



## Research article

# A qualitative analysis of rural fishermen: Potential for blockchain-enabled framework for livelihood sustainability

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## ABSTRACT

Rural fishing communities face numerous challenges related to livelihood security, as they are engaged in a risky and labour-intensive occupation. They often receive only a small portion of the profits, due to the influence of self-serving local intermediaries, lack of transparency in the business processes, trust issues, and power differentials among stakeholders. Although still in its infancy, blockchain technology has been adopted in various urban settings to mitigate similar challenges and to build trust through its security attributes, data ledger transparency, and smart contract automation. Yet, few have explored the efficacy of blockchain technology in addressing the unique challenges faced by rural fishermen in marketing their catch and connecting them to a broader range of customers for improved livelihood resilience. This study aims to examine how the livelihood resilience of fishermen can be increased through the potential of a blockchain, in a fishing community in the coastal village of Alappad in Kerala, India. Thematic analysis of data acquired from 43 semi-structured qualitative interviews and participatory rural appraisal tools revealed five categories of challenges: business cost and profitability, government regulations, low education and digital illiteracy, socio-cultural limitations, and over-dependence on middlemen as inhibitors to fishermen's livelihoods. The study proposes a blockchain-based e-commerce framework to mitigate selected challenges that emerged due to a lack of trust and transparency in the local fish market. It contributes to rural development by exploring an innovative, solution aligned with five UN Sustainable Development Goals, in contrast to the Business-as-usual approach in offering technological solutions.

## 1. Introduction

In recent years, blockchain technology has been developed to mitigate the challenges of database management systems, which essentially store data in a centralised manner, making them highly vulnerable to cyber-attacks, system failures, and consequently, database failures (*also known as a single point of failure*) [1]. Alternatively, blockchain technology adopts a linear data structure for storing information in data blocks (*referred to as the ledger*) and uses a peer-to-peer network of nodes to create an identical copy of the ledger for each node and validate data blocks [2]. Each node updates its ledger with the most recent data block after creating a new block and notifying other peers in the network via a consensus algorithm. Blockchain was first used in Bitcoin, a peer-to-peer payment system created by Nakamoto [3] during the financial crisis to fix the double-spending issue (i.e. spending the same cryptocurrency more than once) [4].

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Since its inception in the financial sector, blockchain technology has been examined for its myriad attributes and applications [5]. Its benefits have been noted in the telecommunications sector [6,7], governmental processes [8,9], traceability and supply chain management systems [10–12], healthcare systems [13], and certifications [14], fiscal services [15,16], and businesses, IoT industries, and education [17,18]. These studies have espoused transparency in recording data, reliability in the veracity of the data stored, guaranteed by several identical versions, auditability, and integrity due to its inbuilt immutable design, preventing data alteration, the facility to automate through smart contracts, build and enhance trust across multiple users.

Potential limitations to blockchain, do exist and may emerge if not properly planned for and addressed at the outset. For instance, the storage capacity is a concern since the ledger is an append-only database [19], or depending on the consensus algorithm, the blockchain may consume a lot of energy giving rise to sustainability concerns [20], misinformed adoption of the blockchain [5], resource constraints, and transaction fees [21,22], interoperability, scalability, and confidentiality concerns [21]. The blockchain Oracle problem makes it very secure and highly reliable for binary-type questions but not suitable for subjective-type questions that require external data that is not easily accessible to every node in the network. This calls into question the veracity of the data collected by the oracles [23]. Finally, splitting of the chain and node breaks due to a lack of integration of the old and new technologies affecting the immutability and transparency of blockchain technology [24].

Despite these challenges, blockchain technology is here to stay and is garnering attention from policymakers and scholars alike to be able to serve the digital world to its full potential [25,26]. The benefits accrued from this technology are potentially centred around offering solutions to urban populations and tend to neglect rural communities. The traditional way of conducting the fishing business in rural Alappad is at risk due to multiple challenges, including lack of transparency, digital divide, and infrastructural limitations, prompting the need for an innovative solution to enhance the sustainability and resilience of the fishing industry. This study aims to address this gap by examining the challenges faced by fishermen in the rural fishing village of Alappad in Kerala, India, and offering a blockchain framework to mitigate select challenges and build resilience in the fishing livelihood ecosystem.

Adopting a qualitative research method design, in-depth face-to-face interviews were conducted with 43 fishermen to answer the following research questions:

- **RQ1:** What conventional business processes do the fishermen adopt, and who are the influential stakeholders within the local fish markets?
- **RQ2:** What challenges do the fishermen community face in selling their catch and ensuring livelihood security?
- **RQ3:** What blockchain-based solution can address the issues identified through the analysis of community data?

The subsequent sections of the paper are organised as follows: Section 2 provides a review of blockchain studies in the rural development and fisheries industry. Section 3 explains qualitative research design and the village context for the study. Section 4 explains the technique applied to analyse the collected information during the study. Section 5 presents the findings that explicate the fishing business processes, the influential stakeholders and the thematic areas of concern affecting the viability of the fishing livelihood. Section 6 provides discussions and suggests a blockchain-based solution to some of the identified challenges. Section 7 concludes the study by synthesising its objectives and directing future research work.

## 2. Literature review

This section follows the trajectory of blockchain technology, initially highlighting its evolution and proven merits in the financial sector. It subsequently delves into the application of blockchain in rural contexts, narrowing its focus to the fisheries sector, which is a defining characteristic of the study community. This section aims to draw insights from existing literature on the attributes, benefits, and limitations of blockchain technology in the context of rural development.

### 2.1. The evolution of blockchain

Blockchain development and use have gone through three major stages since 2008. Starting with the peer-to-peer financial networks and the use of cryptocurrencies suggested by the first blockchain generation, to the Ethereum platform for smart contracts [27] in the second generation. In the third generation of blockchain, decentralised applications (*also referred to as “DApps”*), hosted in decentralised networks of nodes rather than central servers, were made available [28]. This technology is yet again evolving towards Web 3.0 and the Metaverse, where all Internet services can be decentralised and people can have an online representation of their real-world lives [28].

The application of blockchain in financial use cases, especially in creating cryptocurrencies, performed very well after its introduction during the world’s financial crisis in 2008–2009 [29]. According to the most reliable online service on live list of the cryptocurrencies and their market capitalization provided by the CoinMarketCap company (*coinmarketcap.com*), accessed on 5 January 2023, the global cryptocurrency market cap is \$1.66T. By January 2023 there were more than 23,000 cryptocurrencies and the market capitalisation of the top 10 cryptocurrencies was estimated to be worth around 1.2 trillion dollars, with Bitcoin alone owning more than 50% of the market according to the online statistics available at (*investing.com*).

Scholars are suggesting that blockchain technology has the potential to improve and reconstruct the fundamentals of e-commerce and marketing by advancing incremental innovation in organisational marketing, shifting towards a consumer-centric model, and rectifying the challenges of intermediaries, click fraud, related to online markets, and ensuring customer loyalty [30]. Others believe

that the relationships and trustworthiness in conventional business models such as business-to-consumer (B2C) and business-to-business (B2B) can be examined and potentially adjusted by blockchain technology [31]. The technology can also bring great improvements to the online market's performance by utilising the Ethereum platform.

Furthermore, the new e-commerce platform based on blockchain called "PRODCHAIN" with an innovative consensus algorithm named "Proof-of-Accomplishment (PoA)" has helped to reduce the complexity of tracking e-commerce products [32]. Another e-commerce platform [33], takes advantage of the existing Ethereum chain and is purported to remove the centralised intermediaries required for business coordination and implement new decentralised on-chain markets. Authors of [34] recognised the challenges of conventional centralised online market platforms, including high fees for listing products, a lack of privacy of user data, and blocking user access, and developed a new platform on the Ethereum blockchain for mitigating security, costs, and transparency challenges.

Such developments have made blockchain a trust-building technology, through its payment methods and smart contract features, giving it the ability to restore some of the lost reputation and trust issues related to conducting businesses online [35]. Through its record-keeping and distributed ledger system, it can also help address other online markets' challenges such as online payment fraud, or insufficient contact between trading parties, and data privacy issues [36].

## 2.2. Blockchain for rural contexts

The World Bank estimate based on the United Nations Population Division's World Urbanisation Prospectus: 2018 Revision, suggests that the rural population in India was 65% of the total population of the country in 2021 (The World Bank, n.d.). This population is plagued with problems of poverty, hunger, poor health, lack of quality education, gender equality, clean drinking water, sanitation facilities, limited sources of clean energy, job disruptions, dangerous living conditions, and weak institutional support, to name a few. Hence, the United Nations 17 Sustainable Development Goals (SDGs) agenda (2015-2030) especially SDG 8, decent work and economic growth, and SDG 9, foster innovation have a special meaning for rural communities to help solve these pressing problems and build capacities and resiliencies through "smart village" initiatives.

In a seminal article, authors of [24] presented a systematic review of 112 relevant papers focused on key applications, and areas of implementing blockchain technology for smart villages to achieve sustainable rural development. They found that in rural contexts, blockchain technology can help:

- Enhance supply chain management and traceability, enabling farmers to track the origin of their products and ensure their legitimacy and safety more easily
- Enable decentralised energy management and peer-to-peer energy trade in smart villages, allowing people to produce and share their surplus energy
- Increase openness and accountability in government entities by offering a public record of transactions and decisions.
- Make financial transactions safer and more efficient when traditional banking infrastructure might not be accessible in rural communities

In the field of "sustainable finance," authors of [37] proposed "green credits" to enhance agricultural and economic activities in rural settings through a hierarchical model for the nodes in the blockchain network. This multi-layer peer-to-peer approach aims to adapt the blockchain structure to the intricate financial landscape in rural China. However, the incorporation of social and environmental factors into the loan issuance process requires additional time.

Logistics management for the timely delivery of seeds, fertilisers, and pesticides is crucial in rural areas where agriculture serves as the primary source of income. Recognising the significance of logistics improvement, it is worthwhile to consider green mobility for enhanced sustainability and the prevention of environmental degradation [38,39]. Authors of [40] categorised logistics in the agricultural sector under transportation, storage, and distribution of materials sections and suggested that a blockchain-based strategy can solve problems in all these areas by managing order processing delays, reducing damage to agricultural products, and iterative data loss prevention. However, since adopting blockchain technology is very expensive for rural organisations, the uptake of this technology for logistics and supply chain management is slower than anticipated.

## 2.3. Blockchain in the fishing industry

The UN Food and Agriculture Organisation [41], reports that the growth in production of aquatic animals has reached an all-time high, with a rise of +60% and fisheries production, +609% in global aquaculture production, and around +200% total food fish consumption from 1990 to 2020. Over 58.5 million people globally were employed as fishers (catching wild fish) or fish farming (aquaculture) in 2020 with global fish production estimated to have reached about 214 million tonnes, worth about \$424 billion. The countries that accounted for 49% of the total global capture were China, Indonesia, Peru, India, Russian Federation, United States of America and Vietnam. At present, India stands as the world's third-largest contributor to fish production, contributing 7.96% to the global output [42].

This growth in the fishing industry has also led to the loss or wastage of around 30% of the global fisheries harvest and a decrease in the proportion of fish stocks that are within biologically sustainable levels (SDG14) from 90% in 1974 to 64.6% in 2019 [41]. Moreover, the safety of the fishermen is also a major concern. To maintain the viability of fish populations, safeguard marine ecosystems, and ensure the sustainability of fishing livelihoods, the focus is now turning to the prevention of illicit fishing and illicit trade in marine fish catch, through tracing and tagging methods. Another study [43] proposed the use of reusable Radio

Frequency Identification (RFID) tags and Quick Response (QR) codes to track fish products such as Tuna, while study [44] suggested a blockchain-based framework on the Ethereum platform to trace the origin of the fish and track it during transportation and storage for improving transparency in the marketplace.

Where consumers are losing trust in the sources of their seafood and storage mechanisms, blockchain technology has the potential to remedy this and rebuild trust [45]. A well-designed private blockchain solution based on the Ethereum platform that utilising five smart contracts for tracking and authentication was proposed to help authorities prevent food fraud (e.g., substitution of valuable species with cheaper ones, and selling frozen-thawed products as fresh fish), and mitigate health risks for consumers [46].

While most of the use cases of blockchain in the fishing industry are offered for improving the supply chain mechanism and product data sharing, a few are suggested to incentivise fishermen through decentralised finance or by offering access to a wider range of customers [47]. This is vital to ensure the sustainability of fishing-related livelihoods and to bring the majority of the fishing community members out of abject poverty. In this regard, study [48], suggested rewarding honest and responsible fishermen/producers with incentives and better business opportunities, which in the long run would drive out illegal and unethical actors. Authors of [49] proposed the use of blockchain technology for identifying strategic checkpoints in the supply chain, to validate products and provide real-time data.

In 2018, the World Wildlife Fund (WWF) and Sea Quest Fiji Limited, launched a pilot blockchain technology-enabled project called "Bite to Plate" [43] for tracking Tuna fish in the Pacific Islands to prevent illegal, unreported, and unregulated (IUU) fishing and human rights violations in the fishing industry. Study [50] have developed a fish quality tracking solution called "BeFAQT", for the Sydney Fish Market (SFM) which is a multi-layered blockchain structure with attribute-based encryption (ABE) to provide a secure supply chain system. Similarly, the government of the Republic of Indonesia has initiated a system for fish product traceability to mitigate the threats of a centralised tracking system that is prone to data mutation by untrustworthy organisations involved in the system [51]. Others have proposed a supply chain model augmented with blockchain for efficient traceability [52], and the Thai fishing industry has presented a supply chain model with details about data types and record procedures [53]. While these are noteworthy blockchain-based solutions for the fishing industry, they lack the voices of the end-users, i.e., rural fishermen, and tailored solutions with specificity.

#### 2.4. Demerits of blockchain

Although blockchain has several merits such as decentralisation, transparency, security, anonymity, efficiency, and data immutability [9,8,54], it also has some demerits that make its adoption challenging. A possible increase in energy consumption, specifically in blockchains running on the Proof-of-Work consensus algorithm, is one of the drawbacks that make its adoption challenging for the Asian population of fishermen living below the poverty line with poor infrastructure. Data privacy can also be a concern for applications in need of more privacy on a public blockchain, where recorded data on the ledger is accessible by all of its anonymous participants. Additionally, since blockchain is still relatively new and its regulatory landscape is constantly evolving, adoption of the technology is challenging, specifically in countries with a slower pace of policymaking [55,5]. Moreover, to adopt blockchain on a large scale and for the sake of scalability, the process of transaction validation must be performed at a very high pace. Currently, most of the blockchains run independently and are isolated from other blockchains, hence the lack of interoperability between the existing blockchains can cause an absence of unity and standardisation in application developments. Utilising its applications daily requires knowledge and awareness of the system, which raises the concern of how this can be taught and made available to rural communities.

The review of the literature offered an understanding of the evolution and successful applications of blockchain technology, with a specific emphasis on its relevance in introducing innovative solutions for rural development. Despite these potential benefits, there is a noticeable gap in research related to blockchain-based solutions for the fisheries sector in the Indian peninsula. The subsequent section offers a case study analysis of a rural fishing community in the coastal state of Kerala, along the Arabian Sea in India, aiming to understand fishing livelihood challenges from fishermen themselves and offering a blockchain-based framework as a potential solution.

### 3. Methodology

#### 3.1. Village of the study

Located in the south-western coastal state of Kerala, Alappad is a narrow strip of land bordered by the Arabian Sea to the west and the backwaters of the Kollam district to the east (village coordinates: 09.0898° N, 76.4864° E). The village is approximately 16 kilometres long from north to south and had a population of 21,655 inhabitants according to the 2011 census of India [56]. The population is evenly split between males (49.4%) and females (50.6%), and the literacy rate is high at 86.7%. The primary livelihood for 80% of the villagers is fishing, according to the Kerala State Co-operative Federation for Fisheries Development Ltd. (Matsyafed) in Alappad. Fig. 1 provides a map of India showing the location of Alappad village as a narrow strip of land in the southern part.

#### 3.2. Data collection

Involving end users in assessing their needs is crucial [57,58] as this raises their interest in the outcomes, drives technology adoption and ultimately enhances the quality of their lives [59] and livelihoods. To collect indigenous knowledge about the fishing



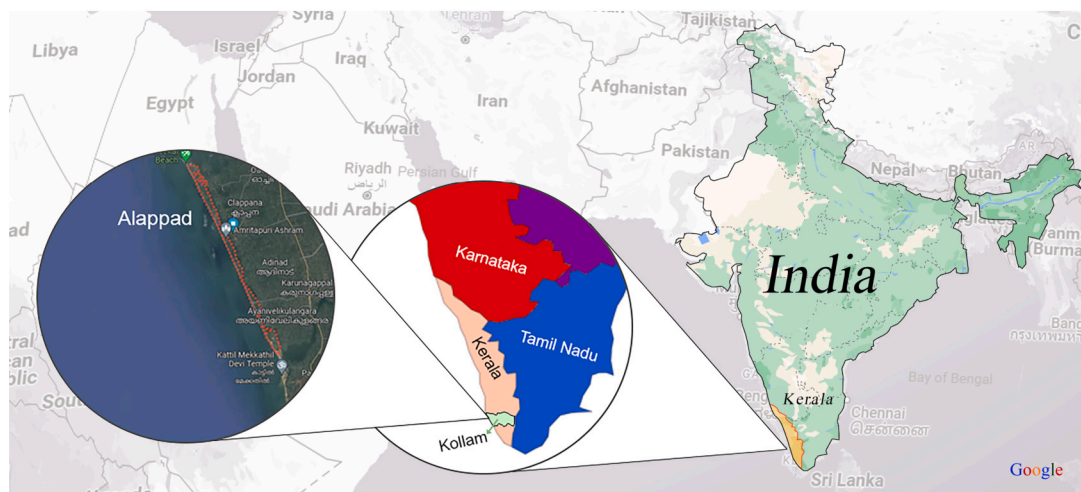


Fig. 1. Alappad village in the southern part of India.



Fig. 2. Large fishing boat in Alappad village.

business, Participatory Rural Appraisal (PRA) tools, including a seasonal calendar and group discussions were conducted. Additionally, face-to-face qualitative interviews were conducted with adult male fishermen in the community, employing a convenience sampling strategy. The sample included large boat owners, medium boat owners, artisanal fishermen, and fishing labourers. See Figs. 2, 3, and 4 for large boats (costs around Rs. 1,50,00,000/\$180,000), mid-sized boats (costs around Rs. 70,00,000/\$85,000), and small catamarans (costs around Rs. 20,000/\$240) respectively.

Following the standard protocol for research involving human subjects, ethical clearance was obtained from the ethical review board at Amrita University. The interview team consisted of the lead author and a village coordinator who served as a translator and helped conduct the interviews in the local language Malayalam and then immediately translated it to English, which was recorded by the researcher. Each interview took just over an hour to complete and utilised a semi-structured questionnaire focusing on general information, fishing-related information, market dynamics related to the fish market, and challenges experienced in the market. Informed consent was obtained by verbally explaining the study to the respondent in Malayalam and making it clear that his participation was voluntary, and that confidentiality would be maintained and findings reported in aggregate. He was then given the opportunity to read and sign the form before the interview commenced.

Interviews with large and medium boat owners were conducted at their homes, while those with others took place at their workplaces or on the coastline when they were done for the day or less busy. The time of the interviews was early in the morning around 7:00 a.m. when the boats were back from the sea or during the evening around 5:00 p.m. when artisanal fishermen gathered around with friends on the beach after a long day. Fig. 5 depicts a gathering of artisanal fishermen who typically assist each other at the seashore whenever any of them return from fishing.





Fig. 3. Mid-sized fishing boats used by local fishermen of Alappad village.



Fig. 4. Artisanal fishermen preparing their catamarans for fishing.

#### 4. Analysis

A total of 43 interviews were conducted, at which point data saturation was achieved, signifying that responses had become repetitive, prompting the cessation of further interviews. This adherence to qualitative data collection strategies aligns with established methodologies such as those outlined by study [60] and [61]. This diversity in responses proved instrumental in identifying the root challenges and speculating on areas that could potentially benefit from blockchain technology. Refer to Table 1 for a breakdown of the interview sample. The interviews were conducted with a diverse group, including boat owners aged between 40 and 70, artisanal fishermen who also assist in larger boats, intermediaries working in groups connecting customers to fishermen at the harbour and determining fish prices, governmental authorities, and other individuals assisting fishermen in preparing for their voyages. Recordings of the interviews were transcribed verbatim into a text file, resulting in approximately 15,000 words. For the analysis of the collected qualitative data, a manual coding technique was employed due to the manageable number of interviews, preventing the costly utilisation of AI-driven analysis software [62,63]. The analysis involved inductive content analysis, encompassing open coding, category creation, and abstraction [64].

In the initial phase of manual coding, the data was thoroughly read to gain familiarity with the challenges expressed during the interviews, the overarching themes, and the different concepts mentioned. Subsequently, the data was revisited with a focus on the study's purpose and questions, resulting in the identification of codes for each quotation. Similar codes were then grouped to form potential categories and themes reflecting the challenges faced by the participants. As the analysis progressed, quotations



Fig. 5. A group of local artisanal fishermen in Alappad while reading the informed consent.

**Table 1**  
Respondents Descriptive Statistics.

Respondent	Number of interviews	Age group	Education level
Big size boat owners	8	40-70	Above 8 <sup>th</sup> Indian standard
Midsized boat owners	3	30-40	10+2 Indian standard
Artisanal fishermen/ crewmen*	25	40-65	Illiterate to 10+2 Indian standard
Intermediaries	1	50-60	10+2 Indian standard
Storage facility operators	1	50-60	10+2 Indian standard
Ice factory operators	1	30-40	10+2 Indian standard
Governmental bodies**	4	30-60	Undergraduate and Postgraduate

\* Majority of the artisanal fishermen are the crewmen who could not find a job on a boat in a day or those too old to work on a boat.

\*\* The Panchayat head of the Alappad village and government fish farming staff.

were colour-coded based on the research questions. The findings from this process were then organised and sorted in a spreadsheet, presenting quotations, codes, categories, and themes at different levels of abstraction. To visually depict the most pressing challenges articulated by the 43 respondents, a word cloud was generated utilising a free tool from the <https://worditout.com> website. As illustrated in Fig. 6, this cluster of words, depicted in different sizes, signifies that the larger and bolder a word appears in the word cloud, the more frequently it was mentioned during the interviews.

The data from the interviews contained 1,250 unique words, of which 86 were selected for illustration based on their frequency of appearance. In the next step, the counts of words with similar meanings, such as *problem* and *challenge*, *buyer* and *buyers*, and *customers*, were aggregated to represent one word. Additionally, some words were excluded from the word set, such as *numbers*, *only*, *others*, *any*, *after*, *each*, *etc.* to have a more meaningful outcome. As the figure illustrates, not surprisingly, the most prominent concerns of the fishermen were related to the PRICE of their products, the BOAT as their main equipment for fishing, FISHING as their primary skill for livelihood, the FISH products as the material in their business, and SELL as one of their main concerns after catching the fish products. However, other unique words indicating a growing concern among fishermen included MIDDLEMEN, who play a significant role in their business, PAYMENT as the most crucial aspect of their livelihood, CUSTOMER to whom their profit is dependent, CREWMEN being one of the main stakeholders in the business, etc. Table 2 depicts the frequency of the first 15 words created in the word cloud. The fishermen interviewed articulated their challenges in diverse ways, reflective of their varying socio-economic statuses and life experiences. Aligned with the qualitative essence of the interviews, the goal was not to quantify the frequency of individual words but rather to assess the widespread usage of these words.







During the interviews, some boat owners and captains mentioned that they were aware that the middlemen were not always honest with them regarding the determined fish price. After the bidding process, the declared price to the fishermen is slightly lower than what the customers agreed to pay, allowing intermediaries to retain a larger profit margin before transferring the money to the fishermen. The money transfer is primarily done in cash with the customers paying middlemen who in turn pay the fishermen. Some artisanal fishermen also mentioned that when the weather was unfavourable for fishing, and they went to the market to purchase fish for their family's consumption, they discovered how the middlemen had purchased it for 20 Rupees and how it was being sold for up to 200 Rupees in the market. This high level of dependency on intermediaries prevents fishermen from raising objections in case of any malicious behaviour, on the part of intermediaries in the future affecting the sale of their catch. This vulnerability leaves fishermen susceptible to exploitation by intermediaries time and again, and is distressing and debilitating.

## 5.2. Thematic analysis

The thematic analysis of the interviews revealed numerous challenges faced by fishermen that impact their livelihoods. These challenges were broadly classified into five themes, aligning with RQ2: what challenges does the fishermen community face in selling their catch and ensuring livelihood security? The challenges were categorised into the following five themes.

### 5.2.1. Business cost and profits

One of the most pressing concerns for the fishermen was the increasing costs of running the fishing business versus the lower margins, which puts the sustainability of this livelihood into question. Most of the fishermen did not have a clear understanding of the pricing procedure since it was handled by the middlemen at the harbour. They confirmed that there was a considerable gap between the fish price at the harbour and the market. Additionally, the cost of basic materials for fishing, the maintenance of the boats requiring steel, and the steady rise in diesel prices, were leaving them with very little profit and increasing their hardships. The following are selected quotes indicating their concerns:

*"...because of the interference of a lot of middlemen we do not make enough profit anymore...(A boat owner)"*

*"...we take the risk and go to the sea and the middlemen take the profit...(An artisanal fisherman)"*

*"...We sell the fish to the middlemen for 20 rupees and they sell the same for 150 rupees per kilo in the market, we receive only a small portion of the profit...(An artisanal fisherman)"*

### 5.2.2. Government regulations

Another theme that emerged was environmental regulations set by the government prohibiting fishing in shallow waters during the breeding season. Artisanal fishermen who cannot go fishing in the ocean because of the weather conditions see these regulations as affecting their livelihood security. Although the government regulations are for the long-term benefit of society, it is not understood by the fishermen and are perceived as rules that are simply making it harder for them even to survive or make a profit. An artisanal fisherman said,

*"The government prohibited catching fish smaller than 9 cm (as tall as a finger) if they catch us having small fish, they make us pay a fine, 15,000 rupees and above for big boats and about 10,000 rupees for artisanal fishermen. If we catch small fish, we sell it to the middlemen for a cheaper price. (An artisanal fisherman)"*

### 5.2.3. Education and digital literacy

According to the census of India (2011), more than 95% of the residents of Alappad village are literate, and most of the fishermen in the studied community face challenges in adopting digital devices and services due to limited familiarity. The select few fishermen, with smartphones, primarily use them for a restricted set of applications, centred around specific social media platforms such as WhatsApp, Facebook, accessing YouTube videos, music, etc. The lack of digital literacy in the community, alongside limited alternative skill sets beyond fishing, significantly amplifies the challenges they encounter. Digital literacy involves utilising digital tools for personal goals, understanding information from diverse sources, recognising ICT's innovation potential, and individuals' awareness, attitude, and ability to use digital tools effectively [65]. It is crucial in today's interconnected world, as it empowers individuals to navigate technology, access information, and participate meaningfully in various aspects of modern life, including economic opportunities beyond traditional occupations like fishing. The following select quotes explain the dire conditions:

*"...we do not use bank payments and only use cash and it is because the crewmen don't have smartphones or they are not familiar with the online payment methods. Approximately half of the crewmen are illiterate and it is hard for them to utilise online payment methods...(A boat owner)"*

*"...all of us are from a fisherman family, our fathers have done the same business. We do not have any other skill besides fishing and we do not have any other job...(An artisanal fisherman)"*

*“...when I came back from Saudi Arabia where I went for work there, given my age and skill set I did not have much of a choice for the job and since I was from a fisherman family I decided to come back to the same business again...(A boat owner- who tried another line of work for a period of time)”*

The gathered quotations underscore the profound impact of digital illiteracy and the absence of alternative skills on the livelihoods of the fishing community. The prevalent use of cash transactions, as highlighted by a boat owner, indicates the hurdles in adopting online payment methods due to a lack of familiarity and literacy, affecting financial transactions. Additionally, the testimony of an artisanal fisherman, expressing a lack of skills beyond fishing, illuminates the restricted employment opportunities within the community. The account of a boat owner, who, after exploring other employment avenues, returned to fishing due to limited options, further emphasises the challenges stemming from constrained skill sets.

The connection between digital literacy and its impact on their business and livelihood remains unclear, hindering their ability to leverage digital tools for financial inclusion and savings. The community's limited exposure to digital platforms hampers their capacity to explore diverse sources of income and venture into alternative business opportunities, thereby perpetuating a cycle of slow growth and dependence on the fishing industry [65,66].

Furthermore, the community's endeavour to break free from this cycle is impeded by the lack of access to high-quality education and vocational training, which are essential to foster diversification into livelihood sectors other than the fishing sector. Addressing the digital literacy gap and promoting access to comprehensive education and vocational training are crucial steps toward empowering the community to expand their horizons and enhance their overall livelihood prospects.

#### 5.2.4. Socio-cultural limitations

Social and cultural norms are also causing some challenges for the fishermen in the study area. For instance, trading in fish is a trust-based business which prevents the fishermen from selling their catch in other markets where they are considered strangers. Additionally, there are only verbal agreements between the boat owners and the crewmen, which makes the fishermen hesitant to raise their voices in times of crisis. Moreover, the majority of the women of the village are literate, yet no woman is allowed in the fish market ecosystem due to socio-cultural norms and practices, that believe it is a man's profession. In addition, the relatives of the boat owners expect them to offer free fish to relatives which reduces their profits and is a cultural concern for some of the business owners in the area. A boat owner mentioned that:

*“...since the process is based on the trust between the sellers (middlemen) and customers it is hard for the new sellers and customers to get involved in the process...”*

#### 5.2.5. Over-dependence on middlemen

Artisanal fishermen are also concerned about the lack of proper logistic support. They normally go fishing in the middle of the night on a catamaran and swim for about 10 kilometres in the process. When they reach the shore, they do not have much energy left, hence they hesitate to take their catch to the harbour and wait for the middlemen to approach them for trade. The middlemen who know this meet them at the shore and bargain for a cheaper price. They sometimes do not even pay the fishermen during trade and only pay after the fish has been sold in the market.

*“...we go to sea at 5 a.m. in the morning with our catamaran and go up to 5-6 KM depending on the situation. It takes us about 45 minutes - one hour to reach the spot. Then we stay there for around 20-30 minutes and come back to shore after that...(An artisanal fisherman)”*

*“...there might be some times that the middlemen do not pay us at the moment, in this case, they would take the fish to the market sell it and bring the money for us in the next day and pay us...(An artisanal fisherman)”*

Besides the challenges mentioned, some fishermen expressed concerns about other issues, such as their health situation, lack of insurance, and the out-migration of the next generation to cities or overseas for better opportunities. These concerns were not emphasised as frequently during the interviews compared to the other challenges.

The word cloud illustration in Fig. 6 partially validates the identified categories of issues faced by the fishermen. It depicts important words such as *price, sell, and business*, which are related to the category of business cost and profit, *government, license* as part of the second category, *trust, auction* representing social and cultural norms, and *bank, payment, cash, online, Internet* related to education and digital literacy. Additionally, words like *location, far, storage* are associated with the lack of logistical support.

Furthermore, in response to the first research question, the analysis of data related to interactions within the fishing business procedure is illustrated in Fig. 7, providing a visual representation of the sequence of interactions and decisions involved in a regular fishing run. The figure emphasises the engagement of multiple stakeholders in the process and the essential interactions that occur among them. Significantly, the figure underscores the substantial burden placed on the captain and the boat owner, who must make numerous informed decisions throughout the fishing journey, covering various aspects of the business. However, all these business-related interactions hinge on trust among the stakeholders, potentially leading to issues.

Building upon insights from the literature on blockchain's potential and its application in trust-building and transparency, the study aims to bridge the identified gap in adopting this technology within the Indian fishery context. The literature review establishes a foundational understanding of blockchain's evolution and its role in rural development, specifically in the fisheries sector. It underscores blockchain's potential to address challenges, fostering benefits like improved livelihoods, ecological viability, and food

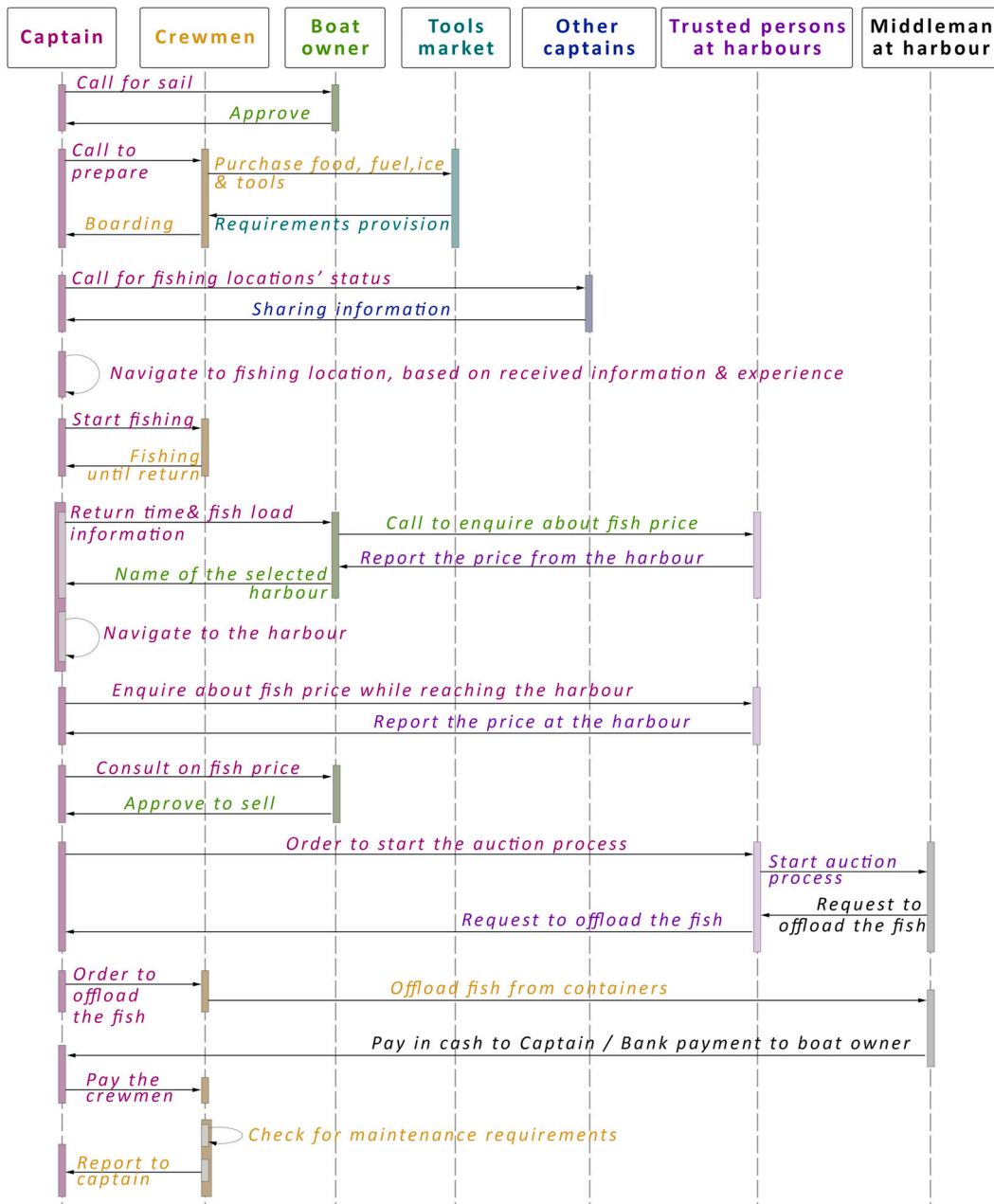


Fig. 7. The sequence of actions taken by different stakeholders involved in one run of fishing with a large boat.

safety. Despite these merits, the review acknowledges a research gap in applying blockchain to Indian fisheries. In response, our study proposes a blockchain-based solution for a rural fishing community in Kerala, India, aligning with the literature’s emphasis on innovative solutions for rural development.

### 6. Discussions: potential for blockchain-based solution

To address the final research objective, this section explores the potential implementation of a blockchain-based framework, drawing insights from the challenges identified. Fishermen, self-reported their regular use of GPS technology, echo sounders, radio, and sea phones during their voyage, underscoring the critical role these tools play in sustaining their livelihoods. Furthermore, despite financial constraints preventing some from acquiring high-end smartphones, they still used various types of mobile phones as tools for their daily communication needs through texts and calls. Comments on the adoption of technological solutions indicated that the community members are open to embracing technologies to address their key issues. Select quotes from the interviews suggest the specific devices used.



“...We use compasses, GPS, echo sounder to find the fish, radio, sea phone, and the GPS and echo sounder are the most important devices...(A captain with 48 years of experience)”

“...Yes, I have a smartphone. But I bought it recently, and I am still learning how to work with it. All in all, I like the technology...(An artisanal fisherman)”

“...If there can be a solution [to the issue of middlemen], we are willing to pay 10% to 20% to get our fish sold...(A group of artisanal fishermen)”

“...We use it [smartphone] for payments, social media, and messages. We do not have access to the Internet [deep into the sea], we only have GPS, radio, and echo sounder for communication and finding fish...(A fisherman with 20 years of experience)”

The complex nature of the identified problems arises from the involvement of multiple stakeholders at different points in the process, along with an underlying lack of trust and socio-cultural, economic, and knowledge differences. Consequently, this complex landscape calls for a blockchain-based solution to effectively address these challenges. A blockchain framework has the potential to mitigate the issues by establishing trust, enhancing transparency, and facilitating access to a wider customer base.

It is noted that addressing challenges related to governmental regulations extends beyond the scope of this study and the capability of blockchain-based solutions, other challenges tied to trust-building, lack of transparency, and limited customer reach can be effectively rectified through the utilisation of blockchain technology.

### 6.1. The design

A blockchain-based e-commerce framework with smart contracts for handling business procedures can help fishermen reach more customers and increase profit margins. Additionally, customers can benefit from the transparency of information about the freshness of the catch (*food security*) in the supply chain management system. Government entities can protect fish species from extinction by constantly monitoring the fish products for sale in the market. Since many of the fishermen have low literacy levels, there will be a challenge in the adoption and utilisation of technologies. Women in the community who are not traditionally involved in the fish market ecosystem but are literate can help in this new e-commerce framework. The proposed solution includes four categories of users, namely, the sellers (*fishermen, middlemen*), the buyers (*consumers and middlemen*), the oracles (*literate women of the society and their helpers*), and the third-party service providers (*e.g. delivery service providers*).

To enhance the efficiency and inclusivity of the existing fishing ecosystem, a decentralised application (DApp) is proposed for development to cater to the various actors involved in the business procedures. The system incorporates oracles who will assist illiterate fishermen in registering as sellers in the market. These oracles will also manage the storage process of the fish received from the fishermen in smart warehouses, serving as proof of existing products listed in the online market.

The price of the products can be determined either through an online auction process initiated by the product owner or by considering the volume of demand in the market (i.e. similar to the procedure for the cryptocurrencies' price determination on the market). To ensure transparency and security, all trades will be executed through smart contracts. Additionally, third parties can participate in the system, acting as intermediaries between the customers and the fishermen. They can receive their wages in their digital wallets, providing further convenience and flexibility. Smart logistics can be implemented to reduce the over-dependence on middlemen by artisanal fishermen transporting their catch to smart warehouses. By leveraging smart logistics solutions, the process can be streamlined and optimised and a realistic competitive price set.

Fig. 8 illustrates the logical design of the proposed framework, structured in three layers: transactions and trades, DApp and software, and blockchain and hosting nodes layers. The upper layer demonstrates the relationship between the actors involved and the movement of fish products within the market. The lines with arrowheads depict the logical connections between the system's actors, while the dotted lines represent the transfer of fish products to and from the smart warehouses. The second layer focuses on the digital medium, showcasing the decentralised applications and software utilised within the smart warehouse system. These applications and software facilitate seamless communication and coordination among the actors, utilising blockchain technology through the implemented DApp. The lower layer represents the blockchain layer, which is hosted by nodes from various entities such as NGOs, government bodies, universities, and factories. By utilising a private permissioned blockchain running on the Proof-of-Connection consensus algorithm [6], the proposed framework ensures privacy, security, and controlled access to the system. All transactions within the ecosystem would be executed through smart contracts, providing a transparent and reliable mechanism for conducting business.

Fig. 9 illustrates the application level of the same framework. The owner of the fish catch, depicted in the top left corner of the figure, has the option to hire an agent if he is unwilling to engage directly in the procedure, providing convenience for businessmen investing in the market. To enhance flexibility in the framework, considering the significant number of illiterate fishermen, they could seek assistance from the managers and operators of the proposed smart warehouses (*oracles*). These literate women from the same community, not typically involved in the fishing business, have an equal chance of participation in society. After receiving the catch at the warehouse, they undergo examination for freshness and type and can then be RFID tagged to confirm their physical existence in the market. To accommodate artisanal fishermen unable to transport products to the warehouse near the harbour, a smart logistics system with bio-scanner systems could collect their products and transport them to the warehouse. Fish owners can monitor their product's market status using a DApp. A public kiosk at the warehouse could serve those unfamiliar with smartphones

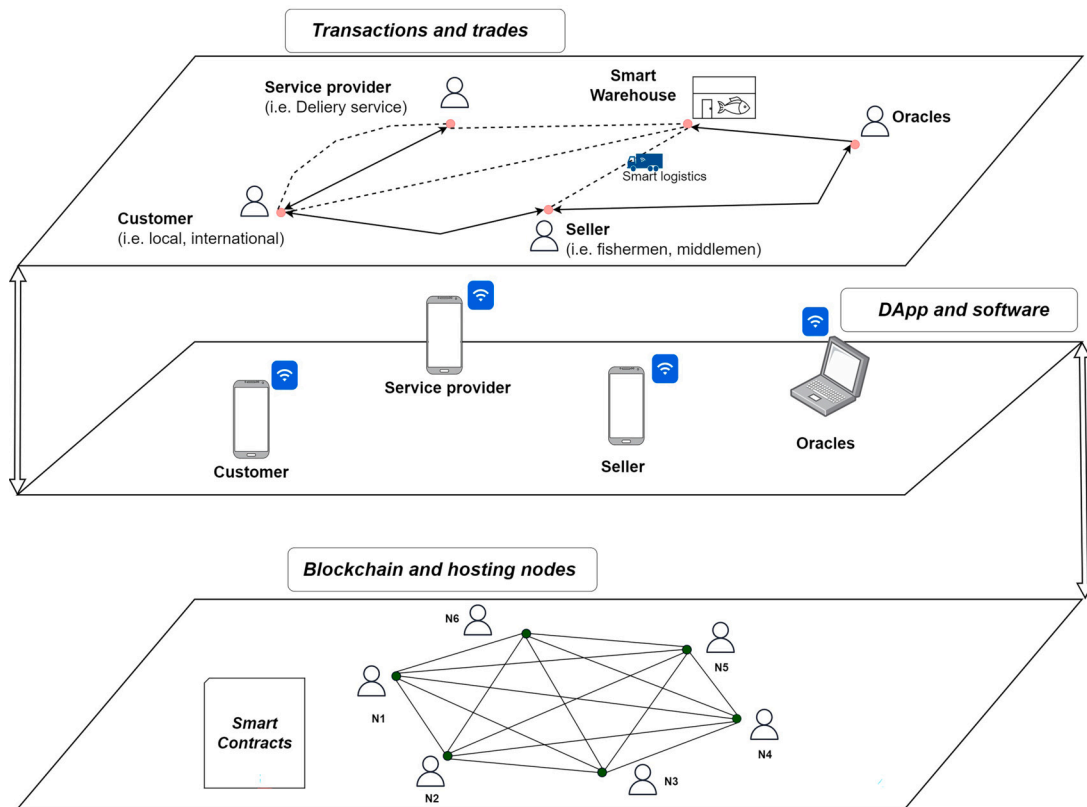


Fig. 8. Logical design of the proposed solution.

or unable to afford one. Buyers on an online e-commerce platform can retrieve products from the warehouse by presenting their order proof. Those distant from the warehouse or unwilling to personally collect their purchase can hire a delivery service similar to *Swiggy* and *Uber Eats*, broadening the customer base and creating job opportunities for a larger delivery service organisation.

By implementing this comprehensive framework, the fishing ecosystem can enhance efficiency, transparency, and inclusivity, ultimately promoting a more resilient and sustainable livelihood for fishermen. In this way the proposed framework aligns with five United Nations Sustainable Development Goals (SDGs): SDG 2, focusing on alleviating global hunger and developing solutions for efficient food commodity markets, timely access to market information, and mitigating extreme fluctuations in food prices (SDG 2.C); SDG 5, aiming for gender equality and empowering women by ensuring their effective participation, equal opportunities for leadership, and economic involvement (SDG 5.5), and by promoting the use of information and communications technology to empower women (SDG 5.B); SDG 8, encouraging communities to improve resource efficiency in consumption and decouple economic growth from environmental degradation (SDG 8.4), promoting decent work (SDG 8.5), expanding access to financial services for all community members (SDG 8.10), and increasing trade support in developing countries (SDG 8.A); SDG 9, aiming to develop sustainable infrastructure for economic development (SDG 9.1) and financial services (SDG 9.3), encouraging innovation in environmentally sound technologies (SDG 9.4), and supporting research to upgrade industry capabilities (SDG 9.5), along with increasing access to information and communications technology (SDG 9.C); and SDG 14, promoting the management of marine ecosystems (SDG 14.2), regulation of harvesting to end overfishing (SDG 14.4), and providing market access for small-scale and artisanal fishermen (SDG 14.B).

All transactions in the proposed framework are autonomously handled by smart contracts. Smart contract 1 in the figure manages the business between the fish owner and the warehouse, making payments to the fish owner after deducting warehouse charges. Smart contract 2 handles the business between the seller and the buyer, transferring money after the purchase. Smart contract 3 connects buyers to delivery service providers, and smart contract 4 allows fish owners to have agents. The framework also permits conventional intermediaries to buy and sell products online, preventing any community member from being left jobless.

## 6.2. Limitations of the study

As with all studies, this study also has its limitations. One notable limitation is the use of convenience sampling, where participation in the interviews was contingent upon fishermen knowing the village coordinator who was from the community and had the trust of some of them. This approach may have introduced selection bias, potentially skewing the representation of the wider artisanal fishing community. The study's reliance on a specific subset of business owners could result in an incomplete understanding

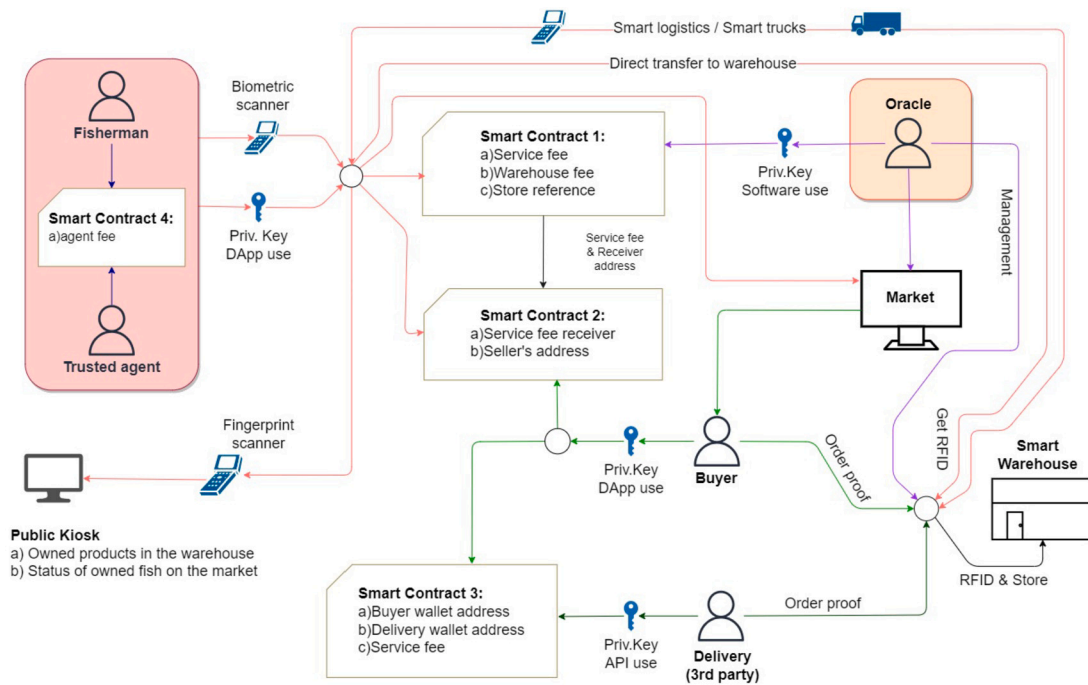


Fig. 9. Application-level design of the proposed solution.

of the challenges faced by the entire community. Secondly, the engagement of artisanal fishermen proved challenging due to their exhaustion after returning from fishing activities and their involvement in post-fishing tasks. The artisanal fishermen, gathered on the beach every evening to play cards or chat and relax and were easy to access, but they did not like being disturbed and thought of the interviewers as a nuisance, hence many refused. This limitation may have affected even those who participated from giving detailed responses as they were not gaining directly from the study. Thirdly, the language barrier may have influenced the depth of information obtained by the village coordinator in Malayalam the local language, and translated to the lead researcher into English. There is a possibility that some elements of the responses were lost in translation introducing some biases in the data collected and missing nuanced insights.

These limitations collectively emphasise the need for caution when interpreting the findings. Future research endeavours could employ a more probabilistic sampling technique in additional fishing communities for comparison; provide food and beverages as incentives for the tired respondents; and address language barriers by employing more number of translators to triangulate the results. Despite the identified constraints, the study sheds valuable insights on the potential of blockchain technology to revolutionise the fishing industry, presenting a robust approach to overcoming challenges and building resilience in fishermen's livelihoods. The proposed framework, outlined in the study, stands as a promising solution.

## 7. Conclusion

The study makes a significant contribution to rural development by exploring innovative, blockchain-based solutions tailored to address the pressing challenges confronting the inhabitants of the studied community. In achieving the first research objective of identifying conventional business procedures and the most influential stakeholders in the market, the study reveals that large and mid-size boat owners still manage to make a profit despite the imperfections of conventional business approaches, such as the lack of transparency and clarity in procedures and dependency on intermediaries. However, artisanal fishermen are under significant pressure and are exploited by middlemen in the process, pushing them further into poverty. Hence, new methods and business approaches are required to uplift their situation and improve their livelihood resilience.

Additionally, concerning the second objective of the study, which aims to identify the most prominent issues faced by fishermen in selling their catch and ensuring their livelihood security, five categories of challenges emerged from the study's findings. The dominant issue that can be addressed by a blockchain-based e-commerce framework and supply chain management system is the lack of transparency in business procedures and the traceability of products, which hinders fishermen and consumers from receiving the best prices. This issue jeopardises the economic safety and security of the fishermen.

The framework opens up opportunities for literate women within the community to become stakeholders in the fish market, a domain traditionally dominated by men. They can manage smart warehouses and assist illiterate fishermen in utilising the digital platform, thus transforming a previously male-dominated livelihood area. Additionally, it establishes an efficient method for authorities to monitor daily fish catches, preventing overexploitation of marine resources. The solution is tailored to accommodate varying



levels of digital literacy within the community and aligns with the UN's Sustainable Development Goals, including SDGs 2, 5, 8, 9, and 14.

However, the study revealed the educational attainment levels among the fishermen were low, and there is a significant digital divide among artisanal fishermen who are from the lower economic strata. This impedes their ability to participate in digital e-governance and e-commerce solutions available in the 21st century over the Internet. Hence, there is an urgent need to first enhance and develop their digital knowledge and capabilities through education and training programs to prepare these communities for digital e-commerce solutions in the near future.

### Ethics statement

This research was conducted in full compliance with ethical principles and standards. Ethical clearance was obtained from the Institutional Ethics Committee (IEC) at Amrita Vishwa Vidyapeetham, with approval granted on October 18, 2022, under the reference number IEC-AIMS-2022-ASSD-278. The research adheres to the ethical guidelines set forth by the Institute of Medical Sciences, Healthcare, Education & Research, and the Institutional Ethics Committee at Amrita Vishwa Vidyapeetham, with registration number ECR/129/1nst/KLJ2013/RR-19. Informed consent was obtained from all participants involved in the study, and all personal data were handled with the utmost confidentiality and privacy protection. The research team is committed to upholding the highest ethical standards throughout the research process.

### CRedit authorship contribution statement

**Mojtaba Enayati:** Writing – review & editing, Writing – original draft, Visualization, Software, Investigation, Formal analysis, Conceptualization. **Sudha Arlikatti:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Maneesha Vinodini Ramesh:** Writing – review & editing, Visualization, Validation, Conceptualization.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Data availability

The data presented in this study are available on request from the corresponding author.

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