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Analyzing decision-making in blockchain governance

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Blockchain systems are a novel technology that allow for innovative business models. However, due to the decentralized nature of blockchains, new organizational challenges arise. Blockchains require intricate governance mechanisms to align all interests of the involved stakeholders. A crucial part of blockchain governance is decision-making, i.e., the way how a community of a blockchain system can reach decisions. While blockchain governance has received considerable interest of academia, decision-making in blockchains has not yet been sufficiently addressed. Through an exploratory multiple case study, we establish a framework for analyzing decision-making in blockchain systems and identify two dimensions along which decision-making in blockchains can be classified—namely community-driven vs. institution-driven as well as off-chain vs. on-chain decision-making. Even though blockchains are decentralized systems, we can show that there are often highly centralized elements present. The degree of this centralization varies across blockchains and might be connected to the business cases and origins of the different systems. Furthermore, many factors of decision-making processes in blockchains are still off-chain and only some factors are truly on-chain. We arrived at these insights through a structured approach for decision-making in blockchains. Thus, we provide new tools for researcher and practitioners and pave the way to novel blockchain applications with sound decision-making mechanisms.

KEYWORDS

blockchain, decision-making, governance, framework, community

1 Introduction

David Chaum (1983) introduced the idea of a digital cash system which should be anonymous but still capable to provide a proof of payment in 1983. Later, the computer scientist Nick Szabo suggested a mechanism for a decentralized digital currency called 'Bit Gold' (Szabo, 2008). A better understanding of the complexities in blockchain governance systems is urgent for building functioning blockchain systems. However, all the proposed digital currency systems could not solve one essential problem in a decentralized way: to make spending of the same digital token more than once impossible. To overcome this 'double-spending problem' all previous iterations of digital cash systems needed to have some sort of centralized authority to keep records of the individual account balances. It was only in 2008, when Satoshi Nakamoto (2008) could finally propose a solution to the double-spending problem by timestamping transactions in a purely peer-to-peer network through hashing them into an ongoing chain of hash-based proof-of-work. This 'chain of blocks' would thereby build a publicly verifiable record that cannot be changed without redoing the proof-of-work. Based on this idea, a group of cryptographers and software developers started to build 'Bitcoin' in 2009, the first purely decentralized peer-to-peer cryptocurrency network based on the later called 'blockchain' technology.

Nevertheless, blockchain is not merely a technology that underpins cryptocurrencies and other decentralized applications. Rather, blockchains form complex socio-economic systems allowing for the creation and exchange of digital values in a decentralized fashion. In the last few years, a wide variety of these systems have emerged (Spychiger et al., 2021). These systems include many different stakeholders such as token holders, network validators, core and application developers, founders and many more (Allen and Berg, 2020). All these different stakeholders play a vital role in the adoption of blockchain systems (Lustenberger et al., 2021). However, it remains a challenge how all these stakeholders collectively reach a common decision that is needed to evolve a blockchain system (Rikken et al., 2019). In other words, a solid blockchain governance is necessary to make sure that a decentralized blockchain system may be governed in a way that guarantees its ability to adjust to future change and assure its survival. The aim of this paper is to draw on other theories of governance to provide insight into the design of blockchain governance mechanisms.

Having said that, the question of what exactly blockchain governance is, can be issued. Several authors have tried to provide a framework in answering this question. Beck et al. (2018) define blockchain governance along the interplay of three dimensions: *decision rights, accountability,* and *incentives.* Compared to traditional IT governance, blockchain governance has more decentralized decision rights, accountability is rather technically enabled than institutionally set, and incentive alignment becomes more important. The dimensions *decision-making* and *incentives* are also identified by van Pelt et al. (2021) among *roles, membership, communication,* and *formation and context.* Along these dimensions, they also differentiate between *on-chain* and *off-chain* processes, referring to elements that are situated within and outside of the blockchain system. This distinction has also been made by Reijers et al. (2021) who point towards a potential tension between strictly *on-chain* and *off-chain* governance mechanisms. Thus, on certain occasions, *off-chain* governance may play a crucial role, and this leads to blockchains becoming vulnerable to private interests exerted through these mechanisms. Consequently, proper *off-chain* governance mechanism needs to be considered in the design of blockchain governance.

A particularly important aspect of blockchain governance is thereby decision-making. As Ziolkowski et al. (2020) demonstrate, blockchain systems are full of decision problems. They identify four main decision areas in blockchain governance: membership considerations, balance between internal and external legitimation, reduction of human interventions, and management of flexibility and adaptability of blockchain systems. Also Leewis et al. (2021) emphasize the importance of decision-making in blockchains. They focus on decision rights and show that it is important to define decision rights early on, as it becomes more complex to introduce blockchain governance in later development phases. Liu et al. (2022) even argue that the purpose of blockchain governance consists of supporting the decision-making process in blockchains. Within a systematic literature review on blockchain governance, Liu et al. (2023) investigated the word count within the definition of blockchain governance. In 37 primary studies the most frequently used word was *decision.*

In short, if we look at the current discussion about blockchain governance it seems to boil down to the question how decision-making power is distributed and executed in blockchain systems. While there are frameworks that study blockchain governance, no such frameworks are out there that specifically allow for the analyses and categorization of decision-making in blockchain systems. However, decision-making is the single most important part of each blockchain system and differs among the various systems. In this study we aim to address this research gap by focusing on decision-making, as previous governance frameworks and studies have not given enough importance to this key aspect. We suppose that understanding decision-making in blockchain systems will help to better define the different governance approaches applied in blockchain systems.

Therefore, we answer the following research questions with this work:

RQ1: How can current blockchain governance frameworks be adapted to specifically analyze and categorize decision-making in blockchain systems?

RQ: How can we distinguish decision-making approaches used in blockchain systems?

The remainder of the paper is structured as follows: in the next section, we elaborate on the related work of blockchain governance and the role of decision-making. Section 3 explains our methodology. Section 4 presents the adapted blockchain decision-making analysis framework for this study. In Section 5, five case studies will be presented and analyzed with the developed decision-making analysis framework. Section 6 discusses the implications of the results. Section 7 concludes and outlines further research opportunities.

2 Related work

2.1 Blockchains and its governance

The focus of this paper lays on decision-making in blockchain systems, which again can be seen as the most important aspect of blockchain governance. Technical details are therefore only of interest to the extent that they are relevant to understand the most important characteristics of this new technology. In line with Ziolkowski et al. (2020), we understand blockchain systems as blockchain technology-based applications and their organizational embedding. Blockchain technology relies on several very specific principles, which have been summarized by Zheng et al. (2017) as i) decentralization (no central authority), ii) persistency (transaction immutability), iii) auditability (traceability of events), and iv) anonymity (key pair authentication). From an application perspective blockchain can therefore be understood as a "general-purpose programmable infrastructure with a public ledger that records the computational results" (Xu et al., 2017) or as Vitalik Buterin (2016), the founder of Ethereum coined it: blockchain systems can be seen as 'shared world computing platforms' or a 'world computer', "(. . .)where anyone can upload and run programs that are guaranteed to be executed exactly as written on a highly robust and decentralized consensus network consisting of thousands of computers around the world."

According to Peters and Panayi (2016) blockchain systems can be classified along two axes: access to transactions and transaction validation rights. These characteristics lead to either public blockchains (public transactions, everyone can validate), permissioned blockchains (public transactions, restricted validation), or private blockchains (private transactions, restricted validation). In practice, we can witness a main difference on application level between public blockchains and permissioned/ private blockchains. Established enterprises are thereby mainly investigating the use of permissioned/private blockchains to set up business structures with other companies in consortia (therefore we can call them 'consortium blockchains') (Rauchs et al., 2019; Vadgama and Tasca, 2021). However, especially in the case of cryptocurrency and digital asset applications (e.g., non-functional tokens), the most common types to date are public blockchain systems, such as Bitcoin or Ethereum (Dupont, 2017).

The governance system of these two different blockchain types is thereby very different. As the main objective of permissioned/private blockchain applications is efficiency, collaboration, and competitive advantages, their approach to governance can be described as 'consortial' with more traditional hierarchical and centralized decision-making processes (Zavolokina et al., 2020). In contrast to public blockchains that emphasize the typical blockchain characteristics of decentralization and (pseudo-)anonymity, which makes their approach to governance more 'tribal', where actors coordinate in loosely defined groups with shared values and interests (Miscione et al., 2017). The open nature of the governing process can lead to the possibility of diverging interests, in which members of a tribe break out ('forking') and create their own tribe ('fork'). (Ziolkowski, 2021).

By evaluating the respective literature, we can make two further distinctions in blockchain governance: *first*, the investigation of blockchain governance can be approached from the perspectives of governance *through* or governance *of* blockchains (Miscione et al., 2017; Ølnes et al., 2017; De Filippi and Mcmullen, 2018), and *second*, blockchain governance can be *on-chain* or *off-chain* (De Filippi and Mcmullen, 2018; Reijers et al., 2021). In respect of the first distinction, our work clearly focuses on the governance of blockchains and is not considering aspects from the governance through blockchain discussion. However, regarding the second distinction, the literature recognizes that the on-chain/off-chain differentiation boils down to the question whether the governance is directly encoded 'on-chain' into the blockchain system itself or is arranged 'off-chain' outside of the blockchain system (Reijers et al., 2021). The main issue with 'off-chain' governance is that it is inherently vague and can lead to centralization in areas once thought to be decentralized (De Filippi and Mcmullen, 2018; Ziolkowski, 2021). In particular, the organizational aspects of governance are often centralized as the decision rights is often allocated to a small group of people (e.g., the founders) (Heo and Yi, 2023).

2.2 Decision-making in blockchains

If it comes to a common understanding of 'governance', Bevir (2012) provides a useful general definition by stating that "governance refers (…) to all processes of governing, whether undertaken by a government, market, or network, whether over a family, tribe, formal or informal organization, or territory, and whether through laws, norms, power or language." Hufty (2011) further defines governance as "the processes of interaction and decision-making among the actors involved in a collective problem that leads to the creation, reinforcement, or reproduction of social norms and institutions." Based on these definitions we can obtain that governance is mainly characterized as a decision-making process between actors of a (social) system.

Our focus on the decision-making process in our research on blockchain governance is justified by previous research. Tiwana et al. (2010) for example define IT system governance broadly as "who makes what decision", and Constantinides et al. (2018) further describe the governance core elements as distribution of decision rights (formal and informal) control mechanism and incentive structure. Ziolkowski et al. (2019) could thereby demonstrate that there is a wide range of how decision rights and power can be distributed between the different actors in blockchain systems and in many cases these distribution models can evolve and change over time. A decentralized decision-making process is one of the most important reasons why actors like application developers, users or investors choose a certain blockchain system over another system in the first place (Arruñada and Garicano, 2018). However, as the technology behind blockchains is evolving rapidly (e.g., proof-of-stake protocols, sharding and cross-chain bridges) (King and Nadal, 2012; Luu et al., 2016; Kannengiesser et al., 2020), there is an inherent need for blockchain systems to make decisions about adaption and changes in their protocol in an efficient and timely manner (Rauchs et al., 2019). Additionally, as the *Dao* hack in 2016 showed (Mehar et al., 2019), flaws in blockchain systems can be very costly and wrong decisions can lead to security breaches. Therefore, how decisions-making is designed on blockchain systems, is understood to be a crucial aspect for the longevity of a blockchain system (van Deventer et al., 2017; Zachariadis et al., 2019).

In an exhaustive study, Ziolkowski et al. (2019) analyzed different blockchain systems by looking at decision-making processes in respect to demand management, data authenticity, system architecture development, membership, ownership disputes, and transaction reversals. The authors identified four main aspects in the decision-making process that characterize different blockchain governance approaches: *first*, the dependance on an external legitimation; *second*, the degree of restrictions imposed on the discretionary power; *third*, the extent of an explicit system access control; and lastly, *fourth*, the extent of a temporal management of the system by core stakeholders. Despite their study being very descriptive, it provides no clear answer to the question, how decisions between unknown participants in blockchain systems are made. By developing a general analytical framework to analyze and categorize decision-making in blockchains our study aims to fill this knowledge gap. Only if we successfully analyze and categorize the decision-making process in blockchains, we might be able to define how decisions are made in a specific blockchain system.

2.3 Blockchain governance frameworks

In their comparative evaluation on governance in blockchain systems, Beck et al. (2018) state that blockchain governance can be characterized by *decentralized decision-making*, which is based on technically enacted *on-chain* processes and properly aligned incentive structures to achieve consensus. However, the authors also state that blockchains are currently still characterized by a high degree of centralized *off-chain decision-making* activities, where accountability and incentive structures are inexistent. The tension between *on-chain* and *off-chain* governance mechanisms, especially when quick decision-making is necessary in case of emergency situations, has been noted by various authors (De Filippi and Mcmullen, 2018; Reijers et al., 2021). Based on the findings within the existent literature van Pelt et al. (2021) proposed an initial blockchain governance framework with the following governance dimensions: 1) the *context and formation* with all the relevant background information of a blockchain system (e.g., purpose, ideology, type of license); 2) the different *roles* within a blockchain system and their responsibilities and accountabilities (e.g., foundation, developers, miners); 3) the *incentives* as motivational factors for the different roles and members to act (e.g., intrinsic, payments, investments); 4) the way *membership* is managed for each role (e.g., open for anyone, access rights to roles); 5) the *communication* between roles and members (e.g., tools, meetings, working groups); and finally 6) the *decision-making* process and how decisions are made, monitored and agreed on (e.g., voting, decision process, consensus mechanism, conflict resolution). According to their governance framework, each dimension—besides the *context and formation*—can be categorized along the distinction of 'on-chain' and 'off-chain' aspects. However, the authors did not explain how this distinction is defined, nor where its relevance within the governance process of blockchain systems lies. Additionally, their governance framework is so extensive and mostly descriptive that it is difficult to find and understand the key differences between the governance approaches applied in current blockchain systems.

A second recent and quite comprehensive framework by Liu et al. (2022) has established six principles for blockchain governance by focusing on the aspects of *decentralization*, *decision rights*, *incentives*, *accountability*, *ecosystem*, and *legal and ethical responsibilities*. Additionally, the authors distinguish four different governance levels starting with *data transaction*, the *platform development*, the *application development* and lastly the *community*. According to Liu et al. (2022), each level follows its own lifecycle from emergence to development and finally to termination, with several different decisions to be made on the way by the community. According to the authors, the main goal of blockchain governance lies in the development and continuation of the system itself. However, with their strong focus on six governance principles, Liu et al. (2022) establish a more general guideline for the development of 'blockchain governance' systems, rather than putting forward an analytical framework to analyze and categorize different governance approaches applicable in practice.

3 Methodology

In the following, we outline the research methodology along the applied method, and we show how the analytical framework has been built and how data has been gathered and subsequently analyzed and evaluated. This research follows the methodological approach of an exploratory multiple case study research. Depending on the author, a methodological research process of such case study research is described differently (Eisenhardt, 1989; Stake, 1995; Ellram, 1996; Burawoy, 1998; Merriam, 1998; Yin, 2018), whereby the main difference is often related to the epistemological stance (Ridder, 2017). For example, Eisenhardt (1989) and Yin (2018) are considered to represent positivism, while Stake (1995), Burawoy (1998), and Merriam (1998) are attributed to the constructivist research paradigm. The former focus on a structured research process including the elaboration of (measurable) constructs, while the later pay more attention to a flexible and creative interpretation of empirical results. In this study we pursue the positivist epistemological stance of Eisenhardt (1989) and Yin (2018). Thereby we follow a clear five steps research process of 1) reasoning for the case study methodology, 2) selection of cases, 3) data collection, 4) data analysis, and 5) interpretation phase as it has been described by Creswell and Poth (2018).

3.1 Reasoning

As shown in the relate work section, decision-making in blockchain systems is a key aspect of blockchain governance that has not given enough importance in previous studies and therefore has not been well studied and understood neither in theory nor in practice. The case study research methodology is thereby an excellent method to get insights and build first conceptional explanations for phenomenon not yet well studied and understood (Eisenhardt, 1989; Yin, 2018). This study is thereby motivated by a lack of an analytical studies of decision-making within blockchains from a governance perspective. Yin (2018) states that a case study should try to explain a contemporary circumstance in a real-world context by answering 'how' or 'why' research questions. In line with Eisenhardt (1989) and Yin (2018) and as shown in Figure 1, we will first develop some conceptional propositions about the phenomenon under investigation, namely the important role of decision-making within blockchain systems. These propositions will be taken from the current literature and theoretical-conceptional blockchain governance frameworks and will be the base for our analytical framework to study decision-making in blockchains. In a second step, we will test and refine the developed analytical framework by analyzing and evaluating the decision-making approach of five different blockchains. In a final step we will conduct a comparative analysis of our findings with the aim to generate a better understanding of decision-making as the key aspect of blockchain governance.

3.2 Case selection

To study the decision-making process in blockchains in more depth, we applied the developed analytical framework to a set of blockchain systems. The selection of case studies is thereby crucial to the success of the research (Eisenhardt, 1989). Depending on the interest and the research question, the cases can be selected according to different aspects. Creswell and Poth (2018) call this process 'purposeful' sampling, where the selection of cases is done in such a way that they allow different perspectives on the same

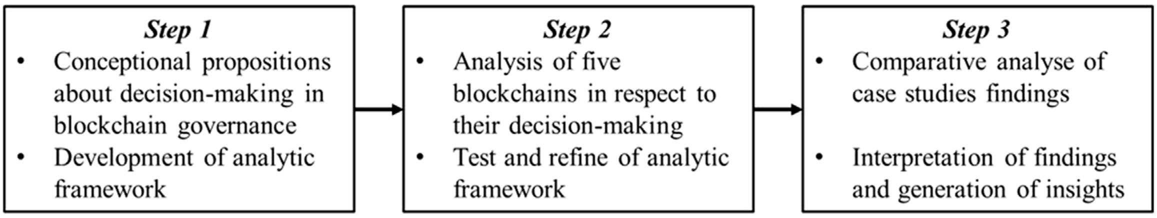

FIGURE 1
3-Step research design.

phenomenon. Alternatively, ordinary cases, accessible cases, or unusual cases can be chosen as well, according to Creswell and Poth (2018). For Yin (2018), case selection should be applied to the 'replication logic' of experiments, where the same outcome is expected for the same case ('literal replication'), while for deliberately different cases, different outcomes should come to fruition ('theoretical replication'). A deliberate selection of cases is what Eisenhardt (1989) calls 'theoretical' sampling. Although in her later articles she argues that to improve the generalizability (i.e., transferability) of the extracted theory to other situations, it is most useful to intentionally select different cases (Eisenhardt, 2021). Following these ideas of 'purposeful' and 'theoretical' sampling we searched for mature blockchain systems to which our analytic framework could be applied with expected different outcomes. The blockchain domain brought forward thousands of alike projects, including forks of major blockchains. For the sake of this research, we focused on five blockchain systems, which are 1) publicly well-documented, 2) have existing scientific material, 3) have run for several years, which proves their maturity, and 4) are based on different technological and conceptional approaches, namely: Bitcoin, Tezos, Stellar, Decred, and Ripple. We believe that different information sources, academic and non-academic, are equally important as research on blockchain systems can be considered in its infancy and especially the research on decision-making processes within blockchains has gotten very little attention so far. In studying these different blockchain systems, maturity and longevity of the projects have proven to be important characteristics, as it can be argued that the decision-making process evolves over time, when technical questions arise, and choices need to be made within the system. Additionally, it is advantageous for this research to opt for long-lasting blockchain systems providing a well-documented set of information.

3.3 Data collection and analysis

Scholars agree on the basic process of analyzing and interpreting a multi-case study, thus, a detailed description of each case should be given first, followed by a within-case analysis, and concluded with a cross-case comparison of the results (Eisenhardt, 1989; Stake, 1995; Creswell and Poth, 2018; Yin, 2018). With this in mind, we follow three clear analytic steps in our case research. However, it should be noted that this analysis and evaluation process is iterative and resembles 'analytical spirals' (Creswell and Poth, 2018) rather than a linear sequence. Accordingly, several iterative loops between the individual steps were necessary in this research, but for reasons of clarity and comprehensibility, they will not be reproduced in the following presentation, and we will rather present the final results. To retrieve data on the five cases (blockchain systems), we initiated a keyword search on various search engines covering the following keywords "(<system>) Governance", "(<system>) Whitepaper", "(<system>) Stakeholder", and variations of these words. In addition, because research on these systems is in its infancy, other internet sources have been included in the search, such as websites, fora, specialized blogs, or social media posts and videos to triangulate our findings. As shown in Table 1, our data search yielded 159 documents, of which 34 are academic papers and 125 are complementary files, with the most academic papers being found on *Bitcoin* (15) and *Ripple* 8), and the complementary files being evenly distributed among the five cases. Different researchers were involved in the data collection and its analysis, which again creates more reliable data due to research triangulation. In addition, the development of a basic conceptual framework from the literature not only helped us during the case selection, but also, in directing and defining our data collection, and analysis through conceptually oriented coding and summarization of data (Yin, 2018). In the case analyses, we used the developed conceptional framework as an analytic lens to study the five different blockchains. Each involved researcher applied the analytic framework first individually, so we could compare and discuss our findings afterwards. For the purposes of this article, however, we will only present the results of our within-case and cross-case analysis in Section 5.

3.4 Interpretation

The last step in a case study research is interpretation and generalization of the results and findings (Eisenhardt, 1989; Yin, 2018). Especially the aspect of generalization of the research findings has been criticized in the literature as being subjective and biased (Gomm et al., 2009; Forrest-Lawrence, 2019). However, especially for multi-case studies, Yin (2018) proposes the concept of 'analytic generalization', which differs from 'statistical generalization' in that it does not draw conclusions from data to a population; instead, it compares the results of a case study with the previously developed theoretical propositions so that these previous concepts can be either modified, rejected, further advanced or even completely new concepts can be developed and put forward. We therefore developed a conceptional framework for decision-making in

TABLE 1 Result of keyword search.

Keyword:*Governance, Whitepaper, Stakeholder* in combination with	Academic sources	Non-academic sources	Total
Bitcoin	15	17	32
Tezos	4	22	26
Stellar	4	31	35
Ripple	8	27	35
Decred	3	28	31
TOTAL	**34**	**125**	**159**

blockchains based on the current literature first. We then collected data and analyzed the selected five cases (blockchain systems) to generalize our findings by applying a framework to analyze and categorize decision-making in blockchain systems.

4 Analytic framework for blockchain decision-making

The literature review conducted showed that there is a lack of knowledge about decision-making in blockchains and that an analytical framework to evaluate and discuss the different approaches used in practice would be desirable. With the aim to establish a first theoretical concept to analyze and categorize the decision-making processes in blockchain systems, we have adapted the discussed governance framework of van Pelt et al. (2021) together with some further inputs from Beck et al. (2018) and Liu et al. (2022) with the final result of five analytical categories (*decision-makers*, *incentives*, *access*, *coordination*, and *approval conditions*) and the two governance-layers of *on-chain* and *off-chain*. In line with our research objectives and questions, we focused on decision-making within the lifecycle of the blockchain system development itself, which, according to Liu et al. (2022), is the main target of any blockchain governance. Therefore, we excluded any further levels of blockchain governance mentioned by Liu et al. (2022) concerning the development of the community, the applications, or the data transactions. However, before we analyze five blockchain systems with the aim to get more insights into how these categories can be configured and how decision-making in blockchain systems can be differentiated from one another, we will first shortly describe the categories, whereas each category can be split between the two governance-layers of *on-chain* and *off-chain*.

4.1 Decision-makers

As our research focuses on the decision-making process, we have renamed the category *roles* of van Pelt et al. (2021) to *decision-makers*. Decision-makers are thereby stakeholders that have decision-making power in the decision-making process of the blockchain system. Excluded are stakeholders that have indirect influence on the decision-making such as the community of a blockchain. Depending on the blockchain system and its defined update processes, these decision-makers can act *off-chain* and/or *on-chain*.

4.2 Incentives

Generally speaking and in line with Beck et al. (2018) and van Pelt et al. (2021) our second category '*incentives*' focuses on the intrinsic and extrinsic motivations to participate in the decision-making process. However, as motivation is a very broad concept and especially 'intrinsic motivation' is difficult to evaluate, we focus on the monetary gains that are enabled by participating in the decision-making process of the blockchain. Those gains could come in the form of a direct reward for the participation or indirectly by increasing the worth of the blockchain itself, which results in an increase in the token price.

4.3 Access

The third category in our analytic framework concentrates on the *access* to the decision-making process, which can be compared to the *membership* dimension of van Pelt et al. (2021). *Access* describes the requirements that need to be met so one can participate in the decision-making process. There are also different ways to restrict access—off-chain and on-chain. Off-chain access to decision-making for example can be restricted contractually, by informal groupings or by copyright protection mechanisms. When it comes to the on-chain decision-making process, access can be restricted by requiring the voter to meet certain criteria, for example holding a specific token.

4.4 Coordination

In our fourth category, similarly to van Pelt et al. (2021) we analyze *coordination* within the decision-making process. Coordination describes the way in which the decision-making process of a specific blockchain system is structured. If the blockchain has a built-in voting mechanism, the process can be coordinated on-chain. It can also be fully off-chain like the coordination in a traditional company, or a mixture between on- and off-chain processes.

4.5 Approval conditions

The fifth and final category we implement into our framework is dedicated to the approval conditions with the goal of better

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Bitcoin	Governance-Layer	
Decision-Making Categories	Off-Chain	On-Chain
Decision-Makers	Bitcoin Core Maintainers	Miners Nodes
Incentives	Speculation	Mining rewards Hardware costs
Access	Public/Open	Mining hardware Node hardware
Coordination	Bitcoin Improvement Process	None
Approval Conditions	None	Absolute majority of 95% of the hashing power

FIGURE 2
Bitcoin decision-making.

understanding the decision-making processes in different blockchain systems. According to van Pelt et al. (2021), approval conditions are an important aspect of the decision process and can be described as the way decisions are agreed upon. Typical conditions in blockchain systems for approval of a particular decision can be, for example, a predefined quorum of participation that a decision must reach so that it can be approved by the relative or absolute majority, or often even by a specific super-majority of all votes.

5 Findings

5.1 Case analysis: Manifestation of the categories

In the following the five blockchain case studies will be analyzed in detailed along the categories defined above and along the two governance-layers of decision-making in blockchain systems. The findings are then summarized for each blockchain system in Figures 2–6. The analysis starts with the first blockchain in existence, Bitcoin, followed by Tezos, Stellar, Ripple and finally Decred.

5.1.1 Bitcoin

In the early years of Bitcoin in 2008, Satoshi Nakamoto was a key stakeholder, and his decisions were very influential. According to DiRose and Manouri (2018) there was no defined process in place that would handle development decisions. Due to the low awareness and popularity of the cryptocurrency, there were only few stakeholders who were interested in participating within the project. Since then, Bitcoin has gained popularity and the upgrade process has been formalized. Today, the so-called Bitcoin Improvement Proposals (BIPs) are used to organize proposed improvements on the Bitcoin blockchain. The BIP process hereby defines how new proposals need to be issued in order to get implemented (Dashjr, 2016). As the Bitcoin Core project is open source, contributing to the codebase is open to anyone willing to do so, though only the Bitcoin Core maintainers have commit access to the Bitcoin Core GitHub. The maintainers merge patches and act as off-chain gatekeepers to ensure the safety of the patches. This restriction does not mean, that the maintainers have centralized power over the Bitcoin Core code. No thresholds are given for off-chain acceptance. If the community deems the maintainers to be unreliable, the repository can be forked, and new maintainers may be selected. Bitcoin is licensed under the MIT license, which allows both free access to the software and free usage (Bitcoin Core GitHub, 2022).

There is no built-in voting-mechanism in Bitcoin, however, votes on protocol updates can be carried out by the node operators. Nodes can be split into two categories: Nodes and miners. Nodes run the Bitcoin software as a full node and act as peers in the Bitcoin peer to peer network. They keep a copy of the ledger and verify transactions and new blocks. Miners also run a full node but additionally, they add blocks to the blockchain. As a recommendation, BIP proposals are considered accepted, when 95% of the last 2016 blocks produced are signaling acceptance. This means, that 95% of the mining power needs to accept the change (Wuille et al., 2015). Because of the high amount of computing power involved in mining, the chances of a single miner mining a block and getting the rewards are low. This has led to the formation of mining-pools where miners combine their hashing power and get rewarded proportional to the hash power they submit to the pool. By pooling the hashing power of multiple users, mining pools also act as delegates for the votes of their users.

The Bitcoin voting system has evolved from only considering miners to also including nodes in the decision-making process. Nodes can choose not to forward transactions or hashed blocks coming from a miner that does not support a specific BIP. This puts economic pressure on the miners and is called "user activated soft fork". It can be seen as a democratization of the voting power within the system (Fry, 2017). There are multiple incentives to participate in the decision-making process for Bitcoin upgrades. People or institutions who hold Bitcoin have a vested interest in the future success of the cryptocurrency. In order to profit from their investments, they are thus incentivized to contribute to the decision-making process in a manner that is most likely to

Tezos		Governance-Layer	
		Off-Chain	On-Chain
Decision-Making Categories	Decision-Makers	Merge Team	Validators Token Holders
	Incentives	Tezos Foundation salary Speculation	Staking rewards Staked tokens
	Access	Public/Open	Node hardware Staked tokens
	Coordination	None	Amandement process
	Approval Conditions	None	Two supermajorities of 80% with a variable quorum

FIGURE 3
Tezos decision-making.

increase the value of the cryptocurrency. Similarly, the miners also have an interest in a positive development of the Bitcoin price. Miners speculate on compensating the upfront costs for the mining hardware with mining rewards that are paid in Bitcoin. The higher the block rewards and transaction fees in Bitcoin and the higher the fiat-price for bitcoin, the better it is for the miners.

5.1.2 Tezos

With Tezos, the decision-making process for the further development of the blockchain has been addressed by utilizing a built-in upgrade mechanism. According to Goodman (2014) the liquid proof-of-stake consensus mechanism prevents diverging interests of those who validate transactions and the users of the blockchain application. This model is intended to prevent the emergence of hard forks. In contrast to the proof-of-work consensus mechanism, the validators, who are called Bakers in Tezos, must themselves hold and stake tokens to perform their function.

In comparison to the BIP-process that takes place off-chain except for the voting, the development of the Tezos blockchain is coordinated on-chain. No off-chain voting process with a threshold exists for Tezos upgrades. Tezos upgrades must pass a multi-stage on-chain voting process, first winning a proportional vote and then two supermajorities to get implemented. The five phases take a total of 2 months and 10 days to be fully implemented and functioning on the blockchain protocol (131,072 blocks). In the first phase, the proposals are submitted. Each delegate can submit up to 20 proposals. If a quorum of 5% is met, the proposal with the most votes moves on to the next phase (Tezos Agora Wiki, 2023). In a second phase, the proposal chosen in the first round is voted on. The quorum for this vote is dynamically set based on the participation of the last vote, but there are fixed upper and lower boundaries in place which are set at 20% and 70% respectively. To pass to the next stage, the proposal needs to achieve a supermajority of 80%. If a quorum and a super-majority are met, the third phase occurs which is a time buffer between the second and fourth phase. The fourth phase is a repetition of the second phase. If the proposal passes the fourth stage, the proposal is activated in stage five (Tezos Agora Wiki, 2022).

All token holders can participate in the vote. If token owners do not want to participate in the voting themselves, they can delegate the voting rights of their tokens to validators. The weighting of the votes follows the proof-of-stake approach, i.e., it corresponds to the size of the tokens in possession (stake).

There are multiple actors influencing the development of Tezos. The Tezos Foundation has been founded with the goal to ensure the long-term success of the blockchain. With a budget of 1′176 million USD, the foundation can influence which projects in the ecosystem get a head start and what development efforts for Tezos get funded. Although the foundation does provide funding, it does not use the TEZ tokens it owns to vote for or against any proposals (Tezos Foundation, 2023). The development of Tezos is handled by protocol developers, off-chain entities who contribute to the Tezos codebase. Like the Bitcoin Core maintainers, the Merge Team is a group of developers that are selected when a merge request is created.

Decision-makers can be incentivized to contribute to the decision-making process because they receive a salary as employees of an organization that contributes to Tezos. As with Bitcoin, speculation is also a relevant aspect of the decision-making process in Tezos and Bakers have an interest in a positive development of the Tezos price because of their locked capital.

5.1.3 Stellar

The Stellar Consensus Protocol (SCP) is used as the consensus mechanism for Stellar which is based on a new Byzantine agreement protocol (Stellar Development Foundation, 2022b). Participants determine who they trust through quorum sets and exchange transaction information with these trusted nodes. Anchors are actors that are responsible for depositing monetary values to create new tokens (Stellar Development Foundation, 2022a). These tokens then function as stablecoins in the Stellar network (Stellar Development Foundation, 2022a). The role of anchors is performed generally by traditional financial institutions, which are also the interface between the Stellar network and its customers. The lack of on-chain rewards means that there are no on-chain incentives for network participants to participate in the decision-making process. As most of the nodes of Stellar are also using the

Stellar		Governance-Layer	
		Off-Chain	On-Chain
Decision-Making Categories	Decision-Makers	Stellar Development Foundation (SDF)	Validators
	Incentives	SDF salary Speculation	None
	Access	Public/Closed	Reputation of validator
	Coordination	Core Advancement Proposals	None
	Approval Conditions	None	Supermajority of validators

FIGURE 4
Stellar decision-making.

Ripple		Governance-Layer	
		Off-Chain	On-Chain
Decision-Making Categories	Decision-Makers	Ripple	Validators
	Incentives	Ripple salary Speculation	None
	Access	Private/Closed	Reputation of validator
	Coordination	Internal process	None
	Approval Conditions	None	Supermajority of 80% of the validators

FIGURE 5
Ripple decision-making.

blockchain for their products and services, they may be motivated to participate to shape Stellar for their use case. Stellar Core is licensed under the Apache License, Version 2.0 (Stellar Github Decred, 2022). Due to the lack of copyleft characteristics of this license, further developed code does not necessarily have to be made freely available.

Stellar upgrades are handled by an off-chain process similar to the BIP-process called CAP-Process. Core Advancement Proposals (CAPs) are used to organize suggestions for improvements to the Core Protocol and take place fully off-chain with no on-chain process in place. CAPs must first be approved by the CAP Core team which is staffed with three members of the Stellar Development Foundation (SDF). There are no voting thresholds in place for this approval. After the approval, a supermajority of validators must implement the changes for a CAP to reach the final “implemented” status (Stellar Github, 2023). Stellar bases its value propositions strongly on partnerships with traditional institutions which are managed by the SDF. While it is theoretically possible for the community to fork Stellar in case of a disagreement, it is questionable whether it could capture the same value after changing into a more decentralized infrastructure.

The SDF has been founded in 2014 with the goal to support the development and growth of the Stellar network. With a budget of almost 30 billion Lumen (the native currency of Stellar), the SDF can influence which projects in the Stellar ecosystem get a grant and steer the development of Stellar (Stellar Development Foundation, 2023).

5.1.4 Ripple

The Ripple network is not so much a cryptocurrency *per se*, but a payment system comparable to traditional payment networks such as PayPal or Mastercard (Ripple, 2022a). It is used by numerous banks and organizations (Ripple, 2022b). Like Stellar, the main use case of Ripple is interbank payments, which take place between individual banks. Thus, the payment solution is not an offer for private customers. To ensure that the respective parties meet their obligations, they must trust each other. To this end, the individual participants determine with whom this is the case and to what

Decred		**Governance-Layer**	
		Off-Chain	**On-Chain**
Decision-Making Categories	**Decision-Makers**	Token holders	Nodes Miners Token holders
	Incentives	Decred grants Speculation	Mining rewards Hardware costs Staking rewards Staked tokens
	Access	Public/Open	Mining hardware Staked tokens
	Coordination	Decred Change Proposal	Consensus Rule Voting
	Approval Conditions	Supermajority of 60% with a quorum of 20% of stakers	Supermajority of 95% of the hashing power and 75% of staked tokens

FIGURE 6
Decred decision-making.

extent. Ripple applies the XRP Ledger consensus protocol as a consensus mechanism (Armknecht et al., 2015). Ripple as a company has been founded in 2014 with the goal to support the development and growth of the Ripple blockchain. Since then, the company has raised over US$ 290 Million. On-chain, validators are responsible for running nodes and validating transactions. Each validating server uses a Unique Node List (UNL) in which it keeps track of the other validating servers it trusts (Armknecht et al., 2015). Similar to Stellar, there are no on-chain incentives and the incentives for nodes are use-case driven.

Ripple is licensed under the ISC license which gives anyone permission to use, copy, modify, and distribute the code (Nik Bougalis, 2020). The XRP Ledger GitHub is public but controlled by the Ripple company. In theory, anyone can contribute, and the Ripple team has a bounty system in place to attract developers. The decision if code gets included in the Ripple stack lays with the Ripple company and is handled off-chain. No on-chain process exists. Ripple updates are called amendments which need to gather support of 80% of the validators in the network for 2 weeks in order to be accepted (XRP Ledger, 2023). The decision-making process of Ripple is not clearly outlined. No public approval conditions are in place. Decision-makers may want to contribute because they are employed at an organization that contributes to Ripple or want to receive a grant. As with the use cases covered beforehand, speculation on the token price may also be involved, but Ripple provides no on-chain rewards or incentives.

5.1.5 Decred

Instead of being secured by one layer of consensus, Decred is secured by both proof-of-stake miners and proof-of-work stakers. Decred is designed as a Decentralized Autonomous Organization (DAO). The Decred Change Proposal (DCP) process enables consensus rule changes. When a proposal is submitted, it must come with the code changes to the node software already implemented. In order to be put to a vote, a proposal needs to first be posted on Politeia, which is a platform built for voting on Decred proposals. Politeia is an off-chain tool that is anchored on-chain. To protect the platform from spam, account creation and proposal creation cost a fee. Moderators of the platform can censor proposals if they are deemed to be spam or illegitimate. Censorship is made public by a cryptography which provides recourse for anyone that thinks that a proposal has been wrongly censored. Proposals need to gather a supermajority of 60% votes in favor with a quorum of 20% of the available voting power in a set period of 2016 blocks (Decred documentation, 2023a). A node upgrade needs approval from both validator sets. To be formally accepted by miners, a proposal has to gather 95% of the aggregated hashing power of 1000 blocks. To gain acceptance by the miners, the proposal needs 75% of the casted votes over the last 2016 blocks in its favor (Decred Documentation, 2023b).

To ensure further development of the blockchain, ten percent of the block rewards are paid into Decred's treasury, which is used to pay employees' salaries and fund projects (Issuance - Decred Documentation, 2023c). The developers are thus paid directly with the cryptocurrency, which provides them with an additional incentive to act sustainably and stay within the interests of the project's overarching goal. The Decred code is licensed under the ICS license, which allows both free access and free reuse of the software (Decred Github Stellar, 2022).

5.2 Comparative analysis: the decision-making quadrant in blockchains

Comparing the actors involved in the decision-making process of the five blockchain systems analyzed, we can observe that all five blockchains have a great similarity; they all have an off-chain development team and on-chain validators as the main actors in the decision-making process of their systems. In addition, for some blockchains such as Decred and Tezos, we can see that token holders also play some role in the on-chain decision-making. However, we can see a difference in the access and incentive to become one of these main decision-makers. Whereas in some blockchain systems access to the off-chain developer team is controlled by a company like Ripple or foundations in the case of Stellar and Tezos, in blockchain systems like Bitcoin and Decred access to the core developer team is open and not institutionalized. Similarly, we can observe that in some blockchain systems, it is not possible for just anyone to become an on-chain validator, but some kind of accreditation is required. While in Bitcoin, Decred, and Tezos everyone can autonomously become a validator themselves by investing in IT infrastructure as well as (sometimes) tokens, in Ripple and Stellar validators are chosen by a central institution based on their (off-chain) reputation.

The differences in access to decision-making also have a significant impact on the differences in the implemented incentive systems. For example, blockchain systems with autonomous access to decision-making like Bitcoin, Tezos and Decred, need to provide an incentive system accessible to everyone so that there are enough incentives to become an active decision-maker and participate in the governance. This is usually done through on-chain rewards for stacking and mining, whereby speculative incentives present in all blockchain systems due to their own cryptocurrency may play a role as well. In contrast, blockchain systems like Stellar and Ripple, which do not have an autonomous access for decision-makers, need to rely heavily on salary payments for their continued development. Here we can observe that Tezos has implemented an interesting middle way in its governance approach, as they have some autonomous access to become an on-chain validator (baker) but rely mainly on employees with a salary for further development and protocol updates.

In terms of coordination, we can note that Ripple, Stellar and Bitcoin have not implemented an on-chain decision-making process, but rather rely on off-chain coordination. In the case of Ripple and Stellar, this can be explained by their clear reliance on known and elected decision-making actors. However, in the case of Bitcoin, this may be more related to its early development, where on-chain coordination of decision-making was not yet discussed when it comes to the governance of blockchains. However, later developed blockchains such as Tezos and Decred have implemented decision-making processes that rely heavily on predefined on-chain procedures, which provides them also a more transparent and verifiable governance approach. Finally, regarding approval conditions, we found that all five blockchains have implemented a final on-chain decision approval based on a supermajority of on-chain decision makers. This shows that all analyzed blockchain systems have implemented a governance approach where the final decision-making is done on-chain. It appears that all blockchain systems believe that at least this final decision approval must be recorded on the blockchain, even though access, incentives, and coordination of the decision-making processes are often neither on-chain nor accessible to all members of the community.

Comparing the decision-making process for protocol changes of the five analyzed blockchains indicates that there are significant differences between them, especially in terms of access to and coordination of the decision-making process. In the following we will look in more detail on these two main aspects of decision-making and therefore key dimensions in the applied governance approach in blockchains. The analyzed blockchain systems incorporate thereby off-chain decision-making processes that are adapted versions of the off-chain Bitcoin Improvement Process. The main differentiation between the analyzed implementations can be found in the way the gatekeepers of the code repository are chosen. The Bitcoin Core maintainers, for example are selected by Bitcoin Core contributors (Bitcoin Core, 2023). Tezos follows a more aristocratic approach, as new Merge Team members are chosen by existing members (Nomadic Labs, 2023). In the case of Stellar and Ripple, the maintainers are employed at their respective institutions, whereas Decred uses a different approach by not relying on a small team to filter the proposals but instead letting the community do the filtering process.

However, the analyzed blockchains differ more on the on-chain side of the decision-making process than on their off-chain processes. The first differentiator is the access to the on-chain decision-making process. Bitcoin, Tezos and Decred are all open for anyone who wants to join to do so. The decision-making power correlates directly with the capital invested in either tokens for stacking for proof-of-stake or mining hardware for proof-of-work. In contrary, due to their consensus algorithms relying on nodes trusting each other, in Ripple as well as in Stellar the decision-making power is determined by the reputation of the validators and therefore not as accessible as of Bitcoin, Tezos and Decred. This also impacts the incentives, as there are no direct rewards for securing the network for those two 'reputation-based' blockchains. Whereas miners and stakers on the other three analyzed blockchain systems have a vested interest in the continued success of their system due to the upfront costs they spent on mining hardware or tokens which is compensated over the long term in the native currency of the blockchain. Nevertheless, the validators of the reward-free blockchains are also interested in future success of their respective system as they spend money running their validator nodes.

In terms of blockchain development mechanisms for the five cases studied, two main differences in the decision-making process can be identified: *first*, whereas in some blockchains the decision-making processes are mainly driven by formal institutions (Ripple, Stellar, Tezos), in other systems the decision-making process is mainly driven by a wider and open community (Bitcoin, Decred); and *second*, whereas some blockchains rely more on on-chain procedures (Tezos, Decred), others make mainly us of off-chain decision-making (Bitcoin, Stellar, Ripple). This leads to the conclusion, that decision-making for blockchain protocol development happens in a two-dimensional spectrum.

As shown in Figure 7, the first axis of the spectrum shows the degree of institutional, respective communal involvement in the decision-making process, where one extreme would be that all decisions are made only by one institution that has control over the entire process and on the other end of the spectrum, the decision-making is completely decentralized without any gatekeepers. The second axis shows whether the coordination and execution of the decision-making process mainly takes place on-chain or off-chain. With respect to on-chain and off-chain governance, we could observe that all our analyzed blockchain protocols implement some sort of off-chain decision-making elements. Consequently, decision-making processes with many off-chain elements are similar to mechanisms in non-blockchain organizations.

Taking the developed arguments into consideration, we can finally place the five analyzed blockchains into the four quadrants between the two axes as shown in Figure 7. *Bitcoin* in the top left corner with a community-driven and off-chain focused decision-making process, whereas *Decred* can be placed top right with a

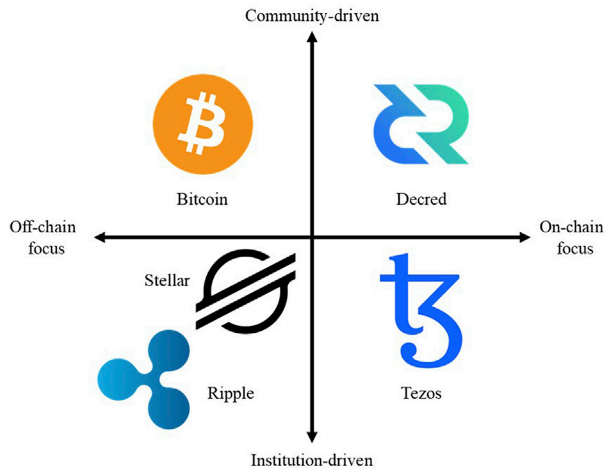

FIGURE 7
Decision-making quadrant for blockchains.

community-driven, but on-chain focused decision-making process. At the lower level with their mainly institutional-driven decision-making process, we can place *Ripple* and *Stellar* on the left side with their stronger off-chain focus, and *Tezos* on the right side with its clear on-chain focus.

6 Discussion

Our research suggests important factors to capture decision-making in decentralized blockchain systems. While there are many applications that can be governed *through* blockchains, we focus on the governance *of* blockchains. To understand the decision-making process in blockchains, it is thereby crucial to determine who the actual decision-makers are. One of the major characteristic of blockchains that can be found in the literature, is that no central authority controls the system (Zheng et al., 2017). This means that no single decision-maker has the power to control a blockchain system. While this might be true for the consensus mechanisms on transaction level in blockchains, our findings show that this must be at least re-evaluated for the decision-making in blockchains, thereby aligning with some evidence from previous research on governance (Heo and Yi, 2023).

Then by looking at the four identified quadrants, we can identify central parties in three of them. In an *institution-driven* decision-making approach with *off-chain focus* such as in Ripple and Stellar, the decision-making process is mainly taken over by a central institution. Systems that use this mode of decision-making place trust in a central authority controlling the main parts of the governance. For the *institution-driven* blockchains with an *on-chain focus* like Tezos, a central entity indirectly influences the decision-making process by their strong position in steering the incentives like salaries and grants. Therefore, no central authority (or group) controls the decision-making process, but there is a single entity (generally a foundation) that at least exerts a certain influence and shapes the decision-making process to some extent. The situation in the *community-driven* and *off-chain focused* approaches like Bitcoin is similar, hereby no institutionalized entity guides the decision-making process, but rather an informal group of historically connected core members have disproportionate power due to their reputation and expertise in steering the outcome of the decision-making process. Eventually, the *community-driven* and *on-chain focused* DAOs like Decred come closest to the blockchain-inherent decision-making process without a central authority, as these types of blockchains enable a broader decentralized community to participate and take influence on the mainly on-chain decision-making process.

Our analysis shows that when institutions are involved, especially when they have a considerable amount of funds or occupy a gatekeeper function in the decision-making process, the governance in a blockchain can be influenced by a small number of individuals. Furthermore, we can observe that blockchains with an institution-driven decision-making process that mainly takes place off-chain, such as Ripple and Stellar, demonstrate a strong focus on institutional partnerships. While being institution-driven and not having on-chain decision-making processes may not be in the spirit of Satoshi Nakamoto it may be more appealing to traditional companies and institutions that prefer having a single point of contact for business relationships and the stability provided by a limited set of decision-makers. However, this is a trade-off, as distributed security and transparency gets lost.

When the decision-making process of institution-driven blockchains takes place predominantly on-chain, such as with Tezos, the processes are inherently more transparent, and the influence of the institution is limited to funding and promoting projects which then provide code for the upgrades. For the institution-driven blockchains with an on-chain focused decision-making process, having the institution in place is a trade-off between the increased efficiency in decision-making and execution, especially when it comes to smaller decisions, that centralized structures can provide. Institutions can also provide stability to an ecosystem, as an institution, that has the sole purpose of benefitting the system, will keep supporting it even if there is a momentary downturn or less interest in the system.

Chains that also have their decision-making process mostly *on-chain* but more of a *community-focus* when it comes to decision-making, such as Decred, profit from decentralization but have more complex decision-making processes and are generally more dependent on the short-term price development of their respective tokens as they have to use it as an incentive for further development. With all processes being on-chain and decentralized, having an active community and high voting participation is important in order to prevent a vocal minority from taking over the governance. Bitcoin and similar *community-driven* blockchains that have a big part of their decision-making process taking place *off-chain* can suffer from volatile governance because off-chain decision-making processes can be less transparent compared to on-chain processes. In combination with the absence of a central entity controlling the governance and providing direction, the off-chain focus may lead within this quadrant to blockchains that are more prone to chaotic discussion-making processes and forking.

We believe that the selected decision-making approach in a system might be connected to the purpose of the system. Ripple and Stellar, for example are both targeting banks as their customers. The financial system is a highly regulated sector that requires standardized and legally conform approaches. Therefore, a rather centralized decision-making approach that can be easily controlled might be more adequate. Tezos on the other side wants to provide a system to build all kind of decentralized applications. They want to include an active community which is also reflected in their delegation-based decision-making process. Bitcoin and Decred in turn want to be a decentralized currency. As a consequence, decentralization is important for both systems. While Bitcoin has avoided to create any institutionalized setting, Decred has opted for a decentralized autonomous organization. However, both heavily rely on high community participation for their sustained governance and survival.

In general, the decision-making approaches of blockchain systems cannot be analyzed and categorized without their purpose. There is no "right" and "wrong", but different configurations may be useful for different applications. A fully decentralized decision-making process is not always sensible and not necessarily the best choice (neither the most realistic). Also, there are many trade-offs that should be balanced in the decision-making process. It seems crucial that blockchain platforms are aware of the nature of their decision-making approach (on-chain vs. off-chain/community-vs. institution-driven) and are also transparent about it.

7 Conclusion

We identified a gap in the current research on blockchain governance. While there are several frameworks looking at blockchain governance in general, the decision-making process in blockchains has been neglected so far. In order to answer the first research question, "how can current blockchain governance frameworks be adapted to specifically analyze and categorize decision-making in blockchain systems", we have collected data on five major blockchain systems to build an analytic framework for the decision-making in blockchains based on existing governance frameworks. Our blockchain decision-making framework contributes to the identified research gap by providing a tool to categorize and analyze decision-making in blockchain systems. We further applied our framework to demonstrate its utility and to answer the second research question, "how can we distinguish decision-making approaches used in blockchain systems?". Our results suggest that decision-making in blockchains has different degrees of decentralization. It can be fully centralized, i.e., in the hand of one company, or rather decentralized and led by a community. However, it seems that most blockchains need a centralized element in their decision-making approach in order to be able to make coherent and also fast decisions if needed. Furthermore, our study showed that the analysis of the off-chain aspects is still crucial in understanding decision-making in blockchain systems as not (yet?) all decision can be programmed and handled only on-chain.

As these are just some first insights into the decision-making in blockchain systems, our work comes with a few limitations. We only looked at a subset of the blockchain ecosystem. To improve our framework and to identify further dimensions, a larger dataset would be helpful. However, we emphasize our contribution to this novel field. Our study is a first step to better understand the decision-making processes in blockchains. From a methodological standpoint, we admit that interpretation of the collected data might had an influence on the framework development. Nevertheless, we stress the equal treatment of the blockchain systems. Further reproducibility and expert involvements could help to strengthen our approach. The categorization into centralized and decentralized blockchain decision-making approaches has been avoided, even though decentralization is a big part of the unique selling proposition of blockchains. We chose to do so because calling an approach centralized or decentralized is a broad definition that misses the smaller nuances of decision-making that we point out in this paper. We strongly believe that decentralization in blockchains is based on two underlying system design elements of *community-driven* and *on-chain focused*—and only blockchains which are pursuing both dimensions in their decision-making approach can be called 'decentralized'.

We hope that the developed framework provides a first step to better understand decision-making in blockchains. It can be a starting point for researchers and practitioners alike to design and evaluate decision-making approaches in blockchains. This should improve conditions and lead the way to blockchain-based applications and business models.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

LS: Investigation, Writing–original draft, Writing–review and editing. ML: Methodology, Writing–original draft, Writing–review and editing. FS: Conceptualization, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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