Applying Blockchain to Systemic Design: Ensuring Project Authenticity via Quantitative Report Verification

RIVERS OF CONVERSATIONS
RELATING SYSTEMS THINKING & DESIGN
RSD13 | OCTOBER 2024

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Comparative Analysis of Current Verification Parameters and the Use of Smart Contracts, Notarization, and NFT for Authenticating Environmental Data in Systemic Reports: Research Applications with Case Studies from Italy and Spain

In the field of systemic design, which spans a wide range of domains and projects, a common element is the production of documents and reports detailing and analysing the work carried out. However, currently, methods of verification and protection for systemic projects have not been identified, representing a lack of protection for designers and all parties involved. This study, starting from this lack of protection, focuses on the treatment of such reports from the perspective of quantitative data, namely through their verification using blockchain technology. Blockchain has been chosen over other verification methods because it is a decentralized and cost-free technology that offers two main tools for verification: notarization and smart contracts. Notarization is a process that allows the document to be notarized and subsequently frozen with all the information contained within it. In this context, notarization is used to increase the attention of designers to the inserted data because it cannot be overwritten. On the other hand, smart contracts are autonomous programs that execute contracts recorded on the blockchain. These contracts can be used to automate the verification of data contained in project reports. The combined use of notarization and smart contracts on the blockchain provides greater assurance on the documents produced in the field of systemic design. This not only increases confidence in the validity of the documents, avoiding cases of greenwashing and speculation, but also offers greater protection to designers. As a symbol of this verification, a Non-Fungible Token (NFT) is issued. An NFT is a type of cryptographic token that represents a unique object. In this case, the NFT is inserted into a node of the blockchain to attest to the project's verification. This provides tangible and immutable proof of the verification that has taken place. The application of blockchain technology in systemic design offers a new method for the verification and protection of projects and the data contained within them. This aims to increase the authenticity of the data and prevent possible fraud with significantly erroneous information.

KEYWORDS: Systemic reports, Data verification, Protection sustainability, no greenwashing, Blockchain verification, Notarization, NFT

RSD TOPIC(S): Methods & Methodology, Policy & Governance

Introduction to the Topic: Prelude to the Research Method

In the context of systemic design, an area that encompasses a wide range of sectors and projects, the generation of comprehensive documentation and textual reports detailing and analysing the work carried out emerges as a common element. However, we face a significant challenge: the need to limit the production of documents that, while oriented towards sustainability, present inaccurate data, thus constituting a form of environmental deception. In this context, accurate data verification represents a crucial aspect. Although established control procedures already exist, such systems often adopt a centralized perspective. The real design challenge lies in implementing a decentralized and cost-effective approach to data verification, thus ensuring the integrity and reliability of information within the scope of systemic design (Ryan, 2014). The research methodology is based on the integration of blockchain into systemic design for validating sustainability reports. This approach merges the principles of systemic design with blockchain technology, combining the ability to delineate material flows aimed at reducing the ecological footprint with the blockchain's capacity to ensure data transparency and immunity to manipulation (Sevaldson, Jones, 2019). The research process follows an iterative approach, characterized by phases of research on current and past conditions, design, implementation, and repeated testing to refine the proposed solution. During development, blockchain has been integrated as a key tool for validation and assurance of data integrity. This integration involved the development of smart contracts, notarization, and NFTs that ensure the immutable recording of

environmental, social, and economic information. The methodology also includes a phase of thorough testing and validation, where the design system is subjected to a series of simulated scenarios and real situations to assess its effectiveness, scalability, security, and adaptability to the needs of the business context and stakeholders. A fundamental element of the methodology has been the active participation of stakeholders, including representatives of companies, who have chosen to actively apply the project. This involvement has ensured a comprehensive analysis of the needs and constraints of the operational context, contributing to ensuring the effectiveness and adaptability of the proposed solution.

The Most Well-Known Applications of Blockchain

The idea of applying blockchain to systemic design stems from the study of its applications carried out in recent years, starting from its inception in the financial world (Tapscott, & Tapscott, 2016). Blockchain technology, thanks to its versatility, has involved numerous sectors worldwide, addressing various issues. Among the many applications of blockchain, one of the most promising is its ability to improve data verification and traceability in a wide range of areas. Firstly, in the financial sector where its application originally emerged in 2008, as part of the Bitcoin whitepaper, written by an individual or group of individuals under the pseudonym Satoshi Nakamoto, blockchain has revolutionized the way economic transactions occur (Nakamoto, 2008). Cryptocurrencies like Bitcoin and Ethereum utilize blockchain technology to enable secure and transparent financial transactions, eliminating the need for traditional financial intermediaries (Wood, 2014). But it's not only in the financial world that blockchain has made its presence felt; in the logistics and supply chain management sector, companies worldwide are adopting blockchain to trace the origin and path of products along the entire distribution and supply chain. This not only ensures greater transparency but also helps prevent fraud and counterfeiting (Puthal, Malik, Mohanty, Kougianos, & Das, 2018). The use of blockchain technology for managing counterfeits in the world of art has gradually expanded, allowing a revolutionary change in both the creative industry and among collectors (Whitaker, 2019). In addition to the aforementioned sectors, blockchain has also found applications in digital identity management, copyright protection, and even in EU-funded electronic voting systems (Netservice, 2024). In all these contexts, blockchain offers an unprecedented level of security and reliability, enabling the creation of transparent and decentralized systems (Zyskind, Nathan, & Pentland, 2015).

Current Parameters for Verification Environmental Data in Reports

Starting from these examples of applications developed since 2008, the analysis delves into exploring the current verification criteria implemented on documents and reports focused on environmental development initiatives for businesses and organizations. In this context, practical scrutiny methods emerge, such as ISAE 3000, an international standard issued by the International Auditing and Assurance Standards Board (IAASB). This directive, originally conceived for assurance engagements not related to financial information, has recently been adopted as a reference for sustainability reporting examinations and assessments (Stern, 2020). This choice is due to its ability to provide a comprehensive view when analysing the reliability and accuracy of non-financial data communicated by companies. It should be noted, however, that ISAE 3000 is commonly employed by auditors who, due to their predominant

expertise in financial matters, may not be as adept at scrutinizing sustainability-related data in detail. To outline specific parameters related to sustainability data, the Global Reporting Initiative (GRI) was established in 2007, an independent international entity that developed and promoted a reporting framework for sustainability (El Alfy, Weber, 2019). Founded in Amsterdam in 1997, GRI formulated the GRI Standards with the aim of facilitating clear, comprehensive, and reliable environmental, social, and economic reporting. These standards are structured into various categories, each dedicated to specific aspects of sustainability reporting. For example, the GRI Standards Series includes the main guidelines for preparing sustainability documents, covering topics such as governance, human rights, labour, environment, procurement, and anti-corruption, among others. The GRI Taxonomy, on the other hand, defines a standardized structure for the presentation and analysis of sustainability data, facilitating comparability and analysis of reports (Thistlethwaite, Menzies, 2016). This series establishes a standardized framework for presenting and analysing sustainability data, facilitating comparability and analysis of sustainability reports. These parameters represent guidelines for companies but not verifications for the data that are reported in the documents, but parameters to adhere to in the representation of quantitative data. Another prominent method for controlling environmental data included in systemic reports is represented by audits conducted by centralized certifiers. In this context, ISO standards are widely used, recognised, and adopted globally, which establish specific parameters for various business areas. Analysing the main cases

dealing with environmental issues, there is ISO 14001, which not only defines the requirements for establishing an Environmental Management System (EMS) but also, through its provisions, requires the acquisition and monitoring of environmental data to assess organizational performance (Boiral, 2007). Similarly, ISO 14064 plays a crucial role in managing greenhouse gas emissions, providing detailed guidelines for the quantification, monitoring, and reporting of such emissions (Dunlop, Hawkins, Levick, Orozco, Vernoit, Wright, 2019). Its provisions provide a framework for external verification of information, ensuring compliance with established standards. To accurately assess their environmental performance, companies can rely on ISO 14031, which offers specific guidelines for implementing internal environmental performance assessments. Finally, ISO 14020 focuses on environmental labeling and declarations, promoting transparency and reliability of environmental information reported on products and services. However, it is worth noting that obtaining ISO certifications requires verification by a centralized entity and entails a fee for certification, which can be a limitation for small businesses and may encourage a decrease in attention to the presented documents. It can therefore be summarized that the technologies involved in verifying environmental data often involve third-party users or certifying entities, which provide guidelines and support for checking such data or providing punctual verification. However, it has emerged that such processes are not uniform and decentralized or scalable on a global level. In response to these challenges, the proposal to adopt blockchain technology in this context also emerges. This approach aims to overcome the

current limitations of the cases analysed, providing a transparent and decentralized verification system for environmental data, thereby enhancing the reliability and consistency of reported information and promoting scalability in environmental data control.

Use of Blockchain and IT Systems for Data Verification

The blockchain, with its notarization capability and implementation of smart contracts, emerges as a revolutionary solution for verifying environmental data reported in systemic reports. This innovative approach is based on a computer system that transforms documents into code and transactions that become part of the enormous chain of blocks continuously mined by miners, hence blockchain (Tapscott, Tapscott, 2016). At the core of blockchain operation lies the cryptographic hashing algorithm, which transforms data into a unique fixed-length cryptographic hash. This process is irreversible, meaning that it is not possible to trace back to the original data from the generated hash. This ensures the integrity and security of the data recorded on the blockchain (Kalendzhian, 2021).

Furthermore, blockchain utilizes a distributed consensus system to validate and accept new transaction blocks in the chain. This process involves a network of nodes or participants working together to verify the authenticity of transactions and reach a consensus on their inclusion in the blockchain. This ensures that all network nodes agree on the current state of the blockchain and prevents any attempt at manipulation by a single malicious actor (William, 2016).

Notarization represents one of the main advantages of blockchain for verifying environmental data, considering the officialization of a document and thus all the information contained therein. A crucial aspect of blockchain is the concept of "verification digest" or "block hash." This is a unique value generated for each blockchain block using the cryptographic hashing algorithm. The verification digest is calculated taking into account all the data contained in the block, including transaction

data and the hash of the previous block. This ensures that even the slightest modification to the block data would generate a completely different hash, immediately revealing any attempted manipulation. With blockchain, it is possible to securely and permanently record environmental information, such as greenhouse gas emissions, natural resource consumption, and environmental impacts of industrial activities, which is what the project aims to do in the tested application fields. This information is stored in cryptographically protected blocks, which serve as undeniable proof of their authenticity and origin, recorded down to the day, hour, minute, and second.
While notarization commits data providers and involved parties to declare the truth as a public act, smart contracts, on the other hand, are self-executing computer programs that allow the automation and automatic execution of specific actions once certain conditions written in JavaScript code are met (Buterin, 2021), (Buterin, 2013). These smart contracts can be used to automate a range of processes related to environmental data management, such as verifying greenhouse gas emissions concerning time and size, monitoring energy consumption based on usage, and distributing environmental credits as in a specific case of application analysed below (Bellassen, Leguet, 2007).
After obtaining data verification through blockchain technology or through notarization or smart contracts, the option to incorporate the verified digest into an NFT (Non-Fungible Token) image represents a next step in the project; to ensure the authenticity and integrity of certified data, the NFT offers an additional level of security and authenticity, making the certification symbol visually distinctive and easily recognizable, a logo. Using an NFT image as a certification symbol offers several practical advantages. First, NFTs are unique and immutable digital objects, registered on a blockchain, making them extremely secure and resistant to counterfeiting, as it is not possible to generate a copy of the issued certification. Incorporating the verified digest into an NFT image thus creates a digital seal confirming the authenticity of certified data and prevents manipulation or falsification (Mullings, 2022). Secondly, the NFT image can be easily shared and viewed on various digital platforms, making the symbol usable in different contexts. This helps promote transparency and trust in certified data, as companies and other stakeholders can easily verify the authenticity of the certification symbol through the blockchain. Furthermore, using an NFT image as a certification symbol adds an element of prestige and exclusivity to the certification itself. This

confers a sense of importance and recognition to certified data while being generatable at low cost and therefore accessible to all economic strata. This can encourage greater adoption of blockchain technology by companies, as they see the tangible benefits it can offer in terms of security and usability (Taylor, 2022). Thanks to the transparency and immutability of blockchain, recorded environmental information can be easily verified by any stakeholder, and personnel can verify what is stated, ensuring greater trust and transparency in the environmental reporting process. For example, years later, it is possible to review a past document and check for inconsistencies compared to subsequently published data, thus avoiding instances of greenwashing.
Undoubtedly, the use of blockchain technology for verifying environmental data offers several distinct advantages over traditional approaches adopted by the Global Reporting Initiative (GRI), ISO standards, and ISAE 3000, which are just some of the existing verification methods but represent the chosen comparison panel in the initial analysis as the most widespread. Therefore, thanks to the transparency and easy accessibility of data guaranteed by the public and transparent nature of blockchain (Antonopoulos, 2022). Another key feature of blockchain is data security against current privacy concerns, although potential attempts at malicious manipulation are not to be excluded (Antonopoulos, & Wood, 2019). Finally, the use of blockchain can contribute to reducing the costs associated with managing and validating environmental data, which represent an annual expenditure for companies or entities. By eliminating the need for intermediaries and streamlining verification processes, this technology can help reduce both actual and overall operating costs of organizations. In comparison, the Global Reporting Initiative (GRI) provides free guidelines but requires subsequent levels to be paid for, ISO standards, and ISAE 3000 are subject to annual review by releasing companies and chartered accountants; therefore, continuous expenditure is required to keep up with market demands and public and private tenders. Blockchain, with its decentralized, immutable, and transparent nature, overcomes these limitations by providing an advanced technological solution for environmental data verification (Maupin, 2017).

Project Application Cases

The project research has yielded significant results in applications, demonstrating the effectiveness of blockchain technology in the realm of corporate environmental management in various domains. Through the use of practical simulations, a clear positive impact on environmental practices and data transparency has emerged. The project was successfully applied at the Antigua Real Fábrica de Hojalata, a highly sustainable winery located in Juzcar, southern Spain, in the province of Malaga. Here, smart contracts were utilized to verify the company's CO2 emissions related to the transportation of annually produced wine bottles and calculate the CO2 absorption of vineyards over the course of a year. This innovative approach allowed the company to accurately and reliably assess its environmental impact and identify opportunities to improve its sustainability practices. The inclusion of blockchain technology had a profound effect on the participatory, co-design, and collaborative processes of the engaged stakeholders. By utilizing this technology, the stakeholders experienced a new level of transparency and trust, fostering a more inclusive environment where every action was verifiable and immutable. The systemic design process was notably enhanced by the integration of blockchain, as it provided a robust framework for collaboration among various parties. Stakeholders could co-design solutions with confidence, knowing that the data they relied on was accurate and tamper-proof. This level of reliability enabled more innovative and effective sustainability practices, as participants were empowered to contribute ideas and strategies with the assurance that their inputs would be accurately reflected and preserved in the decision-making process. Additionally, the project addressed the challenge of wastewater discharged into the nearby Genal River, situated adjacent to the winery. Through the notarization process, an official verification of the actions undertaken by the company since 2023 to reduce the impact of wastewater on the surrounding environment, pursuing the 6th and 12th development goals, will be possible to compare the project's progress in the coming years and avoid retroactive changes to feign fallacious improvements. This notation has provided an additional level of transparency and authenticity to the company's sustainability actions, providing a solid foundation for its reputation and credibility in the industry. As the subject of the master's thesis project, the case study has also shown the potential scalability to all wineries in the area (Schilling & Liboni, 2023). It is important to note that Antigua Real Fabrica de Hojalata was the first company involved in this in-depth analysis, holding the verification digest of its actions. However, it was chosen not to include this digest in an NFT as a public symbol, as it was the initial experimentation phase. The verification of the proposed project's functionality was then applied to Reber S.r.l., based in Turin, which benefited from notarization verification for environmental data present in the 2023 sustainability report and in the development report prepared according to systemic flow analysis covering the company's emissions for the same year and aiming for a reduction by 2030. This approach allowed the company to ensure the integrity and authenticity of information regarding water consumption, CO2 emissions, waste impact, and harmful particles to water, as a waste producer REA (Reber, 2023); in this case as well, the company's commitment can be monitored by comparing data annually. This provided an additional level of security and reliability, eliminating the risk of manipulation or alteration of environmental data being provided, published, and verified in public digital act. Additionally, the use of blockchain made the verification process more efficient and accurate; although the company holds ISO 14001 and the certificate provided by EcoVadis, it chose this verification method to attest to public documents (Reber, 2024). As recognition of passing the verification, Reber S.r.l. received an NFT (Non-Fungible Token) as a symbol of successful certification. This NFT contains the digest representing a cryptographic imprint of the verified data, confirming the authenticity and integrity of the information uploaded in today's public documents. This certification further strengthened the company's reputation and credibility in the facility management sector. The collaborative process among stakeholders in the Reber project also benefited greatly from blockchain technology. The immutable nature of blockchain records provided a secure environment for stakeholders to share information and collaborate on sustainability goals. This transparency encourage active participation from all involved parties, as they could trust that their contributions would be permanently recorded and acknowledged. The systemic design process was, therefore, more inclusive, as it allowed for real-time feedback and adjustments based on reliable data, leading to more effective and coordinated sustainability efforts. The project application has expanded to the world of post-university training; the adoption of blockchain technology by SIAT (Società Italiana di Analisi Tecnica) represents a significant example of the growing adoption of this technology in business operations.

SIAT recognised the potential of blockchain to enhance the integrity and reliability of its processes by implementing a notarization system to verify CO_2 emissions from company events and for issuing exam certifications. Notarization via blockchain allows SIAT to register and store immutable and verifiable records of every CO_2 emission linked to company events, such as seminars, conferences, and workshops during the second half of 2024; the project is currently in development. This will ensure that each event is traceable and that related data cannot be retroactively altered. For each event, SIAT will record details such as date, time, location, and presented content with the respective CO_2 calculation and the products chosen for compensation, carbon credits, but will also implement increasingly sustainable resource usage methods. This information will then be "notarized" on the blockchain, creating a permanent record that can be easily verified by third parties involved in the events. This process increases confidence in the services offered by SIAT, as participants and stakeholders can be certain of the authenticity and accuracy of the information. In addition to notarizing emissions from company events, SIAT will use blockchain by 2025 for issuing certifications for exams. After passing an exam, the candidate's details and results are notarized on the blockchain. This provides tangible and indisputable evidence of acquired skills, facilitating the recognition of qualifications by employers and other institutions and reducing the production of paper documentation. The analysis of environmental data and its verification represent a crucial component for organizations aiming to demonstrate their concrete commitment to sustainability without perpetrating greenwashing. In this scenario, blockchain has proven to be an innovative solution that can bridge these possibilities. As demonstrated by the case studies of Antigua Real Fábrica de Hojalata, Reber S.r.l., and SIAT Società Italiana di Analisi Tecnica, the application of blockchain has allowed for accurate and indisputable verification of environmental data. This has led to increased confidence in the reported information and facilitated the recognition of sustainability initiatives by companies.

Evaluation of the Results Obtained and the Critical Issues

It is essential to approach the chosen design process with a critical eye, recognising not only the benefits that have been

widely reported but also the challenges and limitations inherent in this technology. The technological complexity of blockchain represents one of the main barriers to adoption, due to the low level of understanding. This complexity can be daunting for organizations that do not have the necessary resources to invest in training and technological and computer updates. In the context of systemic design, this complexity highlights the need for a thorough understanding of how blockchain technologies integrate within broader system processes. Systemic designers must account for these technological challenges as they shape both the design process and the potential impact on the system's overall effectiveness. Furthermore, scalability issues arise when transaction volume increases, potentially leading to delays and higher costs that could compromise system efficiency. The lack of interoperability between different blockchains, some dedicated to economic transactions and others to verification transactions like Cardano, may limit data sharing and the effectiveness of the technology on a larger scale. Additionally, the energy consumption of some blockchain implementations, especially those based on Proof of Work, may conflict with environmental sustainability goals. Some blockchains are transitioning from high-energy consensus mechanisms, such as Proof of Work (PoW), to more efficient protocols like Proof of Stake (PoS) or variants thereof, which require significantly less energy to operate (Schilling & Liboni, 2023). Another critical aspect is the quality of data entered into the blockchain. While the technology ensures the integrity of data once registered, it cannot guarantee the possibility of duplication. This means that errors or repetitions in the initial

data will be perpetuated in the system. Systemic designers must be particularly vigilant about the quality of data input, as it affects not only the blockchain itself but the entire system in which it operates. Errors or inefficiencies in data can compromise the integrity and reliability of the whole system. Furthermore, the need for transparency must be balanced with compliance with data privacy regulations, creating tension between information accessibility and protection of personal information (Kulhari, 2018). The challenges do not stop at the technology itself. Adoption and acceptance of blockchain can be slowed down by distrust of new technologies or confusion in considering Bitcoin and blockchain as the same tool. It is therefore crucial for organizations to work to promote understanding and the benefits of blockchain to overcome resistance to change. The core methodologies of systemic design might be impacted by these challenges. Designers and teams may need to adapt their approaches to address resistance, enhance understanding, and integrate blockchain more effectively within the broader system. Additionally, organizations must navigate an uncertain regulatory environment in Italian legislation, which can pose legal and operational risks. Despite these challenges, blockchain, analysed since the late 1990s, has the potential to become a revolutionary tool in the field of environmental reporting (Szabo, 1997). Organizations adopting this technology position themselves as leaders in the field of sustainability, ready to respond to the growing demands for accountability and traceability from stakeholders, consumers, and financial entities. To fully harness the potential of blockchain, a critical and aware approach is

needed that takes into account its limitations and actively works to mitigate associated risks.

Conclusions and Future Challenges

In the context of promoting environmental sustainability through blockchain technological innovation, the project aims to establish itself as a reference point for future sustainable practices. Looking ahead, a series of evolutions capable of revolutionizing how we address environmental and social challenges are outlined below.

The future prospects of blockchain will project towards a horizon of significant transformations that could revolutionize not only how we interact with data but also how we approach sustainability and technological innovation. The widespread implementation of blockchain, thanks to the work of miners who will further develop it from financial and computer science perspectives, will allow its application in key sectors such as manufacturing, sustainable agriculture, and ecological construction, where the need for transparency and traceability will increasingly become urgent to demonstrate. This expansion could lead to a reduction in environmental impact and an increase in operational efficiency.

The advent of Artificial Intelligence (AI) and the Internet of Things (IoT) will enrich the project with advanced analytical capabilities and more sophisticated data collection (European Investment Bank, 2021). AI can offer predictive insights based on data collected through blockchain, while IoT can provide real-time environmental monitoring, enhancing responsiveness and measurement accuracy. This synergy between technologies could lead to smarter resource management and a greater understanding of implemented environmental dynamics, allowing for realistic long-term predictions.

The involvement of local communities will be crucial for the project's success. Through active participation in data collection and evaluation, communities can gain greater environmental awareness and become active protagonists in promoting sustainability. This bottom-up approach could stimulate behavioral change and greater collective responsibility towards the environment (European Investment Bank, 2021). The standardization of blockchain protocols for sustainability and international collaboration will be necessary steps to ensure consistency and effectiveness of data verification practices on a global scale, in addition to the production of specific laws and regulations. This could facilitate the adoption of public policies and regulations that promote transparency and accountability in the sustainability sector; many steps forward have already been taken in 2024 with Bitcoin operating on blockchain computing.

Moreover, the provision of economic incentives and tokenization can play a crucial role in encouraging the adoption of sustainable practices. Sustainability-linked tokens can be used to reward companies and communities that contribute to generating reliable data and adopt environmentally respectful behaviours. This rewards system could stimulate broader commitment to sustainability and innovation. Education and public awareness of the importance of sustainability and environmental data verification will be essential for the project's progress. Awareness campaigns and educational programs can be implemented to engage the public and promote a cultural shift towards more sustainable behaviours. Interdisciplinary collaborations with fields such as sociology, behavioral economics, and environmental psychology can provide a deeper understanding of the human factors influencing sustainability-related decisions. This integration of knowledge can lead to more effective solutions and more targeted engagement strategies. Finally, by promoting transparency and accountability, blockchain can become a key tool in encouraging the adoption of evidence-based practices and guiding policy decisions towards a more sustainable future.

In conclusion, blockchain is emerging as a key technology for the future, with the potential to radically transform our approach to sustainability, innovation, and social responsibility. As we approach this future, it will be crucial to continue exploring and developing its applications to maximize benefits for society and the environment.

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