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Governance challenges of blockchain and decentralized autonomous organizations

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Abstract. The rise of blockchain has resulted in discussions on (new) governance models with multiple actors collaborating. Incidents and problems occurred due to flaws in blockchain protocols, smart contracts and Decentralized Autonomous Organizations (DAOs). Often it is unclear how decisions are made concerning evolvement of blockchain applications. In this paper, we identify and analyze potential challenges regarding governance of blockchain initiatives in various types of decentralized networks using literature and case study research. The governance challenges are classified based on a framework consisting of different layers (infrastructure, application, company and institution/country) and stages (design, operate, evolve/crisis). The results show that in various stages and layers, different challenges occur. Furthermore, blockchain applications governance and blockchain infrastructure governance were found to be entangled adding to the challenge. Our research shows a specific need for further research into governance models for DAO applications on permissionless blockchains, linked to the products and services offered whereas in permissioned blockchains and other type of applications, existing governance models might often be feasible. For developing new governance models, we recommend learning from the lessons from the open source community.

Keywords: Blockchain, Decentralized Autonomous Organization (DAO), governance, IT-governance, permissionless, smart contracts

Key points for practitioners

- Using a framework consisting of different layers (infrastructure, application, company and institution/country) and stages (design, operate, evolve/crisis) is useful to analyze potential governance challenges in blockchain implementations.
- Unlike in non-blockchain applications, in blockchain applications there exists a high entanglement of application and infrastructure, where the application can be dependent on the governance of the infrastructure, which can complicate governance models.
- In permissionless blockchains, especially for DAO applications, further research is needed towards new governance models.
- In permissioned blockchains, although not always easy, existing governance models can be applied.

1. Introduction

A decade ago, the idea for a decentralized, peer-to-peer system, was published by Satoshi Nakamoto in the Bitcoin white paper (Nakamoto, 2008). Although initially designed for a peer-to-peer cash system, the new system offers the possibility of transacting in which the information integrity and security is safeguarded by the system. Such systems are expected to result in a major organization change, as the role of a trusted third party (TTP) would be embedded in the system design instead of an organization or person. This is possible due to a combination of decentralized storage, consensus mechanisms

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and cryptography, leading to characteristics like (semi-)irreversibility and persistent storage (Nakamoto, 2008; Swan, 2015; Wright & De Filippi, 2015). These characteristics make it extremely hard to single handedly reverse or delete a datapoint or transaction.

Yet, trust also dependent on the network participants. As various of these networks are open and anybody is able to join without any entrance barriers, many of the participants in the network are often unknown (Matilla, 2016). Although it is argued that this openness and unknown network participants results to a shift to a trustless environment (Bahga & Madisetti, 2016; Swan, 2015), the trust of correct execution is embedded in the technological solution. The elimination of TTP organization poses various key governance questions: Who is responsible for what? Who decides on changes in the blockchain application and organization? Who can be held accountability for which failures? And who takes risk mitigation measures when incidents happen?

In particular, various of these accidents resulted in the need for arranging *crisis* governance. Three most debated incidents with regards to governance are the DAO incident (Falkon, 2017), Parity multisig wallet hack (Palladino, 2017) and Parity II or token and cryptocurrency freezing incident (Akentiev, 2017), leading to a loss of several $100 million. Due to *entanglement of application and infrastructure* the solving of these issues was dependent on governance of the infrastructure. However, only in the DAO incident, governance action was indeed taken by the infrastructure community. In the other cases, no action was taken by the infrastructure community and the value was lost due to a lack of effective governance possibilities in the application itself. Due to the decentralized character, there is no single owner of the infrastructure which complicates governance. As there was no TTP anymore to (un)do actions or could stop ongoing actions, it triggered discussions around various regulatory and governance questions. It led to the first formal investigation by an American regulator, the Security and Exchange Commission (SEC) (Commission, 2017).

The networked nature of blockchain and DAOs makes governance not straightforward. *Governance* represents the framework for decision rights, incentives and accountabilities to encourage desirable behavior in the use of resources (Weill, 2004). Governance mechanisms determine how communication, responsibilities and decision-making structures are formalized (Weill & Ross, 2005). Governance should define decision-making authorities and accountabilities in a decentralized network consisting of several parties. Often blockchain is associated with automated self-governance, i.e. the governance is embedded in the system, through consensus mechanisms. However, this concerns only the governance of the exploitation or "block-to-block" operation (governance by blockchain) and does not contain the governance about development, updates or dealing with failures (governance of blockchain) (Ølnes et al., 2017). This signifies that other and even new kinds governance models and mechanisms might be required, however, there is limited insight into the governance challenges that should be addressed by these models. The need for new governance models are even presented as one of the main barriers to adoption of the technology (Batubara et al., 2018).

The aim of this paper is to identify governance challenges in blockchain applications. Governance is challenging as the need for governance and the governance challenges are dependent on the many variations of blockchain implementations. The underlying premise of our research is that each variant might encounter different challenges. The main variants are either private or public-closed blockchains (private/public permissioned blockchain) versus public-open blockchains (public permissionless blockchain) (Mainelli & Smith, 2015; Walport, 2015). This paper has three main contributions. First, we elicit governance challenges in the different forms of blockchain variants. Second, we distinguish various decentralized applications types and their specific governance challenges. Third, we classify challenges using various layers and stages of governance in blockchain projects. This paper is structured as follows. In the next section the research method is presented followed by a literature review in Section 3. From the literature review we derive the type of applications which will be used to develop a blockchain governance framework in Section 4. Section 5 describes the governance challenges using the governance framework and finally, we draw conclusions and outline further research needs.

2. Research method

To identify the governance challenges literature review was conducted and interviews were conducted. Structured literature review was performed based on the systematic literature review approach by Kitchenham (Kitchenham et al., 2010). Based on this approach, 51 articles, papers, blogs and transcripts, with total pages of over 850, were analyzed. The initial search was initiated via scholar.google.com based on the keywords "blockchain" AND "governance" in the period of December 2018–February 2019.

In addition to the literature, we conducted interviews with four experts to gain a deep insight into the typical governance challenges and approaches of how to tackle the challenges. The interviewees were selected based on their practical experiences in governance of blockchain projects. The number of people meeting this main criterion is limited due to the limited focus on practical governance of blockchain so far. Interviews were conducted with an industry expert in decentralized Application development from Swarm City, an industry expert in decentralized consensus mechanisms and two researchers (an academic scholar as well as a researcher from a not-for-profit organization) who are researching and teaching various blockchain topics, including blockchain and smart contract governance. Finally, the development of the number of DAOs in time are shown.

Table 1
Basic research data

Type of data	Amount/number of pages (last date searched)
Interviews	4
Papers/blogposts	850+ pages (27 March 2019)
Blockchain protocols analyzed	18 (30 January 2019)
DAO count	516 (21 February 2019)

Although many articles touch upon the subjects of blockchain and governance, the most cited articles are either describing the *application of blockchain to discuss new possibilities of state governance* or *to which extent blockchain and decentralized platforms can be considered as hyper-political tools*. For example the work of Atzori (Atzori, 2017) explores if blockchain is capable in managing social interactions on large scale and dismiss traditional central authorities while Jian and Zhang (Jia & Zhang, 2017), argue that blockchain as a technology should be governed by law by a state. Hsieh and colleagues (Hsieh et al., 2018) focus primarily on governance lessons from cryptocurrencies instead of application build on top of a blockchain whereas Casinoa and colleagues (Casinoa et al., 2019) focus on applications that can support governance like identity management, Voshmgir (Voshmgir, 2017) discusses disrupting governance in itself by using blockchain, and Yermack (Yermack, 2017) the potential corporate governance implications of blockchain technology. Although these provide some insights, they do not target governance of blockchain and blockchain applications and projects as main research area.

We found 51 publications to be relevant. Figure 1 shows the detailed breakdown of the literature. The number of peer-reviewed papers that specifically go into the governance of blockchain in itself and or the governance of blockchain applications is very low. Of the 51 articles, papers and blogs found to be relevant only four were peer reviewed articles in which blockchain governance in itself was the main

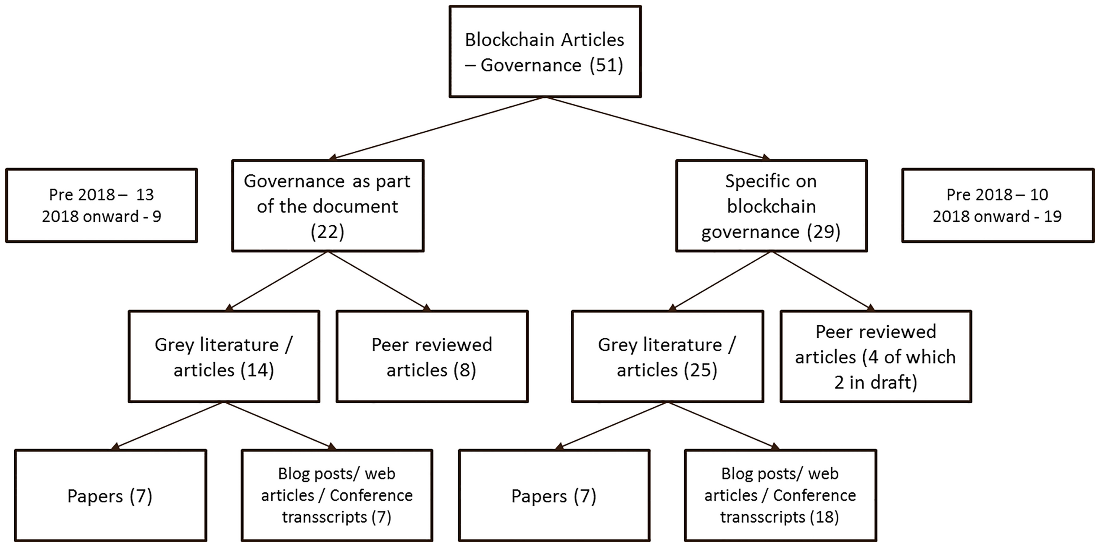

Fig. 1. Literature breakdown.

topic. Two papers were published in 2016, one publication in 2018 and a draft document in 2019. None of these address the entanglement of infrastructure and application specifically. Although we see a clear rise of articles and blogs addressing the topic of blockchain governance, the amount of peer-reviewed literature that specifically addressing blockchain (application) governance lags behind. Some of the most up to date and interesting insights and discussions on this topic can be found in various blogposts on Medium by blockchain core developers like Vlad Zamfir (Zamfir, 2018a, 2018b) and Hareeb Qureshi (Qureshi, 2018).

3. Literature review

3.1. Forms of blockchain: There is no one blockchain

The initial problem with the blockchain governance discussion is that the term blockchain is a generic technology referring to various implementations of blockchain. Blockchain protocols can have crucial differences. The most important distinction made in the literature is the categorizations of public versus private and permissionless versus permissioned blockchains (Beck et al., 2018; Peters & Panayi, 2015).

Permissionless versus permissioned refers to if the protocol is free to anyone to enter as validating or full node, sometimes also referred to as miners. In permissionless networks, everybody is able to submit transactions and validate them (permissionless), or one needs to be accepted by the standing nodes or organization(s) to become a validating or full node (permissioned). Public versus private refers to the distinction if all information is visible for everybody (public) or not (private).

This distinction between these types is important as governance, risk, compliance and privacy aspects varies per quadrant. Besides, the choice of blockchain is also relevant in the "make or buy" decision (van Deventer et al., 2017). This decision refers to if one agrees to use an existing, open and free infrastructure, permissionless blockchain, where all nodes are not in ownership, or closed infrastructure, permissioned blockchain, where one builds and runs their own blockchain. This is a crucial decision in the design of product or service one want to offer.

Table 2
Overview of blockchain types-description-example infrastructures

Type	Description	Examples (Daniels, 2018; Voshmgir, 2019)
Public Permissionless	No entry boundaries for reading, writing and validating. Everyone can become user, node and can develop applications on top. Sometimes referred to as "true blockchain".	Bitcoin, Ethereum
Public Permissioned	Open for reading, boundaries in becoming a validator/node. Open for use, but network control remains with selected validating nodes. Sometimes open for building external applications on top.	Neo, Ripple
Private Permissioned	Boundaries for reading, boundaries in becoming a validator/node. Access granted through owners, network control with selected validating nodes.	Hyperledger, Corda (both can support Public Permissioned as well), consortia blockchain initiatives like R3 and B3i
Private Permissionless	Boundaries for reading, open for validating. Non-existent, although some argue to have set up a model like this. (Daniels, 2018)	None

When questions arise with regards to responsibilities, accountabilities and governance in permissioned environments, it is relatively easy to pinpoint the companies and institutions that run the infrastructure and are in control of the protocol, including elements like access right management as this is with the validating/master nodes (Peters & Panayi, 2015). As these are known it is relatively easy to adopt existing governance models. When governance actions need to be executed, changes can relatively easy be implemented when needed due to limited amount and verified nodes that need to update. Their developers' community is often equally transparent. Traditional approaches of governance of IT can directly be applied as a result and stakeholders can be held responsible (Post & Kas, 2019). Ripple is a clear example of a permissioned blockchain and while it is decentralized across approved nodes, like any other centralized company, it has top managers who make decisions on resource allocation and control the direction for code development (. . .) reflects a more centralized form of governance (Hsieh et al., 2018).

In the permissionless environment actors, nodes, miners, users and developers are less known and reaching consensus over change becomes much harder. In itself not necessarily a negative feature. It is stated that Bitcoin's sustainability can largely be attributed to its recognition of the need for a slow evolution (Curran, 2018). A clear example of how difficult this process can be and can lead to deep division amongst actors, is the Segregated Witness (SegWit) scaling discussion in the Bitcoin network. It took several years to reach consensus and eventually, by lack of full consensus, resulted in a split (hard fork) of the network (van Wirdum, 2017). The reason this process is so difficult is due to the fact that the issue is often political and not so much technical. Bitcoin's block size debate is perhaps the most prominent example of a blockchain community facing complex governance problems that goes beyond the technical (Sclavounis, 2017). The base of this political discussion over a seemingly technical update was that the actors (miners, exchanges, nodes, users and developers), had conflicts of interest of the desired outcomes.

Although both permissioned protocols and permissionless protocols are blockchain, in the permissioned protocols, there is still a clear group of nodes and or owners where in the permissionless environment this group becomes fuzzy, which makes traditional governance methods in permissioned environments still valid. This calls for research into governance models on *public permissionless* blockchain protocols.

	Permissionless	Permissioned
Compared to traditional situations	Unknown group of users No "centralized" and fluid group of nodes running the network Development open to "anyone" Unknown of tradition (IT and Corporate) governance models are possible	Known group of users, "Centralized" group of nodes running the network. Traditional (IT and corporate) governance models possible

Fig. 2. Permissioned and permissionless vs traditional IT situations.

3.2. Types of applications

Applications build on blockchain are called decentralized Applications (dApps) (Raval, 2016). Many of these applications are not directly embedded in the core software of the blockchain itself but use core elements of that particular blockchain, like cryptocurrencies. They are solutions build on top of existing blockchains, through external applications, like wallets, but also often by implementation and deployment of smart contracts. Although smart contracts are developed on top of a blockchain, they are very much entangled with the infrastructure as the infrastructure in a blockchain is also the data layer. Once smart contract application code is deployed, it cannot be taken off-line as it stored in the data layer (blocks) of the blockchain. The name smart contracts is deceiving as they are neither contracts in most cases nor smart, but in basic deterministic computer code or programs that are deployed on a blockchain (Rikken et al., 2018).

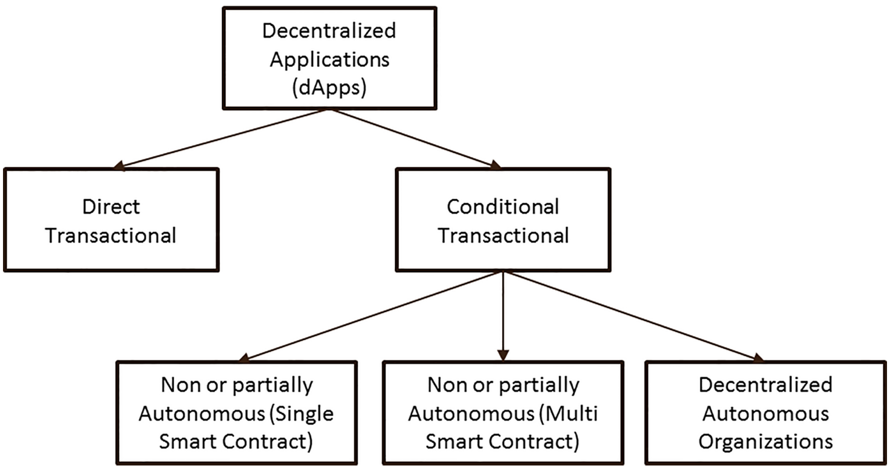

Fig. 3. Types of dApps.

We distinguish four types of dApps that run on and or make use of blockchain, visualized in Fig. 3: types of dApps. The direct transactional applications and under the conditional transactional applications, the single Smart Contract applications, the Multi Smart Contract applications and Decentralized

Autonomous Organizations. Description of the applications and examples are in Table 3: Application types – descriptions – examples. This distinction in types of blockchains and types of applications is important in the analysis of the governance of blockchain projects.

Table 3
Application types – descriptions – examples

Application type	Description	Examples
Direct transactional application	Applications are largely run outside the blockchain on traditional webservers; make use of core applications or characteristics of blockchains as cryptocurrency transactions between 2 parties or; store description in transactions to timestamp and immutably store description as means of evidence; transaction hash or address is stored as pointer off chain to trace the transaction or account; simpler form is search engine like application that allows users to browse transactions, accounts, etc. on blockchain	Wallets, Browser, Evidence trail apps
Conditional transaction application – dApp–partially autonomous (Single smart contract)	Applications representing relatively simple smart contract products and services; can be offered by various companies; can be any product or service that companies can think of where blockchain infrastructure have an added value; always one-off solutions, meaning that per set up, product, or agreement, 1 smart contract is created and discarded after use; whole application is programmed in *one* smart contract deployed on a blockchain; the smart contract can be replicated; once programmed the deployment can be triggered manually, by sending the code to blockchain in a transaction via e.g. an online browser/compiler or via a pre-coded function of a website, creating new smart contract account or automatically through "create" functionality in an already existing smart contract; dApp can be triggered through transactions or messages via interaction through e.g. wallets and smart contract addresses.	Escrow smart contracts, product passports, multisig wallets
Conditional transactional application dApp – partially autonomous (Multi smart contracts	These applications are closely related to single smart contract ones; often more complex; multi smart contract set up is an architectural design choice comparable to modular or monolith IT design; for security reasons, one could prefer multiple contracts interacting to reduce surface of the individual smart contracts. Smaller surfaces are easier to understand and test, posting smaller risk (Everts & Muller, 2018); downside can be that this modular set up leads to smart contract interaction, which could impose the risk of reentrancy .(Atzei, Bartoletti, & Cimoli, 2016), one of the most used hack methods at the moment.	Prediction market, internal cash management, marketplaces smart contract structures
Decentralized autonomous organization	DAOs first described as Decentralized Autonomous Companies (DAC) in 2013; a cryptocurrency as shares in a DAC where source code defines bylaws. Goal of DAC is to earn profit for shareholders by performing valuable services for the free market. (Larimer, 2013); DAOs at the moment mostly in start-up phase; the exact line between conditional transaction applications and DAO is fuzzy; biggest distinctions are: 1) DAOs in principle don't represent a single application, but company without a traditional physical company structure. Idea is that it operates fully autonomously where humans might have, as users, voting power in parts of the processes. Where conditional transactional applications are developed and maintained by companies with earning models, DAOs don't as they are "owned" by the users. 2) Decision making and execution thereof done by business rules of the DAO, based on objective input, votes of the users or use of oracles, being a source (technical, like a database, or person who has been issued this role) that takes up role of "source of truth" for a smart contract (Rikken et al., 2018) or DAOs.	DAOs don't represent single application, but company, often with single product or service; The DAO, Aragon

4. Towards a blockchain governance framework

Governance is a concept that is not easily understood as there are many players involved. Momentarily there is no standard framework for understanding blockchain governance. In general *governance* contains the decision-making authorities, incentives and accountabilities to encourage desirable behavior in the use of scarce resources (Weill, 2004). Contrary to popular belief blockchain governance is often not fully technological enforced, nor autonomously self-governed, as stated by one interviewee: “Now we see mostly off-chain governance. With regards to on-chain governance, not all theoretical models are possible because agreement is often best reached off-line”. At best first forms of on-chain governance, where updates are automatically pushed after reaching a quorum in online voting, are just implemented and experimented with at the moment and only in part of governance processes.

Governance of blockchain applications go beyond solely governance of the infrastructure. We decompose various governance layers, namely the infrastructure layer, the application layer, the company and or individual level and the institutional layer. Others define various layers as well. De Filippi and McMullen identify layers like the internet layer, the blockchain layer and the application layer (De Filippi & McMullen, 2018). The Williamson (1998) framework for economics of institutions distinguished between multiple layers attaching timelines and occurrence frequency per layer.

Here, lower layers have a shorter timeline than the layers on top. Furthermore, governance is not static and typically evolves over time as the situation changes new governance mechanisms might be needed and old ones might not be needed anymore. Therefore, we will distinguish between various stages to show the different nature of governance in time. In the various stages and layers, different actors will have different levels of involvement. The majority of interviewees acknowledges the stages and layers as well, stating “Most definitely multiple levels”, “It makes sense to make a grid with regards to the levels and stages” and “recognizing various layers and stages”. These layers and stages result in the model shown in Fig. 4 and will be elaborated on in following (sub)chapters.

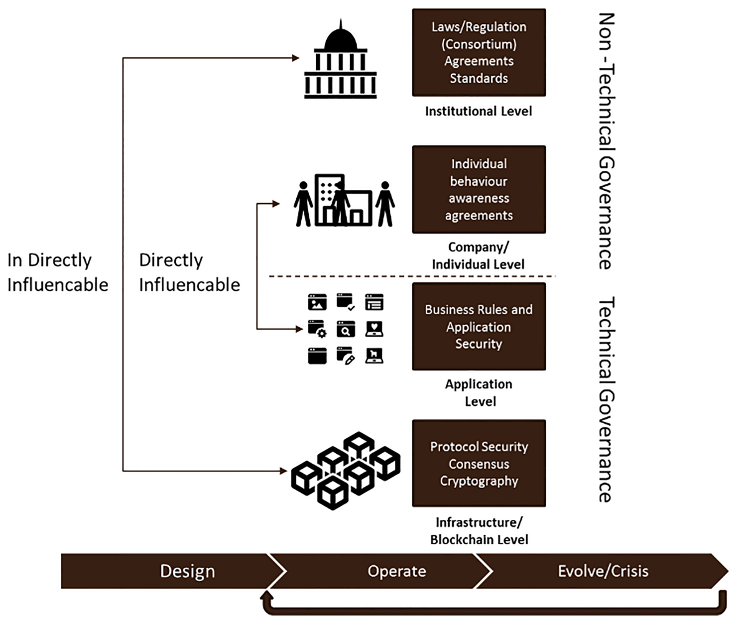

Fig. 4. Blockchain governance framework.

4.1. Stages

Governance evolves over time and in blockchain governance we can identify various stages requiring different actions, decision-making processes and often even models. Different stages likely represent the need for different coordination mechanisms. Besides two described stages of governance, operational governance (governance *by* the infrastructure) and update governance (governance *of* the infrastructure) (De Filippi, 2016), design or creation is seen as third phase in the governance-cycle. Governance is how actors cooperate in order to create, run or evolve inputs that make up a blockchain (Sclavounis, 2017). The stages that are distinguished in our model are design, operate and evolve/crisis. The stages should be seen as a continuum instead of a linear, the evolve/crisis will go into a new design stage or immediately into the operate stage as shown below. The evolve/crisis stage is sometimes referred to as transition (ITIL), maintenance (A2 Data Governance) or control (COBIT) stage.

Table 4
Explanation of the stages

Stage name	Purpose of the stage	Time	Stakeholders roles/decisions
Design	Design of the solution – company – project	Non time critical – except in business continuity	Process/cooperation of an individual or group
Operation	Daily operation – decisions and actions – going concern	Time constraint restricted to rules, protocol and/or business rules of the solution	Executed by the nodes through the consensus mechanism
Evolvement/ Crisis	Update process	Time criticality depends on kind of update Crisis implicates high time pressure	Through (hard/soft) fork software updates of the infrastructure or code of applications through various mechanisms

In general, consensus mechanism is what people have in mind when referring to automated blockchain self-governance. “On paper, blockchain technology seems to be ironclad” (Reiff, 2018). But this just covers the operate stage, the most interesting stage of governance is the evolve or crisis stage as here quick decisions and updates are needed. So far, little formally structured mechanisms where put in place specifically to deal with this. Blockchain governance is still nascent (Zamfir, 2018a).

Although proper design governance can prevent issues, one can never foresee everything upfront. The most important questions lie within evolve/crisis stage instead of design or operate stage. While initial design is important, over long enough timelines, the mechanisms for change are most important (Ehrsam, 2017). As Mario Laul states during the Aracon1 panel discussion, “you need rules to change the rules, . . . , Can’t take humans completely out in this, . . . , Need to have a clear process to change the rules” (Choi et al., 2019).

4.2. Governance layers of blockchain projects

As shown, there are governance differences in the blockchain infrastructure types. In addition, there are differences in the governance stages in blockchain projects. Finally, one can make a distinction between various governance at various layers. By making use of layers the governance complexity can be easier decomposed and described. Our framework distinguishes four layers of governance in blockchain projects; infrastructure, application, company and institutional.

4.2.1. Infrastructure layer

Embedded in the blockchain protocol. What makes the blockchain infrastructure unique is that it withholds both the protocol (rules) and the (immutable) data layer and is decentralized. Although what decentralization means is often debated and open to misinterpretation (Walch, 2019). In infrastructure governance a distinction of the governance *by* and governance *of* the infrastructure can be made. Governance in the operate stage, governance *by* the infrastructure, is arranged through the consensus mechanisms. Here the execution of the protocol itself is arranged fully autonomous. The execution is performed by the infrastructure, the nodes, using the specific consensus mechanism for that blockchain. Once a process is set in motion, the infrastructure will execute this process without the possibility of interference by an individual, for example, disconnecting it to stop execution. The blockchain also contains the data layer. The data is stored in the blockchain. Once submitted, the data is extremely hard to alter, undo or delete, only by consensus of the nodes. In the most common used blockchains alone we can identify 10 different consensus mechanisms, some further literature and use case study lets us identify even more than 15 main categories, multiple even having various sub categories (Cachin & Vukolic, 2017).

With regards to the governance *of* the infrastructure (evolvement governance), there are two main categories, off and on chain governance. Although we can distinguish two main categories, there is basically a unique mechanism per blockchain protocol for upgrade of the protocol with sometimes even possibilities for various governance mechanisms per protocol in itself. In practice, in public permissionless blockchains, no single person or instance can make a decision or determine the evolvement of the infrastructure. There needs to be consensus in the community on updates. Depending on the kind of blockchain the governance of this layer is in-directly (permissionless) or only partially influenceable (permissioned). The level of influence is often determined by the combination of number of full/validating nodes in combination with elements like CPU power contributed in the network or stake reserved in the network depending on the consensus mechanism.

4.2.2. Application layer

This can be a mix between traditional applications (centralized websites and apps) and embedded characteristics like native cryptocurrencies of a blockchain, or decentralized applications (dApps) where the majority of the application is built on a blockchain, by making use of smart contracts. In its most extreme form these are named DAOs. "The general concept of a DAO is that of a virtual entity that has a certain set of members or shareholders which, . . . , have the right to spend the entity's funds and modify its code" (Buterin et al., 2014, p. 22). There are 4 types of blockchain applications, all with different governance structures:

1. Direct transactional – governance of these applications can be either off-chain, in traditional IT environments using traditional governance methods or dependent on governance of the infrastructure.
2. Conditional transaction, single smart contract – execution or operate stage of the smart contract business rules are performed by the infrastructure protocol in combination with external triggers. Regarding evolve governance, in the permissionless blockchains, once deployed, contract code is fixed and cannot be updated. Intervening actions only possible through governance of the infrastructure. To update non-parameterized elements, structures or the business rules in the code, one needs to de-active the smart contract, e.g. through self-destruct commands (if integrated in the design of the smart contract) and deploy a new one. A way to arrange governance responsibilities and process is by employing smart contracts where parameters in the code set up as variables that can be updated. Of utmost importance is that access to functions is properly arranged, e.g. in Ethereum possible through "modifiers", arranging access on function level. Upcoming solutions are "proxy functions" referencing to future deployable smart contracts adding functionality.

3. Conditional transaction, multi smart contract – Governance possibilities of these type of applications largely overlap with governance of single smart contract. A difference is that one can replace modules, in this case individual smart contracts, without replacing the whole application. All applications described are likely to be implemented by traditional company or supplier types and governance of these applications can be tied and often integrated to governance structures as arranged in the company layer. Here is where Decentralized Autonomous Organizations differ.
4. DAO – DAOs are technically and governance wise much like conditional transaction applications, build in single or series of smart contracts, operating, once deployed, exactly as programmed in the business rules of the smart contracts. Possibilities for interference by humans in theory little to non and no formal company structure is behind it.

The amount of direct transactional applications is hard to estimate. With regards to conditional transactional applications and DAOs there are exits estimates. In March 2019, the amount of dApps was around 2650 (Stateofthedapps, 2019). The amount of DAOs have been very low, as DAOs needed to be coded manually. This changed as of October 30st 2018. When Aragon launched, it became possible to deploy a configurable DAO without the need of manual coding. This led to a Cumbrian explosion of DAOs as is shown in Fig. 5.

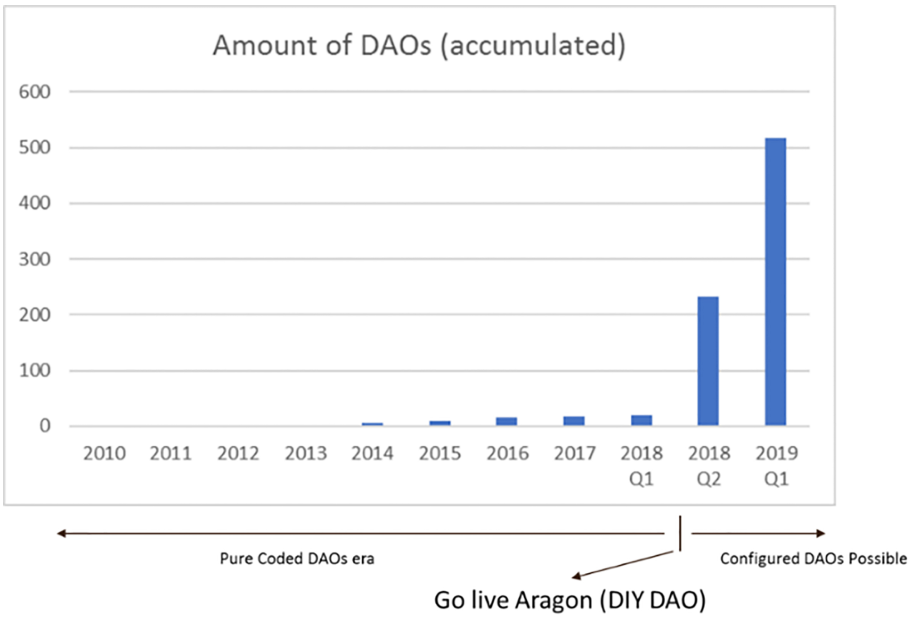

Fig. 5. Accumulated amount of DAOs. 2018 and 2019 count can have a slight double count. Colony makes use of Aragon and it remains unclear if the DAO list of Aragon contains these DAOs.

The governance on the application layer are closely entangled with the governance on the infrastructure level and cannot be separated any more. As in all types of applications, governance possibilities with regards to data, smart contract code and or specific blockchain products/services and or characteristics are dependent on the infrastructure governance actions.

4.2.3. Company layer

Behind most blockchain applications are individuals using the applications and formal organizations or independent projects building/running the application. With regards to individual responsibilities, a crucial responsibility within blockchain, private key management, is back at the individual due to lack of a TTP in the network. Once lost, the individual cannot perform actions with the account related to that private key anymore. Although this responsibility is back at the individuals, projects or companies will have to take responsibility to inform the users on that.

Governance in projects or companies should in the majority of cases not be different for blockchain related initiatives than other IT applications and have to be embedded in roles, responsibilities and processes of the projects or organization. Responsibilities and accountabilities should be clear. There are a few, not specific for blockchain though, situations where governance structures are hard(er) to define.

- open source projects without a formal organization or structure behind it, e.g. a group of (definable) individuals, although not formally organized, working together on a project through sites like GitHub,
- open source developments where people work together via e.g. GitHub without any formal organization behind it, but also not identifiable to (a group of) individual(s). Most public permissioned blockchains are, in theory, developed in this way as anyone can anonymously propose software updates.

Governance is complicated when the application being developed is a DAO, where no legally formal organization is set up, and here is no prior determined set of owners. If users can be seen as the owners, as is the case for various DAOs, the owner base can be extremely fluid and due to the pseudonymity often undeterminable.

4.2.4. Institutional level

Country, industry or overarching countries. Blockchain poses some interesting challenges due to its decentralized nature and as blockchain is developed by people globally, sometimes completely anonymous. Combined with elimination of central controlling parties, the element of jurisdiction is much harder to determine than before (West, 2018), especially in permissionless blockchains. As the network runs independently on servers globally, jurisdiction cannot, in various cases, be determined on presence. Additionally, regulatory views differ per country about products and services on blockchain and even within countries (Directorate, 2019).

There is no logical overarching jurisdiction for blockchain related projects, products and services. Other than the ERC20 standard, developed by the industry itself, there are hardly any global standards. Besides that, power to execute enforcement of regulation is extremely hard. Controlling power of institutionalized organizations are no longer automatically part of the governance ecosystem (Meijer & Ubacht, 2018). Draghi stated even that the ECB has no power to regulate cryptocurrencies (Union, 2017). It poses the same enforcement problems as with websites as "thepiratebay". Although banned in various countries, a practical ban turned out to be difficult. Only due to new business models like Netflix and Spotify, customers changed behavior. Some countries have high regulatory concerns, other less so. On the other hand, some countries need large regulatory reforms, others are need less so. This currently results in four regulatory approaches.

This regulatory quadrant example reflects Initial Coin Offering (ICO) regulation, seen as one of the straighter forward products and services. Regulations becomes even more complex and much less debated with more complex structures like new ecosystem set ups especially in the case of DAOs.

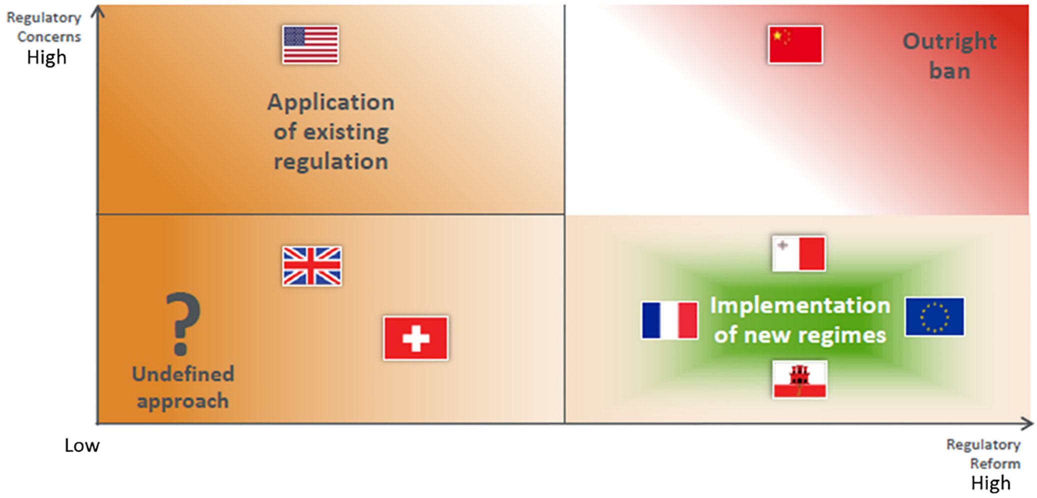

Fig. 6. Global regulatory approaches ICO's (Source: presentation by John Salmon – Hogan Lovells 2018).

5. Governance challenges

As blockchain projects and implementations consist of various stages and in various layers, the challenges can be categorized accordingly. We will discuss the governance challenges hereafter.

5.1. Governance challenges per stage

We identified several governance challenges per stage. In the design stage a main challenge is the "make or buy" choice of the infrastructure (van Deventer et al., 2017). This will influence the governance on all other layers. The amount of control needed on infrastructure is dependent on the product or service, which also could directly connect to choices on institutional level (jurisdiction). Another design challenge is lack of peer review in the design phase. The Cardano protocol is born on this challenge. They want to change how cryptocurrencies are designed and developed. The Cardano protocol embraces a collection of design principles, engineering best practices and avenues for exploration, small groups of academics and developers competing with peer reviewed research (Foundation, 2019).

In the operation stage, on infrastructure, application and company level, the challenge is if it requires a combination of automated and manual decisions. In voting on any topic other than block consensus needed for daily operations, this post practical problems like unresponsiveness of the participants (Buterin, 2017; Vessenes, 2016). When decisions are needed, we should not overestimate the willingness to vote, as Mario Laul quotes: "People don't always want to be involved" (Choi et al., 2019). This was clearly shown in the DAO incident where in the majority of cases, the voting quorum as not met (DAOStats, 2016; Vessenes, 2016).

With regards to the evolvement stage, the biggest challenges are unknown unknowns. There is little known in practice in blockchain project governance. there is a clear need to experiment and research (Ehrsam, 2017; Qureshi, 2018). As some blockchain protocols require agreement by network majority, speed of decision making could be a potential challenge. Evolve and crisis governance can have similar challenges on elements like voting majority as the operational stage or peer review challenges as the design phase. Especially time pressure in crisis situations demands quick responses.

5.2. Governance challenges per layer

5.2.1. Infrastructure layer

There are many infrastructure layer governance challenges, especially in permissionless public blockchains. How to govern permissionless blockchains that are not dominated by single organizations is the area where most work need to be done and research is needed as these show significant governance problems (Hacker, 2019). In permissioned protocols, level of decentralization is limited and participants are known thus traditional approaches to governance can be applied to Permissioned Public and Permissioned Private blockchains (Kadiyala, 2018), although it can still be challenging (Oskar van Deventer et al., 2018). It is appropriate to think about blockchain-based corporate governance forms in terms of their degrees of decentralization (Hsieh et al., 2018).

Permissionless blockchains have not one infrastructure. Due to the many protocols, challenges can differ enormously. With regards to operate challenges or governance *by* the infrastructure this is related the consensus mechanism. Per consensus mechanism, specific governance challenges occur, like "whales" (large token holders) in proof of stake or geographically concentrated mining power in proof of work. The specific challenges should be analyzed in more detail to describe the various pros and cons of these consensus mechanism.

The most common challenge for consensus mechanisms is changing the user or node bases. The most common challenge is immutability being breached by 51% attacks (a (group of) miner(s) obtaining CPU power majority in the network and that can then continuously build the longest chain creating the possibility of transaction alteration), due to changes in or lack of sufficient large base of voters. Long seen as theoretical problem, recent events show that this has become reality in Ethereum Classic (Moos, 2019), leading to changes in transaction history and double spending of cryptocurrencies.

Another challenge is mob democracy/justice (Chinyem, 2018; Qureshi, 2018). Decisions are not made on rationale, but on herd-majority-voting. Voting systems struggle with voting power balancing. The "one man one vote" challenge was found in 5 articles (Berreman, 2018; Choi et al., 2019; Ehrsam, 2017; Qureshi, 2018; Steis, 2018). The unstoppable execution of transactions and code itself is also another challenge. Although a powerful characteristic of blockchain, it renders obsolete the commonly known governance act; take application offline – stop underlying infrastructure from executing – altering or deleting wrong data.

This challenge is an important consideration if blockchain is needed for a solution in the first place, especially in combination with the purpose of the application. Blockchain has been referred to as "most hostile environment for applications" (Everts & Muller, 2018) due to immutability, transparency and permanence nature.

The governance *of* the infrastructure has various challenges as well. As with governance *by* the infrastructure, the evolve/crisis governance mechanisms differ much per blockchain and needs to be researched in more detail.

There are some general challenges that can be identified. In off-chain governance, more traditional processes on voting and stakeholder management are set up in decision making of protocol updates or data changes, through traditional voting mechanisms. The transparency lies in minutes regarding update-meetings are published and in theory any can join the meetings. The challenge is that these are very technical discussions. Few persons can participate in practice (Curran, 2018). This could lead to unbalanced power of developers. Countervailing power is that nodes need to adopt the changes and can choose not to. This could lead though to a hard fork, often seen as undesirable due to potential economic loss of various actors.

In on-chain governance, through smart contracts or DAOs votes are open to all users of that particular blockchain. After a threshold is met, the update is pushed through (Curran, 2018; Qureshi, 2018). The challenge here is that people without proper knowledge regarding the impact can vote as well (Qureshi, 2018).

A popular believe is that a DAO fully autonomous decides for an update, but their governors are inevitably humans (Qureshi, 2018) that cast votes through voting systems, representing democratic like systems. Here the challenge is that often users are not known, acting under pseudonyms and can easily create additional pseudonyms (Qureshi, 2018), breaching the one person one vote principle and do not necessarily represents a real democratic system. Similar challenges of inequality in voting power can be found in other on and off chain governance systems. As there many different systems, this should be further researched.

5.2.2. Application layer

With regards to challenges in the application layer we can identify various challenges per type of application.

Direct transactional applications – this type of applications doesn't build additional integrated logic in the blockchain. The challenges are not specific for blockchain but are, as these applications run on traditional infrastructure, similar to traditional applications, except specific blockchain data storage, being transaction and transaction related data that is stored immutable and permanent (in permissionless blockchains) on the blockchain. Here governance challenges are one-on-one to infrastructure layer challenges.

Conditional transaction application – (*Single smart contract*) – Challenges in these applications are challenges directly related to the infrastructure and transaction applications as well. Any change in underlying data structure or transactional data can influence input and outcome of smart contracts. A specific challenge is in evolvement of these applications. Once deployed, the code of smart contracts cannot be altered on most permissionless blockchains. Besides governance challenges if something goes wrong with the underlying data in the infrastructure, the challenge is the impossibility of altering hard coded logic of smart contracts (Everts & Muller, 2018). Another challenge could be the length of smart contracts. Long smart contracts increase risk of surface attack (Everts & Muller, 2018).

Conditional transactional application – (*Multi smart contracts*) – Challenges in these applications are related to challenges on the infrastructure layer, the transaction applications and single smart contract applications. Additional challenges are that these applications often represent more complex products and services with multi actor environments. Examples are initiatives like Augur and Swarm City. Large part of operational governance is done by pre-defined business rules, executed by the infrastructure, but part of the decisions can be made off chain, as these applications are not fully autonomous. With evolve governance, in principle, applications like Swarm City are developed and deployed by teams with centralized governance (Beck et al., 2018). Responsibilities towards these applications pinpoint to these teams. Additional challenge is the risk of reentrancy attack as result of the modular setup.

DAO – For DAOs same challenges can be identified as with other applications and the infrastructure layer. Besides those challenges, one major additional challenge compared to other application types, is lack of traditional company structure, especially after the design stage as teams/owners become fuzzy. This might not result in governance challenges in operate stage of applications due to predefined business rules and automated execution but lies predominately in the evolve stage. As no governance for evolve or crisis management is arranged on a company level, it must be designed and embedded in the application layer. Specifically on DAOs in the evolve stage, "we need rules to change the rules" (Choi et al., 2019).

Another challenge is how to deal with unethical behavior or mis-use of code. There is only one real example in this regard, “the DAO”. Eventually governance actions were taken on infrastructure level clearly showing the entanglement of application and infrastructure. But also other DAO like cases, like “Swarm City”, clearly demonstrate that the emergence of the blockchain economy demands rethinking of governance (Beck et al., 2018).

A challenge for governance of all blockchain applications is transparency of code base of smart contracts. This can lead to voting behavior for updates in these applications with malicious intends. This was witnessed in “the DAO” incident with “proposal 59” where the hacker voted in favor of an update proposal that contained flaws that he would later exploit (Slacknation, 2016). There is limited knowledge about the governance challenges in the evolvement phase. Most DAOs are not live yet but are in the design/test phase. As they all differ in basic design the, implemented or designed, governance models should be researched in more detail.

The high entanglement of infrastructure and application governance in blockchain also leads to an entanglement of the challenges. Some of these governance challenges might be new due to the hostile development and deployment infrastructure blockchain, but most of the challenges are not different from traditional IT application challenges. Most of the time, a clear (IT)-organization is related to the application and traditional governance actions can be taken. Only in case of DAOs, especially in evolve/crisis stage, governance challenges can differ significantly from traditional applications. Here traditional processes, roles and responsibilities appointed to identifiable human lack as result of no formal traditional organizational forms.

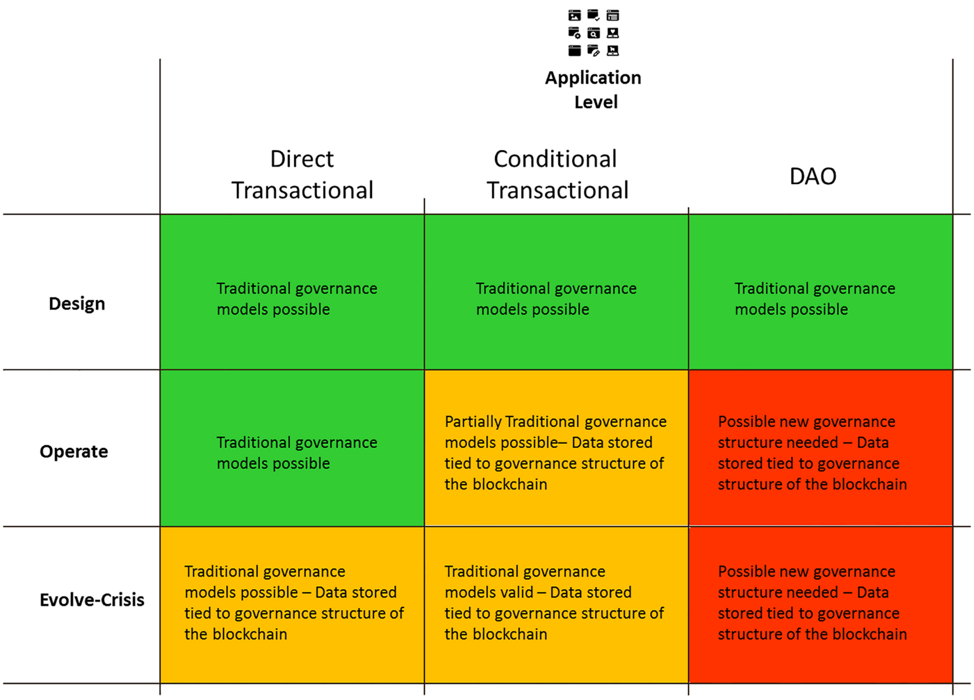

Fig. 7. Applicability Traditional Governance models: Color coding refers to suitability of traditional governance models.

5.2.3. Company layer

If a clear company or project organization is set up for the creation of a dApp, the governance challenges on the company layer don't differ to traditional companies and or projects. Only if there is no traditional company anymore, but a true open source development of a DAO, could post new challenges. Interesting is that almost per definition a DAO is set up as global entity which is not tied to countries. This could lead to cultural differences, including different governance insight (Choi et al., 2019) which can be a complicating factor from the start. Also, DAOs might be subject to different legislation.

If companies have become obsolete due to implementation of DAOs this poses a challenge in accountability in crisis situations. This complicates even further if the DAO was developed in an open source development, where it is virtually undetermined who the developers are.

5.2.4. Institutional layer

A challenge for any blockchain project in this layer is the choice of jurisdiction or accountability over multiple jurisdictions (West, 2018) in combination with the product or service offered, especially if the application is one of the first three types, implying that a company owns the application. If applications run for example financial or data services, choice of jurisdiction is crucial. The challenge is predominately that, in this early stage of the technology, laws and regulations towards products and services like Initial Coin Offerings, can alter much in time (Salmon, 2018) and even in hindsight be enforced.

A complicating factor arises with DAOs. The challenge again is that a DAO cannot be governed as a company. As it is decentralized, no logical jurisdiction can be derived based on location. Additional to this challenge is that, because of open source development, no developer can be pointed as responsible. Deriving jurisdiction based on location or nationalities of employees becomes extremely hard. So far, no clear legislation is known around DAOs.

5.3. Concluding on governance

Many claim that, as we are creating new ecosystems and initiatives on blockchain technology, governance structures need to redesigned or traditional structures are obsolete (Reiff, 2018; Sedgwick, 2018; Zamfir, 2018b). In many cases this might not or only partially be true when taking various levels of governance into account and effectively deploying them. Where blockchain technology can lead to irreversible problems, as in the QuadrilaCX case in December 2018, where due to the death of the owner, access to funds was lost as no one had the password or private key (De & Baydakova, 2019). One could easily argue that this needs new governance structures on infrastructure or application level. But this could easily be arranged on company level, by decent, non-technical, processes and backups in traditional governance manners.

The real challenge is in the governance models in the public permissionless environment. Permissioned blockchains are easier to fit on existing governance models as validating nodes are known and identifiable. Design, operate and evolvement actions are relatively easy to manage. Including updates and roll back actions. Even within public permissionless environments, in various situations like direct transaction application and conditional transactional applications other than DAOs, existing governance models like ITIL and COBIT can be feasible. The fact that an application is built on a public permissionless blockchain by an identifiable person, group of persons or company does not discharge them from the responsibility and accountability of the application they offer. Here governance parts, that cannot easily be enforced by the blockchain, should be covered on company or application level. The only situation where discharge of responsibility might be feasible is a crisis situation where the underlying infrastructure fails, the blockchain breaks down. Or maybe in case the code of the application build can be misused in an unforeseeable way, like the Parity 1 incident. This could give ideas for new crisis management structures, e.g. through ethical hackers. (Rikken & Vroegh, 2018), but does not change initial responsibility, especially if these applications were offered against a premium.

The new questions come forward if these initiatives, on public permissionless blockchains, are created and operated, in an open, decentralized way. Future blockchain applications like DAOs will show an increasing form of autonomy (Angelis & Ribeiro da Silva, 2018). Human interference might fade to the background. If DAOs are developed open source, without identifiable developers, where no humans are needed anymore to run it raises the question of who is accountable and how the evolvement and potential crises can be governed.

A complicating factor is entanglement of infrastructure layer with the application structure. Once deployed, the application code and transacted data cannot be changed nor deleted. In companies lack of technical enforceable operation and evolve governance can be compensated by governance processes and or clear regulation. But what about organizational forms that only exist in code? Regulation might be unclear, nobody might feel responsible and there is a lack of standards, what leads to a range of potentially new governance challenges.

The multitude of challenge like the entanglement, immutability of data, lack of organizational or company structures and fluid and unknown actors clearly show the need for further research towards blockchain governance models. But our overview of challenges also shows that in the majority of blockchain cases, governance models from companies and or IT are still valid. Especially in permissioned blockchains and in the design stage in permissionless blockchains. Also, in the majority of blockchain applications, effective governance can be arranged in other layers than infrastructure or application.

6. Conclusions and further research

Blockchain incidents, due to decentralization and lack of controlling trusted third party, raised a new debate around how the governance of blockchain should be arranged. Governance is not easy due to the decentralized nature, immutability, lack of organizational or company structures, fluid and unknown actors in permissionless blockchains and the entanglement of *application and infrastructure* elements. Governance of applications was found to be dependent on the governance of the infrastructure due to this entanglement. The governance of the infrastructure is often controlled by different groups of stakeholders. This often results in a lack of effective governance actions as a whole.

When analyzing governance challenges of different blockchain types, governance stages (design, operate, evolve/crisis) and governance layers (infrastructure, applications, company, institution/country), our framework proved to be useful for classifying the governance challenges. Furthermore, we expect that this governance framework can be used as a support for developing blockchain governance.

As shown, predominantly applications on permissionless blockchain protocols post potentially new governance challenges. In all other blockchain types existing governance models could be suitable as potential accountable actors are known and directly in control. Furthermore, in permissioned blockchains, updates and data roll backs are relatively easy compared to permissionless environments. As shown in Fig. 8, when zooming in further, potential new challenges are *predominately in DAO applications in the operate and evolve/crisis stage*.

This because distinction between users, developers and infrastructure running base becomes fuzzy and as there isn't necessarily an organization anymore. Once deployed, the users, whom can be highly fluid, and code govern DAOs. The fluid and unknown user base might not be problematic in the operation stage, but might pose real problems in evolve state, especially in crisis. It can even become impossible to pinpoint natural persons or companies resulting in unclear accountabilities. This lack of responsibility and accountability can be very problematic in swift decision making and execution of governance

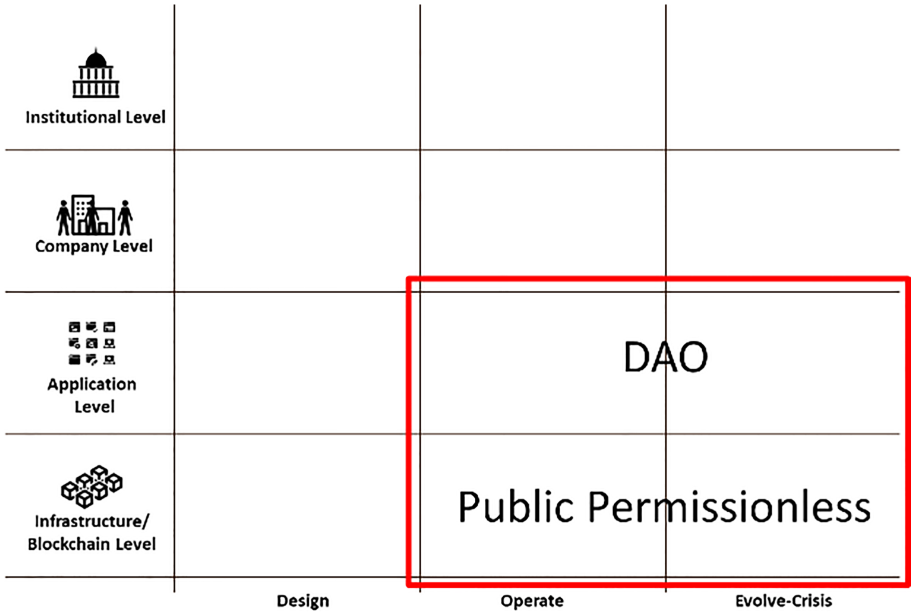

Fig. 8. Area where possible true new governance questions arise.

actions. If DAOs are designed and built open source, traditional roles and responsibilities and accountability might shift completely.

As blockchain is growing as infrastructure and applications develop more towards autonomous applications like DAOs further research must be conducted toward effective governance structures in this area. These governance structures should be put into a model where the link can be made between purpose and regulatory regime of the DAO and the best fit for governance models, taking entanglement with the infrastructure it is built on into account.

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