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Blockchain Technology In Bridging Supply Chain Trust, Traceability, and Transparency

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Abstract

Trust, traceability, and openness are crucial in creating circular blockchain systems for supply chains.[1] The integrated Triple Retry framework is proposed in this study as a method for creating circular blockchain platforms. [2] to bridge the three circular supply chain reverse processes (recycle, redistribute, remanufacture) and the three factors influencing blockchain technologies (trust, traceability, transparency). A circular blockchain platform was built in a supply chain consisting of a manufacturer, reverse logistics service provider, collection center, recycling center, and landfill. The results illustrate the relevance of blockchain as a technical capacity for enhancing the management of waste transportation and product returns.[2]

Keywords **—**A smart contract, Circular economy, Reverse logistics service providers (R.L.S.P.s), Circular supply chain management, Circular blockchain, Distributed ledger, Platform design

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I. INTRODUCTION

Researchers are interested in learning how new technologies might aid businesses in attaining their environmental performance goals and meet the demands of stakeholders at home and abroad who demand that companies do more to promote sustainability. Blockchain technology is a possible solution in this scenario because it can improve the supply chain's trust, traceability, and transparency.[3]

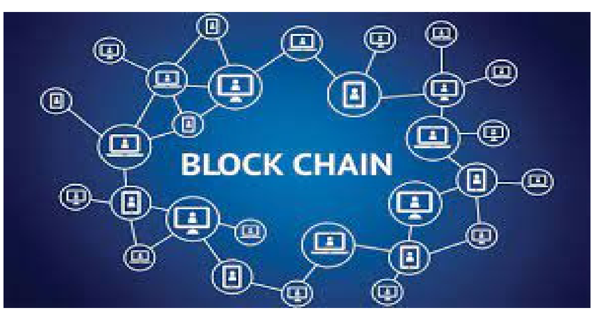

Fig. 1.Blockchain Technology Explained and What It Could Mean for the Caribbean[4]

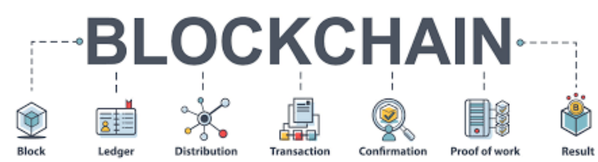

Fig. 2. Blockchain Traceability Applications [5]

Monitoring social and environmental circumstances to manage and prevent the onset of health and safety concerns is a crucial part of the usage of blockchain applications.[2]

Blockchain technology might be implemented at every point in the chain to ensure that all parties in a supply chain are treated fairly and with dignity.

For instance, if the product's production and distribution processes are documented, consumers may rest easy knowing that their purchases support environmentally responsible practices. Smart contracts may be able to do so on their own, well-suited to confirm the validity of sustainable regulatory conditions and policies.[6]

By eliminating mediators and speeding up transactions, blockchain has the potential to streamline the supply chain and cut down on unnecessary waste produced by businesses. To begin, blockchain technology's ability to lessen workload while simultaneously bolstering trustworthiness and security is a significant plus. Examples of this may be seen in the fact that conventional energy systems, for example, have a top-down management structure and include significant pressure dips over vast infrastructure networks.[2] On the other hand, Blockchain-based peer-to-peer networks can decrease network amplitude, significantly reducing energy lost over long distances and the need for fewer storage facilities. That is why several blockchain-powered solutions aim to reduce supply chain inefficiencies.

Second, blockchains can verify the authenticity of eco-friendly goods on the market. One such example is the acceptance of a forest certification scheme that uses blockchain technology to trace the provenance of the roughly 740 million acres of certified forests worldwide. Thirdly, the blockchain can provide better recycling performance in the context of a circular economy. In Northern Europe, for instance, people are incentivized to recycle by receiving digital tokens as compensation. The blockchain-based Social Plastic initiative has shown how plastic waste may be reduced while generating revenue.[7]

Trust, traceability, and transparency are essential in creating circular blockchain platforms based on these premises in supply chains. The research establishes the need to connect the three circular supply chain reverse processes (recycle, redistribute, and remanufacture) and the three primary factors influencing blockchain technologies.[8]

II. LITERATURE REVIEW

This section presents the main results of a literature review conducted to analyse blockchain's state of the art in circular processes.

Using two academic databases (Scopus and Web of Science) from 1960 to 2020 and a set of selected keywords such as "blockchain*" AND "block chain*" in combination with circular economy and supply chain keywords (e.g., "circular economy," "circular process*," "circular supply*," "closed loop*"), the search was conducted to ensure a high level of the rigor of systematic literature review.

Three main topic areas are identified: 1) blockchain and circular economy, 2) blockchain and supply chain management, and 3) blockchain and circular supply chain. Three main subsections will be included to describe and discuss the literature in these three areas.[2]

1.1 Blockchain and circular economy

In the circular economy (C.E.) realm, blockchain and smart contracts can be viable solutions for counterfeits, data security and privacy, operational expenses, and bureaucratic obstacles.

Firstly, the C.E. is a mature sector in which most dynamics are well standardized, and a wide variety of valid key performance indicators are available for usage, providing the necessary inputs for intelligent contract coding.

Second, the C.E. ecosystem is a multi-layered mix of material streams from suppliers, manufacturers, logistics service providers, distributors, and retailers that generates substantial data. Intelligent contracts can process vast amounts of data in seconds, eliminating intermediaries and decreasing transaction costs. Thirdly, much information and data are shared between parties since communications and collaborations are prevalent in the C.E. network. The connection between distributors and consumers is evolving, fourthly. A new dynamic distributor-to-consumer (D2C) process highlights the need to define the function of an innovative contract-based model that may enhance the efficacy of D2C transactions and deter counterfeiting.[2]

In the field of C.E., blockchain technology has several uses. Achieving sustainable development was examined to balance social, economic, and environmental concerns. Blockchain systems will streamline energy supply operations, minimize demand volatility, and enable real-time production of the market's necessary amount. This would allow for the optimization and conservation of natural resources.

1.2 Blockchain and supply chain management

With the advent of Industry 4.0 enabling technologies, supply networks are undergoing a profound transformation. According to Saberi et al., supply chains are becoming increasingly complicated systems, with the management of new partners and the evolution of existing ones geographically dispersed and rigorous focus on satisfying progressively more demanding consumers.[2]

Moreover, traceability and openness have become essential criteria in a multinational supply chain. Utilizing modern RFID and G.P.S. technologies, for example, blockchain technology, may enable the development of supply chains with high levels of traceability and transparency and address environmental, financial, and social sustainability challenges.[6]

Previous technologies, including Electronic Data Interchange (E.D.I.) and other similar technologies, enabled businesses to transition from paper-based to paperless transactions. E.D.I. permits the computer-to-computer exchange of documents in a standard electronic format, resulting in cheaper costs, quicker processing, fewer errors, and improved partner traceability.

Blockchain can influence the supply chain, particularly as a potential successor to E.D.I. for sharing information rapidly and effectively between partners. Adopting blockchain technology can be a game-changer for the supply chain, eliminating its weaknesses and inefficiencies.[8]

In a typical supply chain implementation of E.D.I., data processing and exchange are managed by distinct systems.

However, blockchain technology may retrieve data, information, and knowledge flow in a supply network from a centralized source.

On the other hand, E.D.I. and blockchain may be complementary rather than competitive technology. E.D.I. is a method of exchanging data that blockchain may store in its ledgers, intelligent process contracts, and share and exchange via its consensus mechanism.

It is anticipated that global supply chain platforms utilize blockchain technology on E.D.I. networks to facilitate information sharing between firms and supply chain performance. Each event is evaluated and recorded to create an immutable and transparent log. Consequently, the deployment of blockchain in supply chain networks has the potential to mitigate the problems that are so frequent in conventional management systems.[7]

1.3 Blockchain and circular supply chain

The supply chain applications of blockchain are still subject to interpretation and development. Although most blockchain applications utilize public privacy systems, blockchain-based supply chain networks may necessitate a more restricted, private, permissioned blockchain with a limited number of participants.[2]

Depending on the function of each supply chain member, the administrators choose which data may be shown and added. The blockchain's intrinsic configuration organizes transaction nodes. It specifies their responsibilities in accessing or modifying the blockchain and maintaining the Identification of each member in the supply chain network using the blockchain. Therefore, authorities must specify the function of each member in the supply chain through consensual procedures so that no one feels disadvantaged.[1]

In a blockchain-based supply chain, four entities play a crucial role: the certificate authority (which provides unique identities to the actors in the network), the network administrators (who define standards schemes, such as blockchain policies and technological requirements for the network), the membership service provider (which provides

certifications to the actors for participating in the network), and the other actors (such as manufacturers and reverse logistics service providers).[3]
At least five essential product characteristics may be highlighted and specified using blockchain technology: nature, quality, quantity, location, and ownership.
In this approach, the blockchain allows an organization to define responsibility for the quality of the product or service while also allowing customers to examine the product's history, from raw ingredients to finished products.[1]
In the circular model of the supply chain, blockchain applications are prevalent, particularly in the garbage industry. Swachh coin, for instance, is a blockchain-based platform for micromanaging home and industrial trash that converts it into valuable goods efficiently and ecologically responsibly. A vast array of raw minerals with significant economic value may be extracted from processed garbage. The Swachh ecosystem is a decentralized autonomous organization (D.A.O.) administered autonomously by pre-set brilliant contract instructions. Swachh coin employs many cutting-edge technologies to perform an iterative process cycle, rendering the system fully autonomous, efficient, and productive. This iterative process cycle focuses on the data exchanged by ecosystem participants, assesses this data, and gives real-time recommendations based on predictive algorithms.[2]
A supply chain based on blockchain technology provides a new circular business model. The blockchain-based supply chain enables the implementation of a make-use-recycle paradigm, whereas linear supply chains are mostly built on the take-make-dispose model. Using the blockchain, it is possible to trace all items along the whole supply chain, from origin to market and recycling. The benefit of this strategy is that all items can be monitored using blockchain technology, making it feasible to offer substantial services to end customers, such as certifying the product's provenance.

III. The conceptual framework for the circular blockchain technology

From the material reviewed, Figure 3 depicts a typical circular supply chain process illustrating the movement of commodities and information before and after the deployment of blockchain technology. The circular value chain has two material flows a linear loop and a closed loop. The first is a loop of the direct material stream, whereas the second is concerned with reverse material. There are several ways for materials to circulate through the loop, such as remanufactured, redistributed, or recycled materials. However, the direction of information flow varies based on blockchain technology. Following the adoption of blockchain, each actor can exchange information with all supply chain partners. Every transaction is handled by a smart contract and recorded in a block. Thus, any participant in the supply chain can query the system for information on items and procedures.[2]
The following sections analyze the role of blockchain technology in bridging trust, traceability, and transparency to the circular supply chain operations depicted in Figure 3.

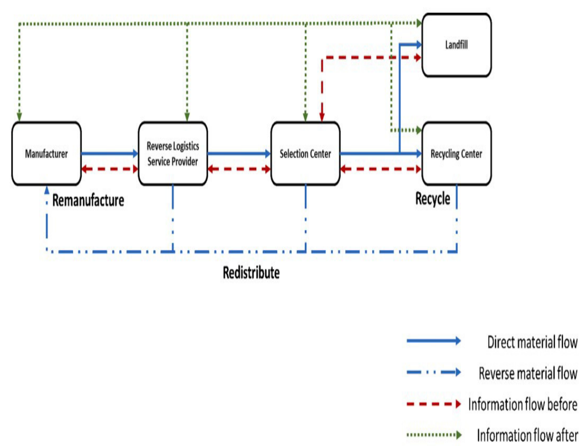

Fig. 3. Representation of typical circular supply chain reverse processes.[2]
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The following sections analyse the role of blockchain technology in bridging trust, traceability, and transparency to the circular supply chain operations depicted in Figure 1.

3.1 Traceability

During manufacture and distribution, traceability allows tracking items and giving information about them (e.g., authenticity, components, and whereabouts). The visibility and traceability of the supply chain are receiving a rising amount of focus from researchers.

In response to these issues, buyers want more traceability and understanding of the origin of products from producers and merchants.

Therefore, the actual economic and social issue is to close the control-related traceability gap in the supply chain, regardless of whether the production is ethical, sanction-compliant, or safe. Due to the complexity of supply chains and product movements over vast networks, determining the origin is frequently challenging. This complexity necessitates monitoring products across their entire life cycle, from raw material acquisition to manufacture, distribution, and consumption.[2]

Origin Chain is an example of supply chain traceability architecture given by Xu et al. Origin Chain utilizes many private blockchains that are geographically dispersed to the traceability service provider. The objective is to develop a reliable traceability platform integrating other organizations, such as government-accredited laboratories, significant suppliers, and merchants with close ties to the enterprise. Our platform is more efficient and less expensive than a public blockchain. Origin Chain keeps two data types on the chain as variables of intelligent contracts to be preserved: the hash of traceability certificates and the regulatory-required traceability data.[3]

3.2 Transparency

Transparency is the degree to which information is readily available to trading partners and outside observers. Transparency is consequently a vital metric for evaluating the performance of the supply chain, given the blockchain's evolving safe environment. Even before reaching the end consumer, items transit through a vast network of many players (e.g., extractors, manufacturers, merchants, distributors, conveyors, and storage facilities).[6]

This way, it is feasible to manage clear and correct information for each process, ensuring compliance, safety, and precision while concentrating on sustainability and social responsibility standards. Current markets necessitate supply chain information transparency and environmentally and socially sustainable economic dynamics.

IV. DEFINITION OF THE TRIPLE RETRY FRAMEWORK

This study presents a blockchain-based circular supply chain architecture that combines trust, traceability, and transparency, beginning with an analysis of the most critical aspects impacting reverse circular supply chain activities (Fig. 4). The suggested Triple Retry architecture seeks to bridge the three circular supply chain reverse processes (i.e., Recycle, Redistribute, and Remanufacture) and the three key elements influencing circular blockchain technology (i.e., Trust, Traceability, and Transparency) described before. The Triple Retry architecture may be utilized to build circular blockchain models and deploy blockchain systems.[1]– [3], [7]

The interactions between partners in the supply chain are founded on mutual trust; each participant has faith in the integrity of the others. This confidence enables the supply chain to boost its networking responsiveness. After incorporating blockchain technology into the supply chain network, each contact between participants is documented via a smart contract. However, the distributed ledger is another property of blockchain technology. In this manner, by reducing information distortions and improving communication velocity, the supply chain is pushed toward a high degree of openness, strengthening cooperation.

The information recorded in the blockchain provides those who can use it the capacity to trace all transactions, enhancing supply management performance, reducing not just the cost of distribution systems but also recall expenditures, and expanding the sales of items with complex qualities. Nevertheless, comprehensive network traceability develops the second degree of trust in which each player raises his or her confidence in the network.[8]

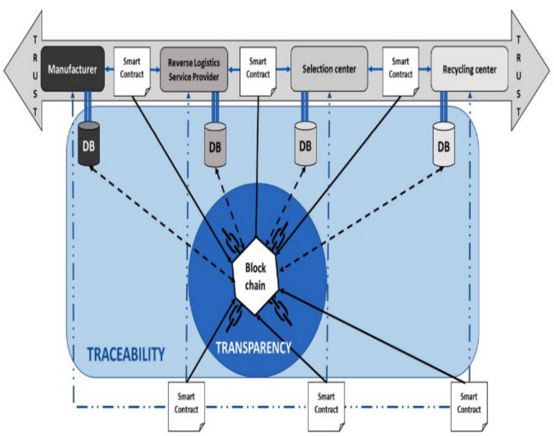

Fig. 4. Triple Retry framework.[2]

1.4 Technological environment

As previously mentioned, blockchain is a system based on the notion of the distributed database. Data is not saved on a centralized server (Client-Server) but rather on a network of networked machines, called nodes (nodes) Peer-to-Peer). The blockchain enables the innovation of current transaction management through a procedure that links distributed cryptographic primitives essential for ensuring the security and traceability of data. The existence of information on all network-connected equipment is the primary benefit of distributed systems in the circular economy area. This type of database is based on two core processes that are effective for ensuring accurate operations and minimizing data loss to zero.[1]– [3], [6]– [8]

1. Database replication: there is software to identify any logical internal change to the database; once the database has been identified, this software allows replicating the change on all the machines connected to the circular economy network.
2. Duplication: This is an excellent process to ensure that the same data is present on each machine connected to the circular economy network. This process allows identifying a master database that will be taken as a model to be duplicated on all the other devices on the network.

The functioning of the blockchain is based on the following components: -

1. Transaction: Logical processing unit which coincides with a sequence of elementary operations that need to be verified, approved, and then archived
2. Node: Representation of a single blockchain actor and physically constituted by a server
3. Block: Logical unit represented by the union of a set of transactions that are grouped to be verified, approved, and archived
4. Ledger: Master book in which all transactions are immutably recorded and sequentially ordered
5. Hash: Non-invertible algorithmic function allows to represent of a text and numeric string of a variable length in a unique string of predefined length

The blockchain is a block of blocks. In this context, a block is the collection of related transactions that must be validated, accepted, and recorded by the nodes participating in the circular economy network.

Therefore, a block may be viewed as a container of transactions containing information necessary to chronologically and geographically reassemble the blockchain. Each block has a reference called hash, which is situated in the header and stores the information for the block at position "n" and the block at position "n-1" Based on this approach, the whole blockchain may be constructed.[6]– [8]

From an I.T. standpoint, the hash, or fingerprint, is the outcome of an algorithm known as the hash function. Hash functions contain two key characteristics:

1. They are distinguished by an input string of indeterminate length and an output string of predetermined length;
2. They are irreversible functions. Each block includes a hash, which enables a safe and unique identification; the hash also enables the building of a spatial map of the whole blockchain, continually updated as new blocks are added.

In addition to the hash, the block also contains a timestamp due to timestamping. This method consists of a precise sequence of characters that enables the unambiguous Identification of blocks and, consequently, their transactions. This timestamp permits the creation of a timeline map that may be used to comprehend the order in which transactions occur. In conclusion, in a distributed system applied to a blockchain, it is crucial to know the hash and the temporal brand to rebuild the spatial and temporal chain of blocks. Instead, the transaction comprises the following information:

1) the I.P. address of the sender and receiver;

2) the cryptographic signature required to ensure the transaction's security; and

3) information on the transaction's content and features.

As the number of transactions fluctuates continuously over time, the blockchain can be continuously updated on all network nodes; this is made possible using cryptographic primitives that guarantee the system's correct operation. Moreover, the transactions are immutable; any modification requires the agreement of all network nodes. The blockchain can facilitate various transactions, including dyadic interactions between partners and the administration of contract-related information via smart contracts. In the ledger, all transactions are recorded with the most incredible clarity and in a manner that cannot be altered.[3], [6], [7]

Several blocks are joined using cryptographic primitives and hash to compose the ledger. The blockchain implements the distributed ledger, representing centralized and decentralized logic progression. In the centralized logic (centralized ledger), each transaction is controlled by a central node with a centralized authority that functions as an intermediary and checks the accuracy and security of information. In the case of decentralized logic (decentralized ledger), there is no central authority to whom one may refer; instead, more central topics are arranged according to the logic of local centralization.

The blockchain is built on distributed logic, and there is no longer a central authority amongst the parties in the circular economy network.

Consensus between network nodes in the circular economy, essential requirements in a centralized system, is replaced by cryptographic primitives and protocols, and the role of intermediary nodes is abolished permanently. In blockchain systems, there is no central point of vulnerability that may be exploited to compromise the system.

These qualities separate blockchain significantly from centralized databases. The modification of a transaction within a block necessitates the modification of the value identifying that transaction and, subsequently, the modification of the block containing the modified transaction. This update should be implemented concurrently with current technology. These criteria ensure the confidentiality of the network's data.[8]

Regarding the mechanism that leads to the creation of blocks from transactions, the interaction with the system follows the steps below:

1) Creation of the transaction and the public cryptographic key;

2) creation of the block containing the transaction above;
3) verification and approval of the block by the actors of the circular economy network;
4) verification of the truthfulness of the information by the actors of the circular economy network;
5) evaluation of previous checks and additions to the block to the network;
6) authorization and validation of the transaction, and
7) public dissemination of the transaction.

V. RESEARCH APPROACH

The research aims to evaluate the circular supply chain management processes and identify the technical and functional specifications that the blockchain's technological architecture must possess to facilitate the development and consolidation of the relationships between the various actors of the circular supply network. In particular, the features of the reference sector, the socioeconomic and technical background, and the enterprises' innovative, technological, and production processes will be considered.[3]
A single in-depth case study (Yin, 2009) was accompanied by primary data gathering conducted directly within the organization: interviews, mapping of supply chain circular processes, operations, skills and timings, and validation workshops. Additionally, secondary data were collected, such as order reports, order modification reports, databases from the previous twelve months, activity descriptions, ERP reports, Excel reports, product requirements, and monthly/quarterly reports. Secondary data were utilized to connect and triangulate primary data sources. Triangulation of data was required to improve the validity and reliability of this study. The initial data gathering involved more than 80 hours of direct contact:[1]

1. Interview with supply chain, operations, and information management department managers.
2. Direct observation of shadowing procedures. The researchers tracked a sample of operations throughout the procedure, charting and timing the activities.

Other data gathering methods employed over the study's 12-month duration included:

1. Active distant dyadic contacts (back and forth). Multiple queries and explanations via the phone, email, and Skype, for instance.
2. A session on validation with management

The deployment of a blockchain-based platform in the circular economy sector is favored, especially for small and medium-sized enterprises that deal with waste management for organizations in high-tech and sophisticated industries. The innovative waste management company analyzed in this study is based in the south of Italy and offers industrial waste disposal services to multinational automobile and railway manufacturers. Its current location and facilities are in a district that is nationally significant for mechanical and railway engineering and production. Sustainability management is a significant aspect of a complicated sector, and rethinking waste management methods is crucial. Thus, this inquiry environment appears appropriate.[3]

VI. DESIGN OF THE CIRCULAR BLOCKCHAIN PLATFORM

This section addresses the circular blockchain platform's design and execution and is this study's empirical contribution. The design process for the use of a blockchain-based platform for the circular economy consists of two major phases:

1. PoC framework design and deployment
2. Modelling of circular supply network

The following paragraphs offer a comprehensive description of each step.

1.5 PoC framework planning and implementation

In computer science, a Proof of Concept (P.O.C.) is a tangible demonstration of the fundamental functions of a software program or a complete system integrated into an existing environment.

P.O.C. development is used to show a software or computer system vulnerability, the exploitation of which may allow unauthorized access to the system's data or compromise its operation.[2]

The research team participating in this study opted to implement this structure using Hyperledger Fabric, an open-source initiative launched by the Linux Foundation in 2015 to facilitate blockchain construction. Hyperledger Fabric is distinguished by its modularity, which enables the definition of consensus mechanisms and membership management.

Permissioned blockchains, in contrast to permissionless blockchains, operate within a group of known, acknowledged, and often confirmed participants that adhere to a governance framework that gives assurance. A permissioned blockchain is a method for securing interactions between entities with a common goal but may not fully trust one another. All operations, including submitting application transactions, modifying network settings, or executing a smart contract, are recorded on the blockchain according to a previously agreed upon endorsement policy. The responsible party is rapidly identified, and the occurrence is handled following the governance model's standards. In this setting, the likelihood of a participant inserting malicious code via an intelligent contract decrease. Permissioned blockchains often utilize Crash Fault Tolerant (C.F.T.) or Byzantine Fault Tolerant (B.F.T.) consensus algorithms that do not require expensive mining. Exceptionally, for a single organization, a fully byzantine fault-tolerant consensus protocol may be unnecessary due to its potential impact on performance and throughput; a C.F.T. consensus approach may be more appropriate. However, the classic B.F.T. consensus technique is necessary for decentralized multi-party applications.[2]

Hyperledger Fabric also enables the creation of private channels, enabling a group of participants to create a ledger in which all transactions are recorded in complete secrecy and can only be viewed by the nodes that participated in the ledger's creation, which is a fundamental requirement for the development of a supply blockchain. Compared to other private and permissioned systems, Hyperledger Fabric was chosen due to its stability, flexibility, and conformance to the unique functional requirements (e.g., 100% control of network access, transactions, and information amongst all network participants). In addition, Hyperledger Fabric has a modular design that is entirely configurable and capable of addressing a variety of data privacy and cloud setup needs. Cloud configuration was required to install blockchain at the level of the supply chain. Hyperledger Fabric is interoperable with the top cloud service providers, including I.B.M. Bluemix, Microsoft Azure, Google Cloud Platform, and A.W.S. Amazon Web Services. Consequently, it was chosen as the best platform to satisfy the defined functional requirements.[3]

The blockchain application is set up on-premises now. Installing software on-premises involves installing it on a local device, such as a machine that physically exists within the organization that utilizes it or is still owned by it (a company server). The following software components are employed:

- Operating System: Windows 10 64-bit, Ubuntu Linux 14.04 / 16.04 LTS 64-bit
- Virtual Machine: Oracle Virtual Box
- Required software: Code editor VSCode and Atom editor plugins; Docker Engine: 17.03; Docker-Compose: 1.8 or higher; JavaScript SDK; LoopBack Connector; Node: 8.x or higher; npm: v5.x; git: 2.9.x or higher; Python: 2.7.x; REST Server; Yeoman code generator.

1.6 Modelling of circular supply network

The network depicted in Figure 3 was utilized to identify the principal actors involved as nodes in the to-be-developed blockchain platform.

The particular testing network comprised:

This node symbolizes the manufacturing business that maintains dyadic ties with the R.L.S.P.

This node establishes the governance architecture of the blockchain network and represents the reverse logistics service provider analyzed in the case study.

This node distinguishes between non-recyclable and recyclable garbage.
This node gathers recyclable trash and transports recycled materials to M.
This node disposes of non-recyclable waste materials.
A differentiated waste management system relies on the following material flow:

1. The Reverse Logistics Provider gathers and transports the garbage to a Selection center.
2. The recycled product is sent to a recycling facility, which creates production-cycle-relevant materials.
3. Selection centers and Recycling centers reject non-recyclable materials sent to landfills.

A crucial feature of the circular blockchain platform is the ability to construct private channels for conducting transactions with each of the network's players, allowing the individual companies to protect the privacy of their data and so increase their position within the network. On the other hand, the circular blockchain platform enables the presentation of any waste and document transit across network nodes while it does not actively engage in activities. In addition to improved transparency in the origin and dependability of the given waste services, this would also simplify the control of potential product returns.

1.6.1 Identification of the partners in the circular supply chain

Figure 4 illustrates the essential characteristics required for finding circular blockchain partners. The primary functional needs for constructing a circular blockchain platform were determined using these characteristics. The functional requirements determine the authorizations necessary to see and authorize transactions. Based on a private and permissioned blockchain approach, the Reverse Logistics Management Provider can view and approve all transactions. In contrast, the Manufacturer, Selection center, Recycling center, and Landfill can only view and approve their transactions.[7]

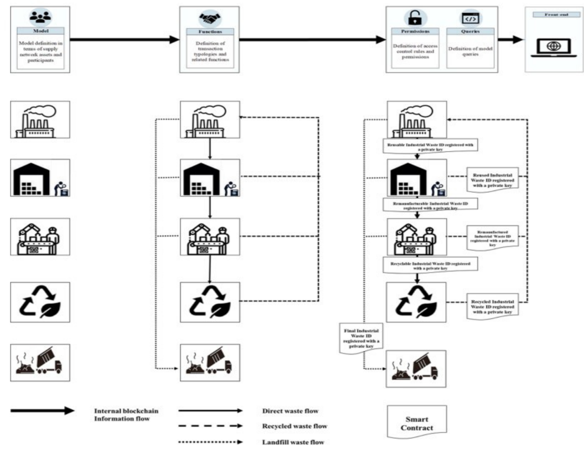

Fig. 5. PoC framework and business network deployment.[2]

VII. DEFINITION OF PROPERTY

An asset is any business's possession that may be converted into cash. Developing and implementing asset traceability saves administrative expenses and streamlines the business, enhancing the quality of customer service and promoting the organization's scalability. These activities promote organizational effectiveness: warehouse, offices, and inventories become automatically available, minimizing waste in management expenses and enabling the administration of corporate assets to anticipate demands.[6]
The Waste and Document classes in the created business case reflect network transaction assets.
The Document class is distinguished by its I.D. Protocol and Type attributes:
- I.D. Protocol

1. ID: I.D. is a code that uniquely identifies a document.
2. Protocol Type (P.T.): The P.T. indicates the type of Document that will be transferred across the network.
3. Notes.

- Type

Request for Quotation In addition to the price, RfQs typically include payment information such as terms and due dates.[1]

Quotation (Q): Q is the list of services that the R.L.S.P. is ready to sell under the stated terms.

A statement of Work (SoW) is a document that specifies the expected activities, tasks, outcomes, and deadlines. In addition to needs and costs, this Document covers terms, regulatory, and governance conditions.

Waste Service Order (W.S.O.): The W.S.O. is a business document that provides the first formal offer given by a Manufacturer to an R.L.S.P., including the types, duties, and agreed-upon rates for services. When both parties agree, a W.S.O. that does not represent a final contract can function as a legally enforceable document.

Delivery Plan (D.P.): A DP is employed if delivery time specifics are available at the contract specification. A DP is not an actual program but rather a program solution for the rapid development of W.S.O.

Quality Notification (Q.N.): A QN is a document that describes the conformance of a service to a quality criterion and contains a request to take corrective action.

Waiver (W): W is an agreement or supplementary provision attached to a policy that excludes a particular type of loss, restricts the claim amount to a predetermined amount, and expands coverage to encompass goods not covered by regular insurance.

Classification of the Product by Waste ID and Category:

- Waste Identification Number: 1 is represented by Part Number Serial Number.

Trash Category (W.C.): W.C. denotes the waste category relating to the classifications indicated in the next section.

Waste Management Service (W.M.S.): The Waste Management Service (W.M.S.) code reflects the specific waste management service supplied.

Notes.

- Category:

Solid (S): Classification of solid substances.

Liquid (L): Category of liquid substance.

Gaseous (M.E.): Classification of gaseous substances.

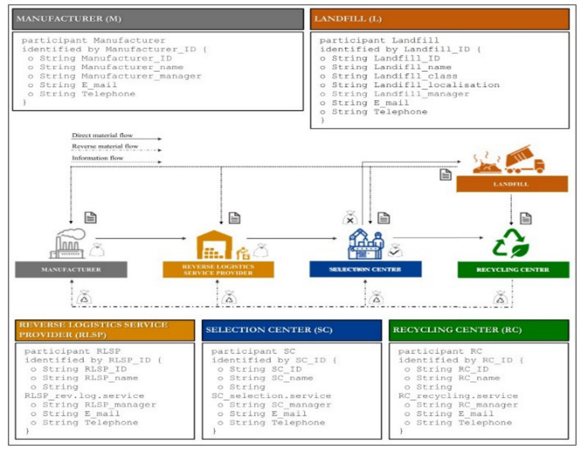

Fig. 6. Identification of circular blockchain partners.[2]

VIII. ANALYSIS OF THE MOST SIGNIFICANT DEALS

The classes Move Waste and Send-Document define the operations that will be conducted on the circular blockchain. On the distributed platform, these operations will be logged. All waste movements inside the network and the associated paperwork will be individually and permanently traceable. Thus, the various nodes will have a platform capable of overcoming the issues associated with integrating information from disparate information systems, which frequently substantially influence management expenses.[6]–[8]

IX. DISCUSSION OF OUTCOMES

This section employs the Triple Retry paradigm to explore the influence of blockchain technology on the circular supply chain. Consider the suggested blockchain platform a prototype deployment for analysing and discussing the consequences on the circular supply chain. Therefore, blockchain technology's pre- and post-implementation characteristics are explained by examining the influence on trust, traceability, and transparency in the analysed circular supply chain operations:

recycling, redistribution, and remanufacturing.[2], [8]

1.1 Impact of Blockchain on trust

Implementation of blockchain technology affects the idea of trust among participants in managing the circular supply chain. Regardless of the lack of a central authority, storing and preserving data, information, and transaction records in a decentralized and distributed ledger fosters trustworthiness and confidence among supply chain stakeholders.

1.2 Impact of blockchain on traceability

Traceability emphasizes the dynamic tracking and tracing of direct and indirect material, and information flows through the circular supply chain. Before the deployment of blockchain technology, tracking systems necessitated the use of labor resources for the collecting, storage, and delivery of up-to-date. They verified information about the localization of products. To control the technical specifics of status tracking, distinct businesses utilized diverse traditional approaches.

1.3 Impact of blockchain technology

The need for openness in circular supply chain activities inspired the impetus to create and execute a blockchain platform. Eliminating centralized authorities improves transparency, which impacts the method of collaboration between partners in the circular supply chain. Moreover, blockchain technology's intrinsic mechanism for preventing tampering contributes to its increased transparency.

The storage of distributed records on a blockchain platform increases the transparency of the flow of process status data, enhancing the operational efficiency of both individual businesses and the circular supply chain in terms of time efficiency and system automation.

X. ADDITIONAL EFFECTS

Using private and permissioned ledgers on a blockchain platform enables faster throughput and reduced latency regarding blockchain's influence on operational performance. Second, the absence of a blockchain system in a supply chain necessitates many manual inspections and transactions, which involve many intermediaries and create efficiency issues. A blockchain and intelligent contract-based strategy may decrease human registration and verification and automate several supply chain operations and activities, increasing efficiency.

XI. CONCLUSIONS

In the realm of the circular supply chain, there is a nascent and fast-expanding body of blockchain literature, according to the report.

In addition to the substantial theoretical contribution, the growing interest in the topic necessitates additional empirical research on the design and implementation of blockchain platforms (Avital et al., 2016) ;) In order to better understand the viability and actual benefits of this enabling technology. Brennan et al., Kim and Laskowski, and Carter and Koh all emphasize the need to strengthen current supply chains using blockchain technology, focusing on the implications of trust, traceability, and transparency.

In order to integrate the three reverse supply chain processes (i.e., recycle, redistribute, remanufacture) and the three main factors that influence circular blockchain technologies (i.e., trust, traceability, transparency), this paper proposes an integrated Triple Retry framework for designing circular blockchain models and implementing blockchain platforms.

This paper explores the use of blockchain technology in a circular supply chain. It directly impacts the trustworthiness, traceability, and transparency of reverse supply chain activities and transactions. This work contributes to the supply chain literature by illustrating the design and implementation of circular blockchain models and platforms.

It outlines the primary aspects required for determining the primary functional needs for constructing a blockchain platform, setting the rights to see and approve transactions, and identifying and monitoring the assets of performed network activities. On the distributed platform, these operations are logged. In this manner, all network trash transfers and associated paperwork may be individually and permanently tracked. Therefore, the many stakeholders in the circular supply chain have access to a digital platform capable of overcoming the issues associated with integrating information from disparate information systems, which frequently substantially influence management expenses.

Using the suggested Triple Retry paradigm, the influence of blockchain technology on the investigated circular supply chain has been evaluated. Precisely, pre-and post-implementation blockchain technology characteristics are elucidated by examining the three primary factors (i.e., trust, traceability, and transparency) influencing the investigated circular supply chain processes, namely recycling, redistribution, and remanufacturing.[2]

XII. IMPLICATIONS

As for the theoretical ramifications, this research contributes to supply chain theory by giving theoretical and practical consequences based on the technical advancements of Industry 4.0 and the circular economy. By constructing a theoretical model that applies blockchain technology principles to the supply chain, it has been possible to comprehend how it is possible to combine the characteristics of these principles in a circular supply chain domain and how this synergy has positive implications for the conception and execution of its transition towards a circular economy. Specifically, it has highlighted how to tie the blockchain ideas of trust, traceability, and transparency to circular supply chain management procedures.[8]

XIII. LIMITATIONS

This research is based on a detailed instance of a single circular supply chain that will be evaluated shortly in many scenarios.

However, it may be claimed that the results are generalizable, and future studies will explore the influence of blockchain on other supply chain processes and players, including customer-supplier dyadic connections and supply network ties.

XIV. FUTURE DIRECTIONS

The supply chain and blockchain applications will undergo significant upheaval in the foreseeable future. In this perspective, time-limited privacy in blockchain and transactional privacy plays a crucial role in allowing applications where privacy is governed and protected by rules.

In addition, it is necessary to conduct additional research on the role of blockchain technology in managing the trust, traceability, and transparency of public and private companies operating in developing countries to highlight the research advancements and contrast them with those of developed nations.

Lastly, an additional study path focuses on the possibility of adopting blockchain technology to bridge the trust, traceability, and transparency elements that impact the flow of knowledge during pandemics.[2]

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