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A conceptual hybrid model based on Ethereum for implementing sustainable development goals

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ABSTRACT

The United Nations' sustainable development goals (SDGs) present a global challenge that demands innovative solutions. Combining emerging technologies can be a transformative approach to achieving these goals and overcoming associated challenges. Blockchain provides a secure and transparent platform, while big data and data mining enable the analysis of vast datasets to identify critical areas and measure progress. Additionally, blockchain facilitates secure knowledge exchange among stakeholders through knowledge sharing and management. Recent research demonstrates the effectiveness of blockchain in implementing SDGs. Our study explores the benefits of various technologies and proposes a hybrid model based on Ethereum. This model leverages additional technologies to enhance performance, increase transparency, and reduce gas fees. This combination empowers informed decision-making and accelerates progress towards a sustainable future.

Keywords: sustainable development goals, Ethereum, smart contracts, blockchain, big data and data mining, knowledge sharing

INTRODUCTION

The United Nations has launched an extensive and diverse worldwide initiative, the 2030 agenda for sustainable development. This pioneering endeavor seeks to address urgent global challenges by adopting a collection of 17 sustainable development goals (SDGs) to propel humanity toward an environmentally sustainable and fair future (United Nations, 2015). The SDGs encompass a set of interrelated objectives that seek to eradicate poverty, safeguard the environment, and promote universal prosperity (Sachs et al., 2022). The objectives encompass diverse concerns, such as poverty, hunger, health, education, gender parity, access to clean water and sanitation, renewable energy, economic advancement, and the establishment of sustainable urban areas (Hák et al., 2016). In order to achieve these objectives, it is essential to employ innovative strategies and utilize state-of-the-art technology to promote progress and encourage international collaboration. Impairments to attaining the SDGs include insufficient financial resources, disparities, hostilities, malfeasance, and ecological deterioration (United Nations, 2015). For example, several developing nations need help attracting the essential resources required to execute initiatives connected to the SDGs (Sachs et al., 2022). In contrast, others confront violence and political instability that hinder advancement. Furthermore, the detrimental environmental impact, such as climate change, presents a significant risk to the long-term viability of development initiatives (United Nations, 2015).

The growing imperative to tackle global difficulties calls for inventive approaches that foster sustainable development. Blockchain technology, specifically Ethereum, has become a viable tool for tackling the issues associated with reaching the SDGs in recent years (Shoker, 2021). Blockchain is a decentralized system that enables the safe and unchangeable storage of transactions and data. The abovementioned technology can enhance transparency, efficiency, and accountability in executing the SDGs (Aysan et al., 2021). Ethereum is a platform that applies blockchain technology to simplify the formation of decentralized apps (dApps) operating on a computer network (Shoker, 2021). Ethereum's blockchain technology has several advantages that can simplify the attainment of the SDGs. One such instance is the smart contract functionality of Ethereum, which facilitates transparent and secure transactions without the involvement of intermediaries. This feature effectively mitigates transaction costs and augments responsibility. This feature can be utilized to tackle difficulties relating to the SDGs, such as corruption, lack of transparency, and accountability in financing (Aysan et al., 2021). Furthermore, Ethereum's decentralized governance architecture facilitates decision-making processes driven by the community, fostering inclusivity and encouraging active engagement in development endeavors. The fundamental characteristics of Ethereum, like decentralization, transparency, and immutability, have the potential to effectively tackle significant obstacles commonly encountered in conventional sustainability endeavors (Parmentola et al., 2022). Nevertheless, current blockchain-based solutions frequently need to be revised regarding scalability and their ability to interact with pre-existing governance frameworks seamlessly.

The lack of an inclusive and transparent framework for tracking and monitoring progress toward the SDGs is a significant obstacle to their implementation. Conventional approaches to monitoring and assessment can be laborious, costly, and susceptible to human fallibility. Moreover, the restricted availability of up-to-date data and tools for data analysis poses challenges for evaluating the effects of interventions and making well-informed choices (Sachs et al., 2022). Ethereum is the most renowned and extensively utilized blockchain technology, enabling the development of smart contracts–autonomous agreements that autonomously execute the conditions established by the participating parties. The aforementioned characteristic renders Ethereum well-suited for advancing a hybrid framework that amalgamates the advantages of conventional centralized systems with blockchain technology's immutability and safeguarding capabilities (Buterin, 2014). Integrating Ethereum's blockchain technology with other technologies and methodologies in a hybrid model might effectively foster sustainable development and tackle specific difficulties related to the SDGs. An Ethereum-based hybrid strategy for achieving the SDGs entails establishing a decentralized network that links parties implementing the SDGs (Sabbagh et al., 2023). Using Ethereum's smart contracts will also make it easier to create impact bonds. These will encourage stakeholders to work toward achieving certain SDGs by offering financial rewards for good results, which will encourage cooperation and make stakeholders more responsible for achieving the SDGs (Aysan et al., 2021).

This study presents an innovative conceptual hybrid architecture that capitalizes on the advantages of Ethereum while simultaneously resolving the current constraints. The approach seeks to connect blockchain technology with executing the SDGs by integrating practical governance mechanisms. This paper introduces a theoretical hybrid framework that effectively utilizes the functionalities of the Ethereum blockchain, seamlessly integrating it with NoSQL databases, data mining techniques, and the interplanetary file system (IPFS). The successful implementation of the 2030 agenda, designed to attain the SDGs, is made possible by a meticulously orchestrated combination of technologies. The primary objective of this integration and streamlining procedure is to enhance operational efficiency and performance. The concept leverages the fundamental attributes of blockchain technology, like decentralization, immutability, and transparency, to establish a system characterized by efficiency and security. Furthermore, the hybrid model demonstrates flexibility in adjusting to evolving circumstances, ensuring its ongoing significance and utility in the future.

The Ethereum blockchain plays a critical role in enabling the implementation of smart contracts, making it a prominent component of this hybrid method. As mentioned earlier, the contracts provide the automated and decentralized execution of operations that align with the SDGs, hence offering the potential for transformation in traditional processes. Innovatively implementing this hybrid model enhances the ability to observe and record processes while concurrently maintaining the accuracy and reliability of data. The surveillance and transparency of progress towards the SDGs are contingent upon this pivotal component. This article thoroughly analyzes the theoretical framework, emphasizing its substantial capacity to revolutionize the incorporation and attainment of the 2030 agenda. This study aims to address the following fundamental inquiries:

1. *How can a hybrid approach utilizing Ethereum be created to efficiently facilitate the achievement of the SDGs?*
2. *What measures may be incorporated into the model to guarantee openness, accountability, and stakeholder involvement in projects connected to the SDGs?*
3. *How can the approach be expanded to accommodate other SDG initiatives and facilitate broader implementation?*

LITERATURE REVIEW AND THEORETICAL BACKGROUND

Using blockchain technology to promote sustainable development is an idea that has been getting much attention lately. Researchers say blockchain technology can promote sustainability and achieve the SDGs (Arshad et al., 2023). Studies have looked at the social effects of blockchain technology and others on the technical aspects of using it for sustainable development. However, many studies have not shown how the Ethereum blockchain might help achieve the SDGs (Sabbagh et al., 2023). Sustainable development efforts can benefit from blockchain technology's ability to build trust among participants and do away with intermediaries; intelligent contracts on Ethereum, for example, might be utilized to guarantee that development project money is being used for their intended objectives (Parmentola et al., 2022). In order to tackle complex global concerns and advance the SDGs, we need to think outside the box and use new technology. The immutability, transparency, and decentralization of blockchain technology have made it a hot topic as a possible tool for accomplishing the SDGs (Mattila et al., 2021). Ethereum is an ideal platform for creating dApps that work towards achieving the SDGs because of its robust ecosystem and capacity to be programmed. Many studies have examined how blockchain technology and sustainable development meet and found its uses across all the SDGs (Arshad et al., 2023). One example is using blockchain technology to improve supply chain management, which would help achieve SDG 12 (responsible consumption and production) and SDG 9 (industry, innovation, and infrastructure) by making global value chains more transparent, traceable, and accountable. Supply chain automation, product provenance verification, and sustainability standard conformance are all possible using Ethereum's smart contracts (Kshetri, 2021).

By increasing efficiency, accountability, and transparency across many industries, blockchain technology has enormous promise for advancing the SDGs. Its decentralized and irreversible ledger technology can lessen corruption, increase resource tracking, and make supply networks more transparent. For instance, blockchain technology can confirm the legitimacy of donations and assistance by tracking their origin, which promotes ethical and sustainable business practices (Boçe & Hoxha, 2024). In addition to helping execute SDGs like climate action, cheap energy, and clean water, it can make transactions in renewable energy markets more efficient and safer. Blockchain technology will allow all parties to track and complete the SDGs more efficiently (Khan et al., 2024).

The 2030 Agenda for Sustainable Development

The 2030 agenda for sustainable development, which includes 17 SDGs, was approved by the United Nations in 2015. These goals aim to tackle various social, economic, and environmental issues. They are crucial since they establish a structure for nations and institutions to collaborate on achieving sustainable development to eradicate poverty, safeguard the environment, and promote prosperity for everyone. SDGs are vital in directing worldwide endeavors toward a future characterized by inclusivity, fairness, and sustainability (Machin & Liu, 2024). In order to improve the lives of billions of people, the world's leading collective has established a set of measurable objectives and outcomes called the SDGs. These goals will help direct evidence-based policymaking (United Nations, 2015). In order to tackle the most critical environmental, social, and economic issues of our day, the international community has come together to create the 2030 agenda for sustainable development. The United Nations General Assembly approved the 2030 agenda for sustainable development on September 25, 2015, which complements the millennium development goals (MDGs) (Weiland et al., 2021). The 2030 agenda will serve as a guide for global efforts over the following fifteen years. The 2030 agenda is an extension and culmination of the MDGs and plans to improve people's lives, the environment, and economic growth. These objectives seek to foster social and economic growth while addressing various problems, including poverty, inequality, and environmental degradation (Colglazier, 2015). The 2030 agenda contains 17 SDGs to build a sustainable future by 2030. These goals encompass growth's economic, social, and environmental aspects while ensuring equal prosperity within the constraints of global limitations (Hák et al., 2016).

In contrast to the MDGs, the SDGs possess universal applicability across all nations; they acknowledge the global character of concerns such as climate change, inequality, and sustainable economic growth, necessitating collaborative approaches for their resolution. The agenda's focus on universality and inclusion aims to guarantee that no individual is excluded, to reach the most susceptible communities, and to include them in the development process (Weiland et al., 2021). A critical advancement of the 2030 agenda is its acknowledgment of the interconnectedness of its objectives. The achievement of a particular objective frequently hinges upon advancements achieved in other areas, hence requiring a synchronized and cohesive strategy for formulating and executing policies (Carpentier & Braun, 2020). An illustration of this may be seen in the interconnectedness between endeavors aimed at enhancing health and well-being (SDG 3) and objectives about clean water and sanitation (SDG 6), gender equality (SDG 5), and sustainable cities and communities (SDG 11).

The achievement of its objectives will be contingent upon the collaborative endeavors of all parties involved to adopt the comprehensive strategy of the agenda; nevertheless, implementing the 2030 agenda poses a significant challenge, necessitating unparalleled collaboration, coordination, and mobilization of resources (Sachs et al., 2022). The primary obstacles are guaranteeing the political dedication of member states, tackling the financial prerequisites of the SDGs, and establishing efficient methods for monitoring and evaluation. Accomplishing the SDGs requires a robust dedication to international collaboration and cooperation (Colglazier, 2015). The agenda advocates for establishing a renewed global partnership for sustainable development, which aims to foster collaboration among governments, the corporate sector, civil society, and various stakeholders to allocate resources effectively, exchange information, and synchronize endeavors (United Nations, 2015). International cooperation and collaboration among governments, industry, and civil society are prioritized in the agenda, as is the need for an inclusive approach that ensures no one is left behind. Because of how interrelated these problems are, it considers economic, social, and environmental factors (Machin & Liu, 2024). Effective implementation and monitoring rely on funding, innovation, and data, all of which are emphasized in the agenda. A society where justice, environmental stewardship, and prosperity coexist is the goal of the 2030 agenda, which promotes sustainable practices and equitable growth (Ricciolini et al., 2024).

Ethereum Blockchain

The open-source platform Ethereum, which Buterin founded in 2014 and runs on a blockchain, is well known for its flexibility and adaptability. Ethereum was created to enable immutable, programmable contracts and applications using its own money rather than its predecessor, Bitcoin, which is mainly a decentralized digital currency (Urquhart, 2022). The Ethereum blockchain enables reprogramming, facilitating the direct execution of other blockchain-based apps on its platform. The Ethereum blockchain is notable in its capacity to facilitate the process of dApps, which may be utilized for several objectives, including monitoring supply chains, recording environmental data, and managing resources for sustainable development (Medaglia & Damsgaard, 2020). Ethereum's innovative contract capability has dramatically aided in creating dApps, enabling developers to design autonomous apps without requiring centralized supervision. In addition to its role as a digital currency, Ethereum can facilitate various financial transactions, conduct intelligent contracts, and retain information for applications developed by third parties (Buterin, 2014).

The application of smart contracts and dApps by Ethereum has brought about a notable transformation in the blockchain domain, establishing a structure for the decentralized web, commonly called Web 3.0. These digital contracts streamline the implementation of a contract, guaranteeing that all parties promptly obtain the result without requiring intermediate supervision (Antonopoulos & Wood, 2018). The contracts above possess the characteristic of self-executing agreements, wherein the terms are encoded directly into computer code and then recorded and copied on the blockchain. Furthermore, they are overseen by the network of computers that operate the Ethereum blockchain (Hewa et al., 2021). This architectural design reduces the potential for censorship, fraudulent activities, periods of system unavailability, and external intervention and introduces a novel framework for creating applications. Nevertheless, this technological advancement presents a range of obstacles, encompassing concerns related to scalability, fuel costs, and network congestion (Urquhart, 2022).

Blockchain and SDGs

Utilizing blockchain technology holds significant potential for promoting sustainable development because of its capacity to enhance transparency, decentralization, and the maintenance of immutable data (Parmentola et al., 2022). Innovative blockchain initiatives, such as the Internet of Value, supply chain management, and governance improvements, can provide socially and ecologically advantageous results. These projects can disrupt established business models and present novel prospects (Medaglia & Damsgaard, 2020). Ethereum provides a distributed and protected data exchange, authentication, and retention platform. Additionally, it facilitates the creation of intelligent agreements that can streamline procedures and guarantee openness and confidence among the concerned parties. The characteristics of Ethereum make it a perfect platform for implementing a conceptual hybrid model to achieve the SDGs (Joshi et al., 2023). Presently, several global institutions, like the United Nations and the World Trade Organization, are examining the application of this technology in diverse domains within their jurisdiction. For instance, the United Nations has initiated initiatives to facilitate monetary transfers to refugees globally (Jiang et al., 2022). Furthermore, Son-Turan (2019) highlights that the "blockchain for zero hunger" program by the World Food Program utilizes blockchain technology to enhance its capacity to deliver efficient and impactful aid to individuals.

The Ethereum blockchain can enhance financial accessibility, another essential facet of its application in sustainable development. The limited reach of conventional financial institutions in reaching marginalized communities has prompted the emergence of blockchain technology as a viable alternative platform for facilitating financial transactions and enabling access to financial services (Pizzi et al., 2022). Fostering inclusive economic growth and mitigating income disparities can aid in attaining SDG 1 (no poverty) and SDG 8 (decent work and economic growth). Within the framework of environmental sustainability (SDG 13), the potential of blockchain and Ethereum have been examined for their ability to provide incentives, monitor renewable energy generation, optimize resource allocation, and address climate change (Arshad et al., 2023). Smart contracts enable the automated execution of energy trading agreements, facilitating the direct sale of excess energy from producers to consumers, adopting renewable energy sources, and reducing carbon emissions (Parmentola et al., 2022). Ethereum can assume a pivotal role in realizing these objectives within the SDGs framework by integrating a conceptual hybrid model that amalgamates conventional and blockchain technology. In addition to supporting SDGs 16 (peace, justice, and strong institutions), blockchain technology is essential for increasing transparency in support distribution, which helps guarantee that resources are utilized efficiently and get to their intended beneficiaries. As a further advantage, blockchain technology can help achieve SDG 7: Affordable and clean energy by facilitating decentralized energy networks and efficient trade of renewable energy sources. By using blockchain technology in these domains, stakeholders may better track and accomplish the SDGs' progress toward a more just, sustainable, and transparent society (Singh et al., 2024).

As a recent study, Di Vaio et al. (2023) emphasized the capacity of Blockchain technology to support the achievement of SDG 5, which focuses on advancing gender equality and empowering women and girls. Technology may enhance the implementation of gender equality and inclusion protocols by integrating corporate governance frameworks with social and sustainable objectives. In addition, it may promote sustainable development by channeling innovation towards inclusive and sustainable solutions and strategically positioning impoverished nations to benefit from technological breakthroughs. Furthermore, blockchain technology can enable the monitoring of gender disparities and the detection and rectification of structural deficiencies that perpetuate gender bias, thereby promoting social conformity. In addition, blockchain technology can assist in attaining gender equity by monitoring female empowerment initiatives and actions promoting diversity inside companies (Di Vaio et al., 2023).

METHODOLOGY

There have been several obstacles that have reduced the efficiency of the conventional method of attaining the SDGs. Corruption, incompetence, and a general lack of trust in the processes all contribute to these problems. Blockchain technology, and Ethereum in particular, can be utilized to overcome these obstacles and make progress toward the SDGs much more rapid (Aysan et al., 2021). This study aims to provide a theoretical framework for a hybrid model that uses Ethereum to help achieve the SDGs. By integrating blockchain technology for SDG integration, our goal is to achieve conceptual integration across many streams of literature and theory about new technologies and their use in sustainable development, which aligns with Jaakkola's (2020) framework for theory synthesis. This study's overarching goal is to present new evidence supporting the SDGs' potential use of a blockchain-based hybrid paradigm. A theory synthesis approach is justified when it is realized that there is a common ground from which a new and better theoretical framework may be built (Jaakkola, 2020). We utilized this framework to develop information and communication technologies and for theoretical and empirical studies of hybrid technologies, blockchain applications, and related topics (Kostoska & Kocarev, 2019).

RESEARCH FRAMEWORK DEVELOPMENT

Big Data and NoSQL

The term big data originated from vast amounts of data generated throughout the current digital age. Conventional relational database management systems (DBMS) can handle big data's quantity, velocity, and variety without assistance. The use of big data is essential in attaining the SDGs since it offers valuable insights and supports evidence-based decision-making, ultimately promoting the development of sustainable value. As an example, using big earth data (BED) technology in China has produced favorable outcomes for the SDGs. A concrete demonstration highlighted the effectiveness of BED in evaluating the LCRPGR (land cover ratio of permanent green space) and EGRLCR (effective green ratio of land cover ratio) in China. The findings indicate that China's urbanization process has been more sustainable in recent decades due to the effective implementation of laudable urbanization policies. Additionally, a water transparency estimation was performed using an inversion approach that integrates the watercolor index and chromaticity angle. This technique demonstrated more precision, showcasing the capacity of BED to monitor several parameters. This example illustrates the successful application of BED technology in China to accomplish the SDGs (Guo et al., 2022).

Therefore, novel database technologies, such as NoSQL, have surfaced. The concepts of big data and NoSQL databases synergize effectively in managing extensive and diverse datasets (Matallah et al., 2020). Big data involves collecting information from diverse sources, such as online transaction records, social media platforms, and sensor-generated data. This dataset type's storage, management, and processing pose significant challenges when utilizing traditional database operations (Mohamed et al., 2020). A NoSQL database does not rely on conventional relational structures to address the difficulties brought about by large amounts of data. NoSQL databases provide more flexibility in data structure than traditional relational databases (SQL databases), which have a more rigid schema (Stonebraker, 2010). NoSQL databases offer a more adaptable and expandable option for managing, storing, and examining vast amounts of data. Nevertheless, conventional DBMSs and data warehouses require assistance to cope with the rapid increase of digital data generated daily in diverse areas such as industry, government, and personal consumption (Matallah et al., 2020) (**Figure 1**).

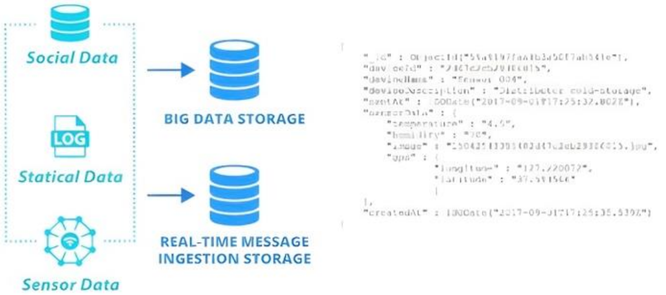

Figure 1. Big data and NoSQL (Source: Authors' own elaboration)

NoSQL databases are highly scalable, handling increasing data and user activity, which makes them ideal for large-scale data processing and analytics. Additionally, they can accommodate diverse data models and do not require a fixed schema, which allows organizations to store and analyze complex and varied datasets (Meier & Kaufmann, 2019). NoSQL databases are designed to efficiently handle many read and write operations, allowing for quick access to data and enabling real-time analysis. As a result, they are suitable for use in content management systems, e-commerce platforms, and digital media archives that require storage and retrieval of large amounts of multimedia content (Stonebraker, 2010). Big data and NoSQL databases are closely connected elements of the contemporary data environment, providing organizations with the necessary tools and technology to leverage the potential of data for gaining insights, fostering innovation, and gaining a competitive edge (Oussous et al., 2017). Before implementing NoSQL technology, organizations must thoroughly assess their requirements, trade-offs, and use cases, even though NoSQL databases effectively tackle several difficulties associated with big data (Matallah et al., 2020).

Data Mining and Its Techniques

Data mining is the systematic process of extracting significant patterns, trends, and insights from extensive databases. It enables the discovery of previously unknown correlations, enhancing the extraction's effectiveness (Haoxiang & Smys, 2021). Data mining is a process that utilizes a range of tools and algorithms to reveal concealed patterns and connections within extensive datasets. Businesses of various scales employ data mining to better comprehend their customers, operations, and market trends, which involves identifying and analyzing data patterns and trends within large datasets, with the ultimate goal of extracting valuable information to make well-informed judgments and data-driven decisions more likely to yield success (Jain & Srivastava, 2013). This insight can be utilized to customize marketing strategies, create focused goods, and enhance customer service. Data mining algorithms can also detect anomalous patterns that may suggest fraudulent behavior. Consequently, researchers can utilize data mining techniques to scrutinize extensive datasets and uncover novel associations or patterns within their domain (Rajan et al., 2021).

Data mining techniques include association, classification, clustering, decision trees, prediction, and neural networks. The optimal data mining technique is contingent upon our research's particular objectives and the data's organization and configuration (Jain & Srivastava, 2013). By proficiently utilizing data mining techniques, we may convert our unprocessed data into valuable insights that can enhance decision-making, streamline operations, and secure a competitive advantage in the current data-centric era. These techniques are frequently used in an iterative and combined manner to extract significant insights from intricate datasets in several fields, such as business, healthcare, finance, and scientific research (Haoxiang & Smys, 2021). Spatial data mining (SDM) extracts information, spatial relationships, and other resources not recorded directly in the database. SDM is employed to identify and comprehend underlying recurring patterns (Rajan et al., 2021). The present study contains a

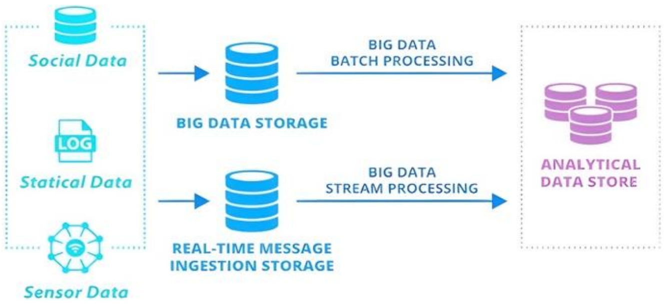

Figure 2. Big data and data mining (Source: Authors' own elaboration)

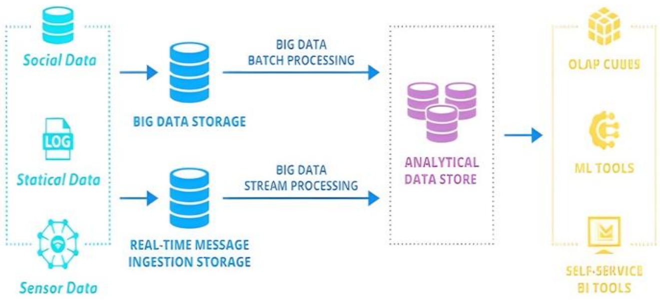

Figure 3. Mapping SDGs using big data, data mining, and BI (Source: Authors' own elaboration)

perspective combining technology and operations, focusing on integrating several data mining approaches. This approach considers each method's benefits and unique effects (**Figure 2**).

Mapping SDGs at the Local Level

Achieving the SDGs necessitates effort at every level, encompassing local governments and communities. It is essential to map the SDGs locally to convert global aspirations into concrete actions (Masuda et al., 2021). How SDGs are addressed is influenced by local factors such as location, population, and economic activities. Adapting techniques to specific local circumstances guarantees their effectiveness. Consequently, business intelligence (BI) software is utilized to aid in mapping and visualizing the present condition of the SDGs at the regional and local levels after the application of data mining approaches (Rajesh & Kumar, 2020). BI technology has successfully tackled the SDGs by improving decision-making, fostering economic development, promoting innovation, and strengthening firm performance and productivity. These results are consistent with some vital SDGs, specifically SDG 8 and SDG 9. Furthermore, applying BI technology can improve the attainment of the SDGs by boosting operational efficiency, customer relationship management, and financial management in small and medium-sized enterprises (Lateef & Keikhosrokiani, 2023).

Local communities possess a profound comprehension of their difficulties and potential. Mapping enables the establishment of local control and involvement in the pursuit of the SDGs (Masuda et al., 2021). After applying data mining techniques to extensive datasets, the resulting discoveries will be utilized as inputs for BI systems. Subsequently, these systems would furnish enlightening reporting indicators pertinent to stakeholders functioning at the local level (**Figure 3**). Local-level mapping is a process that sets initial standards and monitors advancements toward specific SDG targets, which allows for improved monitoring and evaluation of local initiatives. Localizing SDGs empowers local authorities to create evidence-based policies and action plans that meet global SDG goals and address local needs (Nagy et al., 2018). Through diverse strategies, local communities can successfully interpret the SDGs into a customized plan for a more environmentally friendly and enduring future. For instance, involving many stakeholders, such as people, corporations, non-governmental organizations (NGOs), and local government officials, promotes inclusive participation and a collective vision for attaining the local SDGs. In addition, selecting appropriate indicators tailored to the specific circumstances of a particular locality can aid in monitoring the advancement toward individual SDG targets at the local level (Masuda et al., 2021).

Stakeholders' Involvement

The key stakeholders in urban and local development encompass a wide range of groups, including local authorities, national and regional governments, parliamentarians, NGOs and civil society organizations, businesses and industries, universities, professionals, faith-based institutions, financial institutions, international organizations, and city networks (Kanuri et al., 2016). The active participation of stakeholders is a vital factor in generating effective outcomes in many endeavors. Stakeholder engagement is the intentional and proactive effort to include individuals and groups affected by, or that can affect a particular project, decision, or initiative (Kujala et al., 2022). Considering the requirements and concerns of all stakeholders increases the likelihood of making well-rounded, successful, and sustainable long-term decisions. Consequently, when stakeholders perceive that their opinions are acknowledged and appreciated, they are more inclined to endorse the initiative and actively participate in its achievement, promoting a feeling of possession and collective accountability (Ansell et al., 2022). Furthermore, engaging stakeholders proactively can assist in the early detection of possible conflicts and reduce risks related to neglecting stakeholder interests. Open communication and stakeholder collaboration cultivate trust and transparency, leading to a more favorable and efficient atmosphere (Attanasio et al., 2022). After mapping the SDGs at the local level, our proposed blockchain-based platform has the potential to effectively unite the parties responsible for accomplishing the 2030 agenda at the local level (Kanuri et al., 2016) (**Figure 4**).

The initial stage of incorporating stakeholders entails the identification of all pertinent stakeholders, encompassing both internal and external parties. These could encompass impacted communities, governmental entities, industry professionals, and prospective recipients. Stakeholders vary in their level of influence and interest. Therefore, it is crucial to prioritize stakeholders based on their potential impact and the significance of their involvement (Kujala et al., 2022). The subsequent phase entails formulating customized approaches to engage various stakeholder groups, which may encompass convening meetings, conducting workshops, administering surveys, facilitating online forums, or utilizing social media

Figure 4. Local and regional key stakeholders regarding SDG implementation (Kanuri et al., 2016)

platforms, contingent upon the specific circumstances and preferences. Creating systems for continual engagement, such as stakeholder groups or advisory boards, is crucial to guarantee consistent input and feedback (Attanasio et al., 2022). The participation of stakeholders is a deliberate approach that results in improved decision-making and more robust outcomes. Through the active engagement of stakeholders throughout the process, we can utilize their combined expertise, establish confidence, and attain success in a cooperative and influential manner.

Prioritizing SDGs Implementation Using Consensus Mechanism

Prioritizing the implementation of the SDGs through a consensus mechanism entails a collaborative decision-making process in which all stakeholders agree on the most crucial goals and initiatives. This method could improve the success of SDG implementation by guaranteeing widespread consensus and dedication (Zhang et al., 2020). Given the variation in obstacles among countries, mapping the SDGs according to local requirements is necessary. Each locale must customize the SDGs, and implementation plans to suit their circumstances while valuing the input of all local stakeholders described previously (Masuda et al., 2021). Accordingly, it is essential to scrutinize the most urgent obstacles a specific nation or area encounters and concentrate on SDGs that specifically target those requirements. Additionally, it is crucial to consider the available resources, including financial and human resources, and prioritize the SDGs, where these resources may be utilized efficiently or where focused efforts to gather resources are expected to produce substantial outcomes (Ansell et al., 2022). To prioritize the implementation of the SDGs at the local level, we utilize the consensus mechanism, a key element of blockchain technology. In this mechanism, the priorities for implementing the SDGs are determined based on the values and requirements of the local community and the key stakeholders' significant role in influencing and making decisions (Lashkari & Musilek, 2021) (**Figure 5**).

Before achieving consensus, all parties must comprehensively understand the SDGs. Through educational seminars and informational meetings, stakeholders can understand each aim and its possible consequences. Stakeholders collaboratively establish and reach a consensus

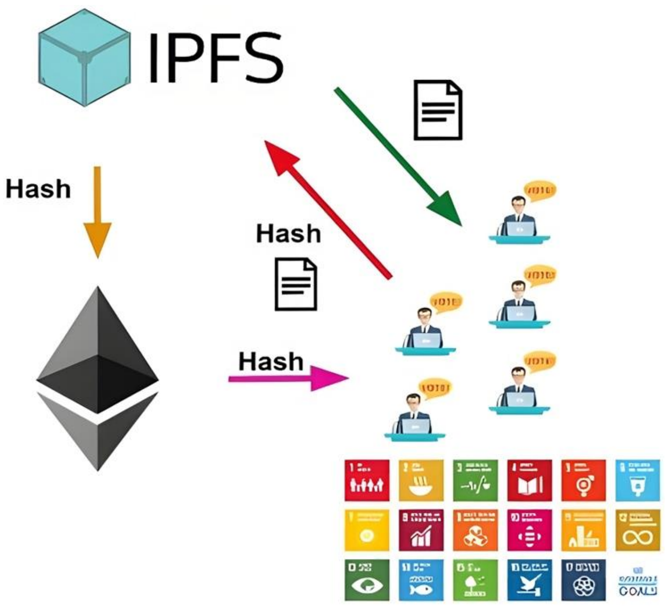

Figure 5. Prioritizing SDGs implementation using consensus mechanism (Source: Authors' own elaboration)

on the criteria for assessing the urgency and effect associated with each SDG (Zhang et al., 2020). The criteria may encompass elements such as regional significance, potential for influence, availability of resources, and the level of urgency driven by local or global trends. Based on the established criteria, stakeholders evaluate and prioritize the SDGs, which may be accomplished using scoring techniques (Han & Liu, 2017). Each SDG is evaluated according to its significance and immediacy. Following the first rankings, a process of consensus-building takes place. After reaching a consensus on the most crucial SDGs, stakeholders may work together to develop precise strategies and action plans for effective implementation. Ultimately, it is crucial to build continuous monitoring and review procedures that guarantee that the techniques are efficient and may be modified as required (Lashkari & Musilek, 2021).

Integrating the IPFS with Ethereum smart contracts enables a novel framework for creating safe, transparent, and dApps. By harnessing the advantages of both technologies, developers may devise groundbreaking solutions that empower users and revolutionize our interactions with data and apps in the digital world (Xu et al., 2021). IPFS offers a distributed and peer-to-peer approach for storing and exchanging data. SDG-related data, such as reports on climate change, poverty levels, or healthcare statistics, may be securely kept on IPFS, guaranteeing its accessibility and unchangeability. By using IPFS for data storage and establishing connections with Ethereum smart contracts, we may generate unchangeable records of transactions or information relevant to the SDGs (Krawiec & White, 2023) (**Figure 6**).

Knowledge Sharing and Management

In today's knowledge-driven environment, effective knowledge sharing, and management are crucial for fostering innovation, facilitating cooperation, and attaining corporate objectives. Information resources are not just a resource but also a social capital. Public access to information resources

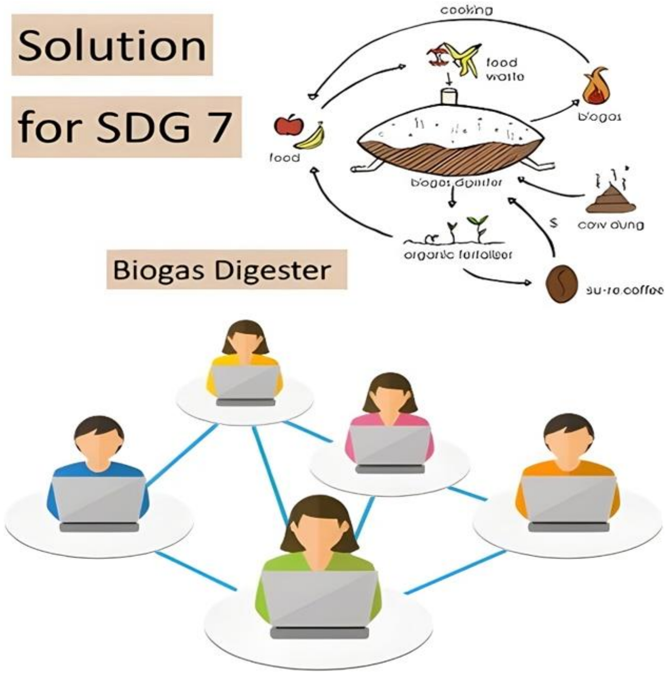

Figure 6. Consensus mechanism to select the best scenario to implement the SDGs (Source: Authors' own elaboration)

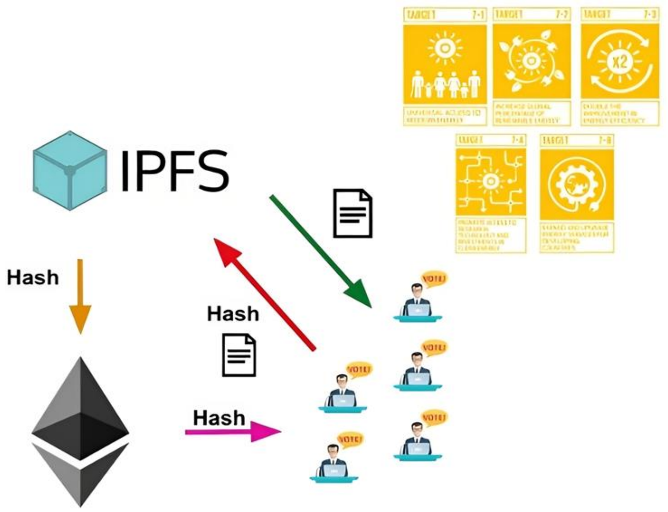

Figure 7. Knowledge sharing and management using IPFS (Source: Authors' own elaboration)

should be facilitated by an effective system of organization and allocation, ensuring fair, orderly, and comprehensive utilization (Asrar-ul-Haq & Anwar, 2016). This culture promotes ongoing learning, innovation, and a lasting competitive advantage. Expanded access to a broader scope of knowledge enables people and teams to make better-informed decisions. Individuals and teams may enhance current knowledge by exchanging information and skills, creating a more inventive workplace. The introduction of new concepts and business forms, including IPFS, blockchain, cloud computing, big data, and artificial Intelligence (AI), has been facilitated by the extensive expansion of social informatization and the rapid improvement of IT technology (Xu et al., 2021).

The fundamental characteristics of blockchain technology, such as decentralization, transparency, immutability, and security, can significantly enhance knowledge sharing and management in SDGs. Blockchain technology enables more efficient and transparent interactions among diverse parties, ensuring their activities towards achieving the SDGs are effective and comprehensive (Treiblmaier, 2018). It allows many entities, including governments, NGOs, economic sectors, and communities, to participate in and access information without depending on a central authority. Decentralized platforms enable the sharing of valuable knowledge, advancements, and information related to the SDGs, ensuring that local community organizations may actively contribute and benefit from these resources (Wang et al., 2019). Furthermore, it improves openness and inclusiveness by guaranteeing that all transactions and data inputs are available to all participants, fostering trust and accountability. Using transparent monitoring techniques for SDG activities may guarantee that the progress and results are freely documented and verified by all stakeholders (Treiblmaier, 2018). Implementing immutable SDG milestones records can authenticate progress and prevent data manipulation, which can be achieved by utilizing secure databases to store and exchange sensitive information, such as healthcare records, educational qualifications, and financial transactions related to SDG projects. In addition, the use of smart contracts to manage the distribution of development funds can ensure that the release of resources is dependent on the fulfillment of certain conditions related to the SDGs (Wang et al., 2019).

Due to the transaction throughput constraints of blockchain, it is not practical to transmit large amounts of data. However, peer-to-peer IPFS may be used as a suitable supplement to blockchain (Zheng et al., 2020) (**Figure 7**).

Integrated Assessment Models

Integrated assessment models (IAMs) are sophisticated computer tools commonly used to evaluate the impacts of different policy options on human and natural systems over a specified time frame. IAMs are quantitative frameworks that synthesize information from several fields, such as economics, climate science, engineering, and sociology. Researchers can evaluate the probable ramifications of various policy choices worldwide (Kostoska & Kocarev, 2019). IAMs enable the creation of simulations that project future scenarios by including various assumptions on population increase, economic progress, technological breakthroughs, and climate change policies. To succeed in evaluations or decision-making processes, it is crucial to meticulously analyze and manage all pertinent components of integrated modelling regarding its intended purpose and contextual aspects (van Soest et al., 2019). The main components encompass concerns of importance, decisions in administration and control, stakeholders, environmental systems, social systems, geographical scopes, periods, academic disciplines, techniques, frameworks, tools, information, sources, and types of uncertainty (Forouli et al., 2020). Through the simulation of diverse policy interventions, IAMs may provide policymakers with insights into the possible economic, social, and environmental consequences of various policy options, such as implementing carbon pricing or investing in renewable energy. Blockchain technology can be incorporated into

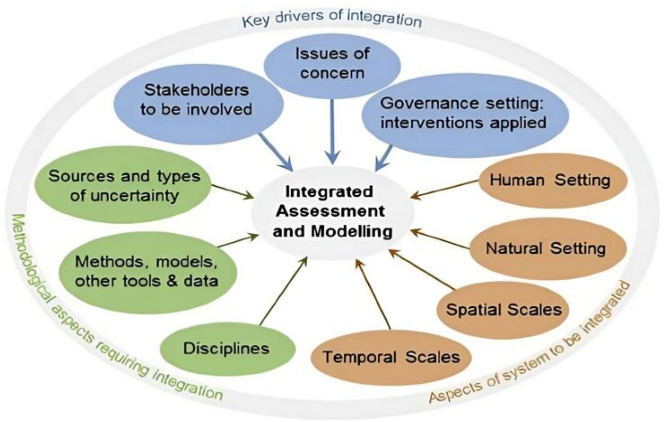

Figure 8. The key dimensions of the IAMs (Hamilton et al., 2015)

participatory processes through its many uses like decision-making and consensus (Hamilton et al., 2015) (**Figure 8**).

Utilizing IAMs within the framework strategies is especially crucial for international and domestic policymakers to determine the order of importance of activities, allocate resources efficiently, and forecast the consequences of their initiatives. Therefore, they are essential to strategic planning for a sustainable future (van Soest et al., 2019). IAMs enable the examination of many future scenarios by considering alternative levels of investment, policy decisions, and technological progress, which facilitates comprehension of how various trajectories might contribute to attaining the SDGs (Hamilton et al., 2015). IAMs are used to model intricate systems that involve feedback loops. For instance, implementing a policy to decrease greenhouse gas emissions may initially decelerate economic growth. However, long-term advantages such as enhanced public health and diminished climate-related hazards might counter this short-term setback. Integrating economic, social, and environmental data allows IAMs to assess the impacts of particular policies on SDGs (Forouli et al., 2020); for example, a model may assess the effect of a carbon tax on decreasing emissions (SDG 13), its effect on economic growth (SDG 8), and its effects on poverty levels (SDG 1). IAMs possess a high level of proficiency in generating forecasts for extended periods, a crucial need for the SDGs considering its 2030 agenda.

SDGs Implementation

When considering governance for SDG implementation, it is essential to consider theories such as adaptive, networked, participatory, fair, and trustworthy governance. These theories facilitate actions at many levels and include players from diverse sectors. Engaging stakeholders in an inclusive and participatory manner ensures that various perspectives are considered and influence the decision-making process for achieving the SDGs (Sabbagh et al., 2023). The suggested platform integrates three interconnected fields–governance, sustainability, and data science–with the notion of digital democracy; accordingly, it facilitates a bidirectional strategy that guarantees individuals' effective engagement in SDGs by establishing communication between the government and the public using inventive blockchain-based solutions.

The use of the Ethereum blockchain in implementing the SDGs entails leveraging blockchain technology to augment transparency, effectiveness, and the capacity to track progress in projects to attain these objectives (Mattila et al., 2021). Potential applications of blockchain technology in partnership with implementing SDGs involve optimizing interagency and cross-sector processes. Specifically, blockchains and smart contracts can automate transactions and enhance the efficiency and effectiveness of interagency procedures by removing the need for intermediaries and automating transaction management (Shoker, 2021). In addition, blockchain enables cooperation across many industries and nations by offering a unified and trustworthy data platform. Fostering cooperation across several stakeholders can boost the effectiveness of SDG projects, leading to improved outcomes and more efficient use of resources (Kshetri, 2021). The inherent openness of blockchain technology can facilitate tracking the allocation and utilization of resources committed to the SDGs. By documenting transactions on the Ethereum platform, those with a vested interest may see the allocation of funds, diminishing corrupt practices and enhancing the level of responsibility (Joshi et al., 2023).

Proposed Model

Utilizing a conceptual hybrid model that relies on digital technologies, particularly Ethereum, to implement the SDGs offers a notable benefit: enhancing transparency and trust in the systems. The platform we propose to execute the 2030 agenda incorporates advanced technologies, such as big data, data mining, Ethereum, IPFS, and NoSQL. NoSQL databases store and administer many kinds of data, including sensor, statistical, and social data, collectively known as big data (Oussous et al., 2017). Data mining techniques applied to large-scale datasets, or big data, provide essential input for BI systems, which allows for creating informative report indicators that are pertinent and advantageous for stakeholders (Rajesh & Kumar, 2020). The model's main features include stakeholder voting and knowledge base sharing and utilizing a consensus mechanism by implementing distributed IPFS and Ethereum smart contracts on the blockchain. The decentralized structure of Ethereum enables the participation of a wide array of stakeholders, such as governments, NGOs, and citizens. Enhanced engagement can result in more efficient and comprehensive decision-making procedures. Moreover, smart contracts on the Ethereum platform guarantee the immutability and transparency of data and transactions, minimizing the possibility of manipulation and corruption (Antonopoulos & Wood, 2018). Implementing this feature can significantly enhance the efficiency of the process and guarantee the effective utilization of resources to accomplish the SDGs.

The chain's methodology commences with verifying the stakeholders inside the system. Stakeholder organizations can engage in the platform by providing initial information and then registering on our platform. Upon completing the verification process, individuals will be given authorization to access a specialized account. Users on our platform have unique identities that empower them to contribute to decision-making processes. Our study employs the IPFS architecture to store documents and ensure robust data

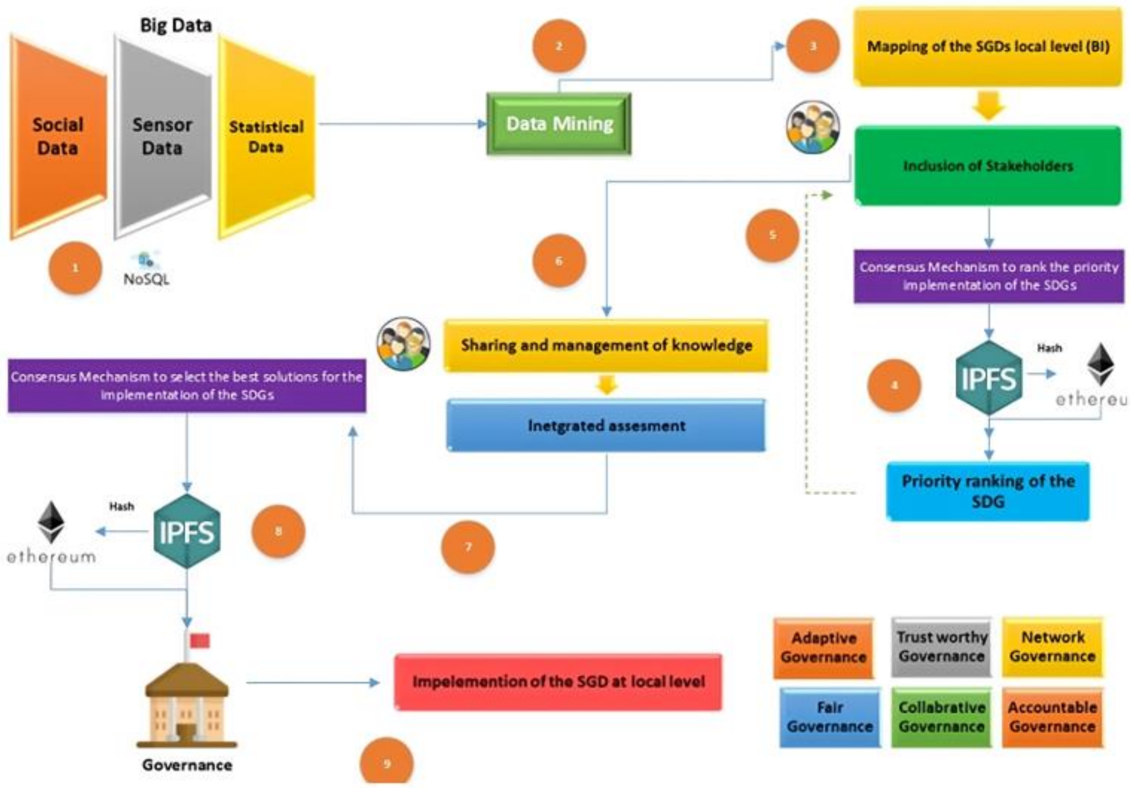

Figure 9. Proposed model (Source: Authors' own elaboration)

security within a decentralized file system. The integration of the Ethereum smart contract and IPFS enables the capacity to timestamp data of any magnitude and guarantees the data's security.

Figure 9 illustrates the proposed framework's all-inclusive structure of 10 consecutive levels. Furthermore, it demonstrates the auxiliary technologies employed in the system.

The suggested concept will be implemented utilizing the Ethereum blockchain network and IPFS. Ethereum and IPFS are compelling technologies in the field of blockchain. However, each of them has some constraints. Ethereum can record the timing of data accurately, but its capability to handle data simultaneously is restricted to small amounts (Urquhart, 2022). The IPFS has a praiseworthy capacity to preserve data, guaranteeing its integrity securely remains unimpaired. However, a significant drawback is the need for a means to determine the exact time when the data was added to the IPFS network (Xu et al., 2021). The integration of Ethereum with IPFS allows for timestamp data of any magnitude, irrespective of its size. Moreover, the incorruptible characteristic of content retrieval provided by IPFS enables confirmation that the information referred to by the hash has not been modified (Zheng et al., 2020). In this model, we used the IPFS and NoSQL for securely keeping our data in storage for pre-processing and main-processing, and then in the consensus mechanism just put the hash generated as a smart contract in the Ethereum blockchain this way can guarantee decreasing gas fees and improve transparency and truth.

The combination of blockchain technology with IPFS, big data, NoSQL databases, data mining, and BI forms a robust hybrid framework for knowledge sharing and management within the framework of the SDGs. The proposed model utilizes the advantages of each technology to improve transparency, security, and efficiency in managing data and resources. The influence on implementing the SDGs is substantial, as it results in more efficient monitoring, enhanced decision-making, and more collaboration among stakeholders, eventually expediting progress towards attaining SDGs.

A SUSTAINABLE FUTURE; SDGS AND BLOCKCHAIN COLLABORATION

IPFS improves the storage and retrieval of data by allowing for decentralized storage and efficient access to massive amounts of data (Xu et al., 2021). Furthermore, big data technologies can manage large quantities of structured and unstructured data, enabling the processing and analysis of information from many sources. This expertise is essential for discerning public health patterns, forecasting disease epidemics, and enhancing healthcare provision. Urban planners may employ big data to comprehend population patterns, resource utilization, and environmental consequences, resulting in more intelligent and sustainable urban planning (Meier & Kaufmann, 2019). NoSQL databases enhance Big Data by offering adaptable, scalable, and high-performing options for managing data. These databases effectively manage unstructured and semi-structured data, enabling fast retrieval and real-time analytics (Oussous et al., 2017). Flexibility is crucial for effectively handling many forms of data created to pursue the SDGs, including social media data, sensor data, and multimedia content.

The hybrid model may successfully manage dynamic data environments and offer real-time insights into ongoing development initiatives by including NoSQL databases. Data mining techniques are used to discover significant patterns and insights from massive databases, uncovering hidden trends and relationships. This feature is precious for discerning employment trends and economic patterns and formulating policies that foster job creation and sustained economic growth (Rajesh & Kumar, 2020). Understanding consumption patterns and resource utilization allows for formulating policies to promote sustainable production and minimize waste. However, BI tools examine data for practical insights, aiding strategic decision-making by employing dashboards, reports, and visualizations, which strengthens the capacity of enterprises to make informed decisions based on data to promote innovation and develop robust infrastructure, hence facilitating sustainable industrial expansion. BI facilitates productive collaborations and the exchange of resources by offering stakeholders precise insights based on data (Lateef & Keikhosrokiani, 2023). Consequently, the integration of these technologies results in enhanced transparency, security, and efficiency, which builds trust among stakeholders, ensuring that resources are used efficiently, and the SDGs are pursued collaboratively.

The proposed hybrid model, which utilizes Ethereum, aims to contribute to attaining the SDGs by providing a vision of a future filled with numerous opportunities. By utilizing blockchain technology, this concept provides a way to achieve a more transparent, efficient, and inclusive method of seamlessly integrating and implementing the 2030 agenda for sustainable development (Sabbagh et al., 2021). Increased openness promotes trust and responsibility within the SDG ecosystem. Efficiency benefits and resource optimization are achieved using smart contracts, which streamline procedures. Local communities acquire increased autonomy over projects, promoting a sense of possession and propelling community-driven solutions (Aysan et al., 2021). Our concept incorporates a wide array of cutting-edge technologies, including big data, data mining, Ethereum, IPFS, and NoSQL databases, to create a cohesive and efficient system that promotes the attainment of the 17 SDGs. Integrating NoSQL databases into our system simplifies storing and managing many data types, commonly known as big data, enabling the creation of pertinent indicators in reports crucial for stakeholder decision-making and involvement. The approach can completely transform transparency within the SDG ecosystem using blockchain technology, which establishes a more advanced and equitable environment, giving communities more authority and ensuring that all participants are responsible for accomplishing the specified objectives.

The model integrates stakeholder voting and knowledge base sharing by utilizing the blockchain's distributed IPFS and Ethereum smart contracts; it enables a decentralized consensus process involving mapping SDGs at the local level, prioritizing their implementation through consensus procedures, and facilitating information exchange using the IPFS. Smart contracts' automated features can significantly improve streaming operations and ease administrative burdens in SDG initiatives, letting valuable human and financial resources be directed to essential project tasks and primary outcomes being reached (Mattila et al., 2021). By efficiently deploying resources, the model can expedite advancements toward the SDGs. Thus, it allows for the secure recording of data timestamps, regardless of their size, by skillfully integrating Ethereum's smart contract technology with IPFS, thereby bolstering data security.

The proposed hybrid approach utilizes advanced technologies to promote the integration and achievement of the 2030 agenda. The model is innovative in promoting stakeholder participation, facilitating informed decision-making, and ensuring data security and integrity. Blockchain technology may empower individuals by giving them more authority to manage and oversee SDG initiatives that directly impact them. This technology enables more control over the planning, execution, and evaluation of these projects (Jiang et al., 2023). However, the model must be constructed to be comprehensive and easily accessible to all parties involved, especially those who have limited technological and financial resources. The effective execution of this strategy depends on promoting cooperation among all stakeholders, i.e., governments, NGOs, enterprises, technical specialists, and local people. We can tackle the difficulties, improve the model, and investigate its practical uses in various SDG projects through collaboration.

RESEARCH IMPLICATIONS AND FUTURE DIRECTIONS

Researchers should focus on finding out what makes people accept and use Ethereum blockchain technology for achieving the SDGs, which includes checking to see how ready governments, businesses, and civil society groups are to use blockchain-based solutions and finding problems that make them difficult to use, like complicated technology, unclear rules, and cultural opposition. It is essential to look at the design ideas, architectural parts, and technical details of the suggested hybrid model that uses Ethereum to reach the SDGs, which includes coming up with ways to combine blockchain with other technologies that work well together, like the Internet of things, AI, and decentralized finance, to create a strong and connected system for promoting the SDGs. Another possible area of research is looking into how Ethereum-based decentralized autonomous organizations or similar structures can help with inclusive decision-making and governance processes in the pursuit of the SDGs, which could mean creating governance frameworks that let stakeholders work together to set priorities, distribute resources, and keep an eye on results clearly and effectively. Researchers could develop frameworks and methods to test how well Ethereum-based solutions work at achieving the SDGs, which would involve coming up with key performance indicators, metrics, and evaluation criteria to see how well the SDGs are being met. Additionally, it entails undertaking empirical research to study the socio-economic, environmental, and governance effects of applying the hybrid model in various settings.

It is crucial to enhance the capabilities of stakeholders, especially in developing countries, to ensure their efficient and advantageous utilization of Ethereum-based SDG models, which entails providing people with knowledge about blockchain technology and its practical uses in promoting sustainable development (Joshi et al., 2023). Therefore, integrating this model with the existing data collection and monitoring systems for SDGs at national and international levels would be necessary to achieve successful implementation. It is also beneficial to perform empirical research and case studies to confirm the efficiency and feasibility of the suggested hybrid model in real-world situations. This process requires carrying out pilot projects, creating samples in various contexts, and assessing their influence on advancing specific SDGs. Researchers can evaluate the enduring viability and socio-economic consequences of Ethereum-based frameworks for attaining the SDGs. This assessment considers environmental effects, social fairness, and economic robustness. Research may include longitudinal studies, stakeholder surveys, and participatory assessments to track progress, find unintended effects, and improve the design of hybrid models so they have the most positive effects on SDGs. By investigating these potential paths, scholars and professionals can contribute to the progress of the conceptual comprehension, practical application, and ethical management of Ethereum-based frameworks for sustainable development.

Finally, to address the limitations of the study, we may refer to the issue of developing a hybrid model that integrates Ethereum with other systems or technologies, which might be intricate. Incorporating blockchain into current infrastructure and guaranteeing compatibility among various technologies might present considerable technological and logistical obstacles. Furthermore, Blockchain technology, including Ethereum, operates inside a legal framework that is unclear in many places. The implementation of blockchain solutions for SDGs might be impeded by legal and regulatory issues, especially regarding data protection, financial transactions, and compliance with local laws. Nevertheless, implementing Ethereum-based SDG solutions can be constrained by insufficient technological proficiency and accessibility. Communities and organizations with limited access to blockchain technology or lack the necessary competence to use it may have difficulties reaping such models' advantages. Finally, numerous conceptual models rely on theoretical frameworks rather than real-world implementations, which might impede the comprehension of tangible obstacles and the efficacy of the hybrid model in attaining the SDGs.

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