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Abstract: -

Seafood is one of the most widely traded food commodities in the world, valued at over USD 150 billion annually. Yet, beneath this thriving global market lies a critical challenge ensuring authenticity, traceability, and sustainability. Illegal, unreported, and unregulated (IUU) fishing contributes to nearly 20–30% of global catches, posing severe threats to marine ecosystems and economic stability. At the same time, seafood fraud, including species substitution and mislabeling, continues to erode consumer trust and hinder sustainable practices.Conventional traceability systems, dependent on centralized databases and manual record-keeping, are often inefficient and susceptible to manipulation. In contrast, blockchain technology offers a transformative solution through its decentralized, transparent, and tamper-resistant ledger. By enabling secure and immutable recording of transactions across all stakeholdersfrom fishers and processors to distributors, retailers, and regulators blockchain fosters trust, accountability, and real-time traceability.This paper investigates the potential of blockchain to revolutionize seafood supply chains by delivering end-to-end transparency and promoting sustainability. It proposes a conceptual framework that integrates digital innovation with stakeholder collaboration to address existing traceability gaps.

Keywords: -supply chain, Blockchain, smart contracts, Traceability.

I. Introduction

The consumption of fish has increased significantly in the last few decades due to population growth and shifting consumer habits. In the human diet, fish has grown in importance as a source of protein. Gephart et al. claim that while fish consumption is rising annually, the seafood sector is likewise evolving. Half of the seafood produced worldwide is currently produced through aquaculture [1]. If non-food applications are taken out of the equation, aquaculture currently accounts for 53% of the consumption of fisheries products [2]. Since the late 1980s, the output of catch fisheries has been rather stagnant; therefore, aquaculture has had to adapt to the changing preferences of consumers. Food safety is now a crucial marketing concern in addition to a public health concern. Customers want to know exactly what they are purchasing or consuming. Governments, like the European Union, are putting out directives that mandate the registration of a product's origin [3], enhancing product traceability and expediting recalls when needed. The benefits of traceability in networks of fish supply are examined by the writers of [4].

In order to identify the information that must be gathered on a common platform to support

the traceability of fish and fishery products from the sea or aquaculture farms to the plate, the main goal of this paper is to identify all stakeholders involved and understand the business processes involved in the value chain of fish products (capture and aquaculture). In order to accomplish two major goals, the project's analysis phase is being described in this article. The project's goal is to create a traceability platform.

- To provide the opportunity for end customers to become fully informed about the fish product they are purchasing. The buyer needs to be able to provide information about the fish's origins (where it was raised or captured), its creator or capturer, when it was captured, how it was stored, where it was transported, how it underwent transformation, and other details.
- If a product lot needs to be recalled due to food contamination or another harm to the public's health, to provide the authorities with the information regarding the fish. All fish that are raised or captured at a specific location on a given date, whether they are delivered by a specific vehicle or kept in a specific warehouse, etc., will be listed on the platform.

One of the primary sources of protein in the human diet is fish and fish products. Gephart et al. claim that while fish consumption is rising annually, the seafood sector is likewise evolving (5). Since the late 1980s, fisheries production has been almost stagnant worldwide, meaning that the majority of the increase in fish consumption has been attributed to aquaculture production (5), which currently accounts for half of the world's seafood supply. Simultaneously, buyers are growing more picky and expect to know not just the nutritional worth of the fish they purchase, but also where it comes from and how well it is preserved throughout the supply chain. To do this, it is essential to monitor every action taking place along the whole fish value chain, from aquaculture or capture to supermarket or plate. The origin (wild or aquaculture), as well as the who, what, when, and where of its capture (or raising), transportation, storage, transformation, and other details, must be known. Stated differently, the implementation of traceability is crucial throughout the entire value chain of fisheries. However, fish may go through multiple businesses during the manufacturing or catch process before reaching the final consumer. This implies that a single fish or fish lot may be used in the operations of multiple businesses. Therefore, in order to fully understand the history of the fish, it is imperative that the internal procedures of each organisation participating in the value chain be integrated. The merging of these processes has been suggested in (6). In this paper, we propose to use blockchain technology to implement traceability in the fisheries value chain. This is primarily because blockchain technology is ideal for product traceability, allowing all chain

activities to be registered in a distributed, transparent, secure, and reliable manner. These days, blockchain is thought to be among the technologies that best satisfies supply chain traceability requirements. (7) Permissioned public blockchains (hybrid blockchains), permissioned private blockchains (closed networks), and permissionless public blockchains are the three categories into which blockchains can be divided (7,8). Here, we make advantage of Ethereum, a public blockchain with no permissions. Many actors in the fishing industry are able to access and change data due to the lack of an open supply chain, which is clearly against accepted legal and ethical standards. The fishing sector is notorious for engaging in illegal, unreported, and unregulated (IUU) activities include fraud, overfishing, and abuses of human rights [9]. To address this issue, fully traceable and transparent fisheries supply chains are necessary, and blockchain technology can help with that [9]. The scope of effective product traceability systems has increased due to the rising acceptance and popularity of digital technology across a range of industry sectors. Quick Response (QR), RFID, and Near Field Communication (NFC) codes are some of the most used methods for product tracking and tracing. Nevertheless, despite their simplicity of use and ease of implementation, these tools and strategies are ineffectual when dealing with fragmented data [10]. Because blockchain is impervious to tampering, it can add security, traceability, and reliability to any system. While current blockchain-based methods in the fishing sector preserve product information continuity in the pre- and post-processing phases, they are unable to track fish data when the fish undergo morphological changes throughout the fish processing phase. Additionally, these methods track and record product movement data using techniques based on RFID and QR codes. While combining blockchain technology with Internet of Things devices guarantees improved data management and integrity, it is unable to effectively manage the supply chain's traceability for aquaculture [11]–[12]. The absence of RFID tags and QR codes during fish processing could lead to supply chain gaps that could facilitate counterfeiting and species adulteration [13], [14]. Therefore, by substituting high-value species for low-value ones, con artists can take advantage of this opening to perpetrate food fraud. Therefore, once a fish species' skin is removed, fraudsters can easily alter the fish goods [15]. A programmable blockchain technology like Ethereum can be utilised to handle the conceivable difficulties and enhance the current fish tracing techniques. These apps can be run by users in the Ethereum Virtual Machine. Smart contracts are often protocols that enable the verification and execution of traceable and irreversible transactions without the need for a third party's involvement [16]. In this work, we present a blockchain-based fish traceability solution that can manage Ethereum smart contract operations in a decentralised, transparent, private, safe, and

trustworthy manner for both wild-caught fish and farmed fisheries supply chains. An overview of the global fisheries supply chain mechanism that is being adopted is shown in Figure 1.

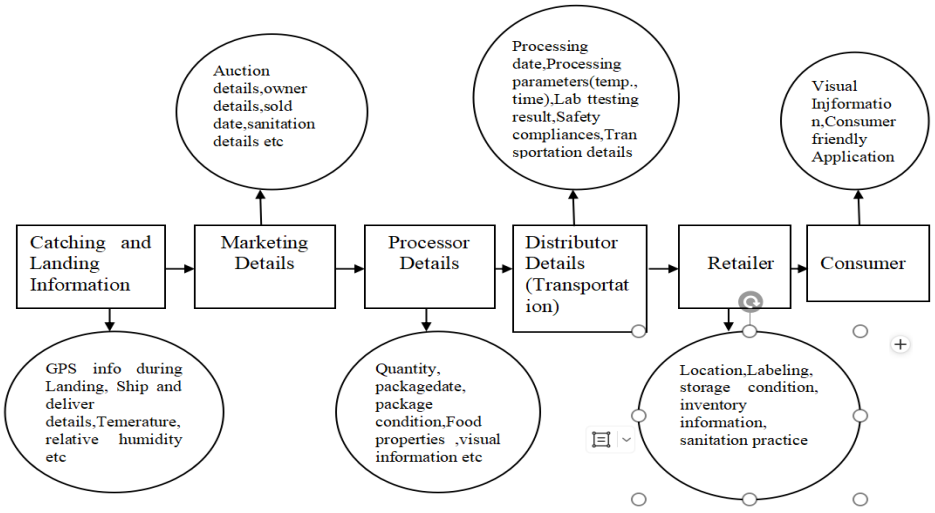

Fig.1. Conceptual framework of fishery supply chain process

The worldwide fishing industry of today face a number of difficulties along their supply chains. Fish capture, overfishing, habitat degradation of important species, shifting global fuel prices, climate change, and so forth are some of the common challenges [17]. Fish harvesting and its supply chain must be closely monitored and managed in order to preserve sustainability in the fishing sector [18]. This technology could help the fishing industry by boosting supply-chain transparency, which could help prevent illicit activities, enhance operational effectiveness, enhance supply-chain coordination, enhance sustainability performance, and recognise market trends [19, 20].

This is how the remainder of the paper is structured. Related work is included in Section II. The proposed blockchain-based system is discussed with all system members in Section III including conceptual framework, model description and proposed smart contract implementation. In Section IV presents the result and discussion with the Details of the suggested solution's generalisation aspect, comparative analysis, and security concerns. In Section V, we offer our closing observations.

II.Related Work

In order to prevent potential risks to public health posed by food products, authorities such as the European Union adopt regulations requiring the registration and control of the origin of specific items, improving product traceability, and permitting faster recalls, when necessary. As a result, numerous initiatives to introduce traceability throughout food value chains—including those involving fish products—have been undertaken. Next, we bring emphasis to the fish and fish product traceability platforms.

i) **Fish Traceability platforms**

Several studies propose traceability systems for fish supply chains, such as TraSiPesc (21), aquatic food traceability platforms (22), and RFID- and WSN-based solutions (23) that track products from production to consumers while monitoring factors like water quality and safety. Other approaches focus on supply chain monitoring (24) and identifying sources of food fraud (25). However, these methods lack a reliable and tamper-proof data management system. To address these limitations, decentralized technologies like blockchain are suggested as effective solutions for improving traceability in the fisheries sector. Fishery traceability based on Blockchain

Each stakeholder in a supply chain should be aware of the present status of the product flow; blockchain technology can assist in developing a platform that makes this data visible to all authorised parties. Additionally, since data transacted in the blockchain system is irreversibly stored in the ledger and cannot be altered, all parties involved in the fishery supply chain are held responsible for the information they provide during business transactions and are unable to retract their actions. Strong points of blockchain, according to Ruoti et al., include provenance tracing, shared governance and operations, resistance to data loss, and auditability (Ruoti et al., 2019). The fisheries value chain greatly depends on these points. Value creators do not have blind faith in one another, but they do desire to be a part of a system. Blockchain technology allows them to share operations and governance. The operators' agreement over the actions that the system will carry out is known as the consensus protocol. Additionally, each node—that is, each value chain operator—stores and replicates the data. that is, resistance to data loss. Conversely, a new block containing the transaction's details, including the timestamp, is added to the blockchain once a transaction is completed. The blockchain can be audited because this new block has been approved by the consensus process that has been approved by the value chain operators. As demonstrated by authors (26), (27) and others, a number of them chose to apply traceability in value chains through the use of blockchain technology.

Traceability in fish supply chains has been explored using blockchain and related technologies. For example, blockchain-based traceability for tilapia was implemented in Ghana (27), while Caro et al. compared Ethereum and Hyperledger Sawtooth in agri-food systems (26). Other

studies used blockchain for tracking carbon impact (28) and enhancing trust in fish value chains (29). Some approaches integrate NFC, RFID, and QR codes for traceability (28), and others highlight the combined use of IoT and blockchain for improved data storage and monitoring (30). Additionally, blockchain solutions addressing scalability and event tracking using IoT devices have been proposed (31). However, these methods often lack prototype implementation or fail to address security and vulnerability concerns in fish supply chains.

ii)Traceability of fishery by blockchain: technical perspective

i) **Conceptual structure of a fish traceability system**

There is no widely recognized conceptual framework for food supply chain traceability, and limited research exists on the use of blockchain in supply networks, particularly in fish supply chains. Existing studies propose frameworks based on key concepts such as accessibility, data integration, data recording, and identification, while also highlighting future directions for digital transformation in food supply chains. Some research introduces hybrid blockchain models to improve certification, traceability, and transparency, especially in prawn export systems. Overall, recent work focuses on developing practical frameworks to better understand and apply blockchain technology for fish supply chain traceability.

ii) **Blockchain based fishery traceability model**

The model represents a blockchain-based fish supply chain that integrates data from all stakeholders to enable traceability. Blockchain technology ensures security, transparency, and easy access, allowing all participants to record and share information about each stage—from catch to consumer. This improves sustainable fishery management by helping track product origins and preventing illegal practices. Smart contracts store and provide complete product history, including location and activities. Overall, the framework supports efficient coordination and end-to-end tracking within the fisheries supply chain.

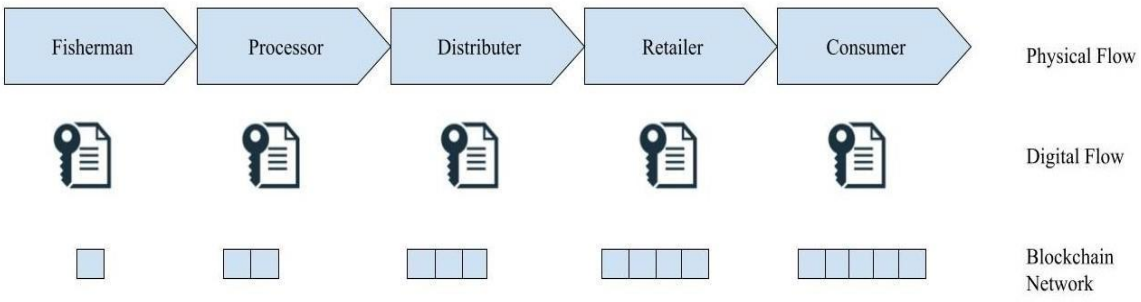

Fig.2. A blockchain-based information system processes the data from fishery products to consumer supply chain

The following roles are carried out by above mentioned entities in figure.,

Fisherman - This is where Processor will get fish lots to make further processing. Processor- This person should adhere to a few rules.

Distributor - The fish lots are distributed to shops here.

Retailer- A typical consumer purchases from the retailer.

iii) Blockchain's technical characteristics that enable the tracking of fish from the source to the consumer

Blockchain technology supports fish traceability through features such as smart contracts, distributed consensus, transaction verification, security, immutability, and uniqueness. Smart contracts record traceability data using standards like GDST (29) and maintain traceable resource units (TRUs) with unique IDs and product history (36). They enable asset tokenisation, secure data storage, and automated execution on platforms like Ethereum, interacting with user accounts. Overall, smart contracts act as core components of decentralized traceability systems, allowing secure storage and controlled access to fish supply chain data

.**Blockchain-based fish traceability System: Smart Contract Implementation**

The traceability platform's central smart contract needs to be registered and provide traceability data. The platform must supply the lot's current location (or locations), as well as its whole history, in order to provide a fishlot number. A solidity smart contract consists of the declaration of the pertinent input and a collection of functions, such as a constructor This code can be found on the Ethereum blockchain at a particular address. The smart contract serves as the cornerstone of the entire application. It outlines the necessary data structures and support functions.

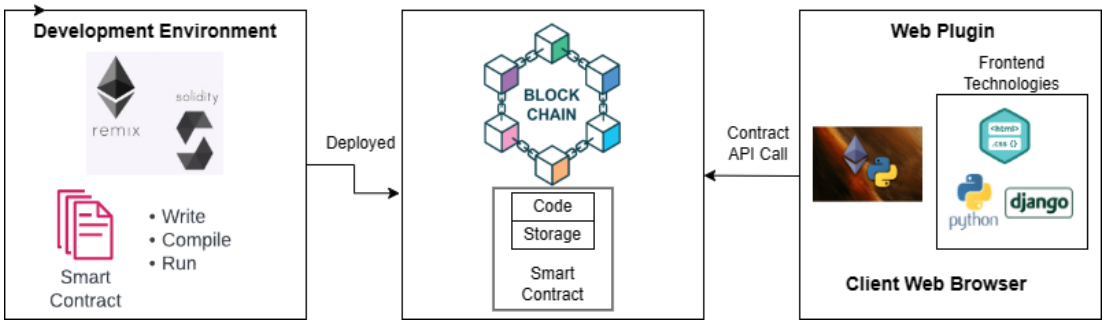

Fig.3. Architecture of traceability in fishery supply chain

The suggested supply chain traceability flow is depicted in Fig. 3. Solidity is used to write the

smart contract, which is then compiled, moved, and deployed on the Ganache blockchain network using Remix IDE. The frontend communicates with the blockchain network and smart contract via Web3.py, HTML-CSS, and the Django framework, as well as through remixing. The Ganache Network is connected to the Ethereum IDE, enabling transactions between all supply chain components.

The proposed smart contract will function as follows:

The smart contract's owner will be the one to implement it; only he has the power to approve various roles, like manufacturer, retailer, etc. Roles such as fisherman are compatible with smart contracts; here, the processor will obtain fishlot details for additional processing. Distributor: This person transports the fishlot to stores; they are subject to several rules. & Retailer: Regular customers make purchases from a provider. We shall keep an eye on every fishlot the owner requests with the use of this. The blockchain will be used by smart contracts to store fishlot data. Additionally, the contract will save all the data about fishermen, processors, distributors, and retailers on the blockchain and verify that the data is still available there. Smart contracts with geotagged picture fields, which provide the precise location and additional image details of a product lot, increase confidence and transparency. The owner has the ability to upload new fishlots to the blockchain and modify any role that is included in the contract. It is possible to add (save) and read data from the blockchain by implementing the addFisherman (), addProcessor (), addDistributor (), and addRetailer () functions. Taking everything into consideration, this smart contract offers a means of monitoring a fishery product's journey through the supply chain while maintaining transparency and responsibility.

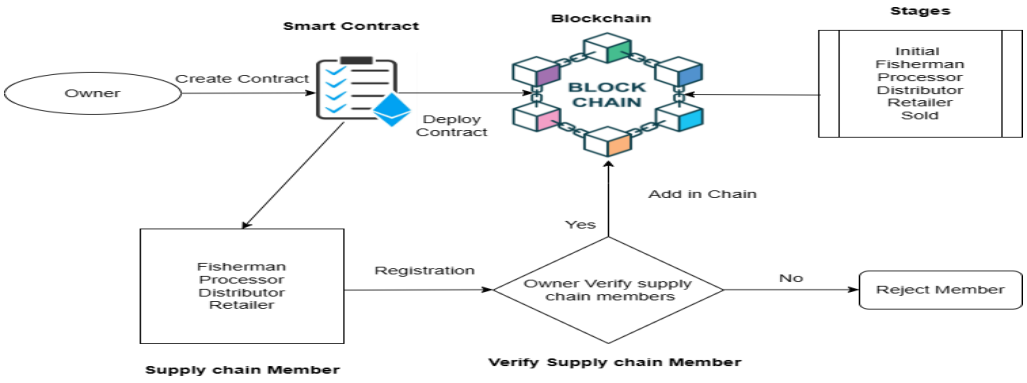

Fig.4. smart contract workflow based on the blockchain supply chain traceability for fisheries.

All immutable objects created by the contract's activities and stored in the designated storage

variables are stored on the blockchain. This suggests that the system is extremely robust and makes use of the blockchain's advantages (segregation, consistency, security, and transparency). Every type of event, including processing, distribution, selling, etc., needs a Fishlot ID in order to accomplish this. The event mappings consist of an event mapping that links the Fishlot ID to the corresponding structure for each sort of event, as well as an event mapping that lets the Fishlot ID be used to identify the kind of event. The function that makes it possible to see the stage of each occurrence is shown. The blockchain stores and prevents modification of any object created using the contract's functionalities and kept in the designated storage variables.

III.Result and Discussion

The outcome and discussion section centres on the outcome in the form of We propose a security analysis of our solution that provides total product traceability from the point of lot packaging to the point of delivery to the ultimate customer with the same lot number. In addition, we investigate the generalisation problem and contrast our solution with the ones that already exist.

The developed blockchain-based application provides a decentralized, secure, and transparent platform where all stakeholders in the fishing supply chain can record and track data at every stage. Its immutability ensures that once data is stored, it cannot be altered, maintaining integrity and supporting food safety and quality. Unlike traditional traceability methods that were inefficient and prone to errors, this system—implemented using Ethereum—enables secure end-to-end tracking of fish products from production to consumption. By allowing consumers to access detailed information about origin, processing stages, and quality, the application enhances transparency, builds trust, and improves overall customer satisfaction.

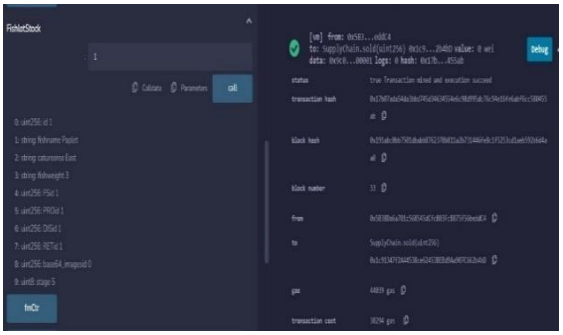

Fig.5. Result of the affected chain

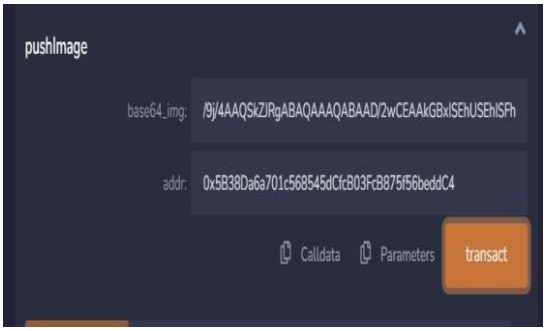

Fig.6. Importing geotag image

IV.Comparative Study

Our approach, in contrast to the previously mentioned research, is integrated; it integrates fishing supply networks with a working prototype solution. The report also recommends using blockchain technology and smart contracts to enhance the fishing supply chain's operations. We created and tested our suggested framework using Remix IDE, and We accomplished the required research to validate our solution's viability and its roles in the fisheries supply chain, bringing the system into compliance with other industries. Our technology enables the application of the fish industry's present product traceability management system on many blockchain platforms, thereby optimising its current features. Our technology can therefore be used by the fish industry as a first step towards bettering its present procedures.

A. Generalization

Proposed Ethereum platform system is designed, tested, and validated to satisfy the security, traceability, and transparency needs of the fisheries supply chain. Also proposed approach offers a secure and practical way to document since blockchain systems can efficiently encrypt data (Fig.7) business dealings. The proposed method may potentially be used by several industries that deal with product traceability, including the pharmaceutical, automotive, and logistics sectors. All of the elements and activities of the suggested fishing supply chain can be effectively tracked and traced thanks to the suggested methodology.

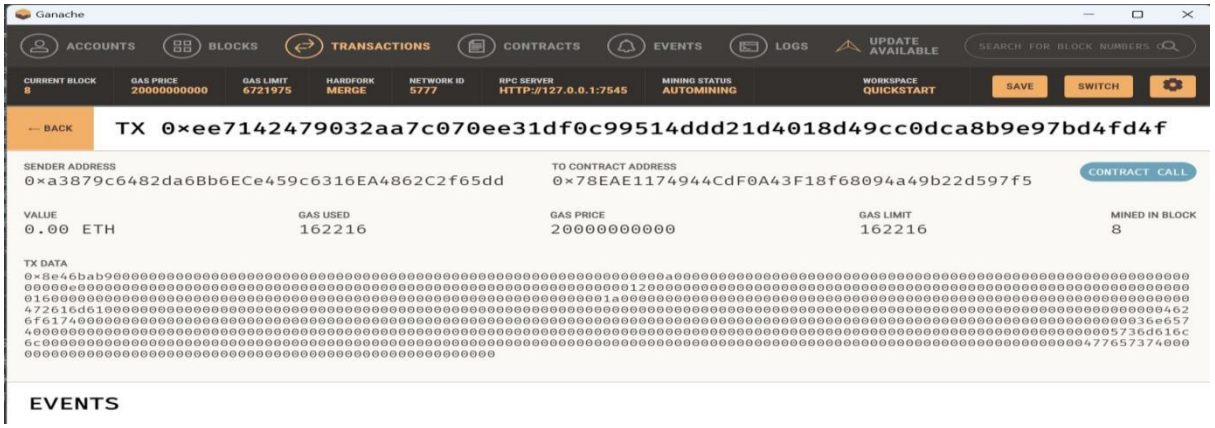

Fig.7. Blockchain platforms for recorded transactions, as they are effective at encrypting data.

V.Conclusion

The proposed blockchain-based approach to monitor and trace fish product lots in the fishing supply chain is transparent, accountable, secrete, protected, and dependable. Suggested method of action guarantees candid communication between stakeholders, averting fish fraud and malpractice of all kinds. The workflow of a smart contract for traceability in the fishery

supply chain using blockchain, including implementation procedures, testing, and validation features, has been established to identify events and automate activities in the supply chain for fishing. The solution's appropriate resilience against security threats and attacks must be demonstrated in the security analysis document. Give the fish supply chain access to a decentralised traceability system in your paper so they can monitor the traceability chain and get aggregated data about fisheries goods. The suggested approach's distinctiveness, effectiveness, and generalisability to cover a variety of supply chain functions are demonstrated by comparing it to existing blockchain and non-blockchain-based alternatives. In the future, plan to install and test our solution on the actual Ethereum network in addition to developing DApps for other stakeholders. In the fishing industry, a proposed platform for supply chain management traceability refers to the ability to track and monitor the movement of goods and services at every stage of the process. It involves employing state-of-the-art technology to track and record the transit of items from the supplier to the client.

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