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NiCuSBlockIoT: Sensor-based Cargo Assets Management and Traceability Blockchain Support for Nigerian Custom Services

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ABSTRACT

As competitive market and globalization continue to ripple a range of issues across the asset chain (i.e. safety, quality, tracing, and overall management efficiency). Pandemics are bound to occur without warning and has revealed the unpreparedness of many nations. Thus, the Nigerian Government aiming to shore up revenue/monetization via customs exercise duties to augment the nosedive in revenue of the oil sector – must formulate policies and adapt technology to harness its inherent benefits therein. Study advances a sensor-based blockchain NiCuSBlockIoT, which will provision a decision-support scheme for cargo goods traceability and asset movement on a value-chain by first ensuring that accurate records of cargo goods are registered, tagged and reported using the sensor-based units. These are then broadcasted on to the NiCuSBlockIoT as record and/or blocks via a P2P chain on the network as a decentralized framework executed on a distributed hyper-ledger fabric via smart-contract transaction logic. Result show model eliminate fraud that often accompanies a centralized scheme via its sensor-layered model that reports all such errors as data on NiCuSBlockIoT supply value chain.

Keywords: BlockChain, Food supply chain, Nigerian Customs Service, NISBlockIoT framework

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1. INTRODUCTION

Interaction among society's resident vis-à-vis their corresponding migration process as the need arises, from one place to another [1] has continued to form baseline as well as foundation upon which globalization is advanced. But, a consequent effect of such interaction, integration, advances and migration activities [2] is the relative ease in acceleration and propagation of infectious disease [3], and its consequent spread evolution from an epidemic to a pandemic [4]. It became globally clear, that covid-19 pandemic witnessed: (a) closure of schools [5]–[7] with limited public gathering in our society [8], (b) adoption of social distancing as means to curb its propagation effects [9]–[11], (c) residents' migration pattern [12]–[14], (d) responses to businesses birthing remote-work with its reduce monetization [15]–[17], and (e) the adoption of nose-masks in public places and especially in schools [18]–[20]. Post-covid-19 reports have revealed that: (a) traditional schools were shut down to curb its widespread propagation, (b) businesses were impacted globally, (c) the short-term disruptions in businesses yielded great significant negative impacts, and (d) such impacts if mishandled – may yield long-term effects that ripple throughout the society with the formation of new businesses as well as sustenance of older businesses [21]–[23].

Globally, covid-19 response to prohibit social gathering, impacted short/long-term costs with reduced economic activities [24], [25], which rippled across the society with a range of associated costs such as reduced infrastructure access, increased population inequality, starvation [26], stratifications in global access to technology, social disparities from widespread revolution with technology in various regions, rise in inefficiencies with harder job schedule, unstable psychomotor health [27], and mental formation adjustments to new realities [12], [28], [29], and complex new logistics adaptabilities – among other costs [30]–[32].

Pandemics are large-scale propagation and outbreaks of infectious disease [33] that greatly increases both the morbidity [34]–[36] and mortality rate [37]–[39] of the populace over a wide geographic area. This in turn, results in significant negative socio-economic impacts with political disruption and ramifications [40]–[42]. Evidence suggests that the likelihood of repeat pandemic has increased in the past century [14], [43], [44]. These have been attributed to the increased (im)migration [45], global integration [46], urbanization [47], technological advances [48]–[50], land-use changes [51]–[53], and exploitation of natural environment vis-à-vis its resources [54]–[56]. These trends will likely continue to intensify and significant attention with well-formulated policies be enforced on the need to identify and limit emerging outbreaks, to expand and sustain investment to build up preparedness and health capacity to handle future occurrence [57]–[59].

Its impact in Nigeria unprojected still ripples across with disruptions still experienced that continues to raise many socio-economic concerns that will help with national recovery [60], [61]. The need arises for society to reflect upon new norms of local realities vis-à-vis the implementation of platforms to exchange ideas and experiences that foster effective strategies to help repair the wreckage impacted upon today's society; And in turn, help to mitigate future pandemic effects of any kind [16], [62], [63].

Evidence continues to suggest that another pandemic alongside projected spread propagation will meet us better prepared to tackle such – even with less migration, the immediate closure of public gatherings, and enforcement of health protocols [26]. Businesses must seek new modes to harness virtual technology as a key integral frontier for today's society in response to our recovery. Robust enforcement and implementation of regulatory policies can help advance and yield high unexpected results [64]. Businesses will thus suffer from recency of purchases by their inherent consumers, experience reduced frequency of both purchases and visits to business vicinity by the customers, and therein experience reduced monetization [65]. Businesses globally, took inventories of their daily production so as to account for goods and services rendered to their client in exchange for money [64]. Inventories are raw materials for finished products, stored to meet supply demand of consumers [55], [66].

Lesser inventory may result in businesses losing opportunity of sales, loss of potential clients, loyalties and anticipated maximum profits [67]. With over-stocking of inventories, it will increase the cost of maintenance and storage, and thus, reduce the profit margins [68]–[70]. With nation left devastated by the pandemic, the International Monetary Fund reported by 2024 ending, it will cost globally about US$13.8trillion [71], [72] for recovery. This socioeconomic impact while enormous, also had indirect impacts to both businesses and society so that all nations through her citizens are now exposed and educated with disaster management due to the rippled consequences [73].

1.1. The Nigerian Customs Services (NCS)

NCS has continued to play a significant, critical and effective role in the transportation therein of goods as asset (in/out) the docks of the nation Nigeria [74]; And thus, has continued to shore up revenue generation within her borders [75] – all targeted at national development [76]. The nosedive trend in monetization from the oil sector, and world-order search for alternatives to fossil fuel [77]–[79], has shift emphasis toward the non-oil sector [80], with customs excise duties as the frontier alternative scheme to backup low-sales from crude oil [81]–[83].

Critical issue faced by NCS during the pandemic that resulted in nosedive of the revenue generation includes: (a) the gradual severance of migration with travel restrictions and border closures with the peak of 2020 [84], (b) increased duty exercise and its related costs in shipping costs vis-à-vis its transport duration [85], and (c) limited access to shipping infrastructure [86]. Pandemics may have caught the globe unaware; But, it immensely advanced digital revolution [87] – to result in new methodologies and paradigms as the new norm for both businesses and government operations.

The World Customs Organization (WCO) and World Trade Organization (WTO) examined blockchain, smart contract, distributed ledgers, and IoTs in relation to how its adoption can advance their operations, ease traceability and manageability today [88]. Other studies have sought to identify how these technologies can promote and facilitate trade agreements, and assist customs administrations with their objectives of safety, security and fair revenue collection [89]–[91]. While, WTO sets rules for international trade – WCO deploys standards, regulations and tools for border formalities. Both organizations provision capacity-building and technical assistance aimed at facilitating trade and customs procedures [92].

Their cooperation coverage are in customs valuation, rules of trade facilitation and mitigating the effects of the COVID-19 pandemic via the adoption and adaption of paperless trade and technologies [93]. The rapid growth of trade volume makes it necessary to increase monetization with safety and security of international trade to leave the flow of goods unobstructed. Adaption of IoT and related tech will yield a resilient system for use in customs administration supply-chain without degraded performance [94]. It will thus, be extremely helpful to capture and share real-time information to fully automate border crossings and customs procedures in national ports and to ensure traceability of goods and means of transport [95].

1.2. Supply Chains as Knowledge-Rich, Inventory Traceability Models

Supply value chain thrives on information transparency and timeliness to yield an efficient and effective decision support system with eased access and retrieval of information, mobility, traceability and dependable. Several studies have sought to enhance supply chains so they are expressed as mathematical models with efficient data management and mining capabilities.

These in turn, yields innovative, knowledge-rich systems allowing their fusion with technology-rich and technology-dependent structures. The recent adoption cum adaptation of wireless sensors, virtualization, optimization, and blockchain [96], [97] has further continued to advance its reach and coverage.

In today, supply chains ranging from agriculture to medicine, pharmaceuticals and oil asset – have since become primary beneficiaries of the blockchain technology. The incorporation of blockchain into the framework of the Nigerian Customs Service – to aid effective management of resources as asset will also advance this supply chain also as a source of livelihood for many of its citizens. Borders opening and manageability has continued to provide the requisite support for the total amount of resources expended by the Nigerian citizen within her territories. This chain can provision and maintain improved productivity and profitability via a concerted effort to address its many concerns that includes (not limited to): (a) disorganized regulatory system, (b) lack of funding and strategic policies formulation to support custom exercise and duties, (c) non-optimal inventory management and traceability systems, (d) poorly structured and functional record-keeping system, and (e) inefficient customs service and exercise duties supply value chain [98].

Supply chains has now become the focal epicenter for diversification of financial portfolios with 3-crucial factors that impact human existence include food, clothing, and shelter-mostly [73]. With import and export duties, products traded as assets and the inherent challenges with manual tracking of assets as cargoes and goods shipment with re-distribution, an optimized value supply-chain structure becomes imperative and critical. An effective cargo value supply chain framework must be able to deliver superior consumer values at a lower cost, with traceability and effectively eased management [99]. Thus, by extension, the supply chain's adoption of sensor-based technologies and the blockchain framework via smart contracts and portfolio will inadvertently yield new paradigm as robust policies framework to drive value chain [98] whilst, satisfying the requirement needs therein of stakeholders [100]. Thus, supply value-chain managers must be able to consider the interactions of known/unknown parameters as well as limitations cum minor shifts from which he/she is expected to create a plan that will render effective and efficient results for the value-chain.

1.3. The Blockchain Models

The blockchain technology has since become one of the best innovations created in the 21st century. Originally designed for adoption as digital currency – it is now a frontier product adapted to a wide range of schemes and value-chains via its adaption of smart contracts to aid its robust use in a variety of sectors such as healthcare [101], [102], electronic voting [103], [104], and supply chain models. It is a shared ledger of digital transactions as executed and distributed amongst shared nodes (blocks) [105]. Each node is device (physical or virtual) on the chain network. Its benefits are poised from the inherent characteristics and feature it possesses such as security, decentralization, smart contracts and portfolios, and auditability [73], [97], [106]. The adaption of the blockchain for new domain tasks is to help decentralize data storage from being manipulated or controlled by a central authority, making records immutable. The chain is a network of nodes to form a chain of blocks that contains data – so that the knowledge stored on each block using a distributed ledger can be assessed by any user from anywhere. A typical chain consists: (a) data, (b) hash of the record, and (c) previous block's hash linking this record to previous records and block(s) as in figure 1. A blockchain uses hashing and proof of work over a distributed peer-to-peer (P2P) network(s) as its safety schemes to ensure records security, integrity, immutability and non-repudiation on the chain [107].

Figure 1. The typical block scheme (source:)

Thus, the addition of a new data/record will ensure that the record be first broadcasted onto the chain via a P2P network verification. So that, once approved by a majority of the nodes according to its pre-approval rules – the record is then added to chain as new block. Next, a record of this transaction as adopted on the smart-contract is then distributed to several nodes to ensure security. The smart contract provisions performance support of all credible transactions on the chain [108], [109].

1.4. Study Motivation

The study posits the following as issues cum motivation therein [14]:

1. Unwillingness of stakeholders on cargo goods supply chain, to disclose accurate data about their asset or produce, and the corresponding chain processes has led to unavailability of data for extensive study. We thus, signed a non-disclosure agreement with the Nigerian Customs Service to get and encode the requisite information needed for the study. However, to combat this-we propose the use of a distributed hyper-ledger fabric framework to help store records as world-state data using key-pair hash values.
2. Studies have explored the adaption of a mobile app to implement the supply chains as a centralized model. The blockchain network with RFID-sensor-based layered IoT ensemble will improve user-trust level, ensure transaction transparency, records security and improve records traceability as required in customs services. And in turn, yield the desired decentralized scheme.
3. The Nigerian Customs Service employs a centralized existing supply chain management system. With no control of such asset, there may/can occur irrational (non-approved) price hikes and monopoly of the chain, which will further threaten monetization, service quality, security, and safety of regulations and its robust implementation is continually impacted by such unregulated policies and decisions. These can be averted via a decentralized system with such records, accurately and timely to all stakeholders.

Study wishes to develop and deploy NiCuSBlockIoT – a blockchain-based framework that extends [98] by utilizing sensor-based RFID to help tag records and register/broadcast them on the blockchain via a P2P network to optimize the custom exercise duties revenue generation in Nigeria by: (i) understudying the current supply-chain network to aid traceability in Nigeria and beyond, (ii) model the NiCuSBlockIoT to facilitate customs services and aid manageability with effective administration of policies and regulation to yield efficient business logic with transaction(s) using the block-chain model, (iii) ensure all transactions are authenticated using the smart-contracts approach via the hyper ledger fabric, and lastly, (vi) the system will ensure that all transactions are validated with data security using cryptographic techniques to eliminate fraud, corruption as well as errors resulting from centralization policies.

2. METHOD

2.1. From Existing to Proposed Sensor-based Customs Service Blockchain (NiCuSBlockIoT)

The operations of the Nigerian Customs Services exercise duties is such that contains a litany of stakeholders ranging from exporter, bank/broker, clearing agent(s), the Nigerian export promotion council, service provider (cobalt), examination body (i.e. NCS, NDLEA, NAFDAC etc), shipping company (service provider), and country's final destination docks, importer, authorized bank, clearing agent and examination body, bank terminal operators (PTML, Grimaldi, APMT etc), customs service, and terminal exit [110].

We adopt Akazue et al. [111] model, which employs an object-oriented methodology for an n-tier fat client blockchain called NiCuSBlockIoT with the following steps: (a) goods assets are registered via sensor-based radio frequency identifier (RFID) tags by the exporter, (b) records are broadcasted on the chain for approval using the proof-of-work scheme by all interacting nodes. It explores the smart-contract as modeled to use the smart-phone due to its eased portability, access ease, mobility, and speed of transaction(s) for all user/stakeholders. For mobile apps, we employ a functional programming mode in the development of the application program interface (API) to implement the blockchain smart contract on the android platform. Our *n-tier, fat-client* model will help users effectively and efficiently resolve the various data inconsistencies from various stakeholders on the blockchain at various points in the Nigerian goods value-chain problem using the hyper-ledger fabric [112], [113].

2.2. The Proposed Sensor-based Customs Service Blockchain (NiCuSBlockIoT)

The smart-contract is explained as thus:

1. **Stage 1: Ledger State** – 'Goods' are represented as a set of properties via a key-pairset assigned values. This record also details the state of the goods namely 'export', 'import' – with a variety of stakeholders namely exporter, authorized banks, bank terminal operators (PTML/Grimaldi/APMT), agent(s), service provider(s) shipping company (i.e. cobalt), inspection body (i.e. NCS, NDLEA, NAFDAC), and terminal exit. The goods asset is a complete key-pairset and a 2-tuple <*state, stakeholder*> recordset that details record of each asset and its corresponding state, initialized in the distributed hyper-fabric ledger as world state. It supports many states with various attributes that allows the same ledger in its world-state to hold various forms of the same asset supply chain. And ultimately, makes possible the capability of the system to evolve and update its state(s) and structure [43], [114], [115].
2. **Stage 2: Proof-of-Trust** – With a variety of roles for those that interact with each good/asset (i.e. exporter, banks, terminal exit, agent(s), service provider(s) shipping company, inspection body, etc – alongside the various transaction(s), as goods/assets transit from one state 'export' to another 'import' or vice-versa between the various stakeholders, the scheme must indicate how different business interests ascertains who approves a transaction, and also how individuals state keys work – are enshrined in NiCuSBlockIoT smart contract logic. Thus, we must set a rule in the namespace to define a business that processes a specific asset, and later, set another rule to update all processed that an asset (i.e. good) should undergo so as to portray trust relations for customs exercise duties and trade transactions. These concepts can be combined to implement the smart contract [116].
3. **Stage 3: Smart Contract** – A smart-contracts code initializes all valid states for an asset as well as the transaction logic that transitions an asset from one state to another. We note that smart contracts are quite essential as they help us set key-business processes and knowledge about

records of goods that can be shared across by the various stakeholders on the NiCuSBlockIoT network as they each interact with the network. It defines also how the various states of a business manages the various processes to move an asset between these states. In the NiCuSBlockIoT chain, the same smart contract is shared and used by the different nodes as well as by the different apps connected. Thus, it jointly executes a shared business data and process. All members of the network must agree a specific version of smart contract to be used.

2.3. Procedural workings of experimental framework

We implement the proposed NiCuSBlockIoT traceability and management system-leveraging both RFID and block-chain model. NiCuSBlockIoT is established with a broad coverage of functionalities that ranges from data gathering, knowledge management within the chain to enhance tracking and goods_asset manageability. This will help to minimize corruption, fraud of all forms as well as other issues as may arise. Thus, yielding figure 2 as the proposed experimental model that uses RFID sensors on a blockchain using hyper-ledger fabric (a key-value database as implemented for the Android platform via a user-friendly mobile API [76]. This fusion results in improved features, and in turn, an improved block-chain system.

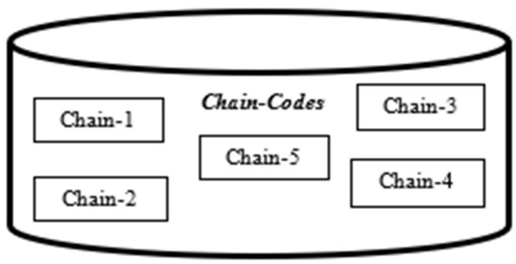

Figure 2. NiCuSBlockIoT Chaincodes Structure for stakeholders (sources: [111], [117])

The framework is thus developed from a business perspective with requirement analysis, processes inquiry, data design, and other major technical activities requisite for smart contract(s). We model the smart contracts as a gateway to the *k-chains* and depending on the business cum transaction rules, this resulting system may vary in complexity, capabilities of both the selected block-chain framework as well as that of the client interfaces for the blockchain. Smart contracts are defined from import to export of goods and employed as certificates to foster and authenticate the traceability of goods asset along the supply chain [118].

Thus, the system should be able to provide a user with a history of the goods being exported, once the said user is registered on the NiCuSBlockIoT network. With registration, each client or user is ceded a public/private key-pair that allows them to digitally sign each operation on the distributed hyper-ledger fabric. The system makes use of weights all through the value chain. Internally, some validation and checks are performed and the system can detect anomalies as well as log in such as records on the network.

3. RESULTS AND DISCUSSION

3.1. NiCuSBlockIoT Performance Evaluation

To implement NiCuSBlockIoT, we measure its throughput using the Riverbed Modeler. The throughput measures a chains capacity for rate of data transfer within the system over a period of time as in figure 3.

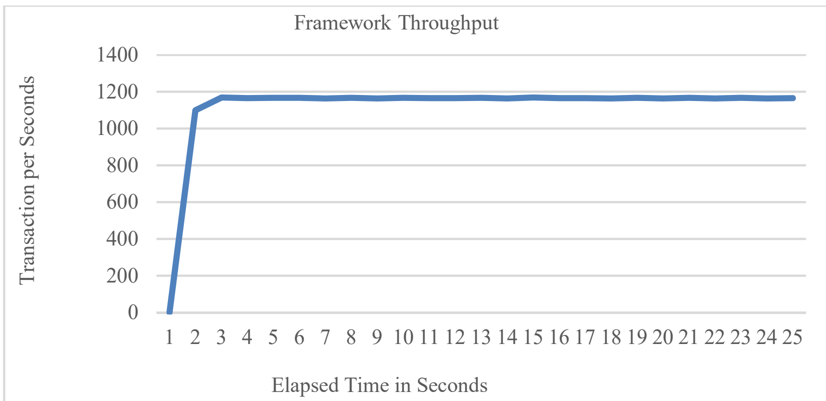

Figure 3. The NiCuSBlockIoT-chain Framework Throughput

The number of transactions per second (TPS) was obtained from the graph above. In tandem with [119]–[121] – transactions per second for other blockchains models were found to be less than 30. This is attributed to their proof of work (PoW) adaptation [122], which is a consensus mechanism that helps each user on the chain to effectively and efficiently, compute the posed task during its mining. The nature of each task requires loads of computational power vis-a-vis processing time. However, our traceability model employs a permissionless chain. Thus, the transaction per second of our experimental framework is about 1101.

3.2. Result Findings: The NiCuSBlockIoT network

With the NiCuSBlockIoT implementation, we have the resultant framework [123]–[125] as in Figure 5. The working of its smart-contract with the various components, is described thus: (a) export contract allows all registered goods for export to be recorded as asset, so it can be broadcasted onto the chain, aprved using the proof of work mechanism, allow for easy tracing/tracking during shipment, and ease asset validation. As it changes its states with the 'export options' transiting from one stakeholder to another – in lieu of export/import (as the case may be) – it is said to be undergoing processing.

We note that all contracts are immutable recorded transaction vis-à-vis these varying export/import options for stakeholders – all of which helps detect record anomalies when they occur, and (b) an examination body such as NAFDAC, SON, NDLEA and other inspection regulatory agencies will then ensure the safety and quality assurances of the goods checked against the recorded asset(s) to aid effective tracking a data-point to another – and easy goods asset identification as coming from a known export/import source. These records can also be employed for recall capability of the processed assets/goods as in Listing 1.

Detailed in the states below are its attributes and values as in Listing 1. The first stage of the asset_1234 is ***export***, which states nature of the transaction; And agrees with [126]–[130], respectively. Thus, if a 1kg goods asset_1234 is exported at Arnold_Holdings by Mr. Dickson Obasuyi for the proposed date of June 1 2024, it will be expressed as in Listing 1:

Listing 1: Dock(s)_A_Export_Goods
Exporter = Arnold_Holdings
Owner_property = Processed Leather
Owner = Dickson_Obasuyi
Goods_Class = Fashion
Export Date = 1st June 2024
Current_State = Export
Value = 200000Naira
Next_State = Processing

The owner [Dickson_Obasuyi], exporter [Arnold_Holdings] and Current_State [export] are the most significant changes to be experienced within NiCuSBlockIoT chain [131] – whereas the current_state_value helps in identifying that the state cum condition of the goods asset [export_processing_import] lifecycle. The asset can thus, be safely transported across the value chain via its consequent distribution chain to start/end the goods asset transaction lifecycle on the value chain. It become mandatory that asset records be approved, validated and kept on the chain to aid traceability, administrative and management purposes. In addition, the value of the owner_property of a goods asset can be used to carry out access control on the trade transaction by comparing this owner_property alongside or against the identity of each transaction initiator or creator. The hyper-ledger fabric supports this through the chain-code API.

4.2. Discussion of Findings

The NiCuSBlockIoT allows users to register as either of the various options for both export and import. Depending on the users' registered role, permissions are thus granted (e.g. only an exporter can add a new good as asset record to the chain). A processor can yield any of the following options of exporter, agent, shipping company etc – can process the asset goods from the system; And consequently, can also update the status of the same goods, as ready for processing and export/import respectively [132]–[134].

Thus, stakeholders are linked therein the network, and can effectively/efficiently trade their goods. Users can track a particular shipment also via the mobile application to know its history and essentially how it has been handled on the goods production network [135]. The distributed hyper-ledger fabric tech uses a P2P network, to establish a decentralized structure for the app. It runs on a 3-tier peer-to-peer scheme/mode (namely orderer, peer-one, and peer-two) [48], [136], [137]. If any of the peer-to-peer mode crashes, any of the active peer(s) is then allowed to perform pending tasks. This feat eliminates manipulation of resources, fraud and corruption that otherwise exist with the demand-supply administration and supervision decisions are controlled from a centralized point [138]–[140].

This study looks at the following parameters [141]–[143]:

- NiCuSBlockIoT yields a resultant network of the goods value chain that provides accurate and timely information on goods in the chain as it gathers information from both demand and supply stakeholders on the chain [144]–[146].
- It yields an API that is easily ported, with ease in mobility, ease of access to the Internet, durability, and speed of processing [123], [147], [148] with its seemingly user-satisfaction upload and download times.

Sample results shows that the blockchain aims to effectively tackle a majority of the corrupt practices for the Nigerian food value chain. It uses a distributed hyper-ledger fabric, a key-value database [149], and a mobile applet interface-resulting in a user-friendly, and open-source permissioned blockchain framework that is ideal for the privacy and confidentiality of transactions and data related to business transactions [150], [151].

4. CONCLUSION

The widespread digital revolution, technological development and its consequent adaption with the proliferation of new technology-driven business strategies, businesses can now operate more efficiently, productively, and profitably. Despite the enormous amount of data generated daily, we have observed that the healthcare industry has always kept up-to-date with technology; However, the adoption of data analytics and data science will bolster the field of medicine. So, for the future of this industry, this study is a positive step and should be improved upon. Furthermore, this research work signifies a paradigm shift in the application of artificial intelligence to mental health diagnostics as supported by [152]–[154].

The study implements NiCuSBlockIoT (with RFID-based scheme layered over a blockchain model using the P2P network) to manage the goods supply chain [155], [156]. It effectively tackles the inherent challenges of the Nigerian Customs Services via the distributed hyper-ledger fabric (a key-value database) for Android mobile smartphones to yield high-performing [157], user-friendly, and open-sourced permissioned block-chain framework that is ideal for the privacy and confidentiality of transactions and data related to business transactions. In conclusion, the NiCuSBlockIoT framework is deployed to help effectively cum efficiently manage the goods value chain in Nigeria.

We present a Nigerian Customs Services IoT-based Blockchain support system that explores and exploits the power of wireless sensor-based RFIDs layered over a permissioned blockchain ensemble. Our contributions include: (a) used the hyper fabric ledger for permissioned blockchain ledger to record world-state key values of generated blocks, (b) used the sensor-based RFIDs to register goods asset as records, (c) it explores the use of smart-contract business logic transactions to records the RFID-based data, which is then broadcasted onto the IoT-based blockchain using a P2P network, and (d) it optimizes the NiCuSBlockIoT scheme for eased manageability, traceability and administration in Nigeria.

REFERENCES

[1] A. A. Ojugo *et al.*, "CoSoGMIR: A Social Graph Contagion Diffusion Framework using the Movement-Interaction-Return Technique," *J. Comput. Theor. Appl.*, vol. 1, no. 2, pp. 37–47, 2023, doi: 10.33633/jcta.v1i2.9355.

[2] R. Amelia, G. Kadarisma, N. Fitriani, and Y. Ahmadi, "The effect of online mathematics learning on junior high school mathematic resilience during covid-19 pandemic," *J. Phys. Conf. Ser.*, vol. 1657, no. 1, p. 012011, Oct. 2020, doi: 10.1088/1742-6596/1657/1/012011.

[3] E. D. Ananga, "Gender Responsive Pedagogy for Teaching and Learning: The Practice in Ghana's Initial Teacher Education Programme," *Creat. Educ.*, vol. 12, no. 04, pp. 848–864, 2021, doi: 10.4236/ce.2021.124061.

[4] R. E. Yoro, F. O. Aghware, M. I. Akazue, A. E. Ibor, and A. A. Ojugo, "Evidence of personality traits on phishing attack menace among selected university undergraduates in Nigerian," *Int. J. Electr. Comput. Eng.*, vol. 13, no. 2, p. 1943, Apr. 2023, doi: 10.11591/ijece.v13i2.pp1943-1953.

[5] A. H. Allam, I. Gomaa, H. H. Zayed, and M. Taha, "IoT-based eHealth using blockchain technology: a survey," *Cluster Comput.*, vol. 0123456789, 2024, doi: 10.1007/s10586-024-04357-y.

[6] W. A. N. A. Al-Nbhany, A. T. Zahary, and A. A. Al-Shargabi, "Blockchain-IoT Healthcare Applications and Trends: A Review," *IEEE Access*, vol. 12, no. January, pp. 4178–4212, 2024, doi: 10.1109/ACCESS.2023.3349187.

[7] A. A. Ojugo *et al.*, "Hybrid neural network models for rainfall runoffs: Comparative study," *Adv. Sci. Eng. Res.*, vol. 1, no. 2, pp. 22–34, 2013.

[8] A. A. Ojugo, A. O. Eboka, and R. E. Yoro, "A Framework Design for Clinical Diagnosis The Expert System Perspective," *J. Emerg. Trends Comput. Inf. Syst.*, vol. 4, no. 5, pp. 470–476, 2013.

[9] M. Belot and D. Webbink, "Do Teacher Strikes Harm Educational Attainment of Students?," *LABOUR*, vol. 24, no. 4, pp. 391–406, Dec. 2010, doi: 10.1111/j.1467-9914.2010.00494.x.

[10] R. E. Yoro, F. O. Aghware, B. O. Malasowe, O. Nwankwo, and A. A. Ojugo, "Assessing contributor features to phishing susceptibility amongst students of petroleum resources varsity in Nigeria," *Int. J. Electr. Comput. Eng.*, vol. 13, no. 2, p. 1922, Apr. 2023, doi: 10.11591/ijece.v13i2.pp1922-1931.

[11] S. R. Channivally, "Blockchain in Internet of Things (IoT) Security," *ICFAI Univ. Fac. Sci. Technol.*, no. November, 2023, doi: 10.13140/RG.2.2.18730.59841.

[12] P. O. Ejeh *et al.*, "Counterfeit Drugs Detection in the Nigeria Pharma-Chain via Enhanced Blockchain-based Mobile Authentication Service," *Adv. Multidiscip. Sci. Res. J. Publ.*, vol. 12, no. 2, pp. 25–44, 2024, doi: 10.22624/AIMS/MATHS/V12N2P3.

[13] A. A. Ojugo *et al.*, "Forging a learner-centric blended-learning framework via an adaptive content-based architecture," *Sci. Inf. Technol. Lett.*, vol. 4, no. 1, pp. 40–53, May 2023, doi: 10.31763/sitech.v4i1.1186.

[14] B. O. Malasowe, D. V. Ojie, A. A. Ojugo, and M. D. Okpor, "Co-Infection Prevalence of Covid-19 Underlying Tuberculosis Disease Using a Susceptible Infect Clustering Bayes Network," *DUTSE J. Pure Appl. Sci.*, vol. 10, no. 2, pp. 80–94, 2024, doi: 10.4314/dujopas.v10i2a.8.

[15] E. Haipinge, N. Kadhila, and L. M. Josua, "Using Digital Technology in Transforming Assessment in Higher Education Institutions beyond COVID-19," *Creat. Educ.*, vol. 13, no. 07, pp. 2157–2167, 2022, doi: 10.4236/ce.2022.137136.

[16] D. Nilam, W. Sari, and M. Mulu, "Explorative study on the application of learning model in virtual classroom during Covid-19 pandemic at the school of Yogyakarta Province," *Proceeding Int. Webinar Educ. 2020 Umsurabaya*, pp. 54–64, 2020, [Online]. Available: http://journal.um-surabaya.ac.id/index.php/Pro/article/view/5951

[17] A. A. Ojugo *et al.*, "Evidence of Students' Academic Performance at the Federal College of Education Asaba Nigeria: Mining Education Data," *Knowl. Eng. Data Sci.*, vol. 6, no. 2, pp. 145–156, 2023, doi: 10.17977/um018v6i22023p145-156.
[18] F. Agostinelli, M. Doepke, G. Sorrenti, and F. Zilibotti, "When the great equalizer shuts down: Schools, peers, and parents in pandemic times," *J. Public Econ.*, vol. 206, p. 104574, Feb. 2022, doi: 10.1016/j.jpubeco.2021.104574.
[19] A. O. Eboka and A. A. Ojugo, "Mitigating technical challenges via redesigning campus network for greater efficiency, scalability and robustness: A logical view," *Int. J. Mod. Educ. Comput. Sci.*, vol. 12, no. 6, pp. 29–45, 2020, doi: 10.5815/ijmecs.2020.06.03.
[20] A. A. Ojugo and A. O. Eboka, "Extending Campus Network Via Intranet and IP-Telephony For Better Performance and Service Delivery: Meeting Organizational Goals," *J. Appl. Sci. Eng. Technol. Educ.*, vol. 1, no. 2, pp. 94–104, 2019, doi: 10.35877/454ri.asci12100.
[21] H. Patrinos, E. Vegas, and R. Carter-Rau, "An Analysis of COVID-19 Student Learning Loss," *Educ. Glob. Pract. Policy Res. Work. Pap. 10033*, vol. 10033, no. May, pp. 1–31, 2022, doi: 10.1596/1813-9450-10033.
[22] M. Brindlmayer, R. Khadduri, A. Osborne, A. Briansó, and E. Cupito, "Prioritizing learning during covid-19: The Most Effective Ways to Keep Children Learning During and Post-Pandemic," *Glob. Educ. Evid. Advis. Panel*, no. January, pp. 1–21, 2022.
[23] A. A. Ojugo and O. D. Otakore, "Investigating The Unexpected Price Plummet And Volatility Rise In Energy Market: A Comparative Study of Machine Learning Approaches," *Quant. Econ. Manag. Stud.*, vol. 1, no. 3, pp. 219–229, 2020, doi: 10.35877/454ri.qems12119.
[24] A. A. Ojugo and A. O. Eboka, "Assessing Users Satisfaction and Experience on Academic Websites: A Case of Selected Nigerian Universities Websites," *Int. J. Inf. Technol. Comput. Sci.*, vol. 10, no. 10, pp. 53–61, 2018, doi: 10.5815/ijitcs.2018.10.07.
[25] A. A. Ojugo and D. O. Otakore, "Redesigning Academic Website for Better Visibility and Footprint: A Case of the Federal University of Petroleum Resources Effurun Website," *Netw. Commun. Technol.*, vol. 3, no. 1, p. 33, Jul. 2018, doi: 10.5539/nct.v3n1p33.
[26] B. F. Komolafe, O. T. Fakayode, A. Osidipe, F. Zhang, and X. Qian, "Evaluation of Online Pedagogy among Higher Education International Students in China during the COVID-19 Outbreak," *Creat. Educ.*, vol. 11, no. 11, pp. 2262–2279, 2020, doi: 10.4236/ce.2020.1111166.
[27] M. I. Akazue *et al.*, "Handling Transactional Data Features via Associative Rule Mining for Mobile Online Shopping Platforms," *Int. J. Adv. Comput. Sci. Appl.*, vol. 15, no. 3, pp. 530–538, 2024, doi: 10.14569/IJACSA.2024.0150354.
[28] A. A. Ojugo and A. O. Eboka, "A Social Engineering Detection Model for the Mobile Smartphone Clients," *African J. Comput. ICT*, vol. 7, no. 3, pp. 91–100, 2014, [Online]. Available: www.ajocict.net
[29] E. A. Otorokpo *et al.*, "DaBO-BoostE: Enhanced Data Balancing via Oversampling Technique for a Boosting Ensemble in Card-Fraud Detection," *Adv. Multidiscip. Sci. Res. J. Publ.*, vol. 12, no. 2, pp. 45–66, 2024, doi: 10.22624/AIMS/MATHS/V12N2P4.
[30] F. S. Hilyana, "Implementation of Schoology-based E-Learning to Improve the ANEKA-based Character," in *Proceedings of the The 1st International Conference on Computer Science and Engineering Technology Universitas Muria Kudus*, EAI, 2018. doi: 10.4108/eai.24-10-2018.2280558.
[31] J. M. Jiménez-Olmedo, A. Penichet-Tomás, B. Pueo, and S. Sebastiá-Amat, "Comparative Analysis of Content Learning Through Schoology and Micro-Teaching in Higher Education," *EDULEARN18 Proc.*, vol. 1, no. July, pp. 6348–6352, 2018, doi: 10.21125/edulearn.2018.1507.
[32] W. H. Goodridge, O. Lawanto, and H. B. Santoso, "A Learning Style Comparison between Synchronous Online and Face-to-Face Engineering Graphics Instruction," *Int. J. Mod. Educ. Comput. Sci.*, vol. 15, no. 2, pp. 1–14, 2017, doi: 10.5539/ies.v10n2p1.

[33] A. A. Ojugo and A. O. Eboka, "Modeling Behavioural Evolution as Social Predictor for the Coronavirus Contagion and Immunization in Nigeria," *J. Appl. Sci. Eng. Technol. Educ.*, vol. 3, no. 2, pp. 135–144, Dec. 2021, doi: 10.35877/454RI.asci130.
[34] M. K. G. Roshan, "Multiclass Medical X-ray Image Classification using Deep Learning with Explainable AI," *Int. J. Res. Appl. Sci. Eng. Technol.*, vol. 10, no. 6, pp. 4518–4526, Jun. 2022, doi: 10.22214/ijraset.2022.44541.
[35] M. Leo, L. Schmitt, M. Erkel, M. Melnikova, J. Thomale, and T. Hagenacker, "Cisplatin-induced neuropathic pain is mediated by upregulation of N-type voltage-gated calcium channels in dorsal root ganglion neurons," *Exp. Neurol.*, vol. 288, no. 2010, pp. 62–74, Feb. 2017, doi: 10.1016/j.expneurol.2016.11.003.
[36] A. A. Ojugo and O. Nwankwo, "Modeling Mobility Pattern for the Corona-Virus Epidemic Spread Propagation and Death Rate in Nigeria using the Movement-Interaction-Return Model," *Int. J. Emerg. Trends Eng. Res.*, vol. 9, no. 6, pp. 821–826, Jun. 2021, doi: 10.30534/ijeter/2021/30962021.
[37] I. O.-E. Eranga, "COVID-19 Pandemic in Nigeria: Palliative Measures and the Politics of Vulnerability," *Int. J. Matern. Child Heal. AIDS*, vol. 9, no. 2, pp. 220–222, Jul. 2020, doi: 10.21106/ijma.394.
[38] A. A. Ojugo and R. E. Yoro, "Migration Pattern As Threshold Parameter In The Propagation of The Covid-19 Epidemic Using An Actor-Based Model for SI-Social Graph," *JINAV J. Inf. Vis.*, vol. 2, no. 2, pp. 93–105, Mar. 2021, doi: 10.35877/454RI.jinav379.
[39] J. Osasume, "Public Policies against COVID-19 Pandemic in Nigeria: Challenges, Effects, and Perceptions," *J. Public Adm. Soc. Welf. Res.*, vol. 6, no. 1, p. 2021, 2021, [Online]. Available: www.iiardpub.org
[40] Y. Bruinen de Bruin *et al.*, "Initial impacts of global risk mitigation measures taken during the combatting of the COVID-19 pandemic," *Saf. Sci.*, vol. 128, no. April, p. 104773, 2020, doi: 10.1016/j.ssci.2020.104773.
[41] A. A. Ojugo and D. A. Oyemade, "Predicting Diffusion Dynamics Of The Coronavirus In Nigeria Through Ties-Strength Threshold On A Cascading SI-Graph," *Technol. Reports Kansai Univ.*, vol. 62, no. 08, pp. 126–132, 2020, doi: TRKU-13-08-2020-10998.
[42] M. Nasajpour, S. Pouriyeh, R. M. Parizi, M. Dorodchi, M. Valero, and H. R. Arabnia, "Internet of Things for Current COVID-19 and Future Pandemics: An Exploratory Study," Jul. 2020, doi: 10.5281/zenodo.4165885.
[43] A. A. Ojugo and O. D. Otakore, "Forging An Optimized Bayesian Network Model With Selected Parameters For Detection of The Coronavirus In Delta State of Nigeria," *J. Appl. Sci. Eng. Technol. Educ.*, vol. 3, no. 1, pp. 37–45, Apr. 2021, doi: 10.35877/454RI.asci2163.
[44] J. H. Reelfs, O. Hohlfeld, and I. Poese, "Corona-Warn-App: Tracing the Start of the Official COVID-19 Exposure Notification App for Germany," Jul. 2020, doi: 10.1145/3405837.3411378.
[45] H. Said, B. B. S. Tawfik, and M. A. Makhlouf, "A Deep Learning Approach for Sentiment Classification of COVID-19 Vaccination Tweets," *Int. J. Adv. Comput. Sci. Appl.*, vol. 14, no. 4, pp. 530–538, 2023, doi: 10.14569/IJACSA.2023.0140458.
[46] A. A. Ojugo and R. E. Yoro, "Empirical Solution For An Optimized Machine Learning Framework For Anomaly-Based Network Intrusion Detection," *Technol. Rep. Kansai Univ.*, vol. 62, no. 08, pp. 6353–6364, 2020.
[47] A. Shahraki, D. K. Kaffash, and O. Haugen, "A Review on the effects of IoT and Smart Cities Technologies on Urbanism," in *2018 South-Eastern European Design Automation, Computer Engineering, Computer Networks and Society Media Conference (SEEDA_CECNSM)*, IEEE, Sep. 2018, pp. 1–8. doi: 10.23919/SEEDA-CECNSM.2018.8544932.
[48] B. O. Malasowe, A. E. Okpako, M. D. Okpor, P. O. Ejeh, A. A. Ojugo, and R. E. Ako, "FePARM: The Frequency-Patterned Associative Rule Mining Framework on Consumer Purchasing-Pattern for Online Shops," *Adv. Multidiscip. Sci. Res. J. Publ.*, vol. 15, no. 2, pp. 15–28, 2024, doi: 10.22624/AIMS/CISDI/V15N2P2-1.

[49] B. O. Malasowe, M. I. Akazue, E. A. Okpako, F. O. Aghware, D. V. Ojie, and A. A. Ojugo, "Adaptive Learner-CBT with Secured Fault-Tolerant and Resumption Capability for Nigerian Universities," *Int. J. Adv. Comput. Sci. Appl.*, vol. 14, no. 8, pp. 135–142, 2023, doi: 10.14569/IJACSA.2023.0140816.
[50] A. A. Ojugo, M. I. Akazue, P. O. Ejeh, C. Odiakaose, and F. U. Emordi, "DeGATraMoNN: Deep Learning Memetic Ensemble to Detect Spam Threats via a Content-Based Processing," *Kongzhi yu Juece/Control Decis.*, vol. 38, no. 01, pp. 667–678, 2023.
[51] D. Paudel *et al.*, "Machine learning for regional crop yield forecasting in Europe," *F. Crop. Res.*, vol. 276, no. October 2021, p. 108377, Feb. 2022, doi: 10.1016/j.fcr.2021.108377.
[52] A. A. Ojugo and I. P. Okobah, "Computational Solution for Modeling Rainfall Runoff Using Intelligent Stochastic Model: A Case of Warri in Delta State Nigeria," *J. Digit. Innivations Contemp. Res. Sci. Eng. Technol.*, vol. 5, no. 4, pp. 45–58, 2017, doi: 10.22624.
[53] A. A. Ojugo, P. O. Ejeh, C. C. Odiakaose, A. O. Eboka, and F. U. Emordi, "Predicting rainfall runoff in Southern Nigeria using a fused hybrid deep learning ensemble," *Int. J. Informatics Commun. Technol.*, vol. 13, no. 1, pp. 108–115, Apr. 2024, doi: 10.11591/ijict.v13i1.pp108-115.
[54] J. Jung, M. Maeda, A. Chang, M. Bhandari, A. Ashapure, and J. Landivar-Bowles, "The potential of remote sensing and artificial intelligence as tools to improve the resilience of agriculture production systems," *Curr. Opin. Biotechnol.*, vol. 70, pp. 15–22, Aug. 2021, doi: 10.1016/j.copbio.2020.09.003.
[55] A. A. Ojugo, A. O. Eboka, E. O. Okonta, R. E. Yoro, and F. O. Aghware, "Predicting Behavioural Evolution on a Graph-Based Model," *Adv. Networks*, vol. 3, no. 2, p. 8, 2015, doi: 10.11648/j.net.20150302.11.
[56] U.S. Bureau of Labor Statistics, "Employment Projections — 2016-2026," 2022. [Online]. Available: https://www.bls.gov/news.release/ecopro.toc.htm
[57] I. M. Ugochukwu-Ibe and E. Ibeke, "E-learning and Covid-19 - The Nigerian experience: Challenges of teaching technical courses in tertiary institutions," *CEUR Workshop Proc.*, vol. 2872, no. May, pp. 46–51, 2021.
[58] D. Soriano-Paños, G. Ghoshal, A. Arenas, and J. Gómez-Gardeñes, "Impact of temporal scales and recurrent mobility patterns on the unfolding of epidemics," Sep. 2019, doi: 10.1088/1742-5468/ab6a04.
[59] A. A. Ojugo, R. E. Yoro, M. O. Yerokun, and I. J. Iyawa, "Implementation Issues of VoIP to Enhance Rural Telephony in Nigeria," *J. Emerg. Trends Comput. Inf. Sci. ©2009-2013*, vol. 4, no. 2, pp. 172–179, 2013, [Online]. Available: http://www.cisjournal.org
[60] A. Hidayat and V. G. Utomo, "Adaptive Online Module Prototype for Learning Unified Modelling Language (UML)," *Int. J. Electr. Comput. Eng.*, vol. 6, no. 6, p. 2931, Dec. 2016, doi: 10.11591/ijece.v6i6.pp2931-2938.
[61] A. Ferrari, E. Schoolnet, Y. Punie, E. Commission, C. Redecker, and E. Commission, *21st Century Learning for 21st Century Skills*, vol. 7563, no. July 2015. in Lecture Notes in Computer Science, vol. 7563. Berlin, Heidelberg: Springer Berlin Heidelberg, 2012. doi: 10.1007/978-3-642-33263-0.
[62] A. A. Ojugo and A. O. Eboka, "Memetic algorithm for short messaging service spam filter using text normalization and semantic approach," *Int. J. Informatics Commun. Technol.*, vol. 9, no. 1, p. 9, 2020, doi: 10.11591/ijict.v9i1.pp9-18.
[63] A. R. Muslikh, I. D. R. M. Setiadi, and A. A. Ojugo, "Rice disease recognition using transfer xception convolution neural network," *J. Tek. Inform.*, vol. 4, no. 6, pp. 1541–1547, 2023, doi: 10.52436/1.jutif.2023.4.6.1529.
[64] U. R. Wemembu, E. O. Okonta, A. A. Ojugo, and I. L. Okonta, "A Framework for Effective Software Monitoring in Project Management," *West African J. Ind. Acad. Res.*, vol. 10, no. 1, pp. 102–115, 2014.

[65] M. Debe, K. Salah, M. H. Ur Rehman, and D. Svetinovic, “Monetization of Services Provided by Public Fog Nodes Using Blockchain and Smart Contracts,” *IEEE Access*, vol. 8, pp. 20118–20128, 2020, doi: 10.1109/ACCESS.2020.2968573.

[66] A. A. Ojugo and A. O. Eboka, “Cluster prediction model for market basket analysis: quest for better alternatives to associative rule mining approach,” *IAES Int. J. Artif. Intell.*, vol. 9, no. 3, pp. 429–439, 2020, doi: 10.11591/ijai.v9.i3.pp429-439.

[67] Z.-P. P. Fan, X.-Y. Y. Wu, and B.-B. B. Cao, “Considering the traceability awareness of consumers: should the supply chain adopt the blockchain technology?,” *Ann. Oper. Res.*, vol. 309, no. 2, pp. 837–860, Feb. 2022, doi: 10.1007/s10479-020-03729-y.

[68] B. Ghaffari and Y. Osman, “Customer churn prediction using machine learning: A study in the B2B subscription based service context,” Faculty of Computing, Blekinge Institute of Technology, Sweden, 2021. [Online]. Available: www.bth.se

[69] N. A. Ananda, M. N. Fietroh, M. Mikhratunnisa, and R. M. Rizqi, “Theory Acceptance Model and Purchase Intention in Online Shopping,” *Proc. 1st Annu. Conf. Educ. Soc. Sci. (ACCESS 2019)*, vol. 465, no. Access 2019, pp. 165–169, 2020, doi: 10.2991/assehr.k.200827.042.

[70] D. M. Dhanalakshmi., M. M. Sakthivel., and M. M. Nandhini., “A study on Customer Perception Towards Online Shopping, Salem.,” *Int. J. Adv. Res.*, vol. 5, no. 1, pp. 2468–2470, 2017, doi: 10.21474/ijar01/3033.

[71] P. I. Tantawi, “The Variances of Consumers’ Materialistic Personality Traits and Reduced Consumption Behavior Among Demographics in Egypt,” *J. Mark. Consum. Res.*, vol. 88, pp. 2020–2022, Jan. 2023, doi: 10.7176/JMCR/88-02.

[72] M. K. Daoud and I. T. Trigui, “Smart Packaging: Consumer’s Perception and Diagnostic of Traceability Information,” 2019, pp. 352–370. doi: 10.1007/978-3-030-30874-2_28.

[73] A. A. Ojugo and A. O. Eboka, “Empirical Bayesian network to improve service delivery and performance dependability on a campus network,” *IAES Int. J. Artif. Intell.*, vol. 10, no. 3, p. 623, Sep. 2021, doi: 10.11591/ijai.v10.i3.pp623-635.

[74] M. G. Omale, J. F. Olorunfemi, and F. O. Aiyegbajeje, “Legal viable options to incessant closure of Nigeria’s international borders,” *African Identities*, vol. 21, no. 1, pp. 1–20, Jan. 2023, doi: 10.1080/14725843.2020.1828037.

[75] D. K. Flynn, “‘We are the border’: identity, exchange, and the state along the Bénin-Nigeria border,” *Am. Ethnol.*, vol. 24, no. 2, pp. 311–330, May 1997, doi: 10.1525/ae.1997.24.2.311.

[76] O. Olofinsao, F. Oluwatusin, and O. Ojo, “Assessment of Agricultural Credit Sources for Food Crop Marketing in Ondo State of Nigeria,” *Asian J. Adv. Agric. Res.*, vol. 6, no. 3, pp. 1–9, Apr. 2018, doi: 10.9734/AJAAR/2018/39515.

[77] K. W. Brown and T. J. Armstrong, *Hydrocarbon Inhalation*. 2023. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/24911841

[78] P. Joshi, A. Solomy, A. Suresh, K. Kachroo, and P. Deshmukh, “Smart Fuel Station,” *SSRN Electron. J.*, 2020, doi: 10.2139/ssrn.3572319.

[79] D. Nahavandi, R. Alizadehsani, A. Khosravi, and U. R. Acharya, “Application of artificial intelligence in wearable devices: Opportunities and challenges,” *Comput. Methods Programs Biomed.*, vol. 213, no. December, 2022, doi: 10.1016/j.cmpb.2021.106541.

[80] M. Jażdżewska-Gutta, M. Grottel, and D. Wach, “AEO certification – necessity or privilege for supply chain participants,” *Supply Chain Manag. An Int. J.*, vol. 25, no. 6, pp. 679–691, Jun. 2020, doi: 10.1108/SCM-07-2019-0253.

[81] D. E. Ufua, E. Osabuohien, M. E. Ogbari, H. O. Falola, E. E. Okoh, and A. Lakhani, “Re-Strategising Government Palliative Support Systems in Tackling the Challenges of COVID-19 Lockdown in Lagos State, Nigeria,” *Glob. J. Flex. Syst. Manag.*, vol. 22, no. June, pp. 19–32, 2021, doi: 10.1007/s40171-021-00263-z.

[82] Z. Sun, S. Sun, J. Zhao, B. Ai, and Q. Yang, "Detection of Massive Oil Spills in Sun Glint Optical Imagery through Super-Pixel Segmentation," *J. Mar. Sci. Eng.*, vol. 10, no. 11, p. 1630, 2022, doi: 10.3390/jmse10111630.

[83] A. Okewale, F. Omoruwuo, and O. A. Adesina, "Comparative Studies of Response Surface Methodology (RSM) and Predictive Capacity of Artificial Neural Network (ANN) on Mild Steel Corrosion Inhibition using Water Hyacinth as an Inhibitor," *J. Phys. Conf. Ser.*, vol. 1378, no. 2, p. 022002, Dec. 2019, doi: 10.1088/1742-6596/1378/2/022002.

[84] D. A. Oyemade and A. A. Ojugo, "A property oriented pandemic surviving trading model," *Int. J. Adv. Trends Comput. Sci. Eng.*, vol. 9, no. 5, pp. 7397–7404, 2020, doi: 10.30534/ijatcse/2020/71952020.

[85] D. Allessie, M. Janssen, J. Ubacht, S. Cunningham, and G. van der Harst, "The consequences of blockchain architectures for the governance of public services: A case study of the movement of excise goods under duty exemptions," *Inf. Polity*, vol. 24, no. 4, pp. 487–499, Dec. 2019, doi: 10.3233/IP-190151.

[86] G. L. Adeola and O. Fayomi, "The Political and Security Implications of Cross Border Migration between Nigeria and Her Francophone Neighbours," *Int. J. Soc. Sci. Tomorrow*, vol. 1, no. 3, pp. 1–9, 2012, [Online]. Available: www.ijsst.com

[87] A. A. Ojugo and A. O. Eboka, "Inventory prediction and management in Nigeria using market basket analysis associative rule mining: memetic algorithm based approach," *Int. J. Informatics Commun. Technol.*, vol. 8, no. 3, p. 128, 2019, doi: 10.11591/ijict.v8i3.pp128-138.

[88] C. Weerth, "Recent Developments in the World Customs Organization," 2016, pp. 787–799. doi: 10.1007/978-3-319-29215-1_34.

[89] J. A. Aluede, "Smuggling across the Nigeria: Benin Border and Its Impact on Nigeria's Economic Development," in *Crime, Law and Society in Nigeria*, BRILL, 2019, pp. 62–94. doi: 10.1163/9789004396289_005.

[90] V. Hnatushenko and R. Sytnyk, "The design and research of a system for monitoring the movements of goods and resources using blockchain," *Syst. Technol.*, vol. 6, no. 137, pp. 167–176, Dec. 2021, doi: 10.34185/1562-9945-6-137-2021-15.

[91] G. Caldarelli, C. Rossignoli, and A. Zardini, "Overcoming the blockchain oracle problem in the traceability of non-fungible products," *Sustain.*, vol. 12, no. 6, 2020, doi: 10.3390/su12062391.

[92] A. Shahzad, K. Zhang, and A. Gherbi, "Intuitive development to examine collaborative iot supply chain system underlying privacy and security levels and perspective powering through proactive blockchain," *Sensors (Switzerland)*, vol. 20, no. 13, pp. 1–27, 2020, doi: 10.3390/s20133760.

[93] C. H. Lee, H. C. Yang, Y. C. Wei, and W. K. Hsu, "Enabling blockchain based scm systems with a real time event monitoring function for preemptive risk management," *Appl. Sci.*, vol. 11, no. 11, 2021, doi: 10.3390/app11114811.

[94] A. Bouras, I. Khalil, and B. Aouni, "Blockchain driven supply chains and enterprise information systems," *Blockchain Driven Supply Chain. Enterp. Inf. Syst.*, no. September, pp. 1–222, 2022, doi: 10.1007/978-3-030-96154-1.

[95] K. Godewa, P. Branch, and J. But, "An Analysis of Blockchain-Based IoT Sensor Network Distributed Denial of Service A tt acks," 2024.

[96] A. A. Ojugo and R. E. Yoro, "Forging a deep learning neural network intrusion detection framework to curb the distributed denial of service attack," *Int. J. Electr. Comput. Eng.*, vol. 11, no. 2, pp. 1498–1509, 2021, doi: 10.11591/ijece.v11i2.pp1498-1509.

[97] A. A. Ojugo and D. A. Oyemade, "Boyer moore string-match framework for a hybrid short message service spam filtering technique," *IAES Int. J. Artif. Intell.*, vol. 10, no. 3, pp. 519–527, 2021, doi: 10.11591/ijai.v10.i3.pp519-527.

[98] I. Okengwu and E. A. Onibere, “Optimizing the food supply value chain in Nigerian agricultural sector via a Smartphone-based mobile application,” Federal University of Petroleum Resources, Effurun, 2021.
[99] C. Nartey *et al.*, “On Blockchain and IoT Integration Platforms: Current Implementation Challenges and Future Perspectives,” *Wirel. Commun. Mob. Comput.*, vol. 2021, pp. 1–25, Apr. 2021, doi: 10.1155/2021/6672482.
[100] J. G. A. . Vander Vorst, *Generating , modelling and evaluating*. 2000.
[101] A. Ibor, E. Edim, and A. Ojugo, “Secure Health Information System with Blockchain Technology,” *J. Niger. Soc. Phys. Sci.*, vol. 5, no. 992, p. 992, Apr. 2023, doi: 10.46481/jnsps.2023.992.
[102] J. K. Oladele *et al.*, “BEHeDaS: A Blockchain Electronic Health Data System for Secure Medical Records Exchange,” *J. Comput. Theor. Appl.*, vol. 2, no. 1, pp. 1–12, 2024, doi: 10.33633/jcta.v2i19509.
[103] M. Chaieb, S. Yousfi, P. Lafourcade, and R. Robbana, “Verify-Your-Vote: A Verifiable Blockchain-Based Online Voting Protocol,” 2019, pp. 16–30. doi: 10.1007/978-3-030-11395-7_2.
[104] Y. Abuidris, R. Kumar, and W. Wenyong, “A Survey of Blockchain Based on E-voting Systems,” in *Proceedings of the 2019 2nd International Conference on Blockchain Technology and Applications*, New York, NY, USA: ACM, Dec. 2019, pp. 99–104. doi: 10.1145/3376044.3376060.
[105] M. Crosby, P. Pattanayak, S. Verma, and V. Kalyanaraman, “Blockchain technology: beyond bitcoin,” *Appl. Innov. Rev.*, vol. 27, no. 4–5, pp. 222–228, 2016, doi: 10.15358/0935-0381-2015-4-5-222.
[106] A. A. Ojugo and R. E. Yoro, “Extending the three-tier constructivist learning model for alternative delivery: ahead the COVID-19 pandemic in Nigeria,” *Indones. J. Electr. Eng. Comput. Sci.*, vol. 21, no. 3, p. 1673, Mar. 2021, doi: 10.11591/ijeecs.v21.i3.pp1673-1682.
[107] A. Abdullah and R. Mohd Nor, “A Framework for the Development of a National Crypto-Currency,” *Int. J. Econ. Financ.*, vol. 10, no. 9, p. 14, Aug. 2018, doi: 10.5539/ijef.v10n9p14.
[108] S. Saberi, M. Kouhizadeh, J. Sarkis, and L. Shen, “Blockchain technology and its relationships to sustainable supply chain management,” *Int. J. Prod. Res.*, vol. 57, no. 7, pp. 2117–2135, Apr. 2019, doi: 10.1080/00207543.2018.1533261.
[109] A. A. Ojugo and O. D. Otakore, “Intelligent cluster connectionist recommender system using implicit graph friendship algorithm for social networks,” *IAES Int. J. Artif. Intell.*, vol. 9, no. 3, p. 497~506, 2020, doi: 10.11591/ijai.v9.i3.pp497-506.
[110] E. Varese, M. Chiara Cesarani, and M. Wojnarowska, “Application of Internet of Things in the Movement of Goods at Customs Level during Covid-19 Pandemic,” in *Supply Chain - Recent Advances and New Perspectives in the Industry 4.0 Era*, IntechOpen, 2022. doi: 10.5772/intechopen.102488.
[111] M. I. Akazue, R. E. Yoro, B. O. Malasowe, O. Nwankwo, and A. A. Ojugo, “Improved services traceability and management of a food value chain using block-chain network : a case of Nigeria,” *Indones. J. Electr. Eng. Comput. Sci.*, vol. 29, no. 3, pp. 1623–1633, 2023, doi: 10.11591/ijeecs.v29.i3.pp1623-1633.
[112] S. Kamble, A. Gunasekaran, and H. Arha, “Understanding the Blockchain technology adoption in supply chains-Indian context,” *Int. J. Prod. Res.*, vol. 57, no. 7, pp. 2009–2033, Apr. 2019, doi: 10.1080/00207543.2018.1518610.
[113] H. M. Kim and M. Laskowski, “Toward an ontology-driven blockchain design for supply-chain provenance,” *Intell. Syst. Accounting, Financ. Manag.*, vol. 25, no. 1, pp. 18–27, Jan. 2018, doi: 10.1002/isaf.1424.
[114] E. O. Okonta, U. R. Wemembu, A. A. Ojugo, and D. Ajani, “Deploying Java Platform to Design A Framework of Protective Shield for Anti– Reversing Engineering,” *West African J. Ind. Acad. Res.*, vol. 10, no. 1, pp. 50–64, 2014.

[115] A. A. Ojugo, D. A. Oyemade, D. Allenotor, O. B. Longe, and C. N. Anujeonye, "Comparative Stochastic Study for Credit-Card Fraud Detection Models," *African J. Comput. ICT*, vol. 8, no. 1, pp. 15–24, 2015, [Online]. Available: www.ajocict.net
[116] A. A. Ojugo and O. D. Otakore, "Improved Early Detection of Gestational Diabetes via Intelligent Classification Models: A Case of the Niger Delta Region in Nigeria," *J. Comput. Sci. Appl.*, vol. 6, no. 2, pp. 82–90, 2018, doi: 10.12691/jcsa-6-2-5.
[117] A. A. Ojugo, P. O. Ejeh, C. C. Odiakaose, A. O. Eboka, and F. U. Emordi, "Improved distribution and food safety for beef processing and management using a blockchain-tracer support framework," *Int. J. Informatics Commun. Technol.*, vol. 12, no. 3, p. 205, Dec. 2023, doi: 10.11591/ijict.v12i3.pp205-213.
[118] A. A. Ojugo *et al.*, "Dependable Community-Cloud Framework for Smartphones," *Am. J. Networks Commun.*, vol. 4, no. 4, p. 95, 2015, doi: 10.11648/j.ajnc.20150404.13.
[119] M. Lei, L. Xu, T. Liu, S. Liu, and C. Sun, "Integration of Privacy Protection and Blockchain-Based Food Safety Traceability: Potential and Challenges," *Foods*, vol. 11, no. 15, pp. 1–31, 2022, doi: 10.3390/foods11152262.
[120] S. J. Damoska and A. Erceg, "Blockchain Technology toward Creating a Smart Local Food Supply Chain," *Computers*, vol. 11, no. 6, p. 95, Jun. 2022, doi: 10.3390/computers11060095.
[121] M. Gasco-Hernandez, W. Feng, and J. R. Gil-Garcia, "Providing Public Value through Data Sharing: Understanding Critical Factors of Food Traceability for Local Farms and Institutional Buyers," 2018. doi: 10.24251/HICSS.2018.285.
[122] M. Iyoboyi and L. Musa-Pedro, "Optimizing agricultural value chain in Nigeria through infrastructural development," *Agric. Econ. Res. Rev.*, vol. 33, no. 2, pp. 205–218, 2020, doi: 10.5958/0974-0279.2020.00032.4.
[123] A. A. Ojugo, A. O. Eboka, R. E. Yoro, M. O. Yerokun, and F. N. Efozia, "Hybrid Model for Early Diabetes Diagnosis," *Proc. - 2015 2nd Int. Conf. Math. Comput. Sci. Ind. MCSI 2015*, pp. 55–65, 2016, doi: 10.1109/MCSI.2015.35.
[124] M. I. Akazue, A. A. Ojugo, R. E. Yoro, B. O. Malasowe, and O. Nwankwo, "Empirical evidence of phishing menace among undergraduate smartphone users in selected universities in Nigeria," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 28, no. 3, pp. 1756–1765, Dec. 2022, doi: 10.11591/ijeecs.v28.i3.pp1756-1765.
[125] A. A. Ojugo and A. O. Eboka, "An Empirical Evaluation On Comparative Machine Learning Techniques For Detection of The Distributed Denial of Service (DDoS) Attacks," *J. Appl. Sci. Eng. Technol. Educ.*, vol. 2, no. 1, pp. 18–27, 2020, doi: 10.35877/454ri.asci2192.
[126] W. E. Soto-Silva, M. C. González-Araya, M. A. Oliva-Fernández, and L. M. Plà-Aragonés, "Optimizing fresh food logistics for processing: Application for a large Chilean apple supply chain," *Comput. Electron. Agric.*, vol. 136, pp. 42–57, Apr. 2017, doi: 10.1016/j.compag.2017.02.020.
[127] S. Despoudi, G. Papaioannou, and S. Dani, "Producers Responding to Environmental Turbulence in the Greek Agricultural Supply Chain: Does Buyer Type Matter?," *Knowl. Towar. a Media Hist. Doc.*, vol. 3, no. April, pp. 49–58, 2021.
[128] S. Despoudi, "Optimized food supply chains to reduce food losses," in *Saving Food*, Elsevier, 2019, pp. 227–248. doi: 10.1016/B978-0-12-815357-4.00008-0.
[129] A. Wright and P. De Filippi, "Decentralized Blockchain Technology and the Rise of Lex Cryptographia," *SSRN Electron. J.*, 2015, doi: 10.2139/ssrn.2580664.
[130] F. Tian, "A supply chain traceability system for food safety based on HACCP, blockchain & Internet of things," in *2017 International Conference on Service Systems and Service Management*, IEEE, Jun. 2017, pp. 1–6. doi: 10.1109/ICSSSM.2017.7996119.
[131] A. A. Ojugo and O. D. Otakore, "Computational solution of networks versus cluster grouping for social network contact recommender system," *Int. J. Informatics Commun. Technol.*, vol. 9, no. 3, p. 185, 2020, doi: 10.11591/ijict.v9i3.pp185-194.

[132] P. A. Zawislak, F. M. Reichert, D. Barbieux, A. M. S. Avila, and N. Pufal, "The dynamic chain of innovation: bounded capabilities and complementarity in agribusiness," *J. Agribus. Dev. Emerg. Econ.*, vol. 23, pp. 1–113, Apr. 2022, doi: 10.1108/JADEE-04-2021-0096.
[133] S. Gokarn and A. Choudhary, "Modeling the key factors influencing the reduction of food loss and waste in fresh produce supply chains," *J. Environ. Manage.*, vol. 294, p. 113063, Sep. 2021, doi: 10.1016/j.jenvman.2021.113063.
[134] F. M. Brofman Epelbaum and M. Garcia Martinez, "The technological evolution of food traceability systems and their impact on firm sustainable performance: A RBV approach," *Int. J. Prod. Econ.*, vol. 150, pp. 215–224, Apr. 2014, doi: 10.1016/j.ijpe.2014.01.007.
[135] F. O. Aghware, R. E. Yoro, P. O. Ejeh, C. C. Odiakaose, F. U. Emordi, and A. A. Ojugo, "DeLClustE: Protecting Users from Credit-Card Fraud Transaction via the Deep-Learning Cluster Ensemble," *Int. J. Adv. Comput. Sci. Appl.*, vol. 14, no. 6, pp. 94–100, 2023, doi: 10.14569/IJACSA.2023.0140610.
[136] F. O. Aghware, R. E. Yoro, P. O. Ejeh, C. C. Odiakaose, F. U. Emordi, and A. A. Ojugo, "Sentiment analysis in detecting sophistication and degradation cues in malicious web contents," *Kongzhi yu Juece/Control Decis.*, vol. 38, no. 01, p. 653, 2023.
[137] A. A. Ojugo and E. O. Ekurume, "Deep Learning Network Anomaly-Based Intrusion Detection Ensemble For Predictive Intelligence To Curb Malicious Connections: An Empirical Evidence," *Int. J. Adv. Trends Comput. Sci. Eng.*, vol. 10, no. 3, pp. 2090–2102, Jun. 2021, doi: 10.30534/ijatcse/2021/851032021.
[138] M. Bartoletti and L. Pompianu, "An empirical analysis of smart contracts: platforms, applications, and design patterns," Mar. 2017, doi: 10.1007/978-3-319-70278-0.
[139] J. Zhang and T. Bhatt, "A Guidance Document on the Best Practices in Food Traceability," *Compr. Rev. Food Sci. Food Saf.*, vol. 13, no. 5, pp. 1074–1103, Sep. 2014, doi: 10.1111/1541-4337.12103.
[140] I. P. Okobah and A. A. Ojugo, "Evolutionary Memetic Models for Malware Intrusion Detection: A Comparative Quest for Computational Solution and Convergence," *Int. J. Comput. Appl.*, vol. 179, no. 39, pp. 34–43, 2018, doi: 10.5120/ijca2018916586.
[141] A. A. Ojugo, C. O. Obruche, and A. O. Eboka, "Quest For Convergence Solution Using Hybrid Genetic Algorithm Trained Neural Network Model For Metamorphic Malware Detection," *ARRUS J. Eng. Technol.*, vol. 2, no. 1, pp. 12–23, Nov. 2021, doi: 10.35877/jetech613.
[142] A. A. Ojugo, C. O. Obruche, and A. O. Eboka, "Empirical Evaluation for Intelligent Predictive Models in Prediction of Potential Cancer Problematic Cases In Nigeria," *ARRUS J. Math. Appl. Sci.*, vol. 1, no. 2, pp. 110–120, Nov. 2021, doi: 10.35877/mathscience614.
[143] B. O. Malasowe, F. O. Aghware, and B. E. Edim, "Pilot Study on Web Server HoneyPot Integration Using Injection Approach for Malware Intrusion Detection," *Comput. Inf. Syst. Dev. Informatics ALlied Res. J.*, vol. 15, no. 1, pp. 13–28, 2024, doi: 10.22624/AIMS/CISDI/V15N1P2.
[144] A. A. Ojugo and R. E. Yoro, "Predicting Futures Price And Contract Portfolios Using The ARIMA Model: A Case of Nigeria's Bonny Light and Forcados," *Quant. Econ. Manag. Stud.*, vol. 1, no. 4, pp. 237–248, 2020, doi: 10.35877/454ri.qems139.
[145] A. A. Ojugo, A. O. Eboka, R. E. Yoro, M. O. Yerokun, and F. N. Efozia, "Framework design for statistical fraud detection," *Math. Comput. Sci. Eng. Ser.*, vol. 50, pp. 176–182, 2015.
[146] D. A. Oyemade *et al.*, "A Three Tier Learning Model for Universities in Nigeria," *J. Technol. Soc.*, vol. 12, no. 2, pp. 9–20, 2016, doi: 10.18848/2381-9251/CGP/v12i02/9-20.
[147] A. . Fatheree, *Immortality: An Economics and Moral Framework Toward Immortality*. 2017.
[148] H. eddine Bedoui and A. Robbana, "Islamic Social Financing Through Cryptocurrency," in *Halal Cryptocurrency Management*, Cham: Springer International Publishing, 2019, pp. 259–274. doi: 10.1007/978-3-030-10749-9_16.

[149] A. A. Ojugo and A. O. Eboka, “Modeling the Computational Solution of Market Basket Associative Rule Mining Approaches Using Deep Neural Network,” *Digit. Technol.*, vol. 3, no. 1, pp. 1–8, 2018, doi: 10.12691/dt-3-1-1.
[150] R. E. Yoro and A. A. Ojugo, “An Intelligent Model Using Relationship in Weather Conditions to Predict Livestock-Fish Farming Yield and Production in Nigeria,” *Am. J. Model. Optim.*, vol. 7, no. 2, pp. 35–41, 2019, doi: 10.12691/ajmo-7-2-1.
[151] D. R. Ignatius, M. Setiadi, K. Nugroho, A. R. Muslikh, S. Wahyu, and A. A. Ojugo, “Integrating SMOTE-Tomek and Fusion Learning with XGBoost Meta-Learner for Robust Diabetes Recognition,” *J. Futur. Artif. Intell. Technol.*, vol. 1, no. 1, pp. 23–38, 2024, doi: 10.62411/faith.2024-11.
[152] N. R. Madarasz and D. P. Santos, “The concept of human nature in Noam Chomsky,” *Verit. (Porto Alegre)*, vol. 63, no. 3, pp. 1092–1126, Dec. 2018, doi: 10.15448/1984-6746.2018.3.32564.
[153] I. A. Omar, R. Jayaraman, M. S. Debe, K. Salah, I. Yaqoob, and M. Omar, “Automating Procurement Contracts in the Healthcare Supply Chain Using Blockchain Smart Contracts,” *IEEE Access*, vol. 9, pp. 37397–37409, 2021, doi: 10.1109/ACCESS.2021.3062471.
[154] I. A. Omar, R. Jayaraman, K. Salah, M. C. E. Simsekler, I. Yaqoob, and S. Ellahham, “Ensuring protocol compliance and data transparency in clinical trials using Blockchain smart contracts,” *BMC Med. Res. Methodol.*, vol. 20, no. 1, p. 224, Dec. 2020, doi: 10.1186/s12874-020-01109-5.
[155] C. O. Obruche, R. A. Abere, and R. E. Ako, “Deployment of a virtual key-card smart-lock system: the quest for improved security, eased user mobility and privacy,” *FUPRE J. Sci. Ind. Res.*, vol. 8, no. 1, pp. 80–94, 2024.
[156] E. U. Omede, A. Edje, M. I. Akazue, H. Utomwen, and A. A. Ojugo, “IMANoBAS: An Improved Multi-Mode Alert Notification IoT-based Anti-Burglar Defense System,” *J. Comput. Theor. Appl.*, vol. 2, no. 1, pp. 43–53, 2024, doi: 10.33633/jcta.v2i1.9541.
[157] S. . Okperigho, B. Nwozor, and V. . Geteloma, “Deployment of an IoT Storage Tank Gauge and Monitor,” *FUPRE J. Sci. Ind. Res.*, vol. 8, no. 1, pp. 55–68, 2024.