Decentralized Autonomous Organizations and Network Design in AEC: a conceptual framework

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Abstract

Digital technologies are revolutionizing collaboration and value co-creation across traditional industry boundaries and thus generating the need for adaptive and innovative business models, new and flexible network forms as well as new digital processes and capabilities. Digital technologies are also changing the innovation logic of an organization. In recent years, digital tools and platforms have emerged as facilitators of innovation and collaboration, enabling loosely coupled networks of firms to merge knowledge and capabilities for the creation of competitive advantage. Exploring interdependencies between organizational structures, technology architecture and the coupling between system components, which would enable better collaborative processes, is currently one of the emerging research questions in the digital economy. In that context, the implementation of blockchain technology calls for a transformation of business models, roles, processes and workflows. It requires a new kind of governance and organization, which diverges from the common management processes present today. To address this gap this paper proposes an integrative conceptual framework for a blockchain-based organization and the resulting decentralized autonomous organizations (DAOs). Due to the complexity of value chains in the Architecture, Engineering and Construction (AEC) industry and the traditionally slow implementation of innovation, the primary aim of our research is to show blockchain-applicability in a general organizational context in this first step. Hence, enabling a better understanding for practitioners and researchers how building blocks of common organizational design need to be re-conceptualized for the implementation of blockchain technologies in AEC, as use cases, practical demonstrations and standards are still missing.

Keywords: DAO, Blockchain, Knowledge Assets, Decision Rights, Value Chain

1. Introduction

In the last decades Information and Communication Technology has been widely used as a facilitator of AEC collaboration, with the application of building information modelling (BIM). Nevertheless, successful implementation of evolving digital technologies, such as BIM or distributed ledger technologies (DLT), and furthermore the generation of innovation processes in the digital economy, require changes in traditional organizational processes, a dynamic strategic fit and the development of adequate organizational capabilities for the implementation of technological advancements.

The rapid development of the digital economy and different technologies has also led to radical changes in traditional business processes and value chains, opening new paradigms for organisational design, where organisations are moving from hierarchical to user-centric resp. actor-oriented and network-centric forms (Koch and Windsperger, 2017). Blockchain and smart contracts, and furthermore the resulting development of novel innovative forms of organizing, such as decentralized autonomous organizations (DAOs), are inevitably changing industries and potentially finding their way into AEC, which is traditionally slower in the implementation of digital innovation than other industries. Thererfor the question arises how to adapt technology advancements stemming originally from the cryptocurrency industry such as blockchain and smart contracts for AEC and furthermore how to implement DAOs in the AEC value chain. In that context use cases, practical demonstrations and standards are still missing but necessary for the testing of adequate applicability of the aforementioned technologies (Adams et al.,2017, Turk and Klinc, 2017).

To address this gap this paper proposes an integrative conceptual framework for a blockchain-based organization and the resulting DAO. Due to the complexity of value chains in the AEC industry and the slow implementation of innovation, the primary aim of our research is to show blockchain-applicability in a general organizational context in this first step. Hence, enabling a better understanding for practitioners and researchers how building blocks of common organizational design need to be re-conceptualized for the implementation of blockchain technologies. Therfore, based on our 3 propositions from chapter 2 we conceptualize the integrative framework for the explanation of DAOs, by answering the following 3 questions: What are the knowledge characteristics of the value chain activities? How are the knowledge characteristics changing due to digitalization resp. digital technologies? How are residual decision rights changing due to digital technologies such as blockchain? As DAOs in AEC are still in their infancy, with only potential use case applications found in literature (Li et al, 2019) the main goal of this research is therefor showing the transformational implications for organizational design in the blockchain economy, and presenting a pathway for future research in the implementation of new technologies.

This paper is organized as follows: In chapter 2 we introduce our conceptual framework, in chapter 3 our model, followed in chapter 4 by the discussion and conclusion.

2. Conceptual framework

The implementation of blockchain technology calls for a transformation of business models, roles, processes (Adams et al., 2017; Li et al., 2019) and workflows. It requires a new kind of governance and organization, which diverges from the common management processes present today. Future research should investigate how decision rights are allocated in the blockchain economy and their degree of centralization/decentralization (Beck et al., 2018). Following this suggestion, we argue that in addition to the allocation of decision rights, characteristics of knowledge assets and the value chain need to be examined for blockchain-based organisation and the resulting DAOs. Therefor, in our interdisciplinary conceptual framework we identify the need to integrate knowledge characteristics (degree of intangibility of knowledge assets), digital technologies (blockchain and smart contracts) and the allocation of decision rights (property rights approach) with the value chain for the explanation of decentralized autonomous organizations. (Fig. 1).

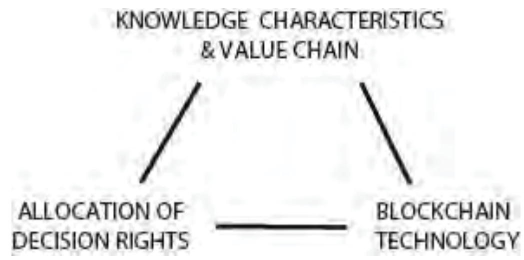

Figure 1: Integrative framework for a DAO

2.1 Knowledge characteristics and the value chain

Hedlund (1994: 75) differentiates between *tacit* or nonverbalizable, intuitive, unarticulated knowledge, and explicit, *articulated* knowledge, which can be expressed verbally or in writing, computer programs, drawings. He identifies four different carriers or agents of knowledge: the *individual*, the *small group*, the *organization,* and the *interorganizational* (network) domain. The knowledge characteristics relevant for allocation of decision rights are the degree of intangibility of knowledge assets. These tacit or intangible knowledge assets (Hall, 1993; Klein & Leffler, 1981) refer to the knowledge and skills (know-how) that cannot be easily codified and transferred to other agents. Tacit know-how is hence characterized by a low degree of contractibility. The transfer of intangible knowledge requires personal and face-to-face contact (Teece, 1981; von Hippel, 1994). In AEC intangible know-how includes emotional, cultural or aesthetical requirements for design, whereas *articulated* knowledge includes explicit know-how, such as time, costs, quantity requirements and discipline-specific skills, all of which can be expressed verbally or in writing, computer programs, drawings.

Intangible and tangible knowledge assets are present at every level of the organization resp. in the value chain (Fig. 2). The performance of activities in the value chain leads to the accumulation of firm's intangible assets, knowledge, routines and skills, which under the circumstances of a relatively stable environment should accumulate over time.

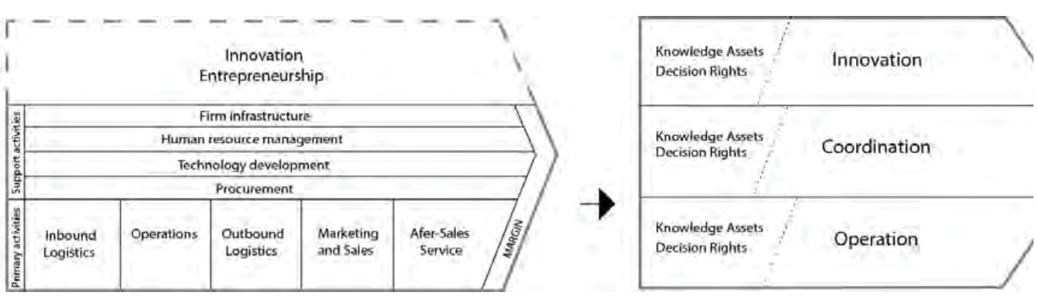

Figure 2: An extended value chain model (adapted from Srećković, 2018)

The value creation processes are specific for each industry or organizational typology and they hold the key sources for competitive advantage. Porter's value chain framework (Fig. 2) disaggregates the firm into a sequential chain of value activities, distinguishing between primary activities as those responsible for producing, marketing, and delivering the product, and support activities defined as those "that create or source inputs or factors (including planning and management) required to do so" (Porter 1991: 102). Several scholars (Armistead and Clark 1993; Stabell and Fjeldstad 1998; Løwendahl 2005; Zott and Amit 2013) argue that Porter's value chain framework, while it is well suited to analyze and describe the main value creation process of a generic manufacturing company, is inadequate for many service organizations or professional service firms (i.e., medicine, engineering, architecture, law), as well as new networked organizational forms, which cannot relate to the descriptive terms of the primary activities (inbound logistics, operations, outbound logistics, marketing, and sales) and their sequential character. In reconfiguring his value chain for the operational flow for the delivery of a service, Porter (1998) focuses primarily on cost advantages that can be achieved through more efficient or differentiated primary activities in the new and improved value chain. Nonetheless, in this reconfigured value creation process, the support activities of a firm's infrastructure, technology, human resource management, and procurement are not explored or amended. Sreckovic (2018) closes this gap by introducing an extended value chain concept of Porter (1985), with the addition of a third dynamic level (innovation and entrepreneurship) to his original model (Fig. 2). The extended value chain is comprised of activities in operation (operational level), coordination (organizational level) and innovation (strategic level). Knowledge and resources from the operational, organizational, and strategic level of the firm are bundled and uniquely combined through time and experience to form capabilities and intangible knowledge assets that generate and sustain competitive advantage. In this constant process, the organization is adapting to the changing market environment, demands, and processes, through innovation and entrepreneurship.

Proposition 1: Intangible and tangible knowledge assets are present at every level of the organization resp. in the value chain. Depending on the complexity of the value chain processes and the number of stakeholders involved, the distribution of intangible and tangible knowledge assets is dispersed in activities of operation, coordination and innovation, and managed accordingly.

2.2 Decision rights and the concept of centralization/ decentralisation

The concept of decision rights refers to the authority to deploy and use the firm's assets (Grossman & Hart, 1986; Hansmann, 1996; Simon, 1951). There are theoretical and empirical studies dealing with the allocation of decision rights in organizational economics. But due the novelty of applying innovations stemming from the cryptocurrency industry to traditional organizations forms, conceptual models and research is lacking in how the new organizational paradigm of DAO, based on a blockchain, will change industries, such as AEC.

According to the property rights theory decision rights are either **nonresidual** (**specific**) or **residual**. Nonresidual decision rights are explicitly specified in contracts (Demsetz, 1988), and refer to the use of contractible (articulated, explicit) knowledge, which can be easily codified and transferred. For instance, ‘‘specific user rights over a computer may be rights to use it to run a particular program in a particular manner in a particular time period for some specific purpose’’ (Foss and Foss, 1998, p: 9). Residual decision rights refer to the authority to influence the use of intangible (tacit) knowledge, not easily codified and articulated in contracts. This tacit, system-specific knowledge as ‘‘sticky’’ information (von Hippel, 1994) cannot be easily communicated and stipulated in contracts due to high transaction cost.

Organizational efficiency requires that those with the responsibility for decisions also have the knowledge valuable to those decisions (Jensen and Meckling, 1992). Colocation of decision rights with knowledge can be achieved by transferring the knowledge to the person who has the decision right or by transferring the decision rights to the person with the knowledge. Such transfers mean that knowledge transfer costs determine the **degree of decentralization or centralization** of decision making. Decision rights tend to remain in the CEO's office when the costs of transferring knowledge to the central office is low, and decision rights tend to be delegated to lower levels of the hierarchy when the firm primarily produces knowledge that is costly to transfer to the CEO (Malone, 1997).

Proposition 2: The allocation of residual decision rights depends on the characteristics of knowledge assets: The more important a person´s intangible knowledge asset for the generation of the residual income relative to another person, the more residual decision rights should be assigned to that person or network.

2.3 Blockchain, Smart Contracts and DAO

Based on Blockchain and Smart Contracts, Distributed Autonomous Organizations (DAOs) are created. Blockchain is a decentralized, transaction-based directory based on a network in which transactions are no longer handled by a central office, an intermediary (e.g., bank), but directly from computer to computer. The transaction data are thus stored locally (Buchleitner and Rabl, 2017). Blockchain offers further advantages over traditional centralized systems (Scherk and Pöchhacker-Tröscher, 2017):

- Transaction data is encrypted (access control) stored on all the computers (single source of truth) of the network members, enabling synchronization of databases;
- Data cannot be manipulated (immutability of record); It ensures that all participants in the system have identical information. Blockchain thus creates a historical source for all data in the system, which means that there is no need for trust between the participants or central authorities (disintermediation of trust), since manipulation of the data is almost impossible; Consensus models ensure that only correct data can be included in the blockchain and not manipulated (data integrity); Participants in the network must agree on what information is included in the system. It must be understood that the first transaction that is recorded is the only valid one and cannot be subsequently changed or removed from the system;
- identical copy is stored on all computers (no potential single point of failure);
- processes in the network run according to a specified program code (process integrity);
- self-executing smart contracts can be used to program complex, conditional transactions and actions (programmability);

Smart contract "is a digital protocol that automatically executes given technological processes within a transaction without an intermediary" (Buchleitner and Rabl, 2017). This digital protocol defines which conditions lead to which decisions and thus creates an automated processing of contracts that are implemented automatically (in codes) by monitoring these conditions in real time and enforcing contract components (Scherk and Pöchhacker-Tröscher, 2017). The advantages that result are: safety, verifiability, transparency and immutability.

Possible applications for Blockchain and Smart Contracts in the built environment include: (Kinnaird et al., 2017, Coyne and Onabolu, 2018, Shen and Pena-Mora, 2018, Munsing et al, 2017): sharing economy, e-government, digital building submission, power industry, microgrids, ownership, and transfer of real etate rights (Real Estate Implementations), Intellectual Property Rights, Supply Chain (Circular Economy in the Life Cycle of a Building), Smart City Applications. With the help of smart contracts, it should also be possible in the future to design and sign contracts, define and evaluate necessary data for real estate valuation, to commission service providers along the value chain, to map real estate data and to store sensitive data (PwC, 2017). The benefits of using smart contracts in AEC are: accuracy, transparency, risk management, compliance, cost efficiency.

DAOs are decentralized organizations with standardized, automated processes that can replace and handle complicated coordination processes (which can be represented as routines) in the value chain through software rules (protocols) (Hsieh and Vergne, 2018). They thus exist as computer code in the cloud and have no management or hierarchy. Changes in the automated, standardized organizational processes happen through a democratic process of the partners of the DAO. For the use of decentralized organizational systems in the AEC it is necessary to find standardized or novel forms of cooperation between project members and teams in segments of the value chain that can be expressed using algorithms. To this end, it is essential to also identify and better understand the role of intermediaries, and what added value they generate at what cost to the project (Belle, 2017) - thereby reducing transaction costs (coordination, information costs), risks minimized and time saved. These forms of organization have not yet been explored in the lifecycle of buildings.

Proposition 3: Blockhain will facilitate a shift toward decentralization when tacit knowledge which was previously exclusive to higher levels of the organization can be codified (in smart contracts) and implemented in a automatized process; blockhain will facilitate a shift toward centralization when the transfer of tacit knowledge moves from lower to higher levels in the organization.

3. The model of DAO

In our integral conceptual framework, we argue that for the explanation of blockchain-organizing and the resulting DAOs, it is necessary to look at the value chain transformation through technology and its effect on decentralisation of activities of operation, coordination and innovation (Fig. 3). Centralisation of decision making is only efficient if the central planner has the knowledge that is specific in time and place (von Hayek, 1935, 1940). Due to the CEO’s limited information-processing capabilities organizations must delegate decision making power (see also Van Zandt, 1999; Van Alstyne, 1997). The question is what means delegation in the context of an organizational form which is managed through rules coded in smart contracts resp. how does the value chain, decision rights and knowledge assets change with blockchain (Fig 4)?

In Fig 3, scenario 1 depicts the value chain of a network organization (which is common in the AEC industry), where knowledge assets and decision rights are available on the innovation, coordination and operational level of the firm. Accordingly in Fig 4, scenario 1, shows decision rights and knowledge assets for a network contract, with a relatively low degree of contractibility, resulting in a relatively low ratio between specific decision rights and residual decision rights. This means that there is a relatively low degree of tangible, codifiable know-how in the network organization which can be specified in contracts; and a higher degree of intangible knowledge assets at different levels of the organization. To summarize, contractual completeness is defined by the ratio between specific and residual decision rights. The lower the contractibility of knowledge (e. g. due to high intangibility of knowledge assets and uncertainty), the lower is the probability to formulate specific rights and the more residual decision rights are assigned to another partner in a network, or within the organization to another person resp. level of the value chain, and the lower is the degree of contractual completeness.

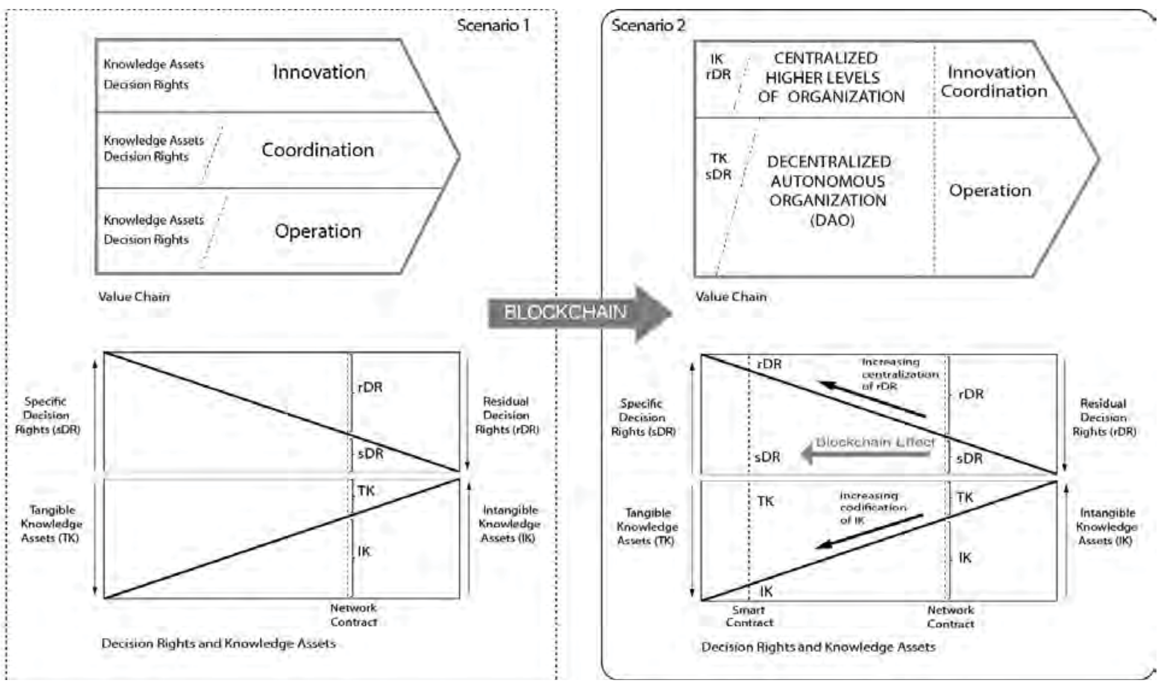

Figure 3: Value chain, Knowledge Assets, Decision Rights transformation through blockchain

The most general feature of blockchain technology is decentralization. Decentralization is closely connected to centralization. DAOs are organizations managed through rules and regulation, specified in smart contracts, running on a blockchain platform. Their resources are organized according to rules agreed in advance. They are actually a system of self-organization. Scenario 2 in Fig. 3 and 4, shows the transformation of the value chain through blockchain technology, where the DAO has the ability to replace centralized intermidieries for operation and coordination activities, under the premise that knowledge assets are codifiable and can be automated. This means that the value chain takes another form, where automated operational processes are organized in a DAO, whereas residual decision rights in coordination and innovation (with intangible knowledge asset) are increasingly centralised, either on the highest level of the value chain in the organisation or the network. This means that the implementation of blockchain makes new forms of governance necessary which are still to be explored, especially concerning the their applicability for AEC.

4. Discussion and Conclusion

Blockchain technology calls for a rethinking of the existing workflows, and this technology has even the potential to help exploit the potential of BIM workflows. Blockchain supported workflows would increase the transparency, speed up the planning processes and simplify the communication by providing real-time insight into the planning stage, and facilitate the enquiry possibilities for each planning step.

But new technological advances such as blockchain and smart contracts are still underutilized for the AEC industry, or not yet scientifically researched in the BIM-based planning and construction process. Complex, time-consuming processes and data management tasks continue to be done by planners, which could be automated. Opportunities to make workflows in building planning more transparent, comprehensible, consistent, efficient, cost-effective and time-saving remain unused. This would also provide the possibility of real-time communication in the model. In an industry where collaboration is based on expertise and a high level of trust, the potential of new decentralized organizational systems (DAOs) should be explored, enabling innovative forms of collaboration between project members and teams in segments of the value chain. These could be expressed in an automated way (based on smart contracts), in particular if it would save the time and costs of administration, reporting, control, accountability and risk transfer. For this purpose, it is also necessary to examine the role of intermediaries and to better understand them, or what added value they generate at what cost for the project or planning process.

With this paper we are contributing to the knowledge in organisational economics, with the aim to first provide a general insight into new forms of organizing with blockchain technology. And in a further step to explore the applicability of blockchain in a use case setting, which is still in development. Furthermore, the goal is to support future research activities into the application of DAOs in the AEC with our integral conceptual framework.

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