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Blockchain for the circular economy, implications for public governance

Eduardo Acosta Llano
University of Oulu, Oulu, Finland, and
Pia Hurmelinna-Laukkanen and Lauri Haapanen
Department of Marketing, Management and International Business, Oulu Business School, University of Oulu, Oulu, Finland

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Abstract

Purpose – This study examines the intricate interplay of blockchain, public governance and the circular economy (CE), aiming to assess the potential of blockchain technology (BT) in addressing challenges associated with the adoption of CE principles, particularly in the public sector.

Design/methodology/approach – Focused on public governance, the research employs in-depth interviews with Finnish policymakers actively engaged in CE initiatives. Qualitative analysis is applied to derive insights and patterns from the gathered data, providing a nuanced understanding of blockchain's transformative role.

Findings – The study uncovers key dimensions for leveraging blockchain in the CE within the public sector. Notable findings include the significance of contextual transparency, the use of incentivization as a regulatory tool, the role of standardization through strategic autonomy and the importance of public engagement and participation.

Originality/value – This research contributes a unique framework that illuminates the transformative potential of blockchain within the CE, emphasizing its relevance to public governance. The identified dimensions offer practical insights for policymakers and practitioners seeking to navigate the complexities of circular transitions in the public sector.

Keywords Blockchain technology, Governance, Circular economy, Decision-makers, Innovation

Paper type Research paper

1. Introduction

Fifteen years have passed since a person – or persons – under the pseudonym of Satoshi Nakamoto published blockchain technology (BT) in 2008. In its inception, this technology sought to reshape the financial landscape with the Bitcoin cryptocurrency (Nakamoto, 2008). Anchored in its decentralized architecture, the technology aimed to supplant the conventional necessity of centralized entities for transaction verification; thereby mitigating vulnerabilities, tampering risks and the entrenchment of corruption within transactions (Swan, 2015). The innovative paradigm of an open, immutable, universally shared ledger with peer-to-peer validation sought to bring transparency to what its creator(s) perceived as a complex and ethically compromised financial sector (Bratspies, 2018).

Since these developments, blockchain's democratic grounding has grown and spread across multiple sectors, embracing areas as diverse as supply chain management, healthcare, marketing, logistics and the sphere of art (Abou Jaoude and Saade, 2019). The expanding

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usage highlights the technology's flexible application and significant ability to transcend sectoral barriers (Chen *et al.*, 2018). Within the public sector, blockchain's benefits have begun to be explored in public processes such as identity management (Sung and Park, 2021), reduction of public costs (Rodríguez Bolívar and Scholl, 2019), e-voting (Kshetri and Voas, 2018) and bureaucracy optimization (Allessie *et al.*, 2019). Thanks to its capacity to speed up official activities, eliminate duplications and improve registration validity, blockchain has the potential to remove public inefficiencies and pave the way for higher operational precision (Warkentin and Orgeron, 2020).

Despite the acknowledged potential, BT is still developing and its implementation is so far limited (Sung and Park, 2021). Considering sustainability and public governance, the complexities and opportunities of blockchain hinder harnessing its capacity to address various challenges concerning public budgeting and accountability (Berryhill *et al.*, 2018), such as having a transparent record of public budgeting. This need is reinforced by the current global political context marked by volatile uncertainty and skepticism (Ahir *et al.*, 2022), as well as the importance of a long-term and strong commitment to attain sustainability goals in policy formulation (Colglazier, 2015).

Considering that sustainability is one of the most pressing concerns confronting countries today, it is not surprising that the need for responsible natural resource management has propelled models like the circular economy (CE) to the forefront of policy discussion (McDowall *et al.*, 2017; Friant *et al.*, 2021). The central goals of the CE revolve around waste elimination and extending product lifecycles. Achieving these goals requires collaborative efforts among multiple stakeholders, focusing on shared actions involving recycling, reuse and reduction (Geissdoerfer *et al.*, 2017).

As the circular model is considered to offer various advantages to society, the environment and the economy, governments are progressively adopting its principles. This adoption holds the promise of promoting sustainable growth, creating new employment opportunities, and attracting investments and income, all in alignment with long-term environmental and societal objectives (MacArthur, 2013). In 2050, improved resource efficiency could add $2tn to the global economy annually, (Ekins *et al.*, 2017). In the CE, this could be realized by increasing revenue through new circular activities and maximizing functionality from existing resources.

BT's core characteristics—transparency, traceability and immutability—naturally align with the foundational principles of the CE: collaboration, cooperation and shared objectives, all of which promote optimizing the use of scarce resources. This alignment has piqued the interest of scholars and practitioners in the private sector seeking to explicitly integrate blockchain and circularity. This interest has grown, particularly with the development of more energy-efficient blockchain types that consume significantly less energy compared to fully public blockchains like Bitcoin, which made meeting the environmental goals problematic.

Exploration of the integration of BT is advancing rapidly also within the public sector. Governments are actively engaged in over two hundred blockchain initiatives, with at least forty-six countries globally either implementing or planning to implement blockchain-based solutions for governance. These applications span various areas, including land registry, knowledge sharing, cross-border inter-bank payments, tax collection and public hackathons (Berryhill *et al.*, 2018).

The intersection of the three domains – BT, the CE and public governance – presents an intriguing, yet underexplored area of research. Prior studies have linked blockchain with the CE, shedding light on aspects like sustainability, social responsibility and ethical considerations (Upadhyay *et al.*, 2021). These studies have also contributed to bridging the gap between research and practice more broadly (Böckel *et al.*, 2021) and have conducted analyses of case studies involving blockchain applications in various industries, including

supply chain tracking, tracing and responsiveness (Kouhizadeh *et al.*, 2020; Nandi *et al.*, 2021). However, these works have often overlooked the perspectives of public governance.

On the other hand, prior research connecting blockchain with governance has primarily centered on conceptual analyses at the process level for network coordination (Brinkmann and Heine, 2019), the creation of public consortia for smart city public participation (Bai *et al.*, 2021), systematic literature reviews on the automation of public processes using smart contracts (Balcerzak *et al.*, 2022) and the identification of blockchain use in public governance through cases studies (Berryhill *et al.*, 2018). Yet, those works often omit the context of the CE or sustainability. Hence, a gap remains in our understanding of how blockchain can be effectively leveraged within governmental contexts to advance CE principles.

This gap is challenging to narrow because it necessitates more than simply combining the thus far accumulated knowledge in the above-described studies by combining two out of three domains. Prior research has often lacked precision when discussing the specific types of blockchain and their relevant attributes that are most suitable for adoption in the CE and public sector. These studies have frequently resorted to making broad generalizations about the technology's advantages and disadvantages. Berryhill *et al.*'s work (2018) stands out for its concrete approach to identifying suitable blockchain mechanisms and types for adoption in the public sector. However, as they have pointed out, the application of blockchain is still in its early stage, and hence, it is important to expand understanding of this technology, explore its potential applications and engage in experimental initiatives (Berryhill *et al.*, 2018).

Our study advances the discussion by taking two important steps. First, we explicitly specify the type of blockchain and consensus mechanism. Second, we analyze BT from four key potential perspectives: as a tool for enhancing transparency and accountability, as a means of incentivizing the transition to a CE, as a means to encourage public participation and as a tool for standardizing metrics.

We explore these four aspects of BT especially to address common issues that governments face while implementing a CE. We aim to contribute to earlier theories that have identified information centralization and limited access (Geng *et al.*, 2019; Sharma *et al.*, 2021), low levels of public awareness and engagement (Obersteg *et al.*, 2019; Katika *et al.*, 2022), the complexity of establishing incentives (Grafström and Aasma, 2021) and a lack of precise and consistent measures in the CE (Vilariño *et al.*, 2017; Bianchini *et al.*, 2019) to be relevant issues for the adoption of the circular transition. By delving into these four aspects of BT, our study advances understanding of the tools enabling improved and informed decision-making in the public sector when transitioning to a more circular and sustainable economy while contributing to existing theory.

The present study aims to answer the research questions: *How could the utilization of BT within the public sector help decision-making and policy formulation in a CE context?*

To answer the research question, we have opted for a qualitative research method, specifically utilizing semi-structured interviews among policymakers in Finland actively involved in the CE. The choice of a qualitative approach is grounded in our research objectives, which seek to delve into the "what," "how" and "why" aspects of the phenomenon under investigation. As qualitative research is well-suited for exploring the intricacies and motivations behind human behavior and decision-making (Merriam and Tisdell, 2015), we consider it appropriate for the exploration of poorly understood phenomena (see Eisenhardt, 1989). To ensure a systematic and rigorous analysis of the qualitative data gathered from our interviews, we have chosen to apply the steps of the Gioia method (see Gioia *et al.*, 2013). We uncover nuanced insights and trends that aid in a deeper understanding of the implications of BT for government decision-making and policy formulation for the CE.

2. Literature review

2.1 Blockchain fundamentals

BT was initially developed to provide secure and decentralized digital transactions, eliminating the need for trust between parties. It initially utilized digital signatures for digital coins to ensure strong ownership control and introduced a consensus mechanism called "proof-of-work" (PoW) to maintain a public record of transactions, preventing issues like double-spending (Swan, 2015).

Consensus mechanisms in blockchain can be compared to a jigsaw puzzle, with each piece representing a transaction within a blockchain network. The consensus mechanism acts as the puzzle's rules. Nodes in the network collaborate to ensure that each piece fits flawlessly, guaranteeing that the final picture (the blockchain ledger) is coherent and accurate. Just as different puzzles have varied rules for piece placement, different blockchains use different consensus mechanisms to confirm transactions and protect the integrity of their ledger (Nakamoto, 2008).

One of the central blockchain features is the minimal coordination required within the network. Participants, known as nodes, operate without explicit identification, allowing them to join or leave the network at any time. In public blockchains, all transactions are transparent and visible to nodes (Nakamoto, 2008). Valid transactions are extended by nodes, while invalid ones are rejected, ensuring compliance with network rules and incentives. This innovative consensus mechanism led to the creation of Bitcoin, a cryptocurrency, which inherently is a unique bit of data that may be traded between two parties (Yadav *et al.*, 2023).

The decentralized nature of BT is another of its standout characteristics. Blockchain was designed to eliminate the need for third-party validation or control when conducting transactions. This distributed approach entails collaboration and co-dependency within the system, as transactions are collectively validated by the network rather than a centralized authority. It empowers users with a level of autonomy and security that traditional centralized systems often lack. This indicates that a replicated database is maintained and that its operation is not dependent on a single party or an intermediary (Yadav *et al.*, 2023).

BT also facilitates transactions to be automatized through smart contracts. Smart contracts in the blockchain refer to self-executing actions with the terms of the agreement directly written into code (Wang *et al.*, 2018). They offer a paradigm shift in how transactions and data are managed, fostering a more secure and inclusive digital environment (Fenwick and Vermeulen, 2019). As BT continues to evolve, its security and trust principles remain at the core of its transformative potential.

2.2 Types of blockchain

Not all the functionalities described above are equally present in every type of blockchains. The technology can be categorized into three main types: public, private and consortium (also known as federated) (Buterin, 2015; Zheng *et al.*, 2017; Zhang and Lee, 2020; Kaur *et al.*, 2020; Yadav *et al.*, 2023). Public blockchains are open to anyone, allowing for a decentralized and transparent ledger accessible to all participants. Bitcoin and Ethereum are popular examples of public blockchains. In contrast, private blockchains are restricted to a select group of participants or entities, offering more control, privacy and scalability but sacrificing some decentralization. Consortium blockchains, on the other hand, balance between public and private by involving a group of trusted organizations or entities in the validation process, enhancing efficiency and privacy while maintaining a degree of decentralization. Figure 1 a summary of the three types of blockchains.

2.3 Consensus mechanisms

For BT, consensus mechanisms are essential in setting network rules, ensuring security, and maintaining transparency. The PoW is a fundamental algorithm that guides miners' tasks.

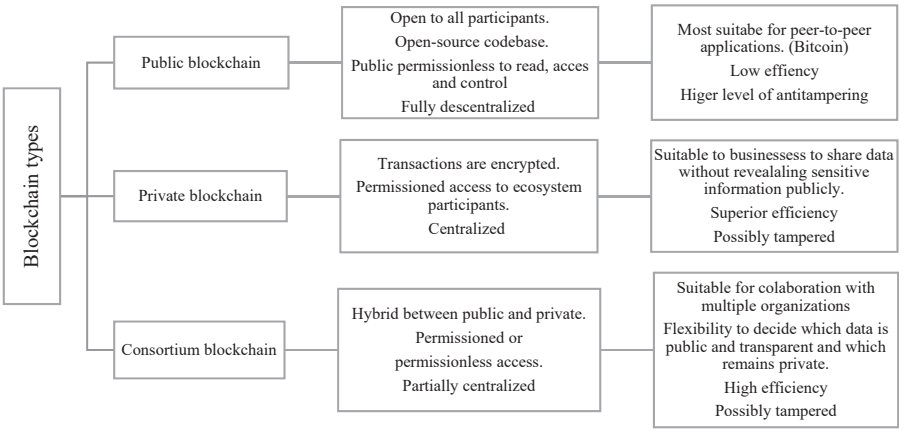

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Figure 1.
Types of blockchain, basic characteristics and suitability

Mining, put simply, is the process of adding valid blocks to the blockchain. By doing this, miners help to extend the blockchain, making it longer and with higher block numbers and consequently increasing the network's confidence in its status. This trust ensures that the blockchain operates correctly (Ethereum, 2022). However, the challenge is that this takes a notable amount of energy when PoW miners compete to solve tough arithmetic problems to win rewards. Bitcoin, for example, consumes enough to power Ireland for a year.

Alternative blockchain consensus mechanisms have been developed to address energy and scalability concerns, as well as to meet the requirements of a wide range of applications and to stimulate an innovation ecosystem. Consensus mechanisms like the Proof-of-Stake (PoS), delegated Proof-of-Stake (DPoS) and Practical Byzantine Fault Tolerance (PBFT) provide distinct approaches with a focus on energy efficiency, scalability, or faster transaction processing (Yadav *et al.*, 2023). For example, the PoS selects validators based on their cryptocurrency holdings and willingness to "stake" collateral, eliminating competitive mining (Duong *et al.*, 2020). The DPoS relies on elected delegates to prioritize transaction speed (Saad and Radzi, 2020), while the PBFT prioritizes fault tolerance and consensus through a multi-stage process (Castro and Liskov, 2002). These alternatives offer versatility and innovation, and they often have a considerably lower environmental footprint, enhancing sustainability in blockchain networks.

Figure 2 illustrates different consensus mechanisms and their basic distinctions.

2.4 Blockchain technology in public governance

The motivation for fostering collaborations on blockchain initiatives stems from the technology's ability to offer an irreversible record of all transactions and operations with new levels of openness and accountability (Swan, 2015). Governments, for example, could save administrative costs and increase operational efficiency by automating processes and optimizing governmental operations (Walport, 2016). However, implementing blockchain in the public sector is not a straightforward undertaking, and existing literature emphasizes this complexity.

Tan *et al.* (2022) propose a comprehensive framework on how blockchain has the potential to alter public governance. Their systematic literature review outlines three interrelated levels (micro, meso and macro) and identifies nine key factors for governments to consider

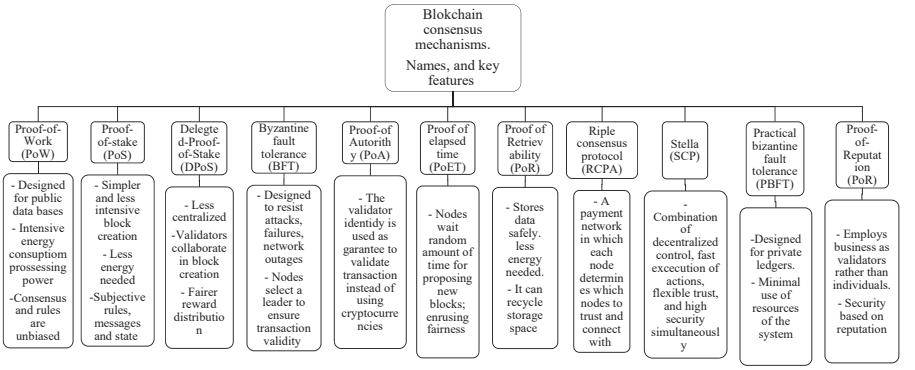

Figure 2.
Consensus mechanisms in blockchain technology

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when implementing blockchain-based solutions: infrastructure, interoperability, decision-making processes, incentives, consensus mechanisms, organizational structures, accountability measures and control mechanisms. This approach builds on Roberts' (2020) notion that governmental strategies at these levels are intertwined. The framework suggests that achieving a successful government blockchain transformation necessitates a thorough integration of technological, political, social, managerial and legal solutions (Tan *et al.*, 2022). Collaboration among stakeholders (both public and private) and strategic processes (both on-chain and off-chain) is necessary.

Addressing these problems, Brinkmann and Heine (2019) analyze BT through the lens of stakeholder collaboration, aligning it with New Public Governance (NPG) principles, a strategic framework for organizing public administrations in collaborative settings (Osborne, 2006). Their initial findings suggest that blockchain provides valuable support for governments managing collaborative networks effectively. However, the extent of these benefits varies based on off-chain processes, as there might be additional new steps like recording information that is not currently being recorded. They also emphasize how BT has the potential to alter approaching trust; the main thing with blockchain will be trusting the network's governance, architecture and control, rather than the data itself (Brinkmann and Heine, 2019).

The public sector also benefits from changes in how collaboration takes place. As for the ease of establishing collaborative initiatives, partnerships among multiple stakeholders for blockchain applications have become increasingly available thanks to the development of Blockchain-as-a-service options, making it easier for governments to set up blockchain networks (ACT-IAC, 2017). Universities, for example, could be crucial participants and collaborators in terms of assessing new technologies, supplying a talent pool, and providing forums for experimentation, information sharing and developing proof of concept (UK House of Lords, 2017).

A notable issue for the public sector is that governments could benefit from those advances gained by enterprises utilizing the BT. For example, blockchain promotes regulatory compliance by retaining transparent and unchangeable transaction records (Pawczuk *et al.*, 2019) and by reducing fraudulent activity in transactions (Mougayar, 2016; Tapscott and Tapscott, 2016a). These features facilitate more transparent and informed decision-making. Furthermore, blockchain provides quick, safe and cost-effective cross-border transactions, reducing delays and expenses (Tapscott and Tapscott, 2016b), which could boost international trade, thereby benefiting also public actors.

The adoption of BT in public governance also translates to increased control over citizens' personal data, allowing individuals to grant access permissions and monitor data usage (Tapscott and Tapscott, 2016a, b). This technology further reduces the risk of identity theft and reinforces online security for citizens (Altman, 2018). Streamlined governmental operations yield a more efficient and accessible public service delivery, including expedited document processing (Pihlak, 2018).

Numerous governments have started blockchain projects, including those in the Netherlands, Estonia, Sweden, Singapore, Dubai and Sweden (Berryhill *et al.*, 2018). Depending on particular demands and applications, several blockchain types and consensus techniques have been chosen. Estonia is known for being a leader in BT, and it became the first country in the world to integrate blockchain into its e-governance system, making it the most frequently referenced example of using blockchain in government applications. The healthcare industry, public property register, company registration, succession registry, digital court and state gazette are just a few of the industries that use it (Jalakas, 2018). The adoption of BT has improved data security by offering a more dependable line of defense against data breaches. At the same time, incorporating BT has presented Estonia with a number of challenges. Developing suitable legal frameworks, addressing cybersecurity issues, integrating blockchain with current legacy systems and increasing public trust and knowledge of the advantages and dangers of BT are a few of these (Sullivan and Burger, 2017; Semenzin *et al.*, 2022).

Another noteworthy example of blockchain application in public governance is Singapore. The government of Singapore has been actively pursuing the adoption of BT in a number of areas, such as energy, healthcare and finance, as part of its digital strategy to become a smart nation that will improve societal well-being and create business opportunities. Notably, to promote blockchain adoption, the government has partnered with businesses and academic institutions, utilizing their technological know-how and aiding startups in creating blockchain solutions (Cheah *et al.*, 2018). In its endeavors, Singapore has experienced similar challenges as the Estonian government. Regulatory uncertainty has proven to be a major obstacle in the country's efforts to foster innovation while maintaining consumer protection and regulatory compliance (Zhou *et al.*, 2020). Likewise, interoperability poses a challenge in terms of integrating blockchain technologies with legacy systems and the current infrastructure (Alam *et al.*, 2021). Another issue is scalability since blockchain networks must effectively manage growing transaction volumes. Furthermore, guaranteeing data privacy and security can be demanding, especially in industries like healthcare and banking. These challenges are exacerbated by the lack of qualified experts in blockchain development, cryptography and cybersecurity. To fully realize the potential of BT and carry out its digital transformation initiatives, Singapore, like other governments, must address these obstacles.

Beyond the identified challenges, in applying blockchain to the CE, the public permissioned consortium blockchain emerges as a particularly cohesive choice. Permissioned blockchain networks collaboratively address challenges among stakeholders, striving to reduce intermediaries and uphold transaction quality. These networks cultivate co-opetition dynamics, evolving into collaborative platforms (Šilenskytė *et al.*, 2023). As previously elucidated, consortium blockchains balance between public and private by involving a group of trusted organizations or entities in the validation process. This approach enhances efficiency and privacy while maintaining a degree of decentralization. This type of blockchain ensures security and integrity, with participating organizations collectively determining the consensus mechanism, thereby fostering collaboration and interaction among actors toward a shared goal (Nadir, 2019). Additionally, it contributes to environmental sustainability by mitigating the impact of energy usage, as it does not involve the resource-intensive mining process.

The above-described aspects may also become relevant when the blockchain is to be implemented in relation to circular transition endeavors in the public sector. The next section grounds these considerations by addressing the CE and public governance.

2.5 Circular economy in public governance

In public governance, the CE is considered highly relevant in responding to sustainability and environmental challenges (Kirchherr *et al.*, 2017). Governments worldwide are recognizing this issue and are actively taking steps to make the CE a reality through policy and regulation (Ghisellini *et al.*, 2016). They enact measures that encourage sustainable production and consumption practices, such as setting waste reduction targets, implementing eco-labeling and adopting extended producer responsibility (Morseletto, 2020).

Public procurement is also a relevant area where governments wield significant influence in driving CE principles. Leveraging their purchasing power, they can prioritize products and services with longer lifecycles, lower resource consumption and higher recyclability. This approach extends the benefits of a CE to government operations and the supply chain (Qazi and Appolloni, 2022). Local governments have been instrumental in implementing CE practices. Cities are at the forefront of CE initiatives, with many of them developing strategies to reduce waste, promote sustainable urban development and engage with local stakeholders (Bolger and Doyon, 2019).

Full adoption of the CE in public governance is not without challenges, however. As with blockchain adoption, collaborative efforts among various stakeholders are essential to reach circularity. Governments must overcome existing regulatory barriers and ensure a just transition in industries affected by the shift (Su *et al.*, 2013). Tapping into these issues, supranational regulation also directs action. Agendas such as the European Union's CE Action Plan include different measures, such as product eco-design and waste reduction objectives, underlining the potential for these policies to create long-term change (Bourguignon, 2016).

In public governance, a relevant issue is following through the impact of the regulatory and policy-induced changes. The ability to measure progress is hence critical. A challenge is that although governments use metrics and indicators to track their progress – allowing them to assess the environmental and economic impact of their policies (Blomsma and Brennan, 2017) – those measures tend to be difficult to verify and differ across regions, which may impede international collaborations for reusing, reducing, or recycling waste (Galvão *et al.*, 2018). In this, BT may become a viable enabling factor.

2.6 Blockchain for the circular economy

BT is emerging as a potential driver for the CE, enhancing transparency, traceability and trust in resource flows (Kouhizadeh *et al.*, 2019). It enables supply chain optimization, leading to more efficient resource use and reduced waste and emissions (Esmaeilian *et al.*, 2020). Smart contracts embedded in blockchain automate processes, streamlining circular practices for greater efficiency (Kumar and Chopra, 2022). Additionally, blockchain empowers consumers by furnishing information about product origins and environmental impact, promoting sustainable choices (Montecchi *et al.*, 2019).

Despite these advantages, several obstacles hinder the seamless integration of blockchain into the CE. Technological integration is intricate and costly, necessitating operational adjustments (Rejeb *et al.*, 2022). Challenges arise from the absence of uniform standards and interoperability across blockchain platforms, which hamper data sharing and collaboration in supply chains (Nurgazina *et al.*, 2021). Concerns regarding data privacy, security, potential data breaches and regulatory constraints present significant hurdles (Böhmecke-Schwafert *et al.*, 2022). Addressing scalability issues in blockchain networks is also crucial to hold

growing transaction volumes (Govindan, 2022). It could be argued that the regulatory and policy initiatives from the public sector could respond to at least some of these challenges. However, a noticeable research gap in the literature is the limited insight into the governmental perspective.

Although existing literature indicates blockchain's potential to advance the CE (Upadhyay *et al.*, 2021; Kouhizadeh *et al.*, 2020), there is a lack of comprehensive studies exploring how governments, with their distinct role in promoting sustainability and circular practices, could harness this transformative technology. Combining what is already known and where gaps seem to exist in the knowledge, Figure 3 below depicts the current study positioning and logic.

3. Method, sampling and analysis

As theoretical knowledge comes across as incomplete, a look into existing practices and empirical materials is scrutinized. To collect empirical insights, we utilized a qualitative semi-structured interview methodology involving key stakeholders from both the public and private sectors in Finland. Our participants represented diverse organizations with substantial influence on policy formulation in both the country and the region. Additionally, we engaged a technical expert specializing in BT and Web 3.0 and providing services to the public sector. Combined, these informants offered invaluable insights into the intricacies of integrating BT into policy governance.

The informants were chosen through a meticulous selection process, guided by pre-defined explicit criteria to ensure their direct involvement in environmental and CE regulatory and policy work. As it was expected that blockchain was not fully implemented, the selection focused first on making sure that the informants were located at the intersection of CE and public governance. The selection criteria underscored a comprehensive

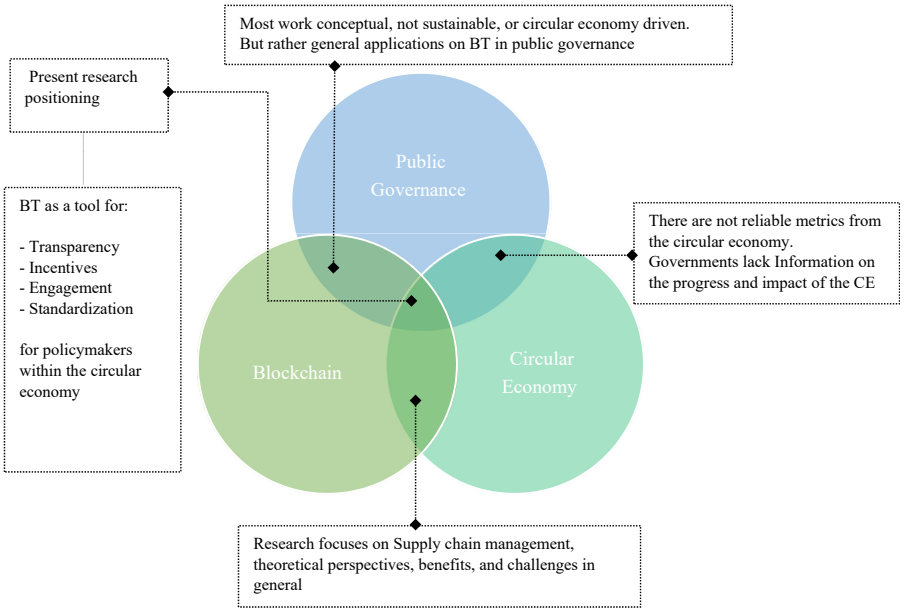

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Figure 3. Theoretical framework. Positioning and logic of the study

understanding and active engagement in both national and international policies, keeping in mind that circular transition is very much an international phenomenon. Finland was taken as the focal research region given its pioneering position in both CE and technology adoption; the country stands at the forefront of policy formulations related to CE, being the first to design a CE road map (Sitra, 2016). In Finland, every industry must adhere to strict sustainability regulations, navigating both national and European-level mandates, which also enables evaluation of the influence of supranational regulation and the related aspects.

Including a BT expert leading a technology firm in the group of informants was considered relevant given Finland's position as an innovative hub hosting numerous technology companies where proficient data management is pivotal (Sitra, 2016). By including a technology expert, we gained firsthand insights into the specific policy requirements for adopting BT in the realm of CE, and how technology firms pursued to meet those. This approach allowed for combining insights from both policy perspectives and the technological landscape. The participant selection process yielded a sample of individuals possessing extensive knowledge and experience across the three primary domains of our research – BT, CE and public governance.

We designed the interview questions to elicit replies from a policy perspective, digging into the complexities of our study subject. Table 1 provides a summary of the informants, highlighting their different backgrounds and expertise that contribute to the diversity of our data. Representatives from institutions such as Sitra, a think-tank known for actively creating research that catalyzes policy initiatives across multiple domains, are included in the sample. Likewise, representatives from the Finnish Ministry of Environment and Climate Protection shared official perspectives shaped by policy formation and execution. Representatives from the Finnish Parliament added legislative viewpoints to our dataset, providing a more complete picture of the policy landscape. Technical perspective was gained from the BT company representative, as mentioned above.

The interviews lasted from 45 to 60 min, and they were carried out virtually through platforms like Zoom and Teams. Recordings and transcriptions were made during these sessions. While the majority of the interviews were conducted in English, one interview was conducted in Finnish. The Finnish interview underwent translation into English using a digital tool, with subsequent review by native Finnish-speaking co-authors to ensure accuracy and precision in conveying responses. All interviews were then uploaded to a shared online folder, allowing co-authors to commence identifying initial patterns and collectively engage in data organization.

Informants	Organization	Type	Department/field	Role
I1	Sitra	Private/ Public	Fair data economy	Leading expert
I2	Sitra	Private/ public	Fair data economy	Leading expert
I3	Finnish Ministry	Public	Environment	Senior specialist
I4	Struggle	Private	BT, Web 3.0	CEO
I5	Finnish Parliament	Public	Environment and climate protection	Member of parliament
I6	Finnish ministry	Public	Environment and climate protection	Negotiating official

Note(s): I = Informants
Source(s): Table created by authors

Table 1.
List of representatives, organizations, and roles

In addition to the interviews, our research leveraged a diverse dataset encompassing corporate reports, official documents and publicly available sources. Given the complexity and unstructured nature of the acquired data, we systematically organized the materials following the method outlined by Gioia *et al.* (2013). Starting with raw data, we derived first-order concepts, which were then synthesized into second-order themes. These themes were subsequently aggregated into dimensions. This systematic organization facilitated a more coherent and insightful analysis of the intricate dataset. We used a constant iteration method to create mutually exclusive and exhaustive categories (Miles and Huberman, 1994). By returning to the data, and refining and reorganizing categories, we ensured that each piece of information fits into a distinct category and that the categories collectively cover all relevant aspects of the data. Figure 4 outlines the analysis process.

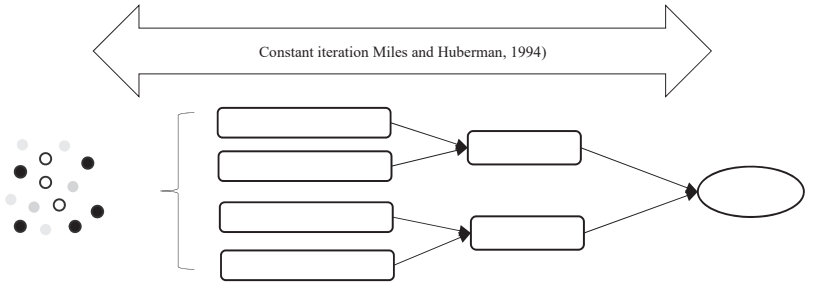
Appendix depicts the analysis steps from the raw data to first-order concepts, second-order concepts, and finally, the aggregate dimensions.

4. Findings

Examination of the information gathered from the participants on the three domains of this study revealed four dimensions as important for policies and regulatory actions that target widespread adoption of the CE and could benefit from utilization of BT. Enhancing transparency, driving incentives, promoting engagement and standardizing data form a framework concisely that encapsulates these dimensions. In the following, each of the dimensions is discussed before providing an illustration of the framework they comprise.

4.1 Contextual transparency

Transparency holds a crucial role in the CE and policy formulation. Reflecting this, one informant stated: *"Transparency is critical, but it must be done at the level required for specific tasks; it is not the same information that all stakeholders require"* (Informant from the Ministry of environment). In particular, this interviewee underscored the necessity for tailored transparency, recognizing that stakeholders require different information based on their roles. For instance, manufacturers may need distinct data compared to consumers.



Source(s): Figure created by authors, adapted from Gioia *et al.* (2013)

Figure 4.
Data analysis process

Furthermore, the interviewee stressed the importance of confidentiality, acknowledging that producers must take action to safeguard certain proprietary processes.

In the context of achieving contextual transparency, a blockchain consortium type could play a pivotal role. Blockchain enables the creation of a transparent yet tailored information-sharing system. Smart contracts within the BT, for instance, can be programmed to provide specific details to different participants based on their roles and responsibilities. This ensures that manufacturers receive the information they need without compromising sensitive details that might be irrelevant or inappropriate for consumers.

Additionally, the immutability and transparency inherent in BT technology can build trust among stakeholders, as they can verify and trace information with confidence. By integrating blockchain into the CE, a consortium could establish a system of contextual transparency, fostering collaboration, trust and effective decision-making.

This corresponds to what informant 2 stated: "*Transparency is critical; it should include not just the origin, but also the components in detail, because if you want to circulate the material, you must first understand what it is and ensure that it is made in a sustainable manner,"* underscoring the critical nature of transparency. The interviewee emphasized that transparency should extend beyond just revealing the origin of materials; it should encompass more detailed information. The rationale behind this comprehensive transparency is rooted in the need for effective material circulation, requiring a thorough understanding of the product and ensuring its sustainability for all of its parts.

Likewise, ensuring sustainability of the production and other such processes by leaning on transparency was emphasized. The interviews highlighted the importance of accurate and secure traceability of relevant materials and the specific components of the product. It was noted that detailed traceability is essential in facilitating smoother material circulation.

As a specific example of adverse effects of problems in transparency, one informant drew attention to the alarming rise in illegal markets for waste, drawing parallels to markets associated with drugs and human trafficking. The informant suggests that the as illicit waste market grows, the urgency for policymakers to prioritize traceability measures increases rapidly to combat illegal activities effectively. Technological tools are needed.

4.2 Incentivization as regulatory leverage

Next to transparency issues, motivating actors to embrace circular models poses a significant challenge in the transition to a CE. Informants highlighted the crucial role of legislation, particularly financial measures, in incentivizing and directing stakeholders to adopt circular practices: *"In the next couple of years, EU regulations will mandate companies to disclose all data related to the products they manufacture, restricting companies to sourcing materials exclusively from compliant suppliers."* (P4) Such legislative approach compels businesses to promote supplier compliance, reinforcing circular practices across value chains and networks. Compliance, in turn, can be verified when technological tools enable retrieving relevant information.

Conversely, the high costs associated with circular materials act as a disincentive for companies to adopt CE practices, as noted by informant from the Finnish Parliament: *"We need legislation for the CE, but we also need economic instruments like taxes; I think those are the most efficient."* The emphasis here is on the necessity of legislation for the CE, coupled with economic instruments such as taxes, as efficient means to incentivize businesses toward circular practices. Again, technological tools that ease cost management and follow-up on taxes could become relevant in reaching the pursued goals.

In particular, a consortium focused on regulatory compliance could play a vital role. By utilizing blockchain, such a consortium could ensure the secure sharing of data in adherence to legislative requirements. This blockchain-driven compliance not only satisfies regulatory

obligations but also fosters trust among stakeholders. Additionally, smart contracts within the consortium could automate and enforce compliance, providing a technologically advanced mechanism to incentivize actors to adopt circular models.

4.3 Standardization via strategic autonomy

Standardization dimension encompasses the strategic pursuit of standardized practices and protocols within the CE. According to Tocci (2021) The term "strategic autonomy" suggests a deliberate and independent approach in shaping standards and norms, allowing for a tailored framework that aligns with specific regional or organizational needs. In the context of the CE, it signifies the establishment of standardized procedures, metrics and regulations guided by a strategic and self-reliant decision-making process. This approach aims to foster consistency, interoperability and efficiency in circular practices, contributing to a cohesive and well-coordinated CE ecosystem (Romanova, 2023).

The EU is also seeking to gain strategic autonomy in terms of information ownership, according to the informants from Sitra who said *"Currently big corporations own the information; they can sell it or use it as they wish. That's what we think must change"* Currently, the dominating role of large corporations that hold information is seen as disadvantaging and unfair, because these corporations can utilize the information as they need it. As a result, the EU is implementing methods to democratize and decentralize information, which match well with distributed ledger technologies such as blockchain. This applies not only to personal data but also to product information, value chains and product traceability in industries such as batteries, building environment, apparel, electronics and electrical appliances. This was said by the informant from the blockchain company *"In really simple terms, in the textile sector, for example, we are changing the current system of product backward tracing to fiber forward tracing, and it will also be applied in other sectors."*

The concerns raised about data dependency and the push to eliminate gatekeepers resonate with the evolving landscape of blockchain consortiums, particularly those emphasizing data decentralization and strategic autonomy. The interviewee from Struggle underscores the EU's efforts to reduce the power of data gatekeepers, anticipating a future where major corporations no longer exclusively control data ownership. In tandem, interviewees from Sitra are actively exploring the concept of strategic autonomy to address data dependency challenges and foster fairness in information dissemination.

In this context, a specialized blockchain consortium could offer diverse functionalities beyond transparency and smart contracts. It could introduce features such as data interoperability, enabling seamless data exchange among diverse entities within the consortium. Additionally, the consortium may incorporate consensus mechanisms to ensure collective decision-making on data governance issues, enhancing democratic control. Immutable data storage can provide a tamper-proof record, bolstering data integrity and security. These functionalities collectively contribute to the consortium's mission of reducing data dependency and promoting equitable information access, aligning with the EU's broader goals.

4.4 Engagement and public participation

The emphasis on public involvement in environmental decision-making resonates with the democratic principles that underlie effective policymaking. The interviewee from the Ministry of Environment stated that *"an important component of general environmental regulation is that people have a say in what happens to the environment in their town or city, or even more locally or nationally."* By acknowledging that individuals should have a voice in shaping their local and national environmental landscapes, a participatory approach is advocated. This inclusion of the public not only strengthens the democratic fabric but also fosters a sense of ownership and responsibility among community members regarding

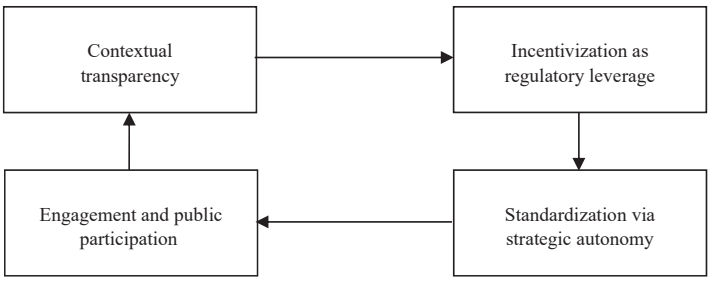
environmental initiatives. The inclusivity facilitated by a blockchain consortium enables reaching situations where decision-making is not monopolized by a single entity. Diverse voices, including those traditionally marginalized, are empowered, contributing to the development of more equitable CE policies. This approach aligns with democratic principles and leverages blockchain's capabilities to trace the entire lifecycle of products, enhancing accountability and addressing the interests and concerns of the community in the design and implementation of circular system.

The informant from the parliament further advocates the commitment to inclusive governance: "*As part of the legislation, we have legally binding means to involve stakeholders and seek the public's opinion on specific [sustainability and CE] projects, especially the big ones*." This legal framework for stakeholder engagement aligns with the ideals of BT, especially its inherent characteristics of transparency and immutability, and suggests that the technology could serve as a technological backbone to ensure that the public's opinions are securely recorded and accessible.

Engagement is particularly relevant from the perspective expressed by the informant from the Ministry of Environment and Climate Protection, who pointed out that *"the CE requires a holistic perspective; we are working with companies, clusters and people"* (P6). This statement underscores the CE's holistic aspect. Collaboration with businesses, clusters and the general public represents an integrated approach to sustainability. The BT enables seamless integration of diverse stakeholders into the CE model. In particular, public participation, when combined with BT, reduces information asymmetry by providing all stakeholders with equal access to relevant data. This approach ensures that CE policies are comprehensive and well-informed, addressing the concerns of a diverse range of stakeholders. The secure and transparent nature of BT reinforces the government's commitment to openness and accountability, fostering public trust in the fairness and effectiveness of circular policies.

4.5 Framework for combining blockchain, circular economy and public governance

The above-described dimensions – contextual transparency, incentivization as regulatory leverage, standardization via strategic autonomy, and engagement and public participation – come together in a frame, where they interact and potentially strengthen the ties between the three domains. Contextual transparency offered by BT provides the basis on which incentives can be built in an impactful way; demanding transparency across value chains becomes feasible and increases trust among relevant actors, for example. Regulatory action, in turn, grounds standardization, which enables engagement and more holistic participation. Democratization and engagement afforded by blockchain further contribute to contextual transparency, as more actors engage in decision-making on circular transition. These aspects are depicted in Figure 5.



Source(s): Figure created by authors

Figure 5.
Blockchain supporting policymakers in the CE

However, our analysis also indicates that there is still limited knowledge of how blockchain could really be implemented for CE initiatives in the public sector. Our informants (apart from the interviewee specialized in BT) noted that they only have limited experience and knowledge of blockchain. They had heard about it, but beyond the one example where smart contracts were already used, the informants admitted that they had varying levels of understanding of how the technology works.

On the other hand, our materials also indicate that there are specialized actors emerging to meet the needs of decision-makers, other public sector actors and private sector operators who pursue circular transition. They have started to offer blockchain-based services to promote the above-described four aspects.

5. Conclusion and discussion

5.1 Theoretical contributions

Our exploration of the intersection between BT, the CE and public governance reveals a complex yet promising landscape. The evolution of blockchain since its introduction by Satoshi Nakamoto in 2008 has seen its application extend beyond cryptocurrency, branching into diverse sectors. While its decentralized architecture initially aimed at transforming finance, the technology's inherent features – transparency, traceability and immutability – resonate with the foundational principles of the CE.

The CE, emphasizing waste elimination and product lifecycle extension, has gained traction globally as governments seek sustainable solutions. Blockchain's alignment with these principles has spurred interest in leveraging its capabilities to enhance circularity, particularly with the development of more energy-efficient blockchain types. Within the public sector, governments are actively exploring blockchain initiatives globally, spanning areas like identity management, cost reduction, e-voting and bureaucracy optimization. However, challenges persist, and complexities associated with blockchain hinder its potential to address public governance issues, especially concerning public budget and accountability.

Our study advances the discourse by explicitly specifying blockchain types and consensus mechanisms and analyzing the technology's potential impact from four key perspectives: transparency, incentivization, public participation (engagement) and standardization. These aspects directly address challenges identified in previous studies, such as information centralization, limited access, low public awareness and the complexity of establishing incentives in the circular transition.

Our qualitative research, among experts in Finland, forms the backbone of our study. We unearth nuanced insights, shedding light on how BT within the public sector could influence transparency, incentivization and metrics standardization, ultimately shaping government decision-making and policy formulation in the context of the CE.

In the era of sustainable development goals, our study contributes to the ongoing dialogue on integrating innovative technologies to propel circular and sustainable initiatives. However, recognizing the nascent stage of blockchain application, we advocate for continued exploration, experimental initiatives and a precise understanding of its potential applications, fostering a holistic approach to circular transition within governmental contexts.

5.2 Limitations and suggestions for future research

This study unveils possibilities for future research acknowledging not only its findings but also its limitations. A limitation is the geographic focus on Finland. While Finland is notably influenced by the EU and is tuned to international activities due to its small domestic market, it has some specific features not necessarily found in the same forms elsewhere. For example,

high levels of trust, low hierarchies, and general adherence to rules and norms characterize the Finnish business and technological landscape. The case examples from Singapore and Estonia included in this study provide some wider insights. To enhance the generalizability and applicability of our findings, future studies could broaden the geographic scope to contexts where the regulation and policymaking have different premises (e.g. common law, cf. continental law; western, cf. eastern cultures, etc.), and where technological developments are at different stages. This could be accomplished through comparative methodologies including perspectives from different regions.

Another, and related, limitation is the qualitative character of this study. Employing quantitative methodologies and examination of cases in different contexts, using varied means of data collection (interviews, observation and shadowing) would enhance the framework's utility and significance, as well as capture blockchain's applicability more widely. Sector-specific investigations may provide tailored insights, while a balance of qualitative and quantitative methods could offer a comprehensive understanding. As technology advances, opportunities for such research endeavors improve.

Topic-wise, staying attuned to technological advancements will be crucial for exploring the implications of emerging blockchain innovations. Looking ahead, coordinated scholarly efforts can help to improve the global understanding of how blockchain enables sustainable circular transitions in public governance. In this, collecting data from various informants enhances the development of comprehensive frameworks that capture, for example, NGOs', research organizations' and other such actor's views. Areas for future research could also encompass exploring the scalability of blockchain technologies and examining their long-term sustainability implications through longitudinal studies over time within the context of the CE.

5.3 Practical implications

The implementation of BT for the public sector encompasses a series of complexities that governments need to consider. Highlighting the potential of blockchain in enhancing transparency, engagement, standardized metrics and incentivization for adopting circular principles, our study suggests that governments could strategically leverage blockchain to foster alliances with private organizations, enabling collaborative implementations of the technology.

If governments successfully navigate the impediments associated with the adoption of BT, including challenges such as insufficient knowledge, the absence of a globally harmonized regulatory framework, and concerns related to scalability and security, the potential impact of blockchain on governmental operations could be profound. The foundational elements of this technology are already in place, presenting opportunities not only for blockchain but also for other technologies such as Artificial Intelligence (AI), Internet of Things (IoT) and big data, collectively shaping the trajectory of societal development. Blockchain could serve as the cornerstone for fostering enhanced communication and fostering more intricate relationships among public and private entities.

Nevertheless, careful attention is needed from governments, as the utilization of technology prompts critical questions about its beneficiaries. The pivotal query governments and other societal actors should pose is, "For whom is this technology functioning?" Emphasizing the use of technology for the positive development of societies, rather than solely for commercial purposes, is an imperative that governments and the public sector should actively support. Ensuring that the evolution of technology aligns with societal well-being and development should be a collective responsibility, urging governments to play a central role in steering the course of technological utilization.

To harness the full potential of BT, governments should remain adaptable and open to experimentation, utilizing the customization options available based on consensus

mechanisms and data access types. This necessitates ongoing interaction between offline and online elements. Recognizing the crucial importance of continuous material tracking, especially considering information leakage related to waste, becomes essential for managing challenges and costs associated with recycled materials.

A key recommendation for governments is to cultivate an environment conducive to collaboration between the public and private sectors, enhancing overall efficiency. Given blockchain's collaborative nature, governments should prioritize specific principles, including promoting ethical technology use, encouraging public–private collaboration, fostering inclusive technology development and incorporating social impact assessments.

References

Abou Jaoude, J. and Saade, R.G. (2019), "Blockchain applications–usage in different domains", *Ieee Access*, Vol. 7, pp. 45360-45381, doi: 10.1109/access.2019.2902501.

ACT-IAC (2017), "Enabling blockchain innovation in the US federal government: a blockchain primer", available at: https://www.actiac.org/system/files/ACT-IAC%20ENABLING%20BLOCKCHAIN%20INNOVATION_3.pdf

Ahir, H., Bloom, N. and Furceri, D. (2022), "World uncertainty index", NBER Working Paper.

Alam, S., Shuaib, M., Khan, W.Z., Garg, S., Kaddoum, G., Hossain, M.S. and Zikria, Y.B. (2021), "Blockchain-based initiatives: current state and challenges", *Computer Networks*, Vol. 198, 108395, doi: 10.1016/j.comnet.2021.108395.

Allessie, D., Sobolewski, M. and Vaccari, L. (2019), "Blockchain for digital government: an assessment of pioneering implementations in public services", Joint Research Centre (Seville Site).

Altman, I. (2018), "How blockchain will transform business and the law", available at: https://www.forbes.com/sites/ianaltman/2018/06/29/blockchain-changes-business-law/

Bai, Y., Hu, Q., Seo, S.H., Kang, K. and Lee, J.J. (2021), "Public participation consortium blockchain for smart city governance", *IEEE Internet of Things Journal*, Vol. 9 No. 3, pp. 2094-2108, doi: 10.1109/jiot.2021.3091151.

Balcerzak, A.P., Nica, E., Rogalska, E., Poliak, M., Klieštik, T. and Sabie, O.M. (2022), "Blockchain technology and smart contracts in decentralized governance systems", *Administrative Sciences*, Vol. 12 No. 3, p. 96, doi: 10.3390/admsci12030096.

Berryhill, J., Bourgery, T. and Hanson, A. (2018), "Blockchains unchained: blockchain technology and its use in the public sector", OECD Working Papers on Public Governance, No. 28, OECD Publishing, Paris.

Bianchini, A., Rossi, J. and Pellegrini, M. (2019), "Overcoming the main barriers of circular economy implementation through a new visualization tool for circular business models", *Sustainability*, Vol. 11 No. 23, p. 6614, doi: 10.3390/su11236614.

Blomsma, F. and Brennan, G. (2017), "The emergence of circular economy: a new framing around prolonging resource productivity", *Journal of Industrial Ecology*, Vol. 21 No. 3, pp. 603-614, doi: 10.1111/jiec.12603.

Böckel, A., Nuzum, A.K. and Weissbrod, I. (2021), "Blockchain for the circular economy: analysis of the research-practice gap", *Sustainable Production and Consumption*, Vol. 25, pp. 525-539, doi: 10.1016/j.spc.2020.12.006.

Böhmecke-Schwafert, M., Wehinger, M. and Teigland, R. (2022), "Blockchain for the circular economy: theorizing blockchain's role in the transition to a circular economy through an empirical investigation", *Business Strategy and the Environment*, Vol. 31 No. 8, pp. 3786-3801, doi: 10.1002/bse.3032.

Bolger, K. and Doyon, A. (2019), "Circular cities: exploring local government strategies to facilitate a circular economy", *European Planning Studies*, Vol. 27 No. 11, pp. 2184-2205, doi: 10.1080/09654313.2019.1642854.

Bourguignon, D. (2016), "Closing the loop: new circular economy package", European Parliamentary Research Service. Belgium, available at: https://policycommons.net/artifacts/1334448/closing-the-loop/1939999/on18Oct2023.CID:20.500.12592/dzf57k

Bratspies, R.M. (2018), "Cryptocurrency and the myth of the trustless transaction", *Michigan Technology Law Review*, Vol. 25 No. 25.1, p. 1, doi: 10.36645/mtlr.25.1.cryptocurrency.

Brinkmann, M. and Heine, M. (2019), "Can blockchain leverage for new public governance? A conceptual analysis on process level", *Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance*, pp. 338-341.

Buterin, V. (2015), "On public and private blockchains", *Ethereum Blog*, Vol. 7 No. 1, available at: https://blog.ethereum.org/2015/08/07/on-public-and-private-blockchains/

Castro, M. and Liskov, B. (2002), "Practical byzantine fault tolerance and proactive recovery", *ACM Transactions on Computer Systems (TOCS)*, Vol. 20 No. 4, pp. 398-461, doi: 10.1145/571637.571640.

Cheah, S., Pattalachinti, S. and Ho, Y.P. (2018), "Blockchain industries, regulations and policies in Singapore", *Asian Research Policy*, Vol. 9 No. 2, pp. 83-98.

Chen, W., Xu, Z., Shi, S., Zhao, Y. and Zhao, J. (2018), "A survey of blockchain applications in different domains", *Proceedings of the 2018 International Conference on Blockchain Technology and Application*, pp. 17-21.

Colglazier, W. (2015), "Sustainable development agenda: 2030", *Science*, Vol. 349 No. 6252, pp. 1048-1050, doi: 10.1126/science.aad2333.

Duong, T., Fan, L., Katz, J., Thai, P. and Zhou, H.S. (2020), "2-hop blockchain: combining proof-of-work and proof-of-stake securely", *European Symposium on Research in Computer Security*, Springer International Publishing, Cham, pp. 697-712.

Eisenhardt, K.M. (1989), "Building theories from case study research", *Academy of Management Review*, Vol. 14 No. 4, pp. 532-550, doi: 10.5465/amr.1989.4308385.

Ekins, P., Hughes, N., Brigenzu, S., Arden Clark, C., Fischer-Kowalski, M., Graedel, T., Hajer, M. and Hashimoto (2017), "Resource efficiency: potential and economic implications", *A Report of the International Resource Panel*, UNEP.

Esmaeilian, B., Sarkis, J., Lewis, K. and Behdad, S. (2020), "Blockchain for the future of sustainable supply chain management in Industry 4.0", *Resources, Conservation and Recycling*, Vol. 163, p. 105064.

Ethereum (2022), "Proof-of-work (PoW)", available at: https://ethereum.org/en/developers/docs/consensus-mechanisms/pow/

Fenwick, M. and Vermeulen, E.P. (2019), "Technology and corporate governance: blockchain, crypto, and artificial intelligence", *The Texas Journal of Business Law*, Vol. 48, p. 1.

Friant, M.C., Vermeulen, W.J. and Salomone, R. (2021), "Analysing European Union circular economy policies: words versus actions", *Sustainable Production and Consumption*, Vol. 27, pp. 337-353, doi: 10.1016/j.spc.2020.11.001.

Galvão, G.D.A., de Nadae, J., Clemente, D.H., Chinen, G. and de Carvalho, M.M. (2018), "Circular economy: overview of barriers", *Procedia Cirp*, Vol. 73, pp. 79-85, doi: 10.1016/j.procir.2018.04.011.

Geissdoerfer, M., Savaget, P., Bocken, N.M. and Hultink, E.J. (2017), "The Circular Economy–A new sustainability paradigm?", *Journal of Cleaner Production*, Vol. 143, pp. 757-768, doi: 10.1016/j.jclepro.2016.12.048.

Geng, Y., Sarkis, J. and Bleischwitz, R. (2019), "How to globalize the circular economy", *Nature*, Vol. 565 No. 7738, pp. 153-155, doi: 10.1038/d41586-019-00017-z.

Ghisellini, P., Cialani, C. and Ulgiati, S. (2016), "A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems", *Journal of Cleaner Production*, Vol. 114, pp. 11-32, doi: 10.1016/j.jclepro.2015.09.007.

Gioia, D.A., Corley, K.G. and Hamilton, A.L. (2013), "Seeking qualitative rigor in inductive research: notes on the Gioia methodology", *Organizational Research Methods*, Vol. 16 No. 1, pp. 15-31, doi: 10.1177/1094428112452151.

Govindan, K. (2022), "Tunneling the barriers of blockchain technology in remanufacturing for achieving sustainable development goals: a circular manufacturing perspective", *Business Strategy and the Environment*, Vol. 31 No. 8, pp. 3769-3785, doi: 10.1002/bse.3031.

Grafström, J. and Aasma, S. (2021), "Breaking circular economy barriers", *Journal of Cleaner Production*, Vol. 292, 126002, doi: 10.1016/j.jclepro.2021.126002.

Jalakas, P. (2018), *Blockchain from Public Administration Perspective: Case of Estonia*, Tallinn University of Technology, Tallinn.

Katika, T., Karaseitanidis, I., Tsiakou, D., Makropoulos, C. and Amditis, A. (2022), "Augmented reality (AR) supporting citizen engagement in circular economy", *Circular Economy and Sustainability*, Vol. 2 No. 3, pp. 1077-1104, doi: 10.1007/s43615-021-00137-7.

Kaur, A., Nayyar, A. and Singh, P. (2020), "Blockchain: a path to the future", Cryptocurrencies and Blockchain technology applications, pp. 25-42.

Kirchherr, J., Reike, D. and Hekkert, M. (2017), "Conceptualizing the circular economy: an analysis of 114 definitions", *Resources, Conservation and Recycling*, Vol. 127, pp. 221-232, doi: 10.1016/j.resconrec.2017.09.005.

Kouhizadeh, M., Sarkis, J. and Zhu, Q. (2019), "At the nexus of blockchain technology, the circular economy, and product deletion", *Applied Sciences*, Vol. 9 No. 8, p. 1712, doi: 10.3390/app9081712.

Kouhizadeh, M., Zhu, Q. and Sarkis, J. (2020), "Blockchain and the circular economy: potential tensions and critical reflections from practice", *Production Planning and Control*, Vol. 31 Nos 11-12, pp. 950-966, doi: 10.1080/09537287.2019.1695925.

Kshetri, N. and Voas, J. (2018), "Blockchain-enabled e-voting", *Ieee Software*, Vol. 35 No. 4, pp. 95-99, doi: 10.1109/ms.2018.2801546.

Kumar, N.M. and Chopra, S.S. (2022), "Leveraging blockchain and smart contract technologies to overcome circular economy implementation challenges", *Sustainability*, Vol. 14 No. 15, p. 9492, doi: 10.3390/su14159492.

MacArthur, E. (2013), "Towards the circular economy", *Journal of Industrial Ecology*, Vol. 2 No. 1, pp. 23-44.

McDowall, W., Geng, Y., Huang, B., Barteková, E., Bleischwitz, R., Türkeli, S., Kemp, R. and Doménech, T. (2017), "Circular economy policies in China and Europe", *Journal of Industrial Ecology*, Vol. 21 No. 3, pp. 651-661.

Merriam, S.B. and Tisdell, E.J. (2015), *Qualitative Research: A Guide to Design and Implementation*, John Wiley & Sons, San Francisco.

Miles, M.B. and Huberman, A.M. (1994), *Qualitative Data Analysis: an Expanded Sourcebook*, Sage, Thousand Oaks.

Montecchi, M., Plangger, K. and Etter, M. (2019), "It's real, trust me! Establishing supply chain provenance using blockchain", *Business Horizons*, Vol. 62 No. 3, pp. 283-293, doi: 10.1016/j.bushor.2019.01.008.

Morseletto, P. (2020), "Targets for a circular economy", *Resources, Conservation and Recycling*, Vol. 153, 104553, doi: 10.1016/j.resconrec.2019.104553.

Mougayar, W. (2016), *The Business Blockchain: Promise, Practice, and Application of the Next Internet Technology*, John Wiley & Sons.

Nadir, R.M. (2019), "Comparative study of permissioned blockchain solutions for enterprises", *2019 International Conference on Innovative Computing (ICIC)*, IEEE, pp. 1-6.

Nakamoto, S. (2008), "Bitcoin: a peer-to-peer electronic cash system", *Decentralized Business Review*, Vol. 4 No. 2, p. 15, available at: https://bitcoin.org/bitcoin.pdf

Nandi, S., Sarkis, J., Hervani, A.A. and Helms, M.M. (2021), "Redesigning supply chains using blockchain-enabled circular economy and COVID-19 experiences", *Sustainable Production and Consumption*, Vol. 27, pp. 10-22, doi: 10.1016/j.spc.2020.10.019.

Nurgazina, J., Pakdeetrakulwong, U., Moser, T. and Reiner, G. (2021), "Distributed ledger technology applications in food supply chains: a review of challenges and future research directions", *Sustainability*, Vol. 13 No. 8, p. 4206, doi: 10.3390/su13084206.

Obersteg, A., Arlati, A., Acke, A., Berruti, G., Czapiewski, K., Dąbrowski, M., Heurkens, E., Mezei, C., Palestino, M.F., Varjú, V., Wójcik, M. and Knieling, J. (2019), "Urban regions shifting to circular economy: understanding challenges for new ways of governance", *Urban Planning*, Vol. 4 No. 3, pp. 19-31, doi: 10.17645/up.v4i3.2158.

Osborne, S.P. (2006), "The new public governance?", *Public Management Review*, Vol. 8 No. 3, pp. 2006-2387, doi: 10.1080/14719030600853022.

Pawczuk, L., Massey, R. and Holdowsky, J. (2019), "Deloitte's 2019 global blockchain survey", Deloitte Development LLC.

Pihlak, H. (2018), "eGoverment and Blockchain: enabling Trust in public services in a digital environment – e-Estonia", available at: https://e-estonia.com/egoverment-blockchain-guardtime/

Qazi, A.A. and Appolloni, A. (2022), "A systematic review on barriers and enablers toward circular procurement management", *Sustainable Production and Consumption*, Vol. 33, pp. 343-359, doi: 10.1016/j.spc.2022.07.013.

Rejeb, A., Rejeb, K., Keogh, J.G. and Zailani, S. (2022), "Barriers to blockchain adoption in the circular economy: a fuzzy Delphi and best-worst approach", *Sustainability*, Vol. 14 No. 6, p. 3611, doi: 10.3390/su14063611.

Roberts, A. (2020), "Bridging levels of public administration: how macro shapes meso and micro", *Administration and Society*, Vol. 52 No. 4, pp. 631-656, doi: 10.1177/0095399719877160.

Rodríguez Bolívar, M.P. and Scholl, H.J. (2019), "Mapping potential impact areas of Blockchain use in the public sector", *Information Polity*, Vol. 24 No. 4, pp. 359-378, doi: 10.3233/ip-190184.

Romanova, T. (2023), "A choice between neoliberal engagement and strategic autonomy? The impossibility of EU's green cooperation with Russia between 2019 and 2021", *Energy Policy*, Vol. 172, 113329, doi: 10.1016/j.enpol.2022.113329.

Saad, S.M.S. and Radzi, R.Z.R.M. (2020), "Comparative review of the blockchain consensus algorithm between proof of stake (pos) and delegated proof of stake (dpos)", *International Journal of Innovative Computing*, Vol. 10 No. 2, doi: 10.11113/ijic.v10n2.272.

Semenzin, S., Rozas, D. and Hassan, S. (2022), "Blockchain-based application at a governmental level: disruption or illusion? The case of Estonia", *Policy and Society*, Vol. 41 No. 3, pp. 386-401, doi: 10.1093/polsoc/puac014.

Sharma, H.B., Vanapalli, K.R., Samal, B., Cheela, V.S., Dubey, B.K. and Bhattacharya, J. (2021), "Circular economy approach in solid waste management system to achieve UN-SDGs: solutions for post-COVID recovery", *Science of The Total Environment*, Vol. 800, 149605, doi: 10.1016/j.scitotenv.2021.149605.

Šilenskytė, A., Butkevičienė, J. and Bartminas, A. (2023), "Blockchain-based connectivity within digital platforms and ecosystems in international business", *Journal of International Management*. doi: 10.1016/j.intman.2023.101109.

Sitra (2016), "Leading the cycle: Finnish road map to a circular economy 2016-2025", available at: https://www.sitra.fi/en/publications/leading-cycle/

Su, B., Heshmati, A., Geng, Y. and Yu, X. (2013), "A review of the circular economy in China: moving from rhetoric to implementation", *Journal of Cleaner Production*, Vol. 42, pp. 215-227, doi: 10.1016/j.jclepro.2012.11.020.

Sullivan, C. and Burger, E. (2017), "E-residency and blockchain", *Computer Law and Security Review*, Vol. 33 No. 4, pp. 470-481, doi: 10.1016/j.clsr.2017.03.016.

Sung, C.S. and Park, J.Y. (2021), "Understanding of blockchain-based identity management system adoption in the public sector", *Journal of Enterprise Information Management*, Vol. 34 No. 5, pp. 1481-1505, doi: 10.1108/jeim-12-2020-0532.

Swan, M. (2015), *Blockchain: Blueprint for a New Economy*, O'Reilly Media, Sebastopol.

Tan, E., Mahula, S. and Crompvoets, J. (2022), "Blockchain governance in the public sector: a conceptual framework for public management", *Government Information Quarterly*, Vol. 39 No. 1, 101625, doi: 10.1016/j.giq.2021.101625.

Tapscott, D. and Tapscott, A. (2016a), "Realizing the potential of Blockchain: a multistakeholder approach to the stewardship of blockchain and cryptocurrencies", World Economic Forum.

Tapscott, D. and Tapscott, A. (2016b), "The impact of the blockchain goes beyond financial services", *Harvard Business Review*, Vol. 10 No. 7, pp. 2-5.

Tocci, N. (2021), "European strategic autonomy: what it is, why we need it, how to achieve it", Istituto Affari Internazionali.

UK House of Lords (2017), "Distributed ledger technologies for public good: leadership", Collaboration and Innovation, available at: https://www.oecd-ilibrary.org/docserver/3c32c429-en.pdf?expires=1697546925&id=id&accname=guest&checksum=D320C16F0CB296AF292D1F35D1B3AA26

Upadhyay, A., Mukhuty, S., Kumar, V. and Kazancoglu, Y. (2021), "Blockchain technology and the circular economy: implications for sustainability and social responsibility", *Journal of Cleaner Production*, Vol. 293, 126130, doi: 10.1016/j.jclepro.2021.126130.

Vilariño, M.V., Franco, C. and Quarrington, C. (2017), "Food loss and waste reduction as an integral part of a circular economy", *Frontiers in Environmental Science*, Vol. 5, p. 21, doi: 10.3389/fenvs.2017.00021.

Walport, M. (2016), "Distributed ledger technology: beyond block chain", Government Office for Science.

Wang, S., Yuan, Y., Wang, X., Li, J., Qin, R. and Wang, F.Y. (2018), "An overview of smart contract: architecture, applications, and future trends", *IEEE Intelligent Vehicles Symposium*, Vol. IV, IEEE, pp. 108-113, doi: 10.1109/ivs.2018.8500488.

Warkentin, M. and Orgeron, C. (2020), "Using the security triad to assess blockchain technology in public sector applications", *International Journal of Information Management*, Vol. 52, 102090, doi: 10.1016/j.ijinfomgt.2020.102090.

Yadav, A.S., Singh, N. and Kushwaha, D.S. (2023), "Evolution of Blockchain and consensus mechanisms & its real-world applications", *Multimedia Tools and Applications*, Vol. 82 No. 22, pp. 1-46, doi: 10.1007/s11042-023-14624-6.

Zhang, S. and Lee, J.H. (2020), "Analysis of the main consensus protocols of blockchain", *ICT Express*, Vol. 6 No. 2, pp. 93-97, doi: 10.1016/j.icte.2019.08.001.

Zheng, Z., Xie, S., Dai, H., Chen, X. and Wang, H. (2017), "An overview of blockchain technology: architecture, consensus, and future trends", in *2017 IEEE International Congress on Big Data (BigData Congress)*, Ieee, pp. 557-564.

Zhou, Y., Soh, Y.S., Loh, H.S. and Yuen, K.F. (2020), "The key challenges and critical success factors of blockchain implementation: policy implications for Singapore's maritime industry", *Marine Policy*, Vol. 122, 104265, doi: 10.1016/j.marpol.2020.104265.

Further reading

MacArthur, E. (2014), "Towards the circular economy: accelerating the scale-up across global supply chains", In World Economic Forum.

MacDowall, W., Geng, Y., Huang, B., Barteková, E., Bleischwitz, R., Türkeli, S., Kemp, R. and Doménech, T. (2017), "Circular economy policies in China and Europe", *Journal of Industrial Ecology*, Vol. 21 No. 3, pp. 651-661, doi: 10.1111/jiec.12597.

(The Appendix follows overleaf)

Appendix
Data analysis

Quotes from data	First-order concepts	Second-order themes	Aggregate dimensions
- "We are creating this type of operating model for ecosystems, especially data related ecosystems. These drive on transparency and there's also trust and other principles fair data economy."	Ecosystem governance	Synergy	Contextual transparency
- "Transparency is critical, but it must be done at the level required for specific tasks; it is not the same information that all stakeholders require."			
- "So actually, when we think about what is included in the fair (data), I think the transparency is one of the keys . . .. we work under the Finnish Parliament with endowment capital, so everything we do needs to be open."	Openness of information		
- "So, the only way for us to get to this transparent and effective data economy, which the European Union is pushing the single market for, is to create effective decentralized data sharing protocols."			
- "Transparency is critical; it should include not just the origin, but also the components in detail, because if you want to circulate the material, you must first understand what it is and ensure that it is made in a sustainable manner."			
- "In Europe we live in a trust-based society, however trust is in constant attack by social media and algorithms. Trust should be maintained and nurture and supported by other means."	Safeguarding	Strengthening Trust	
- "We also need to consider the social implications of who did it and whether or not there was a child involved or similar"			
"We are working on the involvement of municipalities, provinces, and the estate in the process taxation to waste or natural resources and other incentives that could potentially reduce the use of virgin materials."	Financial instruments	Taxation for CE	Incentivization as Regulatory Leverage
"We need legislation for the CE, but we also need economic instruments like taxes, I think those are the most efficient."			
- "In Finland in some cases the companies are asked to follow sustainable and CE practices in a voluntary base, which is not fair"	Sustainability practices by mandate	Regulatory compliance	
- "In the next couple of years, the EU regulation will obligate the companies to provide all the data together with the products they make, companies will only be allowed to buy materials from suppliers that provide information."	Integrated Regulatory Framework		
- "From the ministry we have all the tools in place for the CE, we have regulation, financial direction, communication campaigns, environmental education, etc."			

Table A1.
Data source and classification. Gioia method

(*continued*)

Quotes from data	First-order concepts	Second-order themes	Aggregate dimensions
- "As part of the legislation, we have legally binding means to involve stakeholders and seek the public's opinion on specific projects, especially the big ones."	Stakeholder engagement	Community involvement	Engagement and Public participation
- "An important component of general environmental regulation is that people have a say in what happens to the environment in their town or city, or even more locally or nationally."	Public participation in local and national projects		
- "The circular economy needs a holistic perspective, we are working with companies, clusters and people."	CE holistic approach		
- "the real price of a product should contain the environmental cost of producing it, so the people know what they are buying."	Inclusion of the public by pricing environmental costs	Environmental accountability	
- "The EU is trying to get rid of gatekeepers. Huge companies won't own the data in the near future"	Democratization of data in the EU	Promoting data sharing	Standardization via strategic autonomy
- "In really simple terms, in the textile sector, for example, we are changing the current system of product backward tracing to fiber forward tracing, and it will also be applied in other sectors."	Product information	Traceability of the whole value chain	
- "Now we have to rely on the language models developed in the US by the biggest giants"	Dependance on the US to manage data	Avoid the reliance of data by intermediaries	
- "Currently big corporations own the information; they can sell it or use it as they wish. That's what we think must change"			
- "In Sitra we are considering very seriously the concept of strategic autonomy, to avoid data dependency and to bring more fairness to the information"	Advancements on data independence		
"I'm exploring the "handprint" concept, my own environmental impact. Debating unity, possibly in the EU market. Implementing this policy, particularly on the climate side, is challenging but research institutes are involved, but no international standards exist yet. Working on a national framework, aiming to become an international standard through the EU, but it's in the early stages	Handprint Concept Exploration	Challenges in Implementing Environmental Impact Policies and Standardization	

Source(s): Table created by authors

Table A1.

Corresponding author
Eduardo Acosta Llano can be contacted at: eduardo.acostallano@oulu.fi