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Integrated Agri-Food Supply Chain Model: An Application of IoT and Blockchain

Ikram Hasan[1], Md. Mamun Habib[1], Zulkifflee Mohamed[1], Veena Tewari[2]

[1]Graduate School of Business, Universiti Tun Abdul Razak (UNIRAZAK), Kuala Lumpur, Malaysia
[2]College of Economics and Business Administration, University of Technology and Applied Sciences, Muscat, Oman
Email: h.ikram217@ur.unirazak.edu.my, mamunhabib@unirazak.edu.my, zulkifflee@unirazak.edu.my, veena.ibr@cas.edu.om

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Abstract

In agri-food supply chains (ASC), consumers purchase agri-food goods from farmers. During this process, customers emphasize the need for agri-food safety, while producers hope to enhance their revenues. Due to the dynamism and complexity of the Bangladesh ASC, the traceability and control of agri-food goods encounter formidable obstacles. Due to their reliance on intermediaries, legal financial hurdles, Ethereum-based financial solutions, etc., however, most existing solutions cannot adequately meet the traceability and management needs of Bangladesh ASC. To solve these issues, the authors proposed an integrated Agri-food supply chain (IASC) model. In this study, a systematic review of the literature was conducted using a thematic analysis method. In a portion of the model, the authors depicted a linear physical flow to illustrate the relationship and function of intermediaries and to explain Bangladesh ASC's dependence on intermediaries. The approach incorporates Blockchain technology and IoT to promote transparency, minimize mistake, prevent product delays, remove unethical and illegal actions, improve supply chain (SC) management, track the whereabouts of the goods, and eventually increase consumer and supplier trust. The article also mentions that crypto currency-based financial transactions between stakeholders in the supply chain are now unlawful in Bangladesh. For blockchain API, a mobile banking and digital payment-based solution has been proposed. Finally, the blockchain-based Hyperledger Sawtooth API has been suggested so that clients can trace the entire history of a product by scanning the QR code on the packaging. Since Bangladesh's economy is primarily based on agriculture, this research can assist in boosting Bangladesh's economy. The paper would also contribute to the reduction of corruption and the improvement of firmer/grower and consumer satisfaction. The findings also pave the way for future studies to implement blockchain technology in ASC without relying on Ethereum-based financial flow solutions.

Keywords

Agri-Food Supply Chains (ASC), Blockchain, IoT, Hyperledger Sawtooth, Non-Cryptocurrency-Based ASC

1. Introduction

Agriculture originated during the Neolithic period, thousands of years ago. In addition to its association with agriculture, this period witnessed one of the most significant agricultural revolutions. The Agricultural Revolution, refers to a sequence of research and technology development operations that improved agricultural output worldwide between 1950 and the late 1960s, beginning in the late 1960s (Routroy & Behera, 2017). Since the turn of the millennium, agricultural laborers in developing nations are the most frequent users of the agricultural value chain or the notion of the agricultural supply chain. Even if there is no universally accepted definition of the phrase, it commonly refers to the whole range of products and services required to get an agricultural product from the farm to the person who will ultimately use or consume it. The concept of "value chain" was first introduced to the public in Michael Porter's 1985 book (Porter, 2007). The agricultural value chain is based on the concept of entities connected in the form of a chain to create and transport goods to end users in accordance with a predetermined order of operations (Henriksen, Riisgaard, Ponte, Hartwich, & Kormawa, 2010).

Bangladesh's economy relies on agriculture as one of its primary drivers. BBS estimates that the contribution of agriculture to the GDP in fiscal year 2021-22 is approximately 11.50 percent. Most of the population of Bangladesh resides in rural areas, where 84% of the population is engaged in agricultural activities such as farming, production, and commerce (Gazi, 2020). Approximately 40.6% of overall employment is in agriculture (BER, 2022). In addition to providing raw materials and exports to the nation's industries, agriculture is a vital contributor to the primary source of employment, means of subsistence, and food security for many rural people. Even though the modern economy relies heavily on economy, agriculture remains the cornerstone of many agricultural economies, including Bangladesh's (Bishwajit, Barmon, & Ghosh, 2014). Agriculture and economic expansion are demonstrated to have a good relationship (Wang, Wu, & Gao, 2010).

Agri-food supply chains (ASC) have faced a variety of unique challenges over the past few decades, including the involvement of a very large number of actors, the lack of literacy and skills in most of the workforce, dependence on the weather, rural-based supply, and other factors. As a result, it has become necessary to use information and communications technologies (ICTs).

Internet of things (IoT) is one of the primary technologies utilized in the ASC to manage information over the past several years. The Internet of Things oper-

ates through embedded devices such as sensors, actuators, and network connectivity. These gadgets enable real-time interaction and data sharing between various smart devices in the SC to facilitate the sharing of information (Zhong & Zhong, 2013; Gubbi, Buyya, Marusic, & Palaniswami, 2013).

In addition to IoT, Blockchain is an emerging technology that utilizes cryptographic hashing. It is a decentralized and encrypted transaction ledger system. This assures that neither the transactions nor the user's identity can ever be compromised. If such fraudulent transactions occur, the decentralized mining system will prevent them from entering the encrypted chain. Supply chain logistics is the most obvious use case for Blockchain Technology. In logistics, blockchain provides numerous choices for shipment data (Helo & Szekely, 2005). All products and items could be tracked, which could aid in preparing for any anticipated delays due to unforeseen circumstances. Blockchain technology with the Internet of Things (IoT) can be leveraged to track the complex supply of perishable items in Bangladesh.

Financial flow is another crucial aspect of the ASC procedure. The majority of blockchain and IoT-based ASC recommend using a blockchain-based money such as Ethereum to create a seamless procedure. However, in Bangladesh, the use of blockchain-based cryptocurrencies is illegal. Consequently, an alternative money flow management is also necessary to maintain a safe and tamper-free financial transaction record amongst ASC parties.

Although numerous blockchain and IoT-based agri-food supply chains have been built internationally and are still being analyzed, no Bangladesh-based agri-food supply chain model has been developed. Given that the Bangladesh supply chain relies largely on complicated intermediaries and since crypto currency-based transactions are prohibited by law, it is crucial to develop an integrated Agri-food supply chain (IASC) model for Bangladesh. The purpose of this research is to propose an integrated agri-food supply chain for Bangladesh by implementing IoT, Blockchain Database, and a digital financial solution in order to enhance supply chain transparency.

2. Literature Review

Information and communication technologies are referred to as ICT. Grids, computers, sensors, as well as communication technologies and the networks that link them, are some of these technologies (Chapman & Slaymaker, 2002). The current level of information and communications technology (ICT) in the agriculture and food industry is mostly driven by the availability of enormous amounts of data and information due to the unpredictable nature of ASC. However, there is a significant gap in the integration of information and communications technology (ICT) with the agri-food sector's supply network. Additionally, there is a lack of support for the effective use of data or information that currently exists (Verdouw, Meyer, Sundmaeker, Wolfert, & Verhoosel, 2013; Lehmann, Reiche, & Schiefer, 2012).

Over the past three decades, applications of information and communications technology have significantly improved ASC's performance, especially in the fields of food production and consumer mobility (Nikkilä, Seilonen, & Koskinen, 2010; Murakami et al., 2007). In addition, a few significant obstacles that have persisted to this day have made the development of ICT solutions excruciatingly slow. Whether it is inside a specific function or throughout the whole supply chain, managing information is one of the most important difficulties facing firms in the agri-food industry (Sørensen et al., 2010). The engagement of various stakeholders along the supply chain to ensure the industry's continued viability, in addition to the heterogeneity of these stakeholders and the ever-changing economic relationships they have with one another during food supply, is one of the most significant challenges facing the agri-food industry. Because of this, there is a relatively limited flow of information among all supply chain actors. It has become more obvious over the past few decades that the ASC's information gap has grown into a serious problem. Therefore, there is a need for greater transparency inside the ASC as well as the usage of food monitoring and tracing technology to improve overall performance. As a result, health and safety concerns will be reduced, and the supply chain will be better able to identify and address food emergencies.

Bangladesh ASC relies significantly on intricate intermediaries. Intermediaries serve as the link between the farmer and the consumer. Earlier research on the Bangladesh food supply chain asserts that numerous intermediaries are involved and that they pocket a substantial amount of the consumer price as profit. Five intermediaries comprise the primary distribution chain (Das & Hanaoka, 2010). Farias are minor merchants that transacted in three or four local markets and handled a modest quantity of product. They acquire products from farmers and then sell them to the Beparies. They are typically landless laborers or small farmers without full-time farm jobs (Tasnoova, & Iwamoto, 2006). Their business volume is modest because they have limited capital. Beparies are specialized merchants who purchase agricultural goods from farmers or farias at the local market or in the hamlet. They managed a greater quantity of product than faria. Aratdar purchases the goods from Bepary. Aratdar is a fixed-commission agent who operates between Bepari and retailers and charges a fixed commission for the provision of storage spaces. Retailers are the final marketing channel link (Das & Hanaoka, 2010). They purchase goods from Beparis via Aratdar and sell them to consumers. Based on the analogy, **Figure 1** is a linear physical flow of ASC in Bangladesh (Hasan & Habib, 2022a).

In Bangladesh, intermediaries are vital to the food supply chain. They split

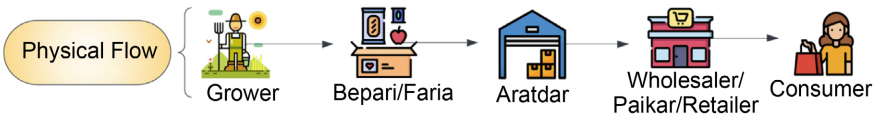

Figure 1. Linear physical flow of Agri-Food Supply Chain (ASC).

earnings with the producer. However, farmers in Bangladesh cannot avoid intermediaries while transporting their goods to market. There are numerous reasons for reliance on intermediaries. The predominant method of agriculture in Bangladesh is small-scale farming. The average size of land holdings is 0.6 hectares (Weinberger & Genova, 2005), and they generate a tiny amount of output. The participation of intermediaries can be attributed to the fact that the average farmer's marketable quantity is typically minimal. It is not always economical to ship such a little quantity using a certain mode of transport. On the other hand, farmer income must be increased through education. Many villagers in Bangladesh are uneducated, and they lack access to current knowledge. Additionally, farmers worry marketing risk (Das & Hanaoka, 2010) and depend on intermediaries to bring their product to market. On the other hand, updated market knowledge is an essential component of an effective marketing system (Hasan & Habib, 2022c). Marketing data assists producers in making sensible decisions. The producer might make decisions based on facts on market demand projections and sales timing. This information can aid in preventing a recurrence of the market glut, as it informs the farmer about the time of harvest. The most essential information is price information, which allows for a reasonable price to be set for a crop. Bangladesh has a very low rate of farmer literacy. They cannot read newspaper prices. The farmer receives information from the trader or truck driver who comes to purchase the produce, which may rely on the trader's profit (Akanda & Isoda, 2006). Most intermediaries obtain market intelligence from market trips, personal observations, and fellow merchants (Tasnoova & Iwamoto, 2006). Directorate Agricultural marketing, Government of Bangladesh is responsible for regularly distributing the market price of agriculture products in newspapers, weekly bulletins, and radio broadcasts; yet its website contains no price information. Supermarkets are a relatively recent addition to Bangladesh's domestic retail sector. Since supermarkets continue to play a modest role in Bangladesh, most of the vegetable output is sold in local markets or to wholesalers who transport it to city marketplaces. As a result, production is poorly organized, and none of the farmers in our sample admitted to engaging in contract farming. Wholesalers and small merchants account for 96% of the market share in the vegetable trade (Das & Hanaoka, 2010).

3. Research Methodology

The initial step for this paper was to review the pertinent literature. The primary objective of a systematic literature review is to identify pertinent literature on the topic. This systematic literature review was conducted according to the method given by Brereton, Kitchenham, Budgen, Turner, & Khalil (2007). There are three primary phases to the process: planning, execution, and result analysis. The authors began by designing the review, determining its requirements, and creating its procedure, which includes research objective, a search strategy, and the selection of papers. The authors then implemented the defined plan and ex-

tracted pertinent information. In conclusion, the authors produced the data and conclusions that were utilized to illustrate the models. The search strategy is the foundation of a systematic review thematic analysis manner (Bermeo-Almeida et al., 2018). The first step of the search strategy was to identify the digital libraries and web resources that would be used to conduct the search for primary studies. Multiple digital libraries, including IEEE Xplore Digital Library, ScienceDirect (Elsevier), Springer, and Scopus, have been selected. In addition, Web sources from Google Scholar and Web of science were used to expand the breadth of the review.

The search strings which are combination of keywords were built by combining the keywords such as agriculture, agriculture supply chain transparency, Bangladesh agriculture supply chain, IoT and Blockchain based agriculture supply chain, cryptocurrency alternative agriculture supply chain, mobile banking in Bangladesh, etc., with the connectors "AND" and "OR". Also excluded were publications written in languages other than English, master's theses and doctoral dissertations, and duplicate articles collected from Google Scholar and Web of Science.

Finally, the authors have illustrated the proposed models using Lucid chart Software. Lucid chart is a web-based diagramming program that enables people to graphically collaborate on developing, modifying, and sharing charts and diagrams to enhance processes, systems, and organizations. It's manufactured by Lucid Software Inc. (Julian, 2019).

4. Conceptual Model Development

Combining IoT technologies, Blockchain database technology, and digital financial solution integration in the Agri Food Supply Chain in Bangladesh, as discovered from the systematic literature research, a conceptual model has been proposed.

4.1. IoT Integration in Agri Food Supply Chain

The Internet of Things (IoT) is essentially a network comprised of hardware, software, devices, databases, objects, and sensors that work inside a system to meet the requirements of the community (Mims, 2022). IoT is a technical revolution in computing and communications that has given rise to a vision of communication at any time, from any location, via any medium (Li, Xu, & Zhao, 2014; Atzori, Iera, & Morabito, 2010). In today's world, numerous cutting-edge technologies are developed to produce food and food products of excellent quality (Käferstein, 1999). Some current technologies, such as irradiation, ICT, genetic alterations, etc., are effective for addressing potential issues in the food sector, such as food products with a shorter shelf life. Radio-frequency identification (RFID)-based data is crucial for addressing this issue (Kärkkäinen, 2003) and is one of the pillars of IoT applications. RFID has been the subject of substantial research in the published literature in recent years (Zhu, Mukhopad-

hyay, & Kurata, 2012). Thus, IoT enables the interconnection of digital and physical elements, enabling ASC to offer an entirely new category of applications and services. The network is predicated on the automatic identification of food products and their location, as well as their tracking, monitoring, and event generation (Sundmaeker, Guillemin, Friess, & Woelflé, 2010; Aung & Chang, 2014).

Several further Internet-based technologies, like artificial intelligence, cloud computing, 3-D printing, biosensors, etc., are performance-oriented processes. The Internet of Things is crucial for reducing food waste (Sundmaeker et al., 2010). However, adoption of these highly efficient IoT-based solutions in AFSCM in south Asian nations is manifestly lacking (Verdouw, Wolfert, Beulens, & Rialland, 2016).

IoT is crucial to ASCM in emerging economies (Ramundo, Taisch, & Terzi, 2016). Based on IoT technologies such as RFID and wireless sensors, the ASC is a supply chain that comprises production, distribution, storage, and retailing facilities in order to satisfy client demands for greater quality and authenticity. The implementation of RFID and wireless sensors traceability helps managers to identify precise product information and preserves product quality. In addition to enhancing food quality, this will reduce food waste.

This technology can also minimize farmers' workloads. IoT will significantly enhance the supply chain's transparency at every step. The whole supply chain for agricultural products can be automatically recorded using RFID tags. In addition to reducing the "bullwhip effect", it will also cut various inventory and labor costs, resulting in enhanced performance (Luthra, Mangla, Garg, & Kumar, 2018). This will further lower costs, and farmers may reap the benefits. IoT will ensure that every link in the agricultural production supply chain is served in the most efficient manner. Adopting technologies such as high-pressure processing, artificial intelligence, vibrational spectroscopy, and tracking-based distribution strategies would increase the capacity of the supply chain for supplying agricultural products and match the demand for such products (Luthra et al., 2018). Most of the Bangladesh's population lives in rural areas that lack not just modern but also fundamental amenities. Through access to ICT tools and services, their health, employment, women's empowerment, agriculture, gender equality, and education challenges can be tackled.

Traditional SC traceability is reliant on centralized systems, such as cloud databases using IoT, which lack transparency and lead to manipulation, security risks, data loss, etc. (Hasan, Habib, & Mohamed, 2023). The primary limitations of the traditional supply chain include the inability to guarantee food safety at any level, the inability to trace the product's origin, the lack of transparency and traceability, and the lack of controllability and controllable life cycle (Madumidha, Ranjani, Vandhana, & Venmuhilan, 2019).

4.2. Blockchain Technology Integration in Agri Food Supply Chain

By utilizing the technology known as blockchain, which performs the function of

a public ledger on a distributed network or all information maintenance including validation, verification, and so on, we are able to maintain records that are provide security, tamper-proof, and do away with the need for third-party intermediaries in transactions (Hasan & Habib, 2022d). It primarily reduces transaction costs and enhances product quality. The encryption mechanism employed here inspires confidence among users, which boosts product demand. The encryption techniques utilized by crypto currencies facilitate the authentication of users and blocks. Consequently, each block in a blockchain contains transaction information and other features. **Figure 2** depicts the ledger chain from the very beginning when the genesis block was produced. Through a hash value, each block contains a reference to its predecessor. The peer-to-peer network validates fresh transactions and user identities (Madumidha et al., 2019). The Proof of Stake (POS) method generates challenges for users to complete, which are then validated and, if valid, added to the block.

A conventional Contract, on the other hand, is inefficient for blockchain technology. In addition, traditional supply chains are comprised of a huge number of paper documents, which may result in inefficient tracking and theft. Smart contracts that are automatically activated when specific criteria are met can assist Blockchain address these shortcomings of transparency, tracking, efficiency, and security (Madumidha et al., 2019). Smart contracts remove or significantly minimize the need for intermediaries. However, a smart contract is a digital contract that automatically executes when certain criteria are met (Leduc, Kubler, & Georges, 2021). These code-based contracts allow agreed-upon activities, such as Payments, to occur automatically, promptly, and without a third

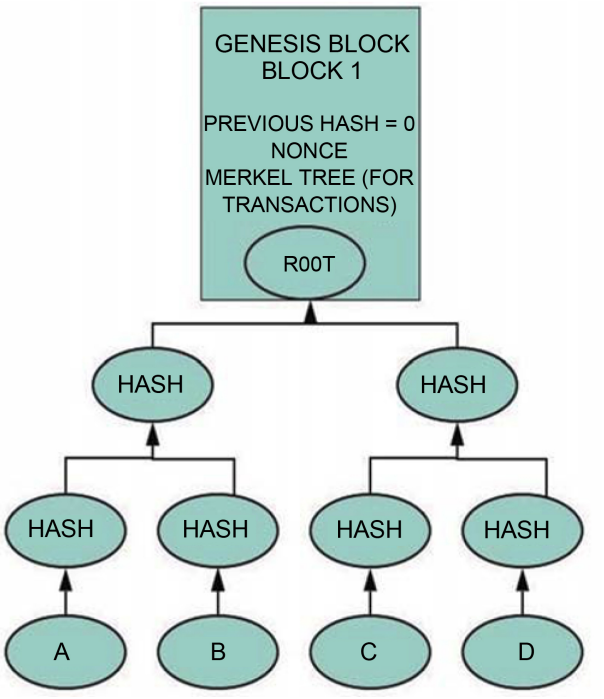

Figure 2. First block-genesis block.

party upon the fulfillment of the contract's requirements. A smart contract may, for instance, transfer payment to a courier when the consumer acknowledges receipt of their package. Smart contracts are unique because they may be programmed with code that executes itself without the need for a third party. This significantly saves time, effort, and money. And anyone can facilitate transactions, with no possibility of user error or fraud. A smart contract is a commitment between parties involved in a transaction that keeps each participant accountable for their role in the transaction and ensures the contract is enforced. Smart contracts enhance the supply chain's visibility, traceability, and transparency, allowing it to be more adaptable in its efforts to establish relationships between stakeholders. Here is an illustration of IoT and blockchain technology integration in ASC based on the comparison (**Figure 3**).

4.3. Financial and Information Flow Solution in Agri Food Supply Chain in Bangladesh

Financial flow is another crucial aspect of the agri-food supply chain. Most blockchain and IoT-based Agri-food supply chain models recommend using a blockchain-based currency such as Ethereum to make the process easy. However, in Bangladesh it is illegal to use blockchain-based cryptocurrencies. Consequently, an alternative money flow management is also necessary to maintain a safe and tamper-free financial transaction record amongst ASC parties.

What is meant by the term "financial inclusion" is the process of ensuring that vulnerable groups, such as lower income groups and weaker segments of society, have affordable financial services available and loans when they are needed (Hossain & Russel, 2017; Rangarajan, 2008). As a proportion of the total population, 62% of Bangladeshis reside in rural areas (The World Bank, 2020), the majority of whom do not have a bank account. The commercial banking sector is passing on a significant market opportunity. Building bank branches throughout Bangladesh's rural areas is not a viable solution, though, because of the high costs and rules' limits. This is due to the fact that the central bank only issues permit for the opening of a maximal of fifteen new branches each year (Kabir, Islam, & Inam, 2013).

Since 2011, a small number of commercial banks have attempted to incorporate unbanked individuals in official financial channels using Mobile Financial

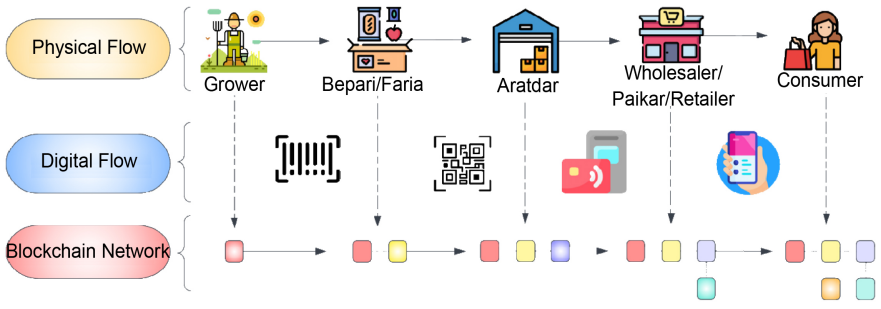

Figure 3. IoT and blockchain technology integration in Agri food supply chain.

Services (MFS). Therefore, branchless banking is the ideal solution for this issue. Branchless banking has the potential to extend the distribution of financial services to poor people who were not reached by traditional bank branch networks. It reduces the cost of delivery, including the cost to banks of building and maintaining a delivery channel as well as the cost to customers of accessing services like travel or waiting times (Ivatuary & Mas, 2008). Users can conduct banking transactions through Mobile Financial Services (MFS), which integrates banking with mobile wireless networks. This includes sending or receiving money and making deposits and withdrawals with a mobile account (Hasan & Habib, 2022e). Most of these services depend on bank agents. Bank agents let mobile account customers do business outside of banks. It provides the ability to construct an additional route beyond the bank branch and ATM network, so facilitating easier access to the official banking system for millions. Bangladesh Bank seeks to develop a commercially successful, competitive, and safe MFS market (Bangladesh Bank, 2015).

Almost everyone in Bangladesh now has mobile banking solutions such as Bkash, Nagad, Rocket, etc. on their mobile phones (Hasan & Habib, 2022b). The digital salary disbursement solution of mobile banking such as bKash has decreased the bother of cash handling in Bangladesh's textiles industry's wage disbursement. In every mobile banking transaction and salary disbursement procedure, a transection ID containing all required information is generated, comparable to the blockchain's tamper-proof hash algorithm. As a result, we propose integrating the mobile banking transaction ID system with a blockchain smart contract rather than a crypto currency solution.

For monitoring the flow of information from grower to consumer, blockchain-based software such as Hyperledger Sawtooth may be employed. Hyperledger is the name of a 2016 Linux Foundation project that spawned the Hyperledger open-source collaborative initiative. Composed of a collection of frameworks and tools that anyone may use for free to construct their own customized blockchain solution to meet the needs of individual businesses. Sawtooth enables the development, execution, and distribution of DLT solutions for both public and private enterprise applications, with an emphasis on private release with public access (Baralla, Pinna, & Corrias, 2019). It provides a modular and adaptable framework for implementing transaction-based modifications to a shared state amongst mutually untrusted participants coordinated by a modular consensus mechanism, which is replaceable even after the system has been deployed.

The integrated agri-food supply chain that has been proposed for Bangladesh can be seen in **Figure 4**, displayed with all the relevant elements such as physical flow, digital flow, blockchain network, financial flow and Hyperledger sawtooth integration.

5. Discussion

When collecting the Agri product from the grower, the Bepari uploads information

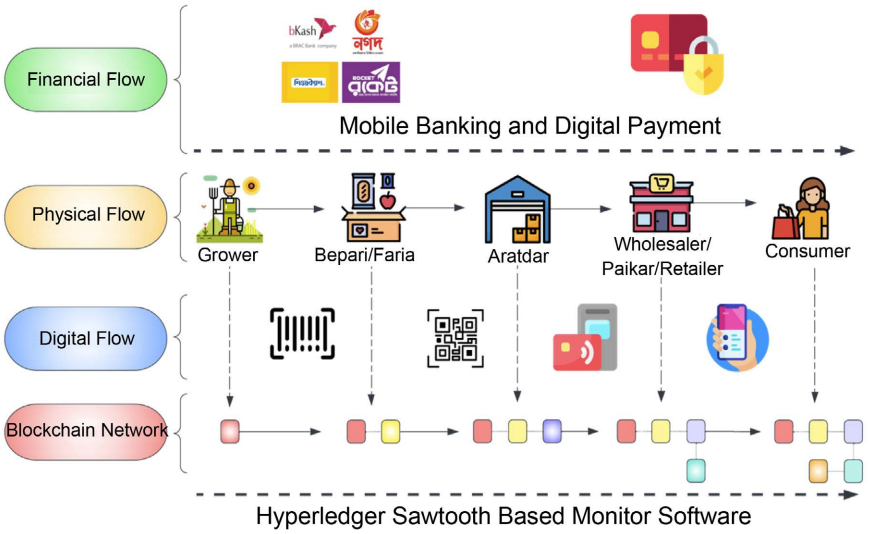

Figure 4. Integrated Agri-Food Supply Chain (IASC) model for Bangladesh.

about the food product, such as the date it was gathered and the price. The food item is subsequently given an RFID tag (Zebra Technologies, 2014). The tags can be attached to small items and shipping labels. RFID tags contain a microcontroller and antennae. Special printers wirelessly load the identification information onto the tags. Tags can be used for several purposes. RFID scanners read the tag's information. This information may include product serial IDs, location logs, order status, product bin locations, and component locations, which can help maintain the supply chain (Madumidha et al., 2019). The system will use RFID data to track stock position and shipment as products travel through warehouses and vehicles. RFID can do this. RFID can verify that the proper products and qualities are obtained at both sites. This reduces errors. Using the internet of things, a product's information may be tracked during transportation and storage, improving accuracy, efficiency, and accountability. The location of the product may be determined via the fully employed IoT equipped supply chain network, ensuring that theft and other criminal behaviors can be quickly identified and dealt with. Following the Bepari's application of RFID tags, Aratdar gathers data regarding the food item and adds a QR code to packaging.

Now that Aratdar is acting as a distributor, the product flows from Aratdar to the wholesaler or retailer, who automatically notifies the retailer about the receipt of food products. Retailers bring a product to market once it is ready for sale. The shop is completely transparent about shipping times. Orders, promotions, etc. are adopted as necessary. All of these transactions happen through digital payments or mobile banking services like Bkash, Nagad, and Rocket. Each party now scans the RFID at every stage of the production process and updates the information on the blocks that are saved in the cloud using a mobile app. So, storing blocks is another crucial function of the cloud. The app or website is used for all transactions, verification, and validation. Websites and mobile apps act as platforms for communication.

When the genesis block is created, details are added to it, and the first grower-Bepari transaction is added to it, the Blockchain Technology will start to work. This will happen when the genesis block is established. Customers can review product information such as its age, origin, shelf life, and expiration date by scanning the product's QR code using an app on their mobile device.

A mobile client, a web client, an off-chain repository, and REST APIs might make up the application subsystem. The production and transmission of transactions and batches to the nodes of the Sawtooth network using REST APIs, which are made available by default by the community, is the major function of the subsystem (Baralla et al., 2019). It is possible to create two separate clients by using the JavaScript Sawtooth Software Development Kit. The mobile client is for people who aren't participating in the study, whereas the web client is for people who are. The community application can serve as the basis for the web client, which can then be constructed. It does this by managing the logic of the front-end application through an interface so that system actions can be carried out. It is primarily responsible for generating and signing transactions and batches, and it can obtain information about the global status of the network from the validator using APIs that are REST-compliant. Client Signing Model is a tool that may be utilized to verify the user's identification for the benefit of the transaction company and batch. The transactions are locally signed utilizing the private key of the user that is currently logged in. An off-chain repository that contains all user information, such as the username, the hash of the password, and the personal key pair for each user, encrypted with the user's AES password, can be used for key management. This repository can also be used to store the encrypted personal key pair. Through the mobile client, a non-member, such as a customer or standard online browser, can view the whole product history; in fact, a QR code is placed on the package of each product that has been registered in the system. The QR code reading will display product-related IoT-generated data and events, such as its temperature and location, the company that owns the batch, harvest and relative fields, certifications, general and specific occurrences, raw materials, etc. Here, Sawtooth serves as a decentralized data maintenance platform.

From the proposed conceptual model, we can see that IoT devices can track the movement of agricultural products from farm to plate in real-time, providing transparency in the supply chain. Blockchain technology can secure and verify this information, ensuring that all actors have access to the same data and preventing fraud and tampering, while digital financial solutions can streamline payments and increase accountability.

6. Conclusion

Since Bangladesh's economy is dependent on agriculture, agriculture is one of the most important fields of study. However, due to a complex supply chain process depending on intermediaries and a lack of effective monitoring oppor-

tunities, Agri product delays, SC error, and unethical and illegal conduct are prevalent in this industry. As a result, the essential stakeholders, namely the grower and the consumer, are harmed by this process. To overcome this issue, an Integrated Agri-Food Supply Chain (IASC) Model has been proposed. Since the Agri supply chain in Bangladesh relies significantly on intermediaries, their roles and significance have also been discussed. On this basis, a linear physical flow for the agriculture supply chain has been established. In the proposed approach, Blockchain technology is used to improve supply chains and enable security and traceability. IoT Implementation ensures the correct products and product attributes are received at both collecting sites, avoiding errors. The proposed digital flow will track product information during transportation and storage, improving efficiency, accuracy, and accountability. A Blockchain and IoT-enabled supply chain network may pinpoint a product's location, allowing theft to be quickly detected and prosecuted. This study also addresses the fact that crypto currency-based financial transactions between supply chain players are illegal in Bangladesh at the present time. As a result, a mobile banking and digital payment-based solution that can be integrated into the blockchain API has been proposed. This financial solution is suitable for this circumstance given that Bangladesh parties in the agri-food supply chain are already utilizing the system. Lastly, the blockchain-based Hyperledger Sawtooth API has been proposed so that clients, including non-participating members and customers, can trace the whole product history by scanning the QR code on the package.

This research has the potential to significantly improve Bangladesh's economic standing by lowering the corruption rate and boosting firmer/grower and consumer satisfaction. This model may be of use to all of the ASC's stakeholders, but it may be of particular assistance to less fortunate farmers and final consumers. By utilizing this, large Bangladeshi Agri-food retailers such as Agora, Meena Bazar, Aarong, and others will be able to simplify and improve the transparency of their supply chains. Having said that, this conceptual model is entirely based on theory. It is necessary to conduct real-time assessments of the proposed model's efficiency as well as its rate of success. This limitation of the paper itself can open a new field for researchers to investigate further. This study also gives a roadmap for future research on the use of blockchain technology in the supply chain without an Ethereum-based financial flow solution.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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