business-to-customer
HTTPS	Hyper Transfer Protocol Secure
OEM	Original equipment manufacturer

WTA Winner-takes-all
 PET Privacy-enhancing Technology

Introduction

Amid the ongoing digital transformation, coopetition—characterized by the simultaneous interplay of inter-organizational cooperation and competition—has become increasingly significant in the domain of supply chain networks (Bengtsson & Kock, 2000; Bouncken et al., 2015; Nalebuff & Brandenburger, 1997). Particularly in the context of supply chain automation, these concepts entail the formation of alliances between suppliers, manufacturers, and distributors that go beyond arm's-length transactions. Firms share real-time data—such as inventory, demand forecasts, and production capacity—to boost decision-making and operational efficiency—all while maintaining market competition (Brandao et al., 2025; Katsaliaki et al., 2024). However, while digital networked information systems aim to streamline cooperative supply chain operations (Hein et al., 2019; Ivanov et al., 2022), they are often built on proprietary, centralized platforms controlled by a single entity. These platforms, designed to consolidate supply chain actors, frequently result in winner-takes-all (WTA) scenarios, where dominant players establish network and, thus, market control at the expense of smaller competitors (Fernandez & Chiambaretto, 2016). For example, Schüttflif, a German digital marketplace for construction supplies, integrates a wide range of construction firms, transporters, and suppliers into a centralized platform (Fivetran, 2023). This structure benefits from strong network effects, reinforcing a self-sustaining cycle that enhances market efficiency. On the one hand, such platforms provide especially smaller supply chain participants, i.e., small- and medium-sized enterprises (SMEs), with cost-effective access to digital solutions they might otherwise lack. On the other hand, they create significant risks by centralizing data and interactions, granting platform owners access to sensitive business information that could be exploited for competitive advantage (Gleiss et al., 2023; Hoess et al., 2024; Loertscher & Marx, 2020). As a result, direct competitors may hesitate to participate in these platforms while fearing a loss of strategic leverage. This reluctance contributes to market fragmentation, as companies endeavor to guard their competitive edge by creating isolated, proprietary solutions. Such strategies impede collaborative data-sharing frameworks, ultimately obstructing the advancement of automated supply chain processes (Abdelkafi et al., 2019).

In this regard, pertinent research highlights blockchain technology as a promising standardizing solution to leveraging network effects while mitigating the disadvantages of centralized market power. Researchers proclaim that the

implementation of blockchain technology has the potential to counteract digital monopolism and foster cooperation and supply chain automation among its participants by facilitating trust, transparency, and seamless data exchange without reliance on a central authority (Babich & Hilary, 2020; Elghaish et al., 2023; Erri Pradeep et al., 2021; Napirata et al., 2023). In addition to enhancing trust and transparency, blockchain-based systems are increasingly recognized as enablers of automated coordination in supply chains—particularly in settings characterized by strategic interdependence and fragmented infrastructures. As such, blockchain not only supports the organizational dimension of coopetition but also contributes to the automation of transactional processes such as delivery invoicing, order verification, or payment triggers (Elghaish et al., 2023; Tezel et al., 2021). However, despite its theoretical potential and its proclaimed promises, blockchain adoption in supply chain networks in practice remains scarce and limited, which might be a result of data confidentiality concerns arising from its inherent transparency extent and the insufficient integration of competitive considerations into system design (Bossler et al., 2024; Sedlmeir et al., 2022).

Thus, to ensure broader adoption and to enable supply chain automation in the first place, blockchain implementations may need to address key business concerns by aligning with core strategies for cooperative supply chain participation. In other words, effective coopetition should balance cooperation and competition—grounded in trust and commitment—to foster strong relationships among supply chain partners (Ketchen et al., 2004; Sternberg et al., 2020). Previous studies within the supply chain domain remain at rather a conceptual level, emphasizing coopetition outcomes (Butt, 2025) structures and relationship archetypes (Katsaliaki et al., 2024; Patrucco et al., 2022) and distinct types of coopetition in supply chains (Brandao et al., 2025). In research emphasizing information sharing, cooperative benefits are praised, while competitive risks are underexplored, particularly regarding the exposure of sensitive business information (Elghaish et al., 2023; Erri Pradeep et al., 2021; Wang et al., 2020; Yang et al., 2020). Addressing this research gap, we emphasize the competitive dimension of blockchain-based coopetition strategies in supply chain management, focusing on confidential data sharing as a key aspect of inter-organizational competition. By applying coopetition as a theoretical lens, we investigate the design of a conceptual blockchain architecture that balances cooperation and competition, mitigating transparency risks while enabling sustainable market participation. Thus, we ask the following:

RQ: How to design a blockchain-based information system to facilitate coopetition in supply networks by fostering cooperative interactions while ensuring data confidentiality?

To address our research question, we adopt a design science research (DSR) approach following Peffers et al. (2007) to develop our design iteratively. We focus on the construction industry as a WTA market, where effective data-sharing management is crucial for decentralized supply chains (Ekeskär et al., 2021; Muchuku, 2018). Characterized by contract-based and project-specific supply networks, the industry relies on seamless data exchange for cooperation and automation, as seen in building information management (BIM) or cloud supply chains (Elghaish et al., 2023; Hijazi et al., 2022; Ivanov et al., 2022). However, its dynamic structure, involving frequently changing stakeholders, presents challenges in maintaining data confidentiality (London & Kenley, 2001). In this context, the inter-organizational exchange of delivery invoices containing sensitive business data serves as a key unit of analysis for examining decentralized data-sharing mechanisms that balance cooperation and competition.

The remainder of our paper is structured as follows: First, we introduce the concept of coopetition (Bengtsson & Kock, 2014; Gnyawali & Park, 2011), how this plays out in the construction industry, and provide an overview of blockchain technologies' functionalities as a potential solution. Second, we describe our methodological approach, including the explanation of our approach providing a systematic literature review (SLR) that forms the basis of our artifact design process following Kruchten (1995), providing an introduction to the *FEDs evaluation framework* following Venable et al. (2016) to assess our conceptual architecture, and introduce the DSR approach we use as overall research guidance. Third, we process the results of our methodical approach and present both the foundational design objectives and the resulting artifact. Lastly, we derive strategic business implications from the given architecture and develop implementation guidelines for developing future decentralized information systems considering the coopetition perspective in supply chain networks.

Foundations

Coopetition

Coopetition, a portmanteau of cooperation and competition, encapsulates the strategically controllable relationship wherein organizations engage in both cooperative and competitive behaviors simultaneously (Bengtsson & Kock, 1999, 2000; Nalebuff & Brandenburger, 1997). The theoretical underpinnings of coopetition draw from strategic management and game theory, amalgamating insights from organizational behavior, economics, and sociology to offer a lens to holistically understand how organizations strategically navigate the complexities of cooperative and competitive

interactions, especially within inter-organizational settings (Bengtsson & Kock, 2014; Raza-Ullah et al., 2014). While traditionally competitive and cooperative perspectives were theoretically advanced as separate research streams, largely operating in silos, introducing the novel concept coined coopetition led to a paradigm shift challenging conventional dichotomies between competition and cooperation (Gnyawali & Park, 2011; Nalebuff & Brandenburger, 1997). Coopetition contends that in dynamic environments marked by uncertainty, rapid technological progress, and complex interdependencies, organizations are compelled to forge strategic alliances, partnerships, and networks with competitors while concurrently safeguarding and advancing their competitive interests (Nalebuff & Brandenburger, 1997). Thus, coopetition theory serves as a lens through which organizational strategies and industry structures can be shaped, accounting for both cooperative and competitive dynamics within inter-organizational relationships (Gnyawali & Park, 2011). In cooperative dynamics, organizations collaborate to achieve mutual goals like innovation, knowledge sharing, resource pooling, and market expansion (Nalebuff & Brandenburger, 1997). This collaboration typically takes the form of joint research projects, consortia, standard-setting initiatives, or knowledge exchange platforms, emphasizing resource pooling to foster innovation, reduce costs, and broaden market reach through shared capabilities and expertise (Cennamo & Santalo, 2013; Patrucco et al., 2022). Conversely, competitive dynamics within coopetition involve firms vying to capture market share, enhance profitability, and maintain or improve their competitive positions (Bouncken et al., 2015).

Pertinent research considers two principles that coopetition management literature has delineated in theoretical strategies being crucial for understanding and navigating the dualism of competition and collaboration within business relationships—the “*Separation Principle*” and the “*Integration Principle*” (Bengtsson & Kock, 2000; Fernandez & Chiambaretto, 2016). First, the *Separation Principle* posits that managing competition and collaboration effectively requires a clear delineation, which can be achieved through functional, temporal, or spatial segmentation (Bengtsson & Kock, 2000; Chen et al., 2010). This approach allows organizations to compartmentalize aspects of competition and collaboration, thereby minimizing conflict and enhancing focus on each dimension independently. Conversely, the *Integration Principle* advocates for a more holistic approach, urging individuals to embrace and transcend the inherent paradoxes of coopetition (Chen et al., 2010). This approach involves developing a coopetitive mindset, enabling managers to internalize the paradoxical nature of coopetition and adeptly manage the ensuing tensions. Such a mindset plays a pivotal role in discerning and capitalizing on the synergistic potentials inherent in coopetition, consequently nurturing

innovation and competitive advantage. Hence, it emerges as a pertinent guiding principle for developing a holistic information system which we will follow to develop our information system to answer the research question (Gnyawali & Park, 2011).

Sustainable digital delivery invoice processes as the unit of analysis for coopeition in the construction industry

The strategic rollout of coopeition strategies finds resonance in real-world scenarios, such as the complex supply networks within the construction industry. The significance of coopeition within the construction industry can be attributed to several factors. Firstly, forming a *virtual* organization for each major construction project underscores the necessity for cooperative efforts to achieve shared benefits (Muchuku, 2018; Saad et al., 2002; Segerstedt & Olofsson, 2010). Often, this necessitates the establishment of comprehensive supply networks that require close cooperation through seamless data exchanges, which is, for example, particularly evident in the context of BIM and further accelerated by the ongoing process of digitalization (Elghaish et al., 2023; Hijazi et al., 2022; Irizarry et al., 2013). Conversely, the transient nature of supply chains within the construction industry, frequently reconfigured for each new construction site, exacerbates complexities surrounding the imperative of data sharing confidentiality (London & Kenley, 2001). This necessity is underscored by operational imperatives and stringent legal considerations, including the imperative to comply with cartel laws during tender processes. Secondly, the concurrent operation of multiple construction projects involving diverse stakeholders accentuates the competitive dynamics inherent within the industry, highlighting the complex interplay between cooperation and competition, where effective data sharing is pivotal (Ekeskär et al., 2021). This dynamic extends across various stages of the construction supply chain, emphasizing the critical role of data sharing in maintaining operational efficiency and facilitating seamless coordination among stakeholders. The broad scope of activities typically undertaken by construction firms further underscores the importance of robust data-sharing mechanisms to facilitate coopeitive decision-making and optimize resource allocation in a competitive environment (Segerstedt & Olofsson, 2010). Within this context, exchanging delivery invoices emerges as a pertinent unit of analysis for exploring the design of an IS that considers the different dimensions for data sharing within a supply network through the conceptualization of coopeition. Here, stakeholders collaborate and compete in a dynamic environment, as exemplified by the digitization of paper-based delivery invoices between construction firms, suppliers, and logistics firms (Ekeskär et al., 2021). This process, involving multiple actors across

the supply chain, underscores the complex interplay of data sharing requirements within cooperation and competition. By examining this practical illustration, we gain insight into how to design an information system that fosters data sharing under coopeition dynamics within complex business environments.

In the construction industry, different stakeholders exchange delivery invoices with each other to document the delivery of goods or services from one party to another and record payment for those goods or services. The current exchange of delivery invoices, typically paper-based, contains a record of orders and delivery details passed on to supply chain stakeholders to ensure they agree on the transaction details. This process involves multiple stakeholders in the construction industry supply chain, such as a construction firm ordering building materials from a supplier, who then hires a transport and logistics firm to deliver the materials to the construction site. Additionally, the process includes the participation of various employees from different supply chain stakeholders, which leads to a long and complex process with many steps. Besides paper-based processes, existing digital solutions in the construction industry use standardized data formats for electronic data interchange (EDI) of digitalized bills (Gibson & Bell, 1990)—e.g., by using *XRechnung* or *EDIFACT*—to handle the processing of delivery invoices (Samuelson & Björk, 2014; Wiehager, 2021). However, despite their promising potential, the effectiveness of digital solutions is limited due to market fragmentation and the absence of a universally accepted digital infrastructure that caters to the diverse needs of firms, regardless of their size. This market structure suggests that current digital solutions, irrespective of their standardization and data formats, face significant challenges regarding practical implementation and widespread adoption in the business market (Demirkenes & Tezel, 2021). A single digital solution tailored to specific industry interests cannot fully address the construction industry's unique requirements. Challenges such as partial services, change orders, retention payments, and industry-specific standards pose interoperability issues for digital solutions. Achieving widespread acceptance requires cooperation among all stakeholders, including contractors, sub-contractors, suppliers, authorities, and customers. However, in the construction industry, processing delivery invoices is complex due to rudimentary and differing information systems and supporting processes. Finally, centralized systems controlled by individual firms or domain-specific solutions hamper information flow and impede widespread adoption and collaboration among stakeholders (Pagel, 2019). Figure 1 shows exemplary the coopeition information systems dilemma of a centralized structure leading to monopolism and data centralism as well as a simplified decentralized network, showing disintermediation potential yet facing a data transparency trade-off.

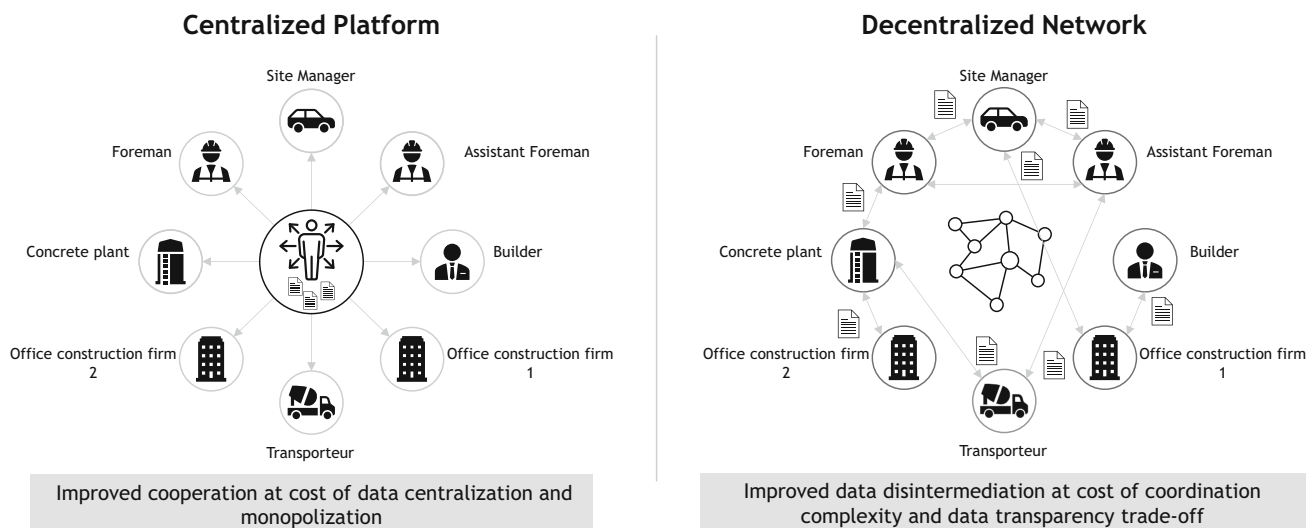


Fig. 1 The competition information system dilemma

In the construction sector, where cooperation among numerous stakeholders is vital, a centralized approach can create barriers and hinder the seamless flow of information between the different parties involved, thus resulting in monopolistic structures without widespread adoption across the market. These centrally organized systems do not prioritize the interests of a supply ecosystem, nor do they include concepts for distributed data storage and shared utilization. Thus, a decentralized system and underlying infrastructure promise benefits for digital delivery invoices to enhance process efficiency, digitalize delivery invoice documents, and ensure auditability (Elghaish et al., 2023). In this context, blockchain technology is regarded a promising solution that can meet these demands and leverage the advantages of an interoperable platform, particularly in terms of secure data exchange (Sternberg et al., 2020). However in such a context, sharing detailed invoice data through existing digital solutions raises concerns about potential antitrust violations and breaches of confidentiality. These concerns are a barrier to the broad acceptance and implementation of digital invoicing solutions provided by single stakeholders and decentralized solutions, as firms prioritize compliance with antitrust regulations to avoid legal consequences (Agdas & Ellis, 2010; Anumba & Ruikar, 2002).

Blockchain technology as potential solution

Blockchain technology has the potential to offer several benefits to handle coopetition in digital supply chain networks and particularly in the construction industry. Most importantly, it provides an alternative decentralized solution approach to break up centralized governed and siloed solutions which are exploiting the benefits of lock-in effects

within the WTA construction market structure (Babich & Hilary, 2020; Fernandez & Chiambaretto, 2016; Sedlmeir et al., 2022). Beside structural benefits towards centralized market exploitation, pertinent research disclaimed blockchain technology with several potential benefits within the field of supply chain management. For instance, blockchain provides real-time end-to-end traceability of the delivery invoices covering the exchange of information even in complex supply chains (Sternberg et al., 2020; Toufaily et al., 2021). These traceability features can help to ensure that materials are delivered on time and in the correct quantity, faster decision-making resulting in increased efficiency striving for an enhancement on construction scheduling, and help to improve accountability.

A blockchain is a decentralized digital ledger built on a peer-to-peer network and replicated across multiple nodes to ensure fault tolerance (Butijn, Tamburri, and van den Heuvel, 2020). It comprises stacks of transactions, referred to as blocks, that are linked together through hash pointers, creating a chain (Beck et al., 2017). The nodes on the network use a *consensus mechanism* to decide which blocks to append and how to order transactions within a block (Sedlmeir et al., 2022; Wüst & Gervais, 2018). As long as a majority of the network is reliable in some metric such as hash rate (*Proof of Work*), cryptocurrency share (*Proof of Stake*), or number or reputation of nodes (*Voting-based* or *Proof of Authority* Consensus), this reliability guarantees the correct execution of transactions and the practical immutability of the ledger. Transactions on a blockchain can represent a variety of activities (Butijn, Tamburri, and van den Heuvel, 2020), such as exchanging goods or the execution of smart contracts (e.g., the exchange of construction material or the conclusion of a supply chain agreement). The ability to trust that a transaction

will have the intended outcome and cannot be altered after the fact is referred to as digital trust (Sedlmeir et al., 2022).

Blockchains can be classified into two main categories: permissioned and permissionless blockchains. Permissionless blockchains allow any entity to participate in the consensus process, while permissioned blockchains require authorization for entities to take on this role. Public blockchains are accessible to anyone, while private blockchains are restricted to authorized entities (Beck et al., 2018; Wüst & Gervais, 2018). Permissionless blockchains are *public*, i.e., any entity can download and read the corresponding state of the ledger. In contrast, permissioned blockchains are often—but not always—*private*, i.e., only authorized entities have read access (Rossi et al., 2019).

There are several blockchain technology implementations, each with unique characteristics, strengths, and weaknesses, resulting in many blockchain frameworks. We investigated the use of *Hyperledger Fabric* as it is well-suited for enterprise and supply chain use cases (Sternberg et al., 2020). It is designed to be highly modular and configurable, allowing organizations to set up networks that meet their specific needs. Notably, channel support allows organizations to create sub-networks within a larger network, keeping certain transactions private and visible only to specified parties within defined private data collections. Explicit endorsement policies determine which specific nodes, known as endorsing peers, must endorse a transaction before it can be considered valid. These policies are specified in the chain code (smart contracts). They can be based on various factors, such as the identity of the submitting user or the specific assets involved in the transaction. Both approaches allow for the sharing of sensitive information among a restricted set of participants

while maintaining the integrity and immutability of the data on the blockchain (Androulaki et al., 2018).

Research method

Design science research

To conceptualize a decentralized solution that processes digital delivery invoices while adhering to the needs of cooperation within the construction industry, we followed the DSR approach as an overarching guideline by Peffers et al. (2007) whose process steps are illustrated in Fig. 2. We applied an empirically grounded and iterative DSR approach, aligning with the methodological differentiation proposed by Bagni et al. (2024), who distinguish between practice-oriented and academically driven DSR studies. Our study follows a hybrid approach, balancing theoretical rigor with practical applicability. DSR entails the design and development of innovative and meaningful artifacts such as constructs, methods, models, or instantiations for a given problem (Gregor & Hevner, 2013; Hevner et al., 2010). Following Peffers et al. (2007), the DSR process consists of six iterative steps: (1) problem identification and motivation, where the research gap and practical relevance are established; (2) definition of design objectives, specifying the design objectives an artifact must achieve; (3) design and development, where the artifact is created based on theoretical and empirical foundations; (4) demonstration, validating the artifact's feasibility through case studies, interviews, or real-world applications; (5) evaluation, assessing its performance against predefined design

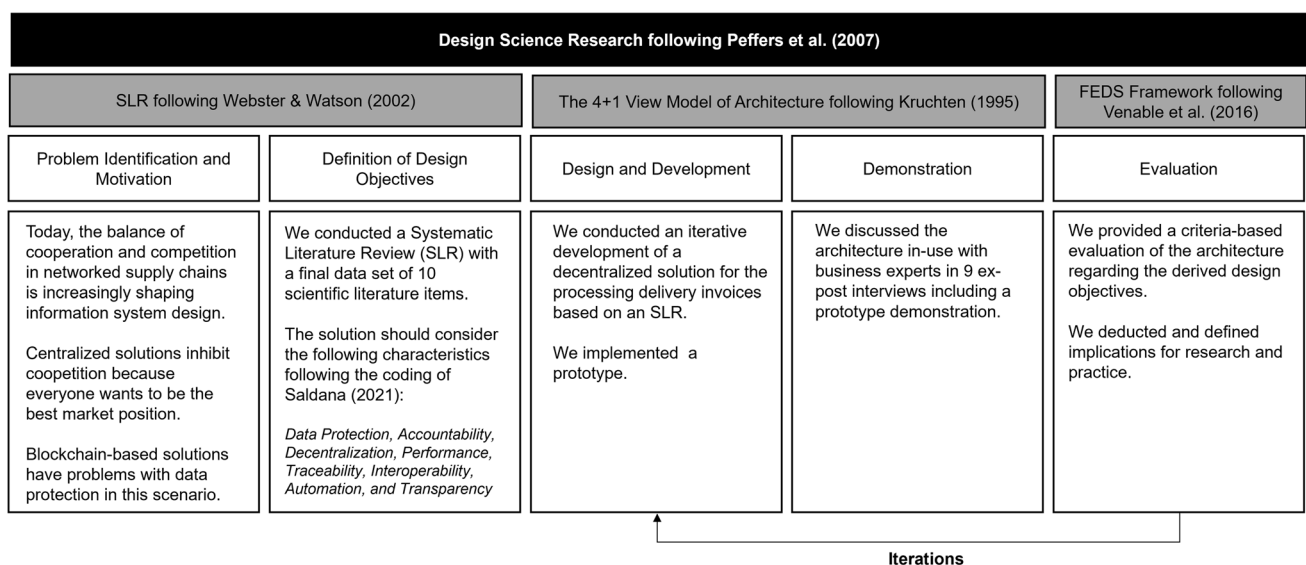


Fig. 2 Design science research following Peffers et al. (2007)

objectives; and (6) communication, disseminating findings to both academic and practitioner audiences.

Following this approach, we developed a decentralized prototype as a comprehensive IT solution for digital delivery invoices in the construction industry (Hevner et al., 2004). We systematically integrated multiple research methods to ensure methodological rigor to enhance coherence and rigor within the individual methodological DSR steps. We first conducted a systematic literature review to identify the problem domain and derive design objectives. This review provided a structured foundation by synthesizing existing knowledge on blockchain applications in supply chain management and competition, ensuring that our research builds upon established theoretical and empirical insights. Following this, we developed and demonstrated an initial prototype in iterative stakeholder engagements, including industry roadshows. These sessions allowed us to iteratively assess the artifact's feasibility in a real-world setting, gather feedback, and refine its design to enhance practical applicability. Alternative methodological approaches, such as controlled experiments or large-scale case studies, could yield additional insights into long-term adoption and scalability, as highlighted by Hevner et al. (2010). However, given the exploratory nature of our study, we prioritized qualitative and iterative evaluation methods.

Data collection

Initially, we conducted an SLR following best practices outlined by Brereton et al. (2007) and Webster and Watson (2002). This method proves especially valuable when the research objective is to synthesize and structure existing knowledge within a specific field of research to develop a conceptual architecture or prototype (Brereton et al., 2007; vom Brocke et al., 2015). We, therefore, explicitly focused on academic literature, such as peer-reviewed conferences and journals. The final update of the literature review was conducted on February 2025.

As a first step, we developed a search string that enables us to query items regarding our topic in scholarly databases which we defined as follows: (“Blockchain” OR “Distributed Ledger” OR “DLT” OR “Decentralized Systems”) AND (“Supply Chain” OR “Supply Chain Management”) AND (“Construction*” OR “Building*”). We applied this string to query the following reputable databases for academic literature search: ACM Digital Library, AIS eLibrary, EBSCO, EconBIZ, IEEE Xplore, ScienceDirect and Web of Science (Chen et al., 2010). To ensure a pluralistic and rigorous result, we selected those multiple databases as they incorporate a diverse range of sources to ensure comprehensive coverage of information systems, blockchain, and supply chain management research, thereby reducing potential bias from relying on a single database. We retrieved an initial set of 677 articles and refined the sample using predefined inclusion and exclusion criteria. The inclusion criteria (*inclusion criteria (IC)*) ensured that selected articles focused on blockchain applications in construction supply chains (*IC 1*, relevance to the research domain), were published in peer-reviewed outlets (*IC 2*, ensuring academic quality and rigor), and were available in full-text format (*IC 3*, allowing thorough analysis and reproducibility). We excluded articles that did not contribute to the academic discourse (*exclusion criteria EC 1*, lack of theoretical or empirical value) or were not in English (*EC 2*, ensuring methodological consistency and accessibility), which may have led to the omission of relevant regional insights but maintains coherence in data analysis. Finally, we performed backward and forward searches to broaden our item set with relevant literature that is then evaluated in the same filter processes (Brereton et al., 2007; vom Brocke et al., 2015). Our final set contains 23 academic literature items up to and including January 2025. Figure 3 comprehensively illustrates our approach and its steps.

In the final literature set, we applied a rigorous coding procedure to derive valid and reliable design objectives. The coding procedure by consisted of three steps proposed by Corbin and Strauss (1994), which are performed consecutively by every author for the sake of data triangulation. The

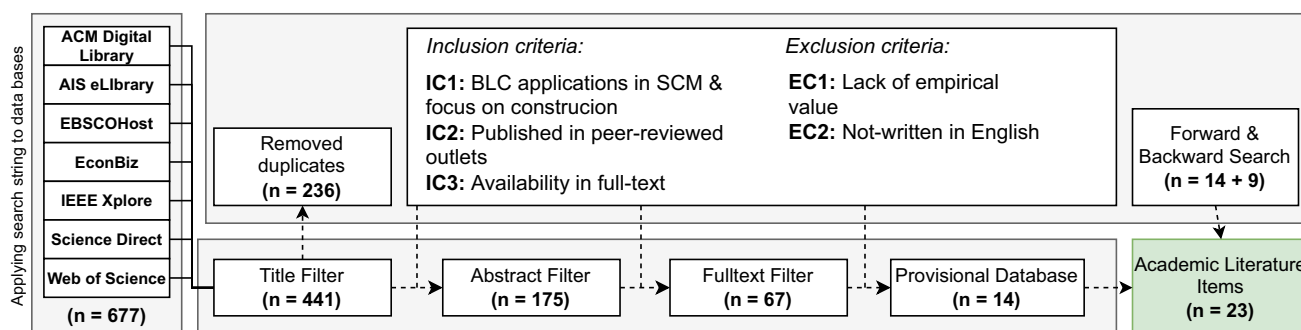


Fig. 3 Systematic literature review following Webster and Watson (2002)

first step was open coding, where we initially delved into the content of the papers to identify concepts, patterns, or themes. We created descriptive codes to label and categorize data segments that capture essential ideas or concepts. The second step was axial coding, in which we established connections between the codes to identify relationships and develop higher-level categories or themes. The final step was selective coding, in which we refined and consolidated the coding (Corbin & Strauss, 1994). During this step, we also applied our theoretical lens on the sample often referred to as *theoretical coding* (Saldana, 2021). We selected core categories that represent the most crucial aspects of the data, providing a coherent framework for analysis (Saldana, 2021). These core categories constitute our design objectives and provide more detailed descriptions.

To gather data for evaluating our design within our conceptual architecture, we conducted semi-structured expert interviews with distributed technology and construction industry experts. Rather than following a rigid set of questions, these nine ex-post interviews were guided by a thematic framework, allowing for flexible and in-depth exploration of relevant aspects of our decentralized system and prototype. We explain the detailed evaluation framework procedure in “Data analysis and evaluation of the architecture.” The experts’ organizational responsibility and professional experience is illustrated in Table 1 (Sonnenberg & Brocke, 2012; Venable et al., 2016).

Data analysis and evaluation of the architecture

In tackling our research question, we rely on systematic literature research and several project workshops on the prototype for digital delivery invoices in the construction industry. Specifically, our research project is embedded in a consortium project. This approach allows us to work with multiple consortium partners from the construction industry

and IT experts to iteratively develop a decentralized system that addresses real-world application challenges considering the coopetition perspective in practice.

To analyze our literature set, we first concentrated on deriving overarching design objectives addressing coopetition within the developed artifact, given that the value generation, as conceptualized through the theoretical lens, necessitates a comprehensive consideration of both cooperative and competitive dimensions. Thus, we reviewed pertinent literature that examines coopetition within the specific realm of supply chain management or focuses on the information systems domain in light of the coopetition principles. In this context, achieving a distinct *separation* between the design objectives is inherently challenging when developing design objectives for an information system, owing to the diverse technical interpretation perspectives these objectives may encompass. For instance, when considering interoperability as a potential design objective, one can understand the concept as the foundation for cooperating digitally. At the same time, another may posit that the distinct level of interoperability can influence the way competition is proceeded within supply chains. Thus, we decided to apply the perspective of the *Integration Principle* as we strive to provide a comprehensive approach to design the artifact within the context of coopetition. Accordingly, we opted for the design of overarching objectives to thoroughly guide our design and assessment processes for a cooperative decentralized solution. This approach allowed us to derive precise design objectives, which were then subjected to a comprehensive holistic analysis encompassing both aspects of coopetition, rather than singularly focusing on either one.

As part of the actual design process, we focused on the presentation according to Kruchten (1995) which introduce the *4+1 View Model of Architecture*. The model helps to provide a comprehensive description of a system from different perspectives (logical view, development view, process view, physical view), facilitating understanding of the system architecture, its components, and their interactions. This

Table 1 Experts’ professional background and experience in the ex-post interviews

#	Organizational responsibility	Experience	Interview duration
1	Blockchain technology expert	≥ 3 years	61 min
2	Expert for decentralized technologies	≥ 5 years	59 min
3	Project manager for lean construction	≥ 3 years	56 min
4	Manager industrial solutions	≥ 8 years	49 min
5	CEO (IT consultancy)	≥ 10 years	31 min
6	IT consultant	≥ 3 years	53 min
7	Construction process management expert	≥ 10 years	54 min
8	Software engineer	≥ 3 years	54 min
9	Software developer (construction firm)	≥ 5 years	52 min

model supports the goal of building an architecture, which is to identify objectives that affect the structure of the application and design solutions that meet these objectives. We focus on the *Process and Physical views* as those allow the authors to ensure that the system can balance and distinguish its functional and non-functional design objectives and present them separately.

To evaluate our solution, we choose the approach of the *FEDs Framework* following Venable et al. (2016). The FEDs evaluation process involves four distinct steps: (1) clearly define the evaluation objectives as we defined as design objectives, (2) select the appropriate evaluation strategy or strategies, (3) identify the specific attributes to be assessed, and (4) plan out the individual evaluation iterations as we inherently provide within our DSR approach. During the development phase, we employed nine qualitative interviews to iteratively assess the feasibility of our artifact and the corresponding prototype concerning the identified design goals as illustrated in “[Data collection](#)” (Sonnenberg & Brocke, 2012; Venable et al., 2016).

Conceptual architecture and prototype

Derived design objectives & features

Building on this theoretical foundation, we emphasize the need to meticulously design our conceptual architecture within a cooperative framework to facilitate data sharing while safeguarding critical information. The decision on which data may be sensitive to share must be formalized ensuring that only authorized stakeholders within the dedicated supply chain have access. This necessitates the incorporation of a decision-making dimension regarding the probability of data relevance to parent companies, independent of specific projects or sites. Such decisions often require informal judgment to determine the significance of information, underscoring the necessity for an IS architecture that supports formalized categorization and protects this information (Fernandez & Chiambaretto, 2016). In this context, the derived objectives serve as *Integration Principle* indicators in identifying the technical features provided by the resulting artifact. Thus, we introduce our design objectives and their integration into a design framework. We illustrate the design objectives in Table 2 as follows:

Design Objective 1–Data protection Providing data protection is essential for the information exchange in competitive business environments (Bélanger & Crossler, 2011; Bossler et al., 2024; Sedlmeir et al., 2022). With its immutable cryptographic ledger, blockchain technology provides a robust framework that ensures data is tamper-proof and resistant to manipulation reducing the risk of data loss (Gao et al., 2018;

Singh et al., 2023; Wang et al., 2020). This immutability serves as a critical component for realizing the full potential of blockchain architectures, as Bader et al. (2021) states, “those sophisticated guarantees are essential for achieving any benefits from utilizing the respective architecture.” Bossler et al. (2024) and Sedlmeir et al. (2022) further explore achieving confidentiality, integrity, authenticity, and availability through blockchain technology, underscoring its reliability. Ensuring data integrity and authenticity—where data remains unaltered, genuine, and accessible—is facilitated by blockchain through encryption, access control, and digital signatures (Bader et al., 2021; Toufaily et al., 2021). Confidentiality and privacy are vital, protecting data from unauthorized access and limiting exposure of sensitive personal or organizational details. In blockchain-based construction supply chains involving many stakeholders, including competitors, protecting sensitive information significant to individual competitors but not crucial for competition (Fernandez & Chiambaretto, 2016). Organizations must balance sharing sensitive business data for automation in cooperative endeavors with the risk of competitive exploitation (Adel et al., 2023; Hijazi et al., 2022; Wang et al., 2020). Bons et al. (2020) emphasize the need for data to be protected yet verifiable by participants, highlighting the necessity of robust data protection solutions. *Hyperledger Fabric* is recommended for this purpose, offering channels and private data collections alongside privacy-enhancing technologies that obscure plaintext data to prevent unauthorized access (Sedlmeir et al., 2022). This ensures efficient processing of delivery invoices compared to current methods while preserving data privacy within a cooperative supply chain. Integrating data protection as a core design objective for our blockchain solution facilitates secure data exchange in a collaborative and competitive supply chain landscape.

Design Objective 2–Accountability

Accountability is a crucial design objective for blockchain systems. It is especially essential for authentication within cooperative business networks, where participants must know with whom they conduct business (Caliskan et al., 2025; Shojaei et al., 2019; Zhong et al., 2020). Identification tools ensure stakeholders are identifiable and accountable, as Bader et al. (2021) and Hijazi et al. (2022) highlight while stating that permissioned blockchains meet these requirements “because stakeholders should be identified and held responsible for their conduct.” Consortium blockchains, such as *Hyperledger Fabric*, are well-suited for the construction industry due to their identity management features, including certification, authorization, and auditability (Zhong et al., 2020). Certification, however, necessitates some trust in the issuing party. To avoid reliance on a single

Table 2 Derivation of Design Objectives

Require- ments	Design Objectives	Description	SLR Results (n=23)
Coopetitive Decentralized Solution	Competition	Data Protection	Adel et al. (2023); Bader et al. (2021); Bons et al. (2020); Bossler et al. (2024); Gao et al. (2018); Singh et al. (2023); Wang et al. (2021)
		Accountability	Bader et al. (2021); Caliskan et al. (2025); Hijazi et al. (2023); Shojaei et al. (2020); Wu et al. (2022); Zhong et al. (2020)
		Decentralization	Badi (2024); Gao et al. (2018); Wu et al. (2022); Yang et al. (2020);
		Performance	Bader et al. (2021); Caliskan et al. (2025) Elghaish et al. (2020); Shojaei et al. (2020)
	Cooperation	Interoperability	Adel et al. (2023); Chou et al. (2023) Hijazi et al. (2023); Lautenschlager et al. (2023), Toufaily et al. (2021)
		Traceability	Bader et al. (2021); Xu et al. (2021); Kumar et al. (2019); Wang et al. (2021)
		Transparency	Caliskan et al. (2025); Hijazi et al. 2023; Tezel et al. (2021); Wang et al. (2020)
		Automation	Li et al. (2022); Kouhizadeh et al. (2021) Tezel et al. (2021); Zhong et al. (2020);

trust source, Gao et al. (2018) suggest a centralized identity management system supplemented by multiple providers. Alternatively, Wu et al. (2022) describe a system with a network owner controlling entry, establishing clear authority, while Adel et al. (2023) propose that each node represents an identifiable organization, an approach extended by Wu et al. (2022), allowing organizations to “*provide identities to sub-members.*” Embedding dedicated identities in blockchain systems empowers stakeholders to conduct business confidently, knowing there is a mechanism for attributing responsibility and ensuring accountability for all participants. This capability is vital for tracing all actions and transactions to their origins, fostering the trust and transparency essential for maintaining effective business operations in a competitive yet cooperative environment. Therefore, accountability is a core design objective, and identity management is essential for the coopetitive blockchain-based delivery invoice system (Elghaish et al., 2021; Li et al., 2022).

Design Objective 3–Decentralization

Decentralization is fundamental for equitable cooperation, leveraging blockchain’s inherent features to integrate coope-

tion perspectives vital for decentralized solutions, especially in WTA-markets where monopolistic dominance is a concern (Gleiss et al., 2023; Loertscher & Marx, 2020). Unlike traditional centralized systems, decentralized blockchain networks distribute control among participants, addressing the fragmentation and distrust in current construction supply chains (Yang et al., 2020). This distribution supports the construction industry’s need for balanced power structures and value co-creation and facilitates “*democratic decision-making through decentralization*” (Badi, 2023; Wu et al., 2022). Blockchain, as a distributed ledger, aligns with the fragmented nature of supply chains, providing a technological foundation for democratic decision-making (Gao et al., 2018). However, managing sensitive business data exchange within decentralized systems is crucial to ensure security and integrity (Sedlmeir et al., 2022). By dismantling centralized authority, decentralization shares control among all entities, mitigating monopolistic dominance and fostering a competitive yet cooperative environment (Hoess et al., 2024). Thus, decentralization is a key design objective for our blockchain-based information system, addressing the modular and multilateral coopetition needs in construction supply networks.

Design Objective 4–Performance

Performance, encompassing scalability, latency, and network throughput, enables a blockchain-based system to handle large transaction volumes and nodes interaction efficiently (Caliskan et al., 2025). This is essential for maintaining reliability and availability in interconnected supply chain cooperation. Given the substantial delivery invoice volumes in the construction industry, the system must support robust throughput and scalability for extensive networks, potentially on a global scale. Optimal performance must be maintained regardless of the technological base layer, reflected in factors like node quantity, ensuring consistent efficiency across various operational scales. Scalability includes computational power, throughput, and affordable system storage (Bader et al., 2021). Performance has been a notable vulnerability in blockchain technology, often due to the design of public-permissionless networks that require strong consensus mechanisms to prevent misconduct (Brotsis et al., 2021). In contrast, consortial or private-permissioned blockchains use accountable identities, as highlighted in Design Objective 2. Network participants uphold integrity, motivated by commercial reputation and compliance with regulations. Participation hinges on the presence of trust (Sternberg et al., 2020). Most literature favors *Hyperledger Fabric* for its modular and efficient design, making it ideal for large supply chain networks (Adel et al., 2023; Elghaish et al., 2021; Shojaei et al., 2019). Therefore, performance is a core objective for designing a blockchain-based delivery invoice solution.

Design Objective 5–Interoperability

Interoperability among existing solutions is critical for adopting blockchain technology and is essential for fostering equitable cooperation. Ensuring interoperability involves integrating blockchain systems with accounting, enterprise resource planning, and customer relationship management systems to create a “comprehensive system” (Toufaily et al., 2021). This integration extends to systems being “compatible with various BIM software packages” emphasizing adoption of standardized data exchange formats (Hijazi et al., 2022). A universally interoperable system facilitates cooperation, attracts stakeholder participation, and lowers market entry barriers. This approach encourages a robust user base by preventing market exclusion and avoiding stakeholder disadvantage. In a competitive context, a lack of interoperability can lead to lock-in effects and dependency on proprietary standards, which can impede broad acceptance throughout the supply base (Lautenschlager et al., 2023). Employing blockchain platforms, such as *Hyperledger Fabric*, exemplifies the importance of interoperability as it is compatible

with numerous commercial blockchain platforms, simplifying implementation and enhancing system integration (Adel et al., 2023; Chou et al., 2023). Thus, interoperability ensures seamless integration across diverse systems and platforms, which is crucial for forming a holistic and efficient network that meets stakeholders’ dynamic needs across the competitive and cooperative spheres of the supply chain. We emphasize interoperability as a key objective in our design approach for a blockchain solution to handle delivery invoices.

Design Objective 6–Traceability

Aligned with the focus on transparency, traceability is a foundational aspect of blockchain technology for tracking materials and goods across supply chains. The literature consistently emphasizes blockchain’s ability to enhance traceability in complex construction supply chains, allowing stakeholders access to essential information at any time (Wang et al., 2020; Xu et al., 2021). Kumar et al. (2019) and Bader et al. (2021) highlight that improved traceability not only boosts quality assurance but also strengthens the ability to identify products affected by specific production issues, enhancing the integrity of supply chain operations. Given the fragmented nature of construction supply chains, effective traceability has been historically challenging (Wang et al., 2020). Blockchain systems aim to improve the tracking of delivery invoices, facilitating smoother transactions and reducing disputes by identifying bottlenecks and inefficiencies. This capability enables timely and collective process optimizations within cooperative supply operations. However, incorporating traceability into decentralized systems presents challenges, particularly in a competitive environment, where safeguarding sensitive information is vital to maintaining trust (Sedlmeir et al., 2022). Despite these challenges, traceability is crucial for accountability and verifiability across the supply chain, allowing precise tracking of goods, enhancing operational integrity, and fostering trust, as noted in design objectives (DOs) 1 and 2. Thus, achieving sophisticated traceability while protecting confidentiality is a key design objective for decentralized solutions in cooperative supply chain contexts.

Design Objective 7–Transparency

Transparency is crucial for facilitating verifiability in data exchanges within supply chain management, serving as a core value proposition of blockchain technology in decentralized solutions (Azzi et al., 2019; Beck et al., 2018; Elghaish et al., 2023). Blockchain inherently enhances transparency “by default” because each transaction is processed

by all stakeholders (Caliskan et al., 2025; Elghaish et al., 2021; Wang et al., 2020). By providing a decentralized, immutable ledger, blockchain ensures visibility and accountability within each construction supply chain process stage. It securely records transactions—such as invoices—and makes them transparently accessible to authorized stakeholders, ensuring transparency from raw material procurement to construction milestones (Wang et al., 2020). Enhanced transparency fosters trust among project participants, facilitating efficient decision-making, risk management, and regulatory compliance (Hijazi et al., 2022; Tezel et al., 2021). However, as Design Objective 1—data protection noted, transparency levels must be adjusted to protect sensitive data, sometimes keeping it hidden or off-chain (Lautenschlager et al., 2023; Sedlmeir et al., 2022). Balancing transparency with data protection is especially important in competition, where businesses need to determine—ideally through a formalized information system—what data to make public or private (Fernandez & Chiambaretto, 2016). Therefore, transparency in blockchain solutions is crucial for creating a trust-based ecosystem where all parties can access and verify transaction data.

Design Objective 8—Automation

The transition to automation is crucial for enhancing the sustainability of supply chain networks, traditionally dependent on paper-based methods and significant human intervention (Gunasekaran & Ngai, 2004; Tradegrift, 2023). Implementing smart contracts that autonomously execute tasks, such as payments upon meeting predefined conditions like the delivery and verification of goods, is central to this transition (Li et al., 2022; Tezel et al., 2021; Zhong et al., 2020). Research highlights that reducing human involvement increases scalability and eliminates delays, thus enhancing overall system availability and reliability by minimizing human error (Bons et al., 2020). In addition to improving efficiency, automating invoicing data enhances security for involved parties and reduces instances of misconduct (Wang et al., 2020). Automation is pivotal in boosting cooperative value creation within a blockchain-based decentralized system for delivery invoices. However, successful automation relies on the ledger's ability to provide adequate data transparency, ensuring sensitive information is disclosed appropriately, considering competitive factors (Sedlmeir et al., 2022; Troncoso et al., 2017). Automation in blockchain solutions streamlines operations by executing processes like payments and verification without manual intervention, significantly enhancing efficiency and reducing error risks.

Blockchain prototype architecture: Functionalities and definitions

Informed by the identified design objectives, we developed an initial conceptual IT architecture for the decentralized processing of delivery invoices in the construction industry. This design was iteratively refined through multiple interview cycles as indicated in “[Research method](#),” incorporating expert feedback to enhance its feasibility and effectiveness. The final architecture is presented through a physical view (Fig. 4) and a process view (Figs. 5 and 6), following Kruchten (1995).

Processing delivery invoices constitutes an inter-organizational process that can significantly benefit using blockchain technology (Bons et al., 2020; Butijn, Tamburri, and van den Heuvel, 2020). We decided on *Hyperledger Fabric* as a suitable blockchain solution to exploit traceability and transparency benefits (DO6/7), and to create an automated and comprehensive decentralized infrastructure (DO8), we systematize our decentralized system and prototype into three levels: *backend*, *frontend*, and *blockchain layer*. It also incorporates an identity provider, which is utilized to establish and implement firm-level rights and role concepts (DO2). This approach allows the firm to integrate existing identity providers, avoiding redundant systems. The backend uses two databases to manage blockchain access and different construction companies (DO3/DO4). The prototype is designed to be adaptable and extensible based on the need for collaboration and the challenge of balancing competition (DO5). The prototype's backend and frontend components serve as a model for best practices that can be tailored to individual requirements. While authorization for different companies is controlled at the blockchain level, the organizational backend allows user-specific administration. These administration features enable each firm to customize its authorization process within the decentralized system of the blockchain delivery invoice system, thus promoting the competition requirement of data privacy (DO1). The decentralized system's technical implementation and schematic representation can be found in Fig. 4. The following paragraphs explain the technologies and how they are implemented across the three levels.

Frontend layer

The system features various views tailored to different user needs. The views can be divided into two categories: those required by companies for an overarching overview of their processes (both ongoing and completed) and those used by process participants for a more focused process view (e.g., weigher, driver, foreman). At the same time, the back office

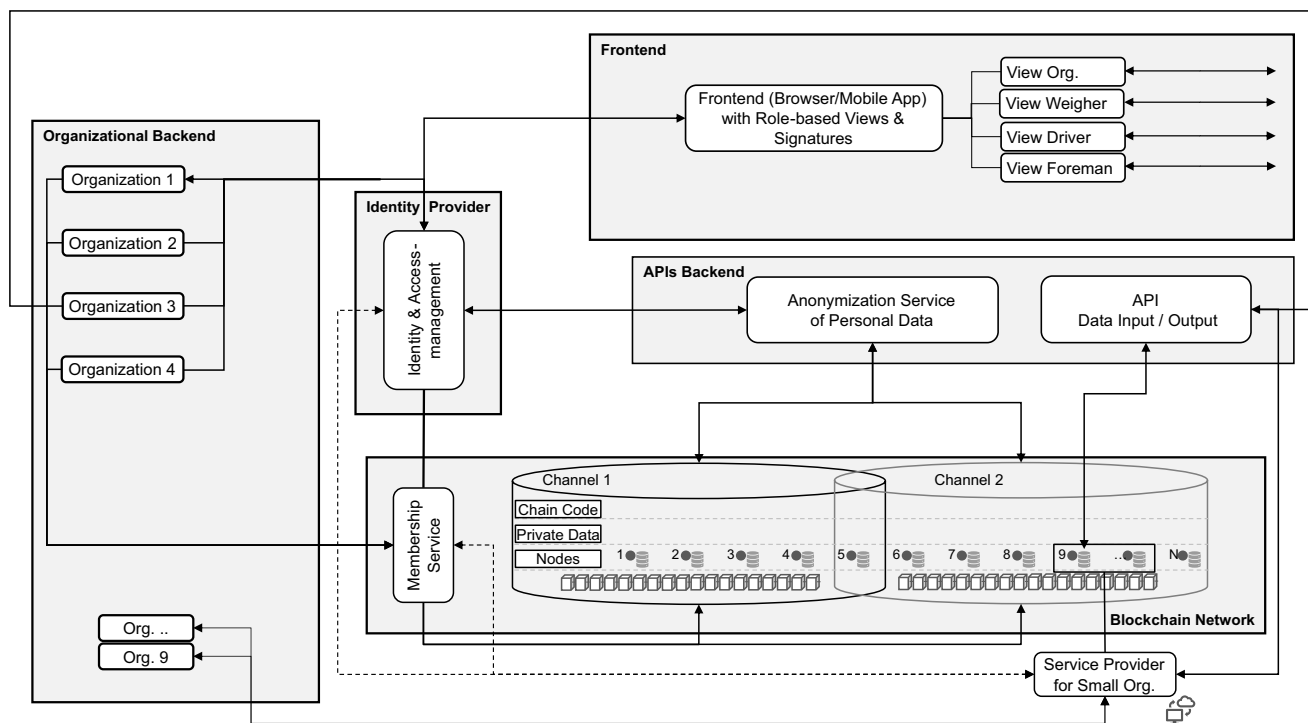


Fig. 4 Decentralized system and components for the processing of digital delivery invoices in the construction industry

of a construction firm may require an overall process view. The foreman at the construction site only needs a process view to, for instance, plan for the arrival of goods. The solution must create and edit a delivery invoice process in this context. Therefore, the frontend layer solution allows transferring data from the inventory systems to the blockchain. The standardization of interfaces and the provision of signing data are necessary to implement the holistic and seamless process.

Backend layer

The backend components are an intermediary layer between the blockchain and frontend that can be scaled and customized to meet the specific requirements of individual users. The respective organization determines the organizational backend functionalities and the corresponding software (e.g., choice of an enterprise resource planning (ERP) system) for connecting to the decentralized network system. Identity management for each organization can be handled by an identity provider, which, for instance, assigns individual identities to different employees within a firm. The application programming interface (API)'s backend extends the identity provider and makes the interaction possible via APIs. Moreover, smaller companies may be unable to host a blockchain network node, so an external service provider, such as a construction association or a regular service provider, can take over this function. The membership service of the blockchain

network is used for onboarding new companies, enabling connections through standardized protocols. However, interfaces for the connection must be defined in the case of individual implementation.

Blockchain layer

The blockchain layer consists of the membership service for onboarding new companies and dedicated channels for handling explicit building materials. In doing so, the privacy of delivery invoice data within each process is paramount particularly from a competition perspective. In our prototype, we ensure this by creating dedicated channels for different types of construction goods (such as a channel for solely processing bulk material) and by establishing private data collections within those channels consisting of only those construction companies involved in that particular supply chain operation. Defining the specific participants involved in the exchange of delivery invoices within a particular supply chain assists in coordinating the disclosure of data to authorized third parties.

Exemplary creation and processing of the delivery invoice

The creation of a delivery invoice can be conducted by any entity involved in the supply chain transaction, including the seller, carrier, or buyer. Nonetheless, sellers predominantly

assume the responsibility for generating the delivery invoices. For successful integration into the system, these invoices must already exist in a digital format suitable for importation, and the specific importation method depends on the data's format. For example, using the delivery invoice system's format requires a direct POST operation to the backend API. In cases where an ERP uses an API, a dedicated connector actively retrieves new delivery slips from the ERP to the API at regular intervals, converting them into the system's standardized format after that. Meanwhile, for importing the delivery invoice format, one must conduct a POST operation to an alternative backend API, which is configured to adhere to the delivery invoice transmission standard. The process is illustrated in Fig. 5.

The process of creating and integrating a delivery invoice commences when the ERP system of a seller, carrier, or buyer receives a request to generate a new invoice. Upon receiving this request, the ERP system transmits the delivery invoice data to the organization's backend associated with the ERP system. Subsequently, the backend converts the delivery invoice into a processable format and validates it to ensure the completeness and accuracy of the required information. Following successful validation, the backend employs an HTTPS request POST to relay the delivery invoice through an interface to the Hyperledger Fabric Client. This client is tasked with forwarding the delivery invoice data to the Hyperledger Fabric network, where the invoice is stored in the "Private Data" and its status is updated to "CREATED." Finally, a webhook is initiated from the client through the organization's backend, culminating in its transmission back to the ERP system, thereby closing the process loop and

confirming the successful creation and storage of the delivery invoice.

Exemplary handover process of a delivery invoice

Upon the successful digital generation of the delivery invoice, the subsequent procedure for the transfer of a delivery invoice is delineated as follows and illustrated in Fig. 6:

The initiation of each delivery invoice transfer necessitates action by the invoice's current custodian, executed through an application or web frontend interface. In this process, generating a QR code is imperative, functioning as a unique identifier for the delivery invoice slated for transfer. Upon scanning this QR code using their application, the recipient prompts the retrieval of the comprehensive delivery invoice data from the blockchain, acknowledging that the QR code's data capacity is insufficient to contain the full details of the delivery invoice. Consequently, the recipient gains the ability to inspect the delivery invoice data within their application, enabling them to deliberate and decide on either the acceptance or rejection of the delivery invoice, thereby finalizing the transfer process. Figure 6 delineates user actions through sequentially numbered steps, with the diagram's remainder detailing the delivery invoice system's execution framework. The diagram omits internal system components, such as the *Hyperledger Fabric Client* and *Hyperledger Fabric Network*, focusing primarily on the delivery invoice process steps themselves while including the blockchain components would primarily illustrate the updates and validation of individual delivery invoices' process status. The core workflow for managing delivery invoice data adheres to the original

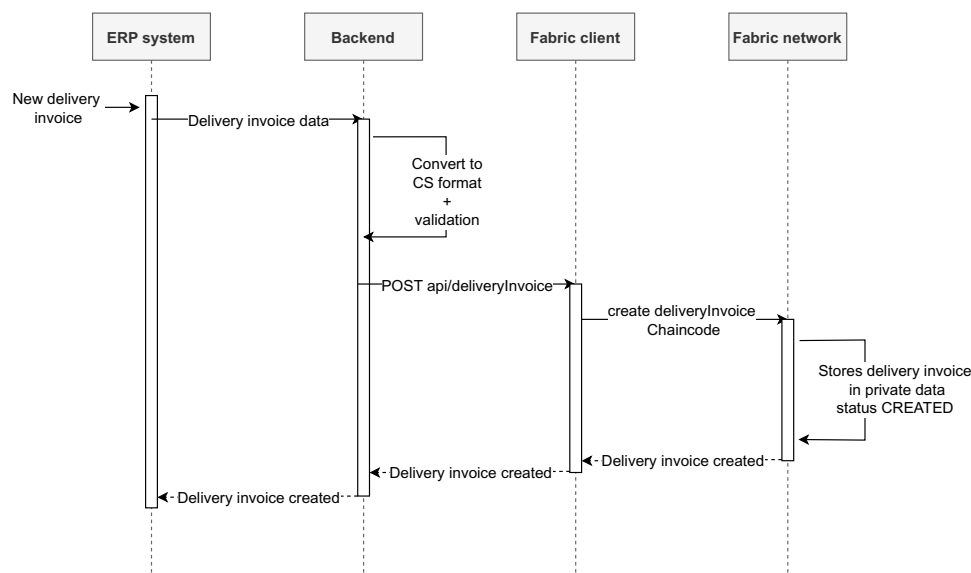


Fig. 5 Exemplary process view for the creation of delivery invoices

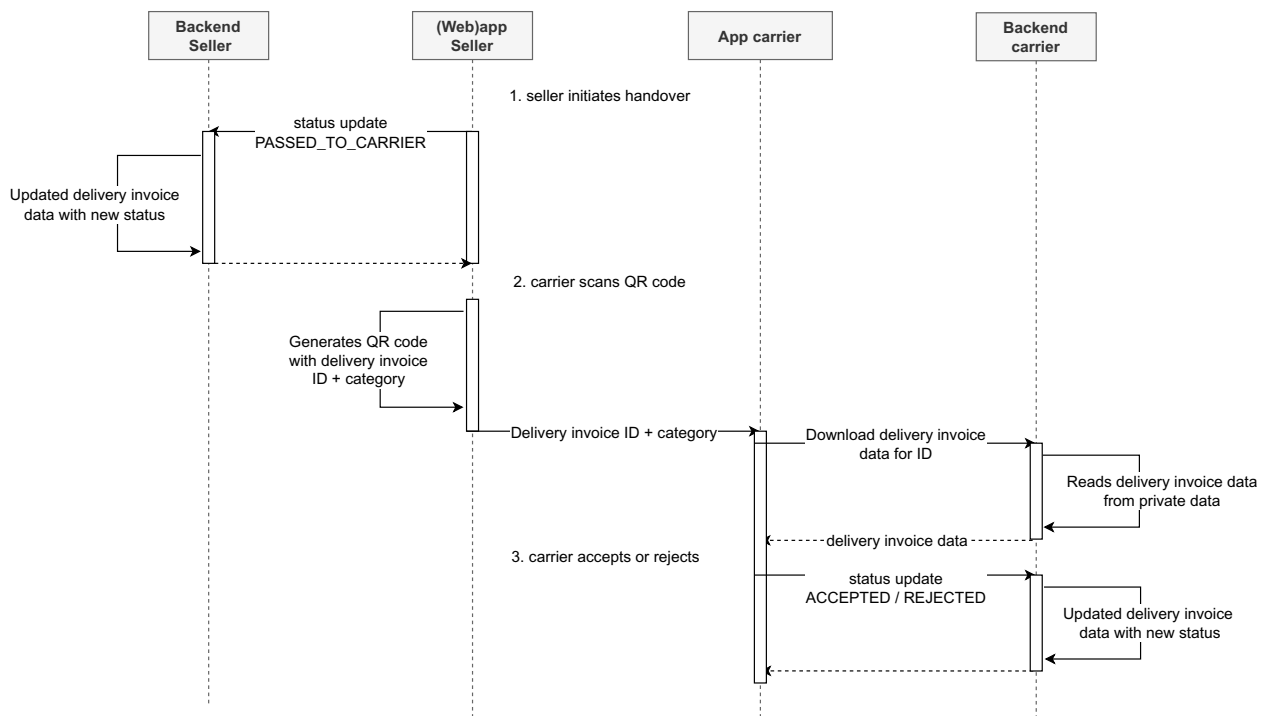


Fig. 6 Exemplary process view for the handover of a delivery invoice

creation protocol, where the backend refines client input and forwards the processed result to the Fabric Client, which, in turn, activates the corresponding chain code function. Delivery invoices designated as final and requiring no further action are assigned a *CLOSED* status. Subsequently, a closed delivery invoice is rendered immutable, eliminating the possibility of any alterations, including status changes and subsequent transfers.

Evaluation

Demonstration of the conceptual architecture and prototype

During our conducted evaluation interviews, we presented our conceptual architecture within a real-world instantiated prototype. The following section outlines the developed blockchain-based digital delivery invoice system based on the process depicted in detail in Figs. 5 and 6. The conceptual architecture was also demonstrated to the experts during the qualitative interviews as illustrated in Fig. 4.

The following case was outlined as part of the evaluation: The construction firm creates and assigns the digital delivery invoice to a specific construction site as a first step. If all stakeholders at the construction site are part of the

decentralized infrastructure, they can either generate the corresponding construction site within the system or select an existing one. However, suppose stakeholders are not part of the decentralized infrastructure. In that case, they must manually input the delivery invoice information or use traditional paper-based methods to create and prepare the invoice for transfer to the supplier. This process is carried out through the individual firm's backend. Figure 7 provides a detailed overview of the completed delivery invoice process, which begins once the delivery invoice and construction site have been created.

This creation marks the starting point of the digital process. Before the delivery invoice is accepted, the transporter inspects the goods and the invoice itself. Acceptance or rejection of the delivery invoice can be done by scanning the QR code on the construction firm's smartphone using their specific frontend solution. Alternatively, manual entry and commenting on delivery invoice data is also possible. Parties involved may include comments on the delivery invoice, particularly crucial in goods damage or insufficient availability. The delivered goods and the corresponding invoice are transported to the designated location, and the involved parties may track their current location through GPS live tracking if agreed upon. In the detailed view, users can access a drop-down interface that displays information such as the QR code that needs to be scanned or the current location

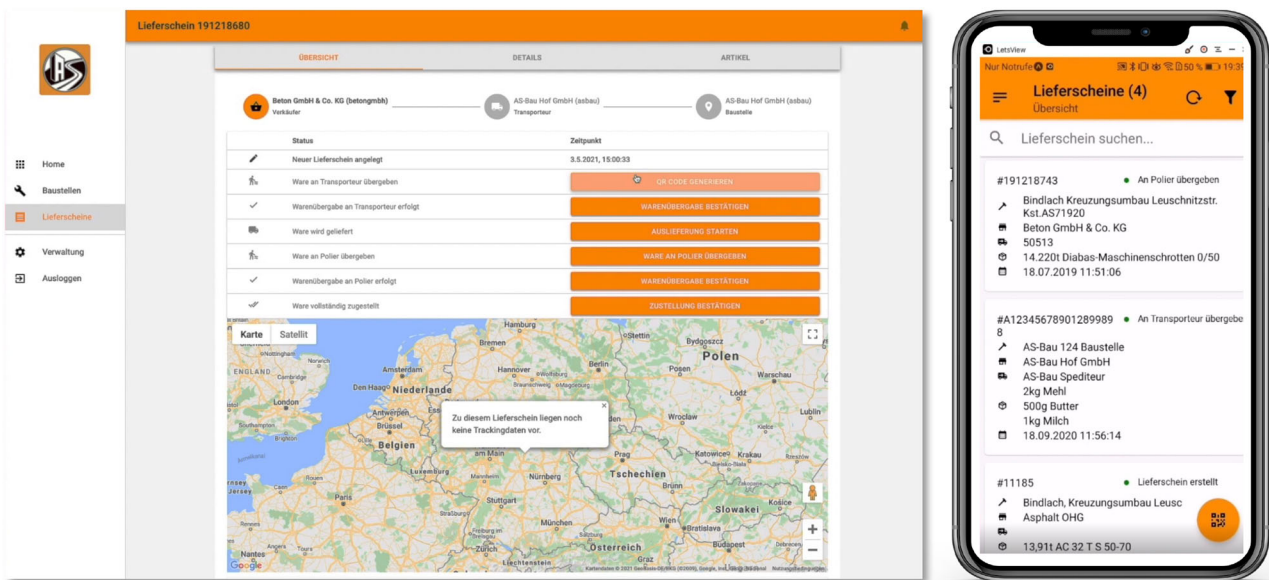


Fig. 7 Prototype overview

through GPS live tracking if necessary. This enables all parties to be informed about the expected delivery time and make adjustments required to subsequent processes. The foreman at the construction site checks the delivery invoice and goods before accepting them. They can accept or reject the delivery invoice by scanning the QR code from the carrier's smartphone. If a digital delivery invoice does not exist, one can be created from the QR code on the paper delivery invoice. Manual entry of delivery invoice data is also possible. Parties can add comments to the delivery invoice in the same manner as during the transportation of goods. Stakeholders can access the delivery invoice status from their back office anytime, as it is synchronized through the decentralized blockchain network. This allows for quicker and automatic adjustments, subsequent deliveries, or invoice audits if needed.

Derivation of the coopetitive blockchain solution implementation guidelines

Our artifact development and expert evaluations resulted in the formulation of three implementation guidelines, which were derived from the insights obtained throughout the design process and evaluation. Drawing on the theoretical concept of coopetition, we emphasize the critical importance of incorporating competitive perspectives alongside cooperative benefits in blockchain technology solutions for decentralized supply chain management. We found that this holistic integration is essential for enhancing the solution's effectiveness. Hence, to address our research question, we present the three implementation guidelines ensuring they are actionable and rooted in the coopetition theoretical lens.

Implementation Guideline 1: Opt for a decentralized solution when the benefits of leveraging network effects in a coopetitive market surpass the complexities and challenges of its implementation.

Implementation Guideline 1 emphasizes the critical evaluation of a decentralized solution when the advantages of network effects in a coopetitive market outweigh the complexities involved. Blockchain technology offers notable benefits for supply chains, such as enhanced product traceability, increased stakeholder trust, and improved data availability, surpassing centralized EDI solutions for invoice handling (DO: 2, 6, 7) (Alt, 2020; Bons et al., 2020; Toufaily et al., 2021). Expert 3 outlines that *"the blockchain offers the advantage of rapid data exchange within its network, which fosters trust among its users"* enhancing interoperability and collaboration in construction scheduling and between network participants (DO: 4, 8). However, implementing blockchain solutions poses challenges, especially for small and medium-sized enterprises (Sternberg et al., 2020). While initial operating costs of running a blockchain node are minimal (DO: 4), establishing a firm's system integration with blockchain involves complex tasks such as IP whitelisting and data pipeline integration with legacy systems. Firms also face decisions regarding server capacity management, either in-house or through service providers (Expert 8) (Guggenberger et al., 2022; Sedlmeir et al., 2022). Additionally, training staff to adapt to new front-end features and maintaining an IT department may lead to higher costs that need careful consideration against the potential benefits of a blockchain solution. Therefore, to ensure strategic alignment, firms must evaluate the long-term value of blockchain

integration compared to existing processes. For example, small and medium-sized construction firms in Germany handle approximately 55,000 delivery invoices annually, with current processing costs estimated at 4.50 per invoice, resulting in a considerable amount of circa 250.000 of potential cost savings when streamlining document handling processes (Logistics, 2021). Therefore, firms should balance the exact costs and potential savings from blockchain transactions against traditional operational costs over time from a competitive perspective. Firms must define their primary implementation objectives: deciding whether to focus on digitizing delivery invoices for efficiency through bilateral data exchange and standardized solutions like EDI or to leverage network effects to enhance overall construction planning (DO: 4). Experts also stress the importance of secure data exchange (DO: 1), particularly for information such as quantity indicators of construction materials exchanged among supply chain stakeholders. This remains essential, even with more straightforward data exchange solutions, as these may not fully address the requirements met by blockchain-based solutions (expert 1,2). Through thoroughly evaluating these factors, firms can determine whether adopting a decentralized blockchain solution aligns with their strategic goals and offers a competitive advantage in supply chain management.

Implementation Guideline 2: Utilize private data collections and private channels to protect inter-organizational data exchanges from unauthorized third-party access

Implementation Guideline 2 advises the implementation of private data collections and private channels to safeguard inter-organizational data exchange from unauthorized access, addressing the identified need for secure data exchange (DO: 1). Despite blockchain's strengths in availability and integrity, data confidentiality emerged as a primary challenge while developing our solution within the cooperative setting. Our experts commend using *Hyperledger Fabric* over public blockchain solutions like *Ethereum*, as it offers enhanced options for implementing access controls and ensuring data confidentiality for participating organizations (DO: 2). *Hyperledger Fabric* enables the use of private data collections, ensuring data privacy by allowing blockchain usage without sharing all information in plain text with all parties (Guggenberger et al., 2022). This ensures that only the parties directly involved in processes, such as changing the status of delivery invoices, can access the relevant data (experts 4, 6). For example, processing delivery invoices for bulk materials can be done through a dedicated channel, thereby safeguarding sensitive business data from disclosure to those outside the specific supply chain process (DO:3). Expert 2 underscores the importance of granular data access management “*particularly when organizations poten-*

tially can view data which would be processed on other construction sides and within other supply chains.” Storing delivery invoices solely on process participants' servers ensures that information remains within the respective organizations. This approach is crucial for cooperation between construction firms, as market rivalries require concealed data exchanges within cooperative efforts. High data integrity is achieved through the distributed storage of hashes, which enhances system automation and performance by avoiding unnecessary data storage (DO: 1, 3, 8). As Expert 4 comments that “*decentralized networks make much sense, because they strengthen the issue of security, but also trust and transparency,*” thus addressing shortcomings in existing digital invoicing solutions that lack the necessary features for data integrity hindering widespread adoption (DO: 3). Finally, maintaining data privacy is essential for legal compliance, particularly in the construction industry, where antitrust regulations prohibit sharing specific information, like procurement prices, with competitors. Therefore, implementing private data collections and channels is crucial for ensuring compliance with these regulations (experts 3, 4).

Implementation Guideline 3: Enhance private data collections and channels with additional privacy-preserving technologies to ensure complete data confidentiality

Implementation guideline 3 suggests ensuring complete data confidentiality; enhancing private data collections and channels with additional privacy-preserving technologies is essential. During our evaluation, experts noted that while channels and private data collections for dedicated building materials enhance data security, they are not foolproof against unauthorized disclosure of sensitive information to third parties (experts 1, 3). Although private data collections control data access, they do not entirely prevent participants within the collection from viewing confidential data concerning intermediate supply chain steps, a critical issue in complex, multilateral supply chains with competing organizations. In such settings, a firm should only have visibility into the bilateral supply chain where it is directly involved. Complex supply chain interactions necessitate sophisticated channels and private data collections, but these mechanisms, despite offering higher privacy, may still expose data to unauthorized third parties inadvertently. To address these concerns, experts recommend deploying additional privacy-enhancing technologies (experts 1-3). For instance, Expert 1 highlights that “*the utilization of blockchain technology using zero-knowledge proofs (ZKPs) becomes intriguing when there is a requirement to document precise quantitative records of construction materials but not having to reveal it in plain text.*” Practically, ZKPs (Goldwasser et al., 1989) allow participants to prove that a delivery invoice meets agreed-upon

business conditions (such as quantity thresholds or delivery confirmation) without disclosing the actual values to other parties in the network. This enables confidential validation while maintaining auditability and trust. Integrating ZKPs provides cryptographic proof of data authenticity without disclosing the actual data, while multiparty computations enhance data automation without compromising confidentiality (DO: 1, 2) (Sedlmeir et al., 2022). This approach effectively mitigates the trade-off between data disclosure and automation in construction industry's cooperative supply chains.

Discussion

Contributions

Organizations operating in cooperative supply chain environments face significant challenges in balancing the benefits of collaboration with the need to protect competitive interests Bengtsson and Kock (2014); Gnyawali and Park (2011). Our design science research approach provides valuable practical and theoretical insights into how decentralized technologies can navigate the tension between cooperation and competition as follows:

Practical contributions

Our research contributes significantly to supply chain management practice by focusing on integrating blockchain technology in supply chains. We advance the understanding of how to enhance cooperation and maintain competitive advantages. First, our implementation guidelines emphasize the need for a blockchain-based solution that balances competition dynamics while enabling data sharing, to enhance cooperation without undermining competitive advantage. In this context, we extend existing literature that found information systems support crucial for communication management in determining cooperation success (Chin et al., 2008). Specifically, our design and implementation guidelines fully support the findings of Chin et al. (2008) in outlining that such information systems that facilitate seamless and efficient data interchanges and effective coordination between the competition parties are essential prerequisites within the cooperative environment within supply chain management. In addition, our study aligns with the research of Bossler et al. (2024), highlighting the role of blockchain in mitigating two-sided opportunism in inter-organizational information sharing. While their study focuses on preventing both information poaching and manipulation, we emphasize blockchain's role in fostering information exchange and providing a potential design for cooperative supply chain relationships. In line with this, our study extends Brusset et al.

(2024), which demonstrates how blockchain enhances trust and information sharing in supply chains by emphasizing its role in secure data exchange within cooperative settings. While they highlight blockchain's impact on willingness to pay, we focus on its ability to balance transparency and competitive concerns among cooperating organizations beyond payments.

Second, our study expands the current discourse on supply chain automation by illustrating how decentralized and cooperative system designs can serve as enabler of automated coordination processes in complex inter-organizational environments (Bossler et al., 2024). While existing automation efforts in supply chains are often embedded in centralized platforms while depending on bilateral EDI standards or built within blockchain solutions with an excessive degree on information disclosure (Sternberg et al., 2020; Toufaily et al., 2021), our cooperative architecture demonstrates, in line with Sedlmeir et al. (2022), that blockchain allows for distributed automation – particularly in use cases where transparency must be balanced with strategic confidentiality. By automating key coordination activities by implementing, for instance, ZKPs such as the generation, validation, and handover of delivery invoices with a suitable degree of information disclosure, our prototype contributes a concrete, technically grounded solution approach to the broader challenge of automating sensitive transactions in fragmented supply chain ecosystems (Fernandez & Chiambaretto, 2016).

Third, by analyzing digital invoice exchanges in construction, we tackle the challenge of sharing versus protecting sensitive data and provide practical insights into implementing blockchain in cooperative supply chains (Lacoste, 2012). Therefore, our findings highlight the importance of actively moderating and managing the tensions inherent in monopolistic information structures, which can lead to self-reinforcing mechanisms that detrimentally impede market competition and fortify the market dominance of solution providers (Constantinides et al., 2018). These structures are often exemplified by “*key accounts*” serving as central nodes within a WTA market structure, thereby hindering the development of beneficial vertical competition scenarios and adversely affecting the potential advantages of advanced cooperation. Nevertheless, our findings also indicate that firms have to factor in the increased complexity considering all aspects of competition intricacies of setting up and operating a corresponding network. For example, providing secure and cooperative governance processes or hosting and maintaining a blockchain node may result in higher operational overhead costs Wang et al. (2020). Construction firms must carefully evaluate whether setting up such a network pays off or may opt for potentially less complex solutions, such as the bilateral exchange of signed and verifiable certificates gaining momentum and acceptance in research and practice (Guggenberger et al., 2023). Yet, if construction

firms adopt blockchain-based solutions, the use of channels and private collections as introduced by *Hyperledger Fabric* offers a promising option for processing fine-grained data cooperatively, exchanging it securely and considering the trade-offs of cooperation in the supply chain. Moreover, these processes must also be designed to be completely secure through implementing privacy-enhancing technologies (PETs) such as multiparty computation or ZKPs to provide equitable market competition (Sedlmeir et al., 2022).

Theoretical contributions From a theoretical perspective, leveraging a blockchain-based solution design, we present a novel approach to designing information systems that effectively balance data exchange's cooperative and competitive aspects. Our design marks an initial step toward realizing decentralization while maintaining efficient and secure supply chain networks. Our work, thus, builds on Fernandez and Chiambaretto (2016) findings on managing challenges in sharing information in competitive yet cooperative settings, which suggests that involved parties should each “*build a separate IS that is dedicated to the sharing of information.*” Our solution offers a foundational and theoretical baseline to address the redundancy and inefficiencies inherent within the demand of such “*Seperation Principle*” by providing the foundation for three implementation guidelines to develop the required balance of cooperation and competition within decentralized supply chain networks. As a result, our design emphasizes the “*Integration Principle*” in a unified information system as the baseline for all cooperation parties, advocating for a strategic approach that uses blockchain to provide a cooperative data platform and protect sensitive data amid competition to balance cooperation.

Moreover, our conceptual architecture contributes to the emerging theoretical discourse on automation in digitally networked supply chains by illustrating how automation strategies can be designed under conditions of strategic interdependence and information sensitivity. This aligns with findings from Sternberg et al. (2020) and Toufaily et al. (2021), who emphasize the need for automation architectures that go beyond centralized control, and supports the argument made by Bossler et al. (2024) and Fernandez and Chiambaretto (2016) that information sensitivity must be a central consideration in systems facilitating cooperative collaboration. While automation is often associated with centralized systems or bilateral EDI infrastructures (Gibson & Bell, 1990; Wiehager, 2021), our blockchain-based approach demonstrates that decentralized and privacy-preserving architectures can serve as viable enablers of automated coordination within multi-sided digital supply chain platforms (Abdelkafi et al., 2019). By mapping our design objectives to architectural elements, we show how information systems can formally embed cooperative logic into transactional processes.

Finally, we propose that the challenges of safeguarding such sensitive business information between supply chain participants are a mandatory requirement to guarantee competitive market dynamics. Specifically, we identify the blockchain components most suitable for addressing competitive aspects and guide their application. In this regard, we examine the extent to which PETs can resolve the dilemma of reaping the benefits of cooperation while protecting sensitive business data. Among these, ZKPs represent a promising cryptographic approach that enables entities to verify the validity of transactions or shared data without revealing the underlying sensitive information. By incorporating ZKP, our framework could further strengthen privacy-preserving mechanisms in decentralized supply chain networks, ensuring that competitive advantages are maintained while fostering trust and compliance among cooperation partners (Sedlmeir et al., 2022). Advancing the body of literature in this area, our findings propose a blockchain-based design that aids in formally determining data sharing or protection among cooperation partners. By introducing a decentralized infrastructure aligned with established design guidelines, this approach facilitates the precise allocation of data to specific recipients and appropriate timing decisions. Furthermore, and in conjunction with the incorporation of PETs, this permits the formalization of data classification, such as (non-) appropriability and (non-) criticality (Fernandez & Chiambaretto, 2016). Consequently, such data may be automatically disseminated or concealed for cooperative or competitive business operations based on their designated status.

Limitations and future research

Our research, however, has limitations that provide opportunities for future investigation. First, despite employing a comprehensive multi-database search strategy and strict inclusion criteria to prioritize credible sources, our literature review is still constrained by inherent biases and integrity issues in citation and publication databases. While our approach aims to mitigate these limitations, we acknowledge that these structural biases cannot be entirely eliminated and may influence the scope and findings of our review. Second, our research primarily addresses the cooperation dilemma of sharing and protecting sensitive business data, focusing on adapting blockchain technology for processing delivery invoices in the construction industry. However, other challenges, such as integrating diverse strategic business perspectives and overcoming technical obstacles like scalability issues, can significantly influence the practical adoption of our solution (Napirata et al., 2023). Third, our research remains conceptual, relying on expert feedback rather than

real-world deployment, which limits its immediate applicability. While nine industry experts have evaluated our prototype qualitatively, large-scale operational testing is still needed. Fourth, while our study offers conceptual insights into the design of automation strategies under conditions of strategic interdependence and information sensitivity, further research is needed to empirically investigate how such decentralized and privacy-preserving architectures perform in practice. Specifically, future studies could explore the dynamic trade-offs between transparency, control, and automation in diverse supply chain contexts and examine how design objectives translate into actual behavioral and performance outcomes when implemented at scale.

While this study provides a structured design and empirical validation for blockchain-based information systems in cooperative supply chains, several limitations open avenues for future research. First, our solution is tailored to the construction industry, raising questions about its adaptability to other sectors with different cooperative dynamics. Future studies should assess its generalizability across various regulatory and competitive environments. While the construction sector is characterized by fragmented networks, low IT maturity, and a high sensitivity to opportunistic behavior in data sharing (Fernandez & Chiambaretto, 2016; Lautenschlager et al., 2023), other industries feature different operational, strategic, and regulatory contexts. For instance, in manufacturing, the architecture may support integration across multi-tiered supplier networks with shared quality and inventory data, whereas in healthcare, data privacy and regulatory compliance would necessitate stricter access control and auditing mechanisms. These contextual differences could influence adoption dynamics and the design of governance and trust mechanisms. Future research should therefore examine how our architectural principles translate to these settings and where industry-specific adjustments are required. Second, while we emphasize the use of privacy-enhancing technologies like ZKPs, the trade-offs between privacy, transparency, and computational efficiency require further exploration. Optimizing privacy-preserving blockchain architectures for seamless integration into supply chain management remains an open challenge. Additionally, governance structures are critical for decentralized adoption, yet we did not empirically analyze long-term governance mechanisms. Future research should explore governance models that build trust and incentivize participation while preventing centralization. Third, while our study provides a conceptually and technically grounded prototype for decentralized, automation-enabled coordination in cooperative supply chains, we acknowledge that further research is needed to validate the system in real-world settings and explore its applicability at scale. Future work could build on our architecture to examine performance, adoption dynamics, and long-term impacts across diverse industries and supply

network configurations. Finally, our evaluation relies on expert feedback and conceptual validation, lacking large-scale empirical testing. Future studies should conduct field implementations and longitudinal case studies to investigate adoption barriers (e.g. by investigating the technology acceptance by Davis (1989) or the diffusion of innovations over time and target group following Rogers et al. (2014)), economic feasibility, and behavioral responses, contributing to a deeper understanding of blockchain's role in digital supply chains. To guide such empirical efforts, relevant evaluation criteria may include adoption rates among stakeholders and cost-benefit analyses comparing decentralized and centralized architectures. These metrics can help assess both the practical viability and economic value of the proposed solution. In particular, cost-benefit considerations should account for industry-specific factors such as regulatory compliance costs, existing IT infrastructure, and the scalability requirements of the respective supply chain context. Consequently, platform economics (Rochet & Tirole, 2003) and (in combination) transaction cost economics (Williamson, 1979) could be facilitated to examine the influence of the solution on enabling a shift towards a sharing economy (and thus cooperation) within B2B relationships and related cost reduction potential from a platform economic perspective by reducing platform dependencies, vendor lock-ins, privacy issues and power of central (non-disciplinary) stakeholders in more detail.

Conclusion

Navigating cooperation in digital supply chains requires solutions that balance transparency in collaborative processes with the protection of competitive interests. To answer our research question, we developed a blockchain-based solution that integrates privacy-preserving architectures to enable secure, verifiable data exchanges while mitigating risks associated with data monopolization. In the construction industry context, where project-based supply networks require cooperation and confidentiality for automation, our design incorporates permissioned architectures and private data collections. It suggests privacy-enhancing technologies such as ZKPs to facilitate decentralized yet controlled information flows. Our findings demonstrate that blockchain can provide a structured framework for selective data transparency, ensuring that information sharing fosters cooperation without undermining market dynamics. The interplay between transparency and confidentiality emerges as a central design consideration of supply chain information systems for supply chain automation, requiring mechanisms that enable flexible and fine-grained data access control. Beyond technical feasibility, the results highlight the significance of governance structures, interoperability, and privacy-enhancing

mechanisms in facilitating adoption. The effective use of blockchain in cooperative settings depends not only on its capacity to prevent data monopolization but also on its ability to support nuanced decision-making regarding information disclosure and protection. By formalizing data classification and integrating selective sharing models, blockchain-based solutions can mitigate the risks of centralized control while fostering sustainable and fair competition. However, the inherent complexity of implementing such systems requires firms to carefully evaluate the trade-offs between decentralized coordination, operational overhead, and the strategic benefits of digital trust. Addressing these interdependencies is essential for ensuring the long-term viability of blockchain-based information systems in cooperative supply networks.

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Declarations

Conflict of Interest The authors declare no competing interests.

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