# DLT-based Regulatory Systems Dynamics

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## Abstract

*In this research, we examine the interplay between 'actors' and 'agents' in Distributed Ledger Technology (DLT) systems. We identify regulatory interactions between off-chain agents setting the rules, as well as on-chain code as actors regulating the behavior of DLT users. We theorize about the relationship between agents and actors that mutually regulate each other in certain ways through the DLT system and identify the significant dimensions related to the trifecta in which the soft system agent sphere regulation of DLT is likely to interact with the hard system actor sphere regulation by DLT. By proposing the trifecta between DLT design, DLT protocol, and DLT use, we explain the relationship between these three and the role of DLT protocol as a mediator between DLT design and DLT use. Our research sheds light on the dynamics within DLT systems and the regulating forces at play from a systems' thinking perspective.*

**Keywords:** Blockchain, Distributed Ledger Technology, Governance, Regulation

## 1. Introduction

The way how individuals, communities, or companies interact with each other and among each other has changed fundamentally due to information technology (IT) over the last decades. How we conduct online transactions is gradually changing from a rather reactive and automated process toward a proactive and autonomous process, driven by technologies such as artificial intelligence, Internet of things, and blockchain.

While the combination and amalgamation of these innovative technologies is driving organizational and societal change, it also challenges IT regulation, especially due to the duality of regulation of IT, and regulation through IT. Blockchains, or more, generally speaking, DLT systems, have accelerated the regulation and governance debate in the context of shared infrastructure (Thomason et al., 2018). It is argued that DLT systems can effectively regulate the public discourse (e.g., in form of DLT-powered social media platforms), government functions (e.g., through DLT enabled smart administration) and enterprise applications (e.g., through DLT-based logistics and supply chain solutions) while maintaining the interests of the different entities involved (Zwitter, A. and Hazenberg, J., 2020). Thus, it is not a surprise that regulation and governance of and through DLT systems has garnered some attention in information systems (IS) research to explain the phenomena at play.

While decentralized socio-technical systems such as DLT environments provide new possibilities to regulate through enforceable code, they are also creating new challenges as decentralized, polycentric networks are less tangible in contrast to clearly identifiably, hierarchically organized entities when it comes to regulation. From a system thinking perspective, a decentralized DLT is a hard system embedded in a soft system best characterized as a 'network organization'. When it comes to the regulation of DLT systems or through DLT systems, the interplay between the soft and the hard system must be examined (Checkland, 1981). While the idea of conceptualizing the 'natural system' as a soft system and the 'designed system' as a hard system has been applied before to provide systemic insights of the interplay between technology and systems, the nature of DLT systems acting autonomously on behalf of agents and the need to regulate technology as well as using DLT systems as actors to regulate is raising new questions about governance and regulatory systems dynamics.

DLT systems create a social reality based on technology-enforced rules and their interpretation based on the social context within which transactions are conducted (Checkland, 1986). Transactions in such systems are co-created by two or more entities with different functional roles, one as a transactional agent and the other as a transactional actor. Thereby, the relation between hard systems (the actor or DLT protocol) and soft systems (the agent or DLT owner) as a combined system needs to be examined holistically when it comes to regulation.

Like the interplay of on-chain and off-chain governance (Beck, Müller-Bloch, and King, 2018), any effective regulation of DLT and through DLT needs to take the "agent actor interaction" into consideration. In management science, governance is often based on a hierarchically organized, top-down power structure with interdependent and interrelated entities. Thereby, the

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power structure determines rules and regulates how resources are applied in transactions, while human agents execute those rules as embedded in the system, thereby reinforcing it. In a DLT environment, the structure, determined by the DLT protocol, and the agents, determined by the DLT owners and users, are the central elements of DLT regulation, as each conducted transaction follows implicit and explicit rules and regulations. While transactions performed by the DLT protocol follow "the Rule of Code" (Wright and De Filippi, 2018), transactions performed by DLT agents from outside the protocol follow less codified rules (Reijers et al., 2018). Protocol- and agent-based transactions combined can be considered as system of structuration, by having a structure to gain legitimacy through code, and validity through human agents or legal entities, respectively (Rose and Scheepers 2001). With the growing number of publications on the realm of the structuration of DLT systems related to governance and regulation, a detailed analysis regarding DLT systems regulation has been performed in this research to identify meta characteristics of regulation of and regulation through DLT systems.

As per Giddens's structuration theory (Giddens, 1984), a social phenomenon is formed by sub-systems, while the structure and agent sub-systems enable social practices (Rose and Scheepers 2001). DLT systems are a combination of protocol (on-chain) and surrounding agents/organizations (off-chain). This research has two major contributions, first, it explains the dynamics within a DLT system and its regulating forces from a structuration perspective, and second, it uses the systems thinking perspective to theorize how regulation of DLT systems and regulation through DLT systems depends on each other and interacts. Thereby, it contributes to the conceptual development of a theory by theorizing meta characteristics to address the social structure change through DLT systems by answering:

*How do on-chain and off-chain governance instruments interact to regulate decentralized systems?*

The remainder of the paper is organized as following. In section two we introduce our methodological approach how we derived our research results. Section three provides the literature background on blockchain in general, as well as governance and systems thinking as foundation for our analysis, which follows in section four. The developed insights are reflected on in section six in the context of prior literature, before section six concludes and provides some future research outlook.

## 2. Methodology

To address the outlined research questions, this study conducted a systematic literature review (SLR) methodology in order to develop a structural framework. The SLR is an efficient technique to structure and synthesize the results based on published literature (Petticrew, 2001). The number of publications on blockchain technology has increased over the years; therefore, only peer-reviewed high-quality journal publications were considered. As the initial step of the SLR, various databases were analyzed to acquire and consolidate the available published research. Since blockchain is a relatively new phenomenon, there is not a lot of published research on regulation and blockchain as such. Hence, we defined a rather broad scope and delineated the subjects by considering the research's interdisciplinary nature. To fulfill the fundamental process of objectivity and reliability, a detailed research methodology was designed in the first step of the SLR. The research process includes research databases, search methods, methods of extraction, and synthesis.

The search comprised several keywords that were used for search in different scientific databases like ScienceDirect, Scopus, and Web of Science. We extracted papers based on their title, abstract and critical findings and conducted additionally forward and backward searches. Our research devised five major steps such as preparation, collection, evaluation, selection, and final theme connection (Booth, Sutton, and Papaioannou, 2016; Machi and McEvoy, 2016) and resulted in 122 articles that have been analyzed.

For the search, we used permutations of different search strings such as "blockchain AND regulation!" and "distributed ledger technology AND regulation." Using such keywords, the complete search performed on multiple databases helped extracting many relevant articles without losing the context and in-depth detail (Silverman, 2013). Further, a network analysis was performed on the extracted articles to get the deep detail pertaining to the main topics (Webster and Watson, 2002). Finally, we shortlisted 20 articles after the initial database extraction, screening, text mining, and manual selection through reviewing. Finally, we conducted a forward and backward citation search and identified 24 additional relevant articles, leading to 44 articles in total. All these articles were analyzed using a narrative (synthesis) method (Popay et al., 2006) to produce the meta-dimensions (Braun and Clarke, 2006) that will be discussed in the analysis section as illustrated in Figure 1.

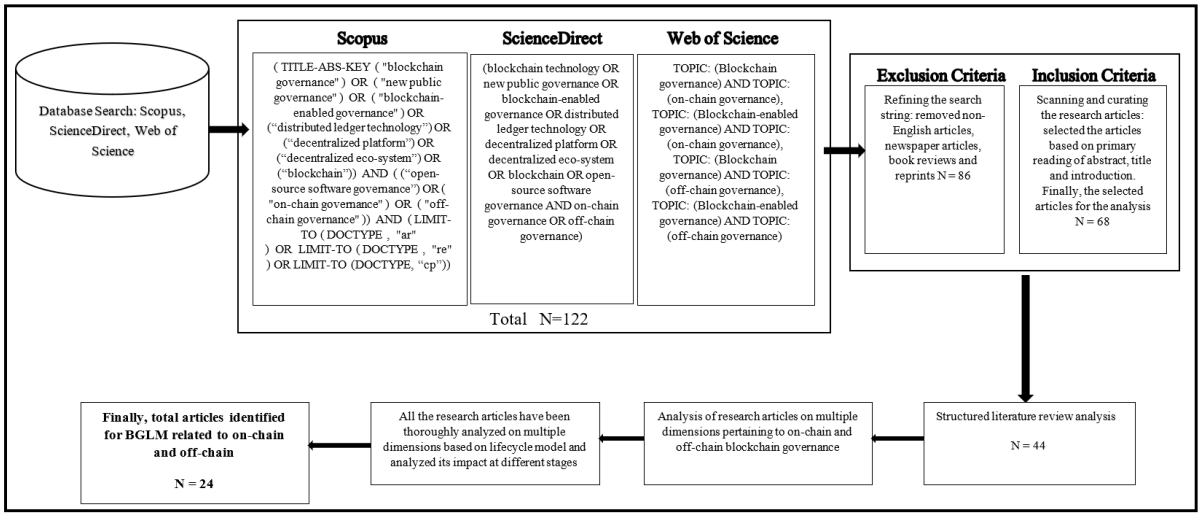


**Figure 1: Systematic literature review methodology.**

# 3. Literature background

## 3.1. Blockchain foundation

Blockchain is a decentralized technology that has the capacity to provide complete transaction disclosure by reducing uncertainty in networks (Beck et al., 2016). Blockchain has been first introduced by Santoshi Nakamoto (2008), as the technology behind Bitcoin that functions as a decentralized database of transactions (Glaser, 2017). As second generation blockchain, Ethereum and others have extended that functionality and integrated programming languages, allowing for all kinds of transactions executed based on a set of encoded rules called "smart contracts" (Glaser, 2017). The combination of a decentralized database together with a decentralized execution of software provides additional reliability and transparency in executing transactions (Beck et al., 2017). Blockchains also use consensus mechanisms to maintain consistency and reliability within the whole network (Lumineau et al., 2020). Unlike more traditional, centralized systems, blockchains facilitate transactions in a decentralized environment and are controlled by the nodes operating the network (Constantinides et al. 2018). Decentralization or polycentricity can vary based on the type of blockchain, like permissioned private, public, or hybrid (Casino, Dasalakis, and Patstakis, 2019).

## 3.2. Blockchain governance

The area of governance in fully- or semi-autonomous systems constituted by DLT systems with its polycentric distribution of incentives, decision rights, and accountability (Beck, Müller-Bloch, and King, 2018) is under development. Governance through DLT systems like algorithmic governance for autonomous systems is characterized by machine-to-machine interaction (Wright and De Filippi, 2018). The role of governance in DLT systems has been researched from an organizational perspective (Davidson et al., 2016) and studied from a more traditional form of organizational structure (Khan et al., 2020). An alternative view has been applied by Reijers et al. (2018), where the fact is highlighted that blockchain governance is an interaction between society, organizations, and individuals. Furthermore, blockchain governance has been sub-divided into two major parts, which are on-chain and off-chain blockchain governance. In the context of DLT systems governance, the duality and interplay between the governance of DLT systems and through DLT systems are discussed in more detail in the following.

**3.2.1. Governance of DLT systems – off-chain.** From a socio-technical perspective, governance of DLT system is the enforcement of norms and values from the agent or social sphere on the DLT protocol as the interaction between organizations and human beings and technology. Off-chain blockchain governance functions primarily based on fundamental properties like the structure of ownership, model of process execution (Di Ciccio et al., 2019; Xu et al., 2017), the definition of transaction processes (Rikken et al., 2019), control of access (Hardin and Kotz, 2019), or ways of identification (Calcaterra, 2018; Kavanagh et al., 2019; Reed et al., 2018; Reijers et al., 2018; Rikken et al., 2019; Xu et al., 2016). Certain instruments clearly relate to off-chain blockchain governance like disposal rights or data storage (Reijers et al., 2018). But off-chain governance instruments also connect the owners and agents deciding

over the regulation of a system with the embedded protocol in a legally binding way. Complying to regulator frameworks is also something taken care of by off-chain governance, which is vulnerable to attacks and threats like human errors, unethical maneuvers, and fraudulent behavior in the same way as any other traditional governance system is. Off-chain blockchain governance is embedded in the overarching regulation of DLT systems based on the legal, contractual, and regulation framework within which the DLT system operates.

**3.2.2. Governance through DLT systems – on-chain.** Governance through DLT system follows a techno-social logic, where DLT systems work as an operating actor that is exercising governance. On-chain DLT system instruments enforce governance based on smart contracts, or rule of code (Reijers et al., 2018). On-chain functioning depends on data, voting system, identity, permission structure (Kavanagh and Ennis, 2019; Lesavre, Varin, and Yaga, 2020; Swanson, 2015; Xu et al., 2016) and pre-defined rules (Buterin, 2014), where pre-defined nodes can read, write, edit, and validate transactions (Naerland et al., 2017). In essence, the DLT protocol enables the DLT system to operate in an autonomous and decentralized way (Alex, 2018).

## 3.3. System thinking

Hard systems and soft systems thinking have different paradigms underlying. Hard systems thinking is close to an engineering approach where systems are constructed end-to-end to achieve objectives as defined (Checkland, 1988). Thus, hard systems thinking is close to "code as rule" as it can be found in on-chain governance instruments, or DLT protocols. On the other hand, soft systems thinking originates from defining solutions to uncertain or vague and unstructured problems or where precise rule-based solutions would be difficult to define. In other words, soft systems thinking is close to regulation of DLT systems off-chain and related governance instruments.

In the context of regulation of DLT systems or regulation through DLT systems, the interplay between the off-chain soft system and on-chain hard systems thinking must be taken into consideration (Checkland, 1981). The nature of DLT systems acting autonomously on behalf of agents and the need to regulate technology as well as using DLT systems as actors to enforce rules on users is an interplay between hard and soft systems thinking that creates challenges which we will investigate in more detail in the following. A systems thinking approach allows for linking the off-chain social or soft system with the on-chain computer or hard systems perspective where regulation can be considered as an interplay between the two spheres, with defined bridges between rules and practices in the agent sphere on the one side, and protocols in the actor sphere. The concept of systems thinking can be used as theoretical foundation explaining how regulation through DLT systems in an interplay between soft and hard systems can be conceptualized to improve regulation focusing on off-chain or on-chain instruments.

## 3.4. Systems as structures enforced by actions

Systems thinking in social science has a long tradition of explaining the interaction between society, organizations, and individuals when it comes to the development and use of new technologies. Giddens's formulation of structuration theory gained some prominence in IS research (Giddens, 1984) and has been extended to explain the trifecta of organizational regulation (De Vaujany et al., 2018), which also inspired our research. Trifecta revers to the triadic relationship between rules, IT artifacts, and practices which can be considered as an extension of Giddens who posits two prongs of social thinking and the relation between an infrastructure or structuration on the one hand with the based action of human agents on the other hand (Rose, 1998). De Vaujany et al., (2018) in contrast add "rules" as third element and elaborate how in a dynamic system, rules encoded in IT artifacts shape practices, which in turn may challenge the encoded rules which need to be adapted accordingly, and so on. From there, it is only a short step to DLT systems, where rules are encoded into the DLT protocol which is then to be used, thereby enforcing, and sometimes challenging the rules embedded in the system. Furthermore, governance rules reside on-chai and off-chain in DLT systems, which make how effectively they interact specifically relevant. DLT protocols or on-chain instruments might be rule-based infrastructures, while off-chain rules are practice-based. In other words, while not all rules in the off-chain world are hard codifiable in a mechanistic way, off-chain regulation must be enforced on the DLT protocol and in some way implemented on-chain. The interplay between on-chain and off-chain can be understood as some sort of recursive dialogue or discourse (De Vaujany et al., 2018). The recursive character of off-chain rule-setting agents and on-chain rule executing actors that subsequently force agents to behave accordingly is a rule-based but dynamic regulatory system. Social systems' structuration is mediated by a constant discourse to collect, store, and disseminate information between human agents and organizations (Checkland and Holwell, 1998). In the case of DLT systems, a major part of the organization is mechanistically hardcoded into the DLT protocol. In this research, structuration theory and built upon IT-based regulation systems thinking (DeVaujany et al. 2018) has been used to analyze DLT systems to

delineate the categories of DLT based regulatory systems, specifically the discourse between rule-setting off-chain human beings or agents and rule-enforcing on-chain DLT protocols or actors, thus closely investigating the duality of technology (Orlikowski, 1992).

## 4. Analysis

In the following, we will illustrate how we researched DLT-based regulatory systems by analyzing the characteristics of IT at hand (Orlikowski and Iacono, 2001), which are DLT systems, and their ability to regulate and is being regulated in a recursive dynamic regulatory process (Yeung, K., 2019). In studying a DLT-based regulatory system through a structuration theory lens, the DLT protocol as an actor and the DLT owner as an agent perform jointly with the embedded regulatory system. Figure 2 illustrates the relations in a DLT-based regulatory system where agents and actors interact in the trifecta of "agent sphere soft system" and "actor sphere hard system". Following De Vaujany et al. (2019), the agent and actor interaction has been divided into three dimensions where DLT system design and DLT system use are conceptualized as soft system *regulation of DLT*, while DLT protocol operation as a hard system is conceptualized as *regulation by DLT*. The recursive character of each dimension illustrates the connecting modalities between the dimensions; accordingly, it posits that 'Rule' describes the regulating statements to an active agent in the network (Giddens, 1984), 'Practice' functions as the set of temporary activities to give the background knowledge (Giddens, 1984), and finally 'DLT protocol' defines the functional modalities to encode, store, and enforce the rules within the practices (Hosein et al., 2003; Yeung, 2019). As the dimensions illustrate, regulation of DLT systems enables the cooperation on the materialization of rules towards practices, whereas rules are related to multiple practices through sense-making. Eventually, regulation by DLT system exchange the rules and practices embedded under the protocol through materialization and elicitation.

Figure 2 depicts the three prongs of a DLT-based regulatory system and the interaction dimensions between the two spheres, the soft system off-chain sphere of agents and the hard systems on-chain sphere of acting protocols. It starts with DLT system design where rules are defined which materialize in form of coded governance instruments on-chain in the DLT protocol. Subsequently, during the use of a DLT system, an elicitation process takes place between the protocol on the hard systems side and the emerging practices on the soft systems side. As different user groups may interact with the DLT protocol, heterogenous practices can emerge in the elicitation process that might lead to a changing perception of rules that need to be enforced in a DLT system. Such considerations can trigger the sense-making process where the practices and rules are assessed, which can lead to new rules and thus an adaptation of the protocol and practices, and so on.

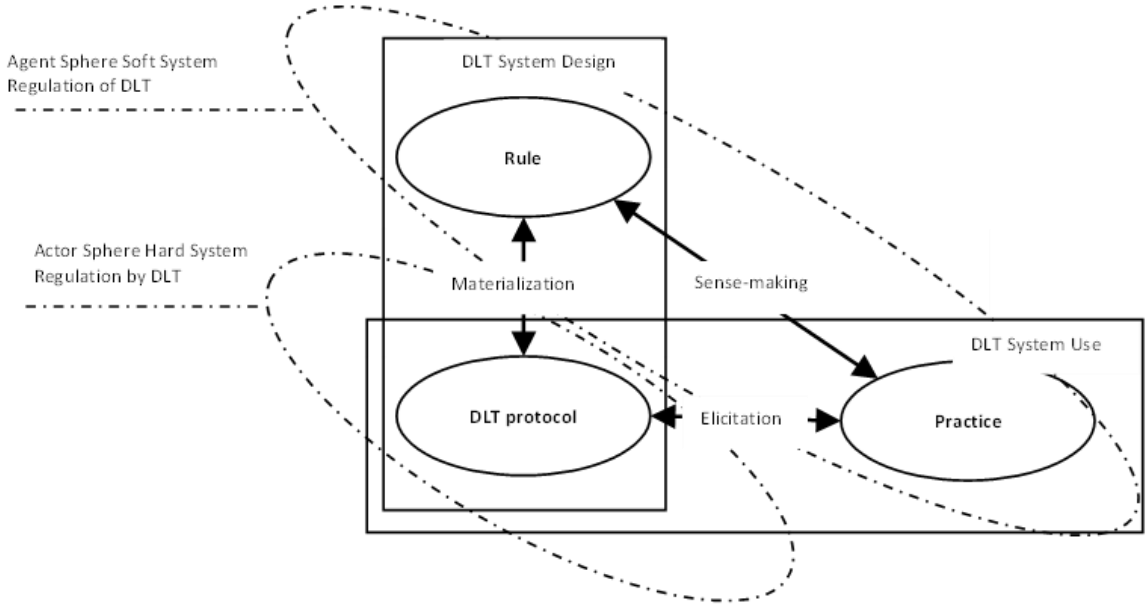


**Figure 2. DLT-based regulatory system dynamics.**

## 5. Discussion

Our research on DLT-based regulatory systems contributes to the theorizing about decentralized systems and the duality of DLT systems as object of regulation, as well as DLT systems as instrument to execute regulation. Taking the dependency between social and technical worlds into consideration.

DLT-based regulatory systems consist of two relational spheres, the agent soft system sphere and the actor hard system sphere. The spheres are connected along the three mechanisms of a) DLT design materialization, b) DLT use elicitation, and c) DLT maintenance sense-making. Table 1 illustrates the three DLT regulatory systems mechanisms and related regulation categories.

*DLT design materialization:* The agent sphere displays the rules that are integrated dynamically into the DLT protocol as part of the actor sphere. Thereby, the process assures that the rules are implemented into the DLT protocol. DLT design materialization highlights the strength between off-chain regulations and on-chain regulation instruments encoded in the DLT protocol during the materialization. Regulation instruments that are specifically of relevance in that relational discourse are the definition of fundamental properties (Xu et al., 2017), dispute resolution and disposal rights (Reed et al., 2018), the definition of DLT access rules (Kumar, Liu, and Shan, 2020) and so on. The materialization of rules is characterized by the intercourse between the social sphere and norms and regulations that need to be enforced in the technical actor sphere and its abilities to execute norms and regulations in the DLT use relation. The DLT design materialization depends on the agents' capability to grasp norms and decode norms into their logic rules (Gherardi, 2012) and then code them as software in the DLT protocol (Christiaanse and Venkatraman, 2002).

*DLT use elicitation:* A DLT system in the use phase is characterized by the interaction between the hard systems DLT protocol and the soft systems practices in the elicitation of the system. Here, the DLT protocol as an actor is executing rules autonomously in the interaction with the agents. In other words, the code of rule and its functioning in the use phase interact with heterogeneous practices that unfold over time where agents using the DLT protocol adjust to it (Jones and Karsten, 2008). While temporally the embedded rules and regulations are followed as encoded, the DLT-based regulatory systems is assessed and opinions are formed about their usefulness. The DLT use phased is characterized by regulatory aspects such as identification of entities and items, enforcement of access control (Kumar, Liu, and Shan, 2020; Reniers et al., 2019), adjustment to changes in scalability needs (Smit et al.,2020; Eberhardt and Tai, 2017), or adhering to the outcome of transaction validations through the consensus protocol (Kampik and Najjar, 2020; Rikken et al., 2019), just to mention a few.

*DLT maintenance sense-making:* The relationship between rule and practice highlights the sense-making aspect to understand the intersubjective and negotiated nature of the rules and regulations, that are encoded in the system. Several studies have tried to understand the relationship between practicing rules and deriving rules in the social sphere where agents explore and evaluate the state of existing rules and regulations to adjust, revise or formulate new ones. Regulatory sense-making is the decoding of practices to identify underlying causes for certain practices and the re-coding and comparison with already coded rules which themselves guide the DLT design materialization process (Gherardi, 2012). The DLT maintenance sense-making thus comprises regulatory aspects such as evaluation of the underlying process execution model (Di Ciccio et al., 2019), analysis of the transaction processing (Paik et al., 2019), assessing the importance and needed adjustment to interoperability needs (Hardin and Kotz, 2019; Kumar, Liu, and Shan, 2020), and constant assessment of the requirements of security requests and if they are fulfilled (Reed et al., 2018; Brinkmann and Heine, 2019).

Our research on the interplay of rules and regulations between the soft systems agent sphere and the hard systems actor sphere allowed us to shed some light on the dynamics of DLT-based regulatory systems with the DLT protocol as IT artifact that requires regulation yet at the same time is an instrument to enforce the regulation.

## 6. Conclusion

In our conceptual and literature-based research on the on-chain and off-chain governance instruments and their interplay in DLT-based regulatory systems we have been able to combine systems thinking with structuration theory inspired modelling of reinforcing interaction systems. While prior research on DLT governance already analyzed the duality of regulation of DLT and regulation through DLT (Beck et al. 2018), the process of materialization, elicitation and sense making as described by De Vaujany et al. (2018) has not been analyzed and explicated yet for autonomous decentralized IT systems such as blockchain and other DLT implementations.

Our research focusses on the interplay between the agent sphere and the actor sphere and thus departs from most DLT research as we do not consider DLT implementations as static systems that need to be followed, but as a dynamic rationalization process where the DLT protocol structures practices, while changing practices are leading to new rules and regulations that will change

the DLT protocol, e.g., in form of forking. In our research we explain the mechanisms of regulation execution through three processes between two spheres that combined define DLT-based regulatory systems. While the peer-to-peer interactions in an autonomous contract-based system often is perceived as a DLT environment that is unchangeable that enforces rules users or agents have to obey to, we illustrate the circular and dynamic relationship of re-enforcing regulatory dynamics, combining a techno-social view of regulation through DLT with a socio-technical view of regulation of DLT in one model.

| | A) DLT Design Materialization | B) DLT Use Elicitation | C) DLT Maintenance Sense-making |
|---|---|---|---|
| Related regulation characteristics | • Fundamental properties<br>• Disposal rights<br>• Access rules<br>• Scope<br>• Access policies<br>• Authentication<br>• Application access<br>• Censorship resistance<br>• Identity disclosure | • Identification<br>• Access control<br>• Confirmation<br>• Auditing<br>• Community rules<br>• Decision-making process<br>• Scalability<br>• Implementation<br>• Consensus protocol<br>• Validation | • Process execution model<br>• Transaction process<br>• Flexibility<br>• Interoperability<br>• Security<br>• Operational alignment<br>• Data validation<br>• Performance<br>• Cost efficiency<br>• Transferability |
| References | Xu et al., 2017; Reed et al., 2018; Kumar, Liu, and Shan, 2020; Khan et al., 2020; Rikken et al., 2019; Paik et al., 2019; Lesavre, Varin, and Yaga, 2020; Swanson, 2015; Di Ciccio et al., 2019; Reniers et al., 2019 | Reed et al., 2018; Kumar, Liu, and Shan, 2020; Reniers et al., 2019; Hardin and Kotz, 2019; Colomo-Palacios et al., 2020.; Khan et al., 2020; Reijers et al., 2018; Eberhardt and Tai, 2017; Kampik and Najjar, 2020; Rikken et al., 2019; Smit et al., 2020; Xu et al., 2016; Swanson, 2015 | Di Ciccio et al., 2019; Paik et al., 2019; Xu et al., 2017; Hardin and Kotz, 2019; Kumar, Liu, and Shan, 2020; Reed et al., 2018; Brinkmann and Heine, 2019; Eberhardt and Tai, 2017; Swanson, 2015;; Lesavre, Varin, and Yaga 2020 |

**Table 1. DLT-based regulatory system characteristics.**

As prior literature lacks a critical reflection of the interaction between regulation of DLT and regulation through DLT, we consider it as our contribution to fill this gap. Our formation of agent and actor sphere regulation has been structured to describe the interplay between agent and actor explicitly.

This study provides an overview to which extent DLT systems can regulate systems in a network with a set of rules and norms. Earlier studies loosely described the phenomena of the regulatory relation between the soft and the hard system, which we have taken to then next level in our study. The specific introduction of agent and actor sphere regulation allows for more structured regulatory approaches and explains the interplay between agents and actors explicitly. It is worth mentioning that this study has adopted the socio-technical view rather than a techno-social view of DLT systems governance, with the source of control residing with agents such as human beings or legal entities rather than with technical entities. This study provides deep insights on various dimensions of regulatory mechanisms and systems that are the part of system dynamics due to the change in technology infrastructure. The core contribution of this research is to understand the dynamics of DLT-based regulatory systems with the DLT protocol as IT artifact that will enforce the regulation in the network from the technological and social dimension perspective.

Apart from the theoretical relevance of explaining in more detail the regulatory dynamics within DLT systems from a system thinking perspective, taking rules, the IT artifact, and practices simultaneously into consideration by integrating regulatory aspects from an on-chain and off-chain perspective, our research also provides concrete guidance for regulators and DLT systems developers alike. Regulators can structure, set, and monitor their regulatory frameworks along the materialization, elicitation, and sense-making of DLT systems. Using the related regulatory characteristics as guidance, rules and compliance systems can be defined that cover both the DLT protocol as IT artifact, a well as the corresponding social system with its rules and practices that ideally complement the rules embedded on-chain. DLT systems developers can be sensitized in the design and implementation of DLT systems for the need of having regulatory characteristics addressed, not at least to make systems legally viable, depending on the jurisdictional system within DLT systems are used.

While this research has been able to shed light on DLT-based regulatory systems dynamics, more research is needed. For example, how sensemaking as form of DLT maintenance functions to implement agility in system dynamics while DLT systems are supposed to stay immutable both on the ledger as well as protocol level. Furthermore, how rules and norms off-chain from multi-jurisdictional spheres can shape commonly accepted rules on protocol level is an open question as well. Research on governance through DLT systems, where ethical issues may emerge when norms are enforced in a techno-social system also need to be researched, and potential negative spillover effects should be investigated.

As any other research, our research also is limited by some restrictions. Our theorizing is based on a structured literature review where we focused on prior research dealing with DLT and blockchain in the context of regulation. We may have missed out relevant literature that has not specifically mentioned those terms but might have been relevant, nevertheless. We then mapped the found characteristics on regulation along the three mechanisms at play that lead to dynamics in DLT systems regulation, as illustrated in Figure 2 and Table 1. The mapping of characteristics per mechanism was done by the authors of this paper, sorting them where they might be most relevant, and discuss where we deviated from each other. We consulted the corresponding literature and might sure as much as possible that the sorting is following good guidance, but as with any conceptual research, empirical testing is now necessary to test how robust our "DLT-based regulatory system characteristics" framework actually is.

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