A Smart Contract Approach for Efficient Transportation Management

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***Abstract*—Transportation management in Egypt faces challenges such as congestion, inefficiency, and a lack of transparency. This work proposes a smart contract-based transportation framework to address these issues and enhance the efficiency of Egypt's transportation system. By leveraging blockchain technology, smart contracts can facilitate and enforce decentralized and immutable transportation agreements. This approach also fosters increased trust among stakeholders and improves interactions between service providers. This paper presents a conceptual framework that integrates smart contracts, blockchain technology, GPS data, and sensor technologies to further optimize transportation operations. Empirical analysis and case studies demonstrate the effectiveness of smart contracts in improving the shipping registration system. The survey results show that smart contracts streamline processes enhance data security, reduce costs, and improve accuracy. The proposed model, developed on the NEAR platform, outperforms traditional methods and Ethereum-based models by offering faster registration, better cost-efficiency, and improved transaction tracking. This demonstrates the potential for modernizing and optimizing Egypt's transportation sector**.

***Keywords*—Blockchain; cryptography; logistics; smart contracts; transportation; security and privacy; supply chains**

I. Introduction

This Transportation is vital to the global economy, as it connects resources for manufacturing and delivers finished products to customers. However, this fundamental industry faces challenges such as speed, cost-efficiency, and safety [1]. The process of transportation is intricate and demands careful planning, coordination, and implementation. The transportation process commences with route planning and the selection of carriers [2]. Companies must determine the most efficient and cost-effective routes while selecting the appropriate transportation carriers based on various factors. This decision impacts both the timeliness of delivery and the cost-effectiveness of the entire process. Freight booking, loading, unloading, and proper documentation ensure the security, tracking, and legal compliance of goods throughout their journey [1]. Freight tracking, last-mile delivery, risk management, effective communication, and coordination are essential components that keep the supply chain running smoothly [3]. Modern technology, including GPS and communication systems, has revolutionized transportation by enabling real-time tracking and responsive problem-solving. In the end, transportation serves as the linchpin that ensures products reach their intended destinations efficiently, reflecting its pivotal role in modern commerce and customer satisfaction [4]. An innovative solution gaining attraction in the transportation sector is the utilization of smart contracts. Smart contract technology is a digital transaction protocol that seeks to establish agreements between multiple parties by automatically executing the contract's conditions. Smart contracts are disintermediated and typically transparent, offering reduced legal and transaction costs, enhanced business efficiency, and the possibility of anonymous transactions. Due to these attributes, smart contract technology is in high demand, particularly in the financial industry where it can mitigate the risks of fraud and nonpayment and enhance the quality of financial contracts with a certain degree of confidence, all without the involvement of intermediaries.

Smart contract technology has emerged as a robust tool for enhancing efficiency and security in various industries, including transportation [5]. However, its implementation in transportation faces specific challenges related to standardization, interoperability, reliable data inputs, and alignment with regulations and compliance requirements.

In general, smart contracts hold significant promise for building more reliable and effective transportation systems, ultimately improving product security, safety, and the timely delivery of shipments. This research paper investigates the potential applications of smart contracts in the field of transportation management. It explores a set of applications for smart contracts, including functions like shipment tracking, digital documentation management, and route optimization. Our analysis suggests that smart contracts have the capacity to revolutionize the transportation and logistics landscape, ushering in improvements characterized by swifter operations, cost-effectiveness, and heightened safety protocols.

This paper introduces a multi-layered smart contract framework tailored for logistics and smart transportation in Egyptian transportation, with the aim of addressing tracking and security issues inherent in transportation processes [6]. Smart contracts can enhance performance, reduce risks, mitigate fraud, and improve efficiency, transparency, and tamper-proof capabilities [6]. These smart contracts are typically deployed on blockchain technology platforms like Ethereum, which provide a secure, transparent, and tamper-proof environment [8]. Blockchain's trusted and decentralized infrastructure is ideal for executing self-executing contracts. In the transportation industry, smart contracts can play a pivotal role in automating the execution of agreements among various parties involved, such as shippers and carriers [7]. Their applications encompass verifying the authenticity of goods, tracking shipments, ensuring compliance with rules and contractual obligations, automating processes, mitigating fraud risks, and enhancing security. Furthermore, they streamline payment procedures and automate financial transactions.

This paper is organized as follows: Section II provides a background on smart contracts. Section III introduces the related works in using smart contract in transportation. Section IV presents the proposed framework for Smart Contracts in transportation. Section V discusses the proposed framework. Implementation is given in Section VI. Results are analysed in Section VII. Finally, Section VIII presents conclusion.

II. Background

Smart contracts are software components that automate the execution of contract terms and function as self-executing agreements. They address the limitations of traditional procedures and offer a performance level that reduces risks, minimizes fraud, and enhances efficiency, transparency, and security. Blockchain technology is an ideal platform for implementing smart contracts, providing a trusted and decentralized infrastructure for executing these agreements. Platforms such as Ethereum frequently utilize blockchain technology to offer a secure, transparent, and tamper-proof environment for smart contracts.

Smart contracts have diverse applications across industries, including finance, real estate, healthcare, transportation, and supply chain management. In the healthcare sector, they facilitate the secure exchange of patient data, while in real estate, they automate and secure property transfers. In supply chain management, they create transparent transaction records that assist managers in tracking products from their origin to their final delivery destination.

In transportation, smart contracts enable real-time tracking of goods, offering companies increased visibility and insights into their operations. These contracts streamline transportation processes by swiftly and securely automating various tasks, thereby enhancing overall efficiency. They facilitate agreements among parties such as shippers and carriers, verify the authenticity of goods, track shipments, and ensure compliance with rules and contractual obligations. Beyond process automation, smart contracts reduce fraud risks, enhance security, streamline payment procedures, and automate financial transactions, ultimately contributing to the development of more reliable and effective transportation systems. This improves product safety, ensures on-time delivery, and enhances overall security.

However, challenges exist in implementing smart contracts in transportation, including standardization and interoperability across different blockchain platforms and the need for reliable data inputs to ensure accurate contract execution. Additionally, smart contracts require careful preparation of contract terms and adherence to regulatory and compliance requirements.

A. Layers of Blockchain and Smart Contracts

The fundamental elements of blockchain and smart contracts can be categorized into five layers, as illustrated in Fig. 1: buyer and seller, applications, verification, blockchain types, and network.

First Layer: In this layer, Real Estate Registration and Documentation Authority employees are responsible for inputting buyer data.

Second Layer: In the second layer, developers create various applications for smart contracts, including back-end programs, front-end programs, and decentralized applications (DApps).

Third Layer: In this layer, individuals are responsible for transaction verification before registration, as well as the types of consensus algorithms employed.

Fourth Layer: In the fourth layer, we focus on the methods used for recording and storing transactions, including options like Private Blockchain, Public Blockchain, or Consortium Blockchain.

Fifth Layer: The final layer addresses the network used for registering smart contracts, which is a peer-to-peer network. This network consists of interconnected computer systems via the Internet, without a central server. It incorporates various cryptographic technologies, public-key encryption, and platforms for smart contracts such as NEAR, Ethereum, and Hyperledger. Transaction storage is managed through virtual storage for all participants on the platform.

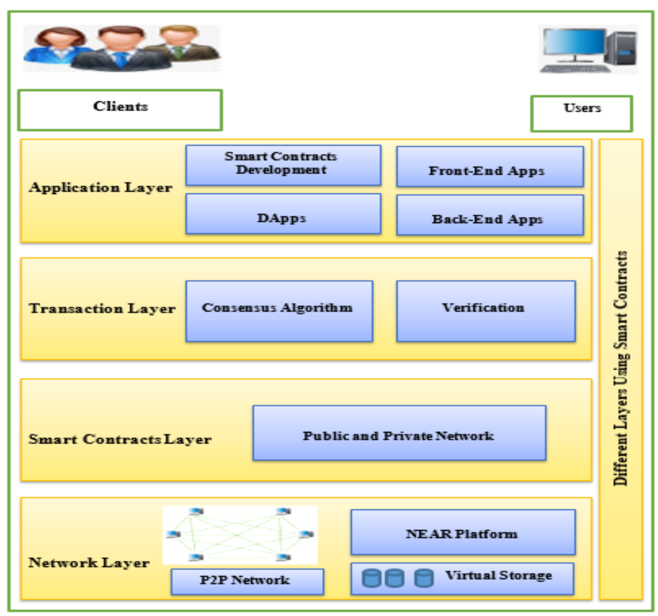

Fig. 1. Layers of smart contracts using blockchain.

B. Blockchain Types

1) Blockchain technology is categorized into three types: federated blockchain, public blockchain, and private blockchain. Each type is elaborated on as follows:

2) Public blockchain: A public blockchain allows anyone to join the network, verify transactions, and participate in consensus processes without disclosing their identities. Participants can send and receive transactions, validate blocks, and offer incentives to those who validate blocks. Public blockchains are unrestricted, and examples include platforms like Bitcoin and Ethereum [9].

3) Consortium or federated blockchain: Consortium or federated blockchains are not open to everyone; they are semi-private, with each participant having equal authority. Platforms like Corda and R3 are examples of this type [10].

4) Private blockchain: Private blockchains are networks accessible only to specific companies or banks, with stringent access control and a predefined set of nodes that are aware of each other. Examples include Monax and Multichain [11].

C. Blockchain Characteristics

Blockchain technology possesses a set of characteristics that make it a compelling solution for addressing various challenges [23].

1) Decentralized: One of blockchain's fundamental characteristics is its decentralization. It eliminates the reliance on centralized nodes to record and store data, opting for a decentralized, distributed ledger [12].

2) Immutable: Records stored in a blockchain are permanent and unalterable unless someone gains control of more than 51% of the network nodes simultaneously [24].

3) Open source: Most blockchain systems are open for public inspection, and users can harness blockchain technology to develop various applications, including smart contracts, cryptocurrencies, voting systems, healthcare solutions, insurance platforms, and supply chain tracking [13].

4) Transparent: Data records in a blockchain are transparent to all nodes, fostering trust during data updates.

5) Autonomous: Blockchain nodes can securely transfer data based on consensus algorithms [14].

6) Anonymity: Blockchain transactions provide anonymity by concealing the identity of the transaction executor and stored data [15].

7) Security: Blockchain offers enhanced security as there isn't a single point of breakdown capable of disrupting the entire network.

8) Increased capacity: The collaborative efforts of thousands of computers within a blockchain network enhance the overall network capacity [12].

D. Structure of Blockchain Data

The core data structure used in blockchain systems is a 'block,' with each block containing a distinct number known as a 'hash value.' This hash value is cryptographically generated using the SHA-256 algorithm and stored in the block's header. The cryptographic hash function takes any input string and produces a 64-bit hash value as output [15].

Key components of the block header include the block number and metadata, which encompass identification numbers, reference numbers, timestamps, and dates. Each block also references the previous block through its hash value or block number, forming a chain that allows all connected blocks to access the complete history [16]. The 'nonce' is the result of transaction processing with the assistance of a cryptographic hash algorithm (SHA-256) following encryption and data validation [25].

E. The Peer-to-Peer (P2P) Blockchain Network

The peer-to-peer network (see Fig. 2), often referred to as a P2P network, is a decentralized architecture in which computer systems are directly interconnected via the internet, eliminating the need for a central server. [21] This approach to networking follows a decentralized and distributed application model, dividing tasks or workloads among peers [26]. Participants in this network enjoy significant freedom in terms of connectivity. Additionally, the blockchain network relies on data cryptography technology for secure data transfer [22].

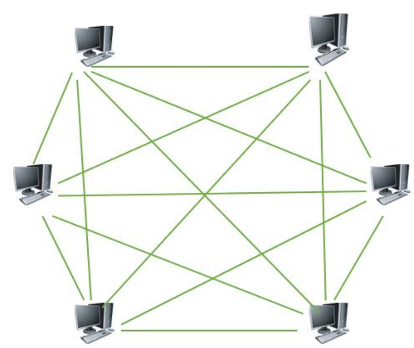

Fig. 2. Peer-to-peer blockchain network.

III. Related Works

In this section, the utility of smart contracts in transportation is investigated. The following subsections are categorized based on their applications of smart contracts to address transportation-related tasks. These tasks include intelligent electric vehicle systems, supply chain management, safety, security, traceability, mobility-as-a-service ecosystems, data management, real-time tracking, and cargo information [27].

A. Intelligent Electric Vehicle Systems and Road Safety

Several studies have demonstrated the effectiveness of using smart contracts in a blockchain-based electric vehicle transportation system. Byun et al. [29] developed an inference engine that enhances security and privacy by processing EV sensor data on the blockchain. This system efficiently manages the growing data flow from electric vehicles. On the other hand, Singh et al. [30] utilized smart contracts to establish trust in a blockchain-based Internet of Vehicles. Their approach addressed security and privacy concerns among untrusted vehicles, ultimately improving road safety and traffic efficiency. They also introduced measures to enhance scalability and transaction throughput. In addition to these works, Hou et al.

[42] explored the use of smart contracts within Decentralized Autonomous Organizations to streamline governance in Intelligent Transportation Systems (ITS). They proposed a DAO framework to simplify complex transportation systems. This innovation represents a promising future trend in ITS development.

However, these studies have focused on the security and trustiness of the blockchain based system. This gap in knowledge highlights the need for further research to explore the effectiveness of these systems to satisfy managerial needs of the stakeholders and the managers.

B. Supply Chain Management and Logistics

Several studies have demonstrated the effectiveness of using smart contracts in a blockchain-based supply chain management and logistics for automatic payment, cost reduction and transparency enhancement. For automatic payment in supply chains, Banerjee et al. [32] implemented smart contracts within an Intelligent Transport Management System based on blockchain (I-TMS) to automate toll-tax collection in supply chains. This approach ensures data security, transparency, and privacy through the decentralized and transparent nature of blockchain. Through the authentication of vehicle data, smart contracts enable automatic toll collection without the need for vehicle stops, resulting in fuel savings, improved time efficiency, and enhanced data security compared to traditional RFID-based systems. Furthermore, Baygin [33] employed smart contracts in a blockchain-based fast shipping management architecture for local cargo networks to establish an automatic payment and approval mechanism. To reduce costs in transportation, smart contracts, as introduced by Philipp et al. [11], utilize blockchain technology to automate processes, reducing intermediaries and transaction costs within the transportation industry. [28] These contracts promote cross-organizational collaboration, particularly benefiting entrepreneurs and small and medium-sized enterprises by facilitating their entry into transnational supply chains. The abstract emphasizes the role of blockchain smart contracts in enhancing collaborative logistics and ensuring SME integration in sustainable maritime supply chains, highlighting their potential in transnational and multimodal supply chain environments.

In a study by Manimuthu et al. [17], smart contracts were employed in transportation to improve sustainable supply chain operations within the Autonomous Vehicles industry. This approach enhances traceability, transaction transparency, and sustainability, while also fostering the emergence of innovative AV business models. In personalized transportation, Chinaei et al. [38] utilized smart contracts within the transportation sector to promote the Mobility-as-a-Service concept. These contracts enable personalized transport service ownership through blockchain technology, providing a secure and private exchange of ownership. Their paper introduces a blockchain-driven MaaS platform that utilizes smart contracts to personalize service ownership, address congestion, and facilitate data trading among stakeholders, ultimately enhancing transportation service efficiency and convenience. To enhance transparency and security, Terzi et al. [63] employed smart contracts in supply chain management. These contracts enable product logging and tracing, ensuring unique item identification from factory to customer. Blockchain technology is also employed for user authentication and authorization, enhancing network security and trust while preserving data confidentiality. These smart contracts facilitate efficient interactions and trust among supply chain participants in real-life scenarios.

However, these studies have focused on partial aspects of the blockchain based systems. This gap in knowledge highlights the need for further research to explore the expandability and completeness of these systems to satisfy managerial needs of the stakeholders and the managers.

C. Safety, Security, and Traceability

Several studies have focused on ssafety, ssecurity and ttraceability of using smart contracts in a blockchain-based supply chain management. For example, in [18], Zichichi et al. employed smart contracts to coordinate data sharing in a smart transportation system using distributed ledgers such as Ethereum, IOTA, and IPFS. [19] These contracts enable secure and automated sensor data exchange while preserving privacy through Zero Knowledge Proof, fostering innovative smart services and societal benefits in user mobility. Similarly, Valencia-Payan et al. [36] utilized smart contracts to monitor and ensure coffee bean quality during transportation and storage via Blockchain technology. Their Hyperledger Fabric-based smart contract automates condition verification and enhances traceability, offering fast throughput and low latency suitable for real-world applications in the transportation and quality control of coffee beans. On the other hand, Imeri et al. [28] applied smart contracts to enhance security and traceability during the transportation of hazardous materials. Their conceptual approach employs blockchain-based smart contracts to securely share sensitive information while maintaining transparency and auditability. Authorized parties' access and interact with the data, ensuring the safe movement of dangerous goods. Moreover, Valchanov et al. [39] utilized smart contracts in transportation to improve safety in the transportation of special and hazardous cargo. Their model combines blockchain and IoT technology to record real-time sensor data and trigger smart contracts for stakeholder notifications when thresholds are breached. This expedites insurance claims and enhances safety. Finally, Mihelj et al. [41] developed a system for real-time identification of road traffic events and evaluation of source reputation using smart contracts in the transportation industry. This approach effectively detects manipulative behaviors, maintaining data integrity for safer transportation.

Generally, this research enhances trust and eliminate single authority control, ensuring reliable and secure traffic data collection and assessment.

However, these studies have focused only on safety, ssecurity, and ttraceability of the smart contracts in transportation systems. This gap in knowledge highlights the need for further research to explore the business requirements and the managerial needs of these systems.

IV. Mobility-as-a-Service (MaaS) Ecosystems

Several studies have focused on using smart contracts to serve as Mobility-as-a-Service (MaaS) ecosystems in transportation systems. For example, Chinaei et al. [37] employed smart contracts in transportation to advance the MaaS concept using blockchain technology. These contracts enable personalized ownership of transport services, ensuring secure exchanges with privacy preservation. The paper introduces a blockchain-based MaaS platform, powered by smart contracts, to customize service ownership, manage congestion, and facilitate data trading among stakeholders, thus enhancing transportation efficiency and convenience. Additionally, Tallyn et al. [40] explored smart contract applications in transportation, with a specific focus on optimizing last-mile deliveries to improve precision, coordination, and accountability.

Furthermore, Karinsalo et al. [44] harnessed smart contracts in transportation to enable seamless and reliable transactions within Mobility-as-a-Service (MaaS) ecosystems, leveraging both blockchains and artificial intelligence. The proposed model, exemplified by Travel Token, employs blockchain-enabled smart contracts to store travel data, ensure data integrity, and automate value-sharing and compensation processes, thereby enhancing the efficiency and reliability of travel experiences while meeting industry demands.

However, these studies have focused on personalized ownership of transport services in transportation systems. This integration of smart contracts raises important questions about balancing automation with personal values, relationships, and individual agency within the transportation sector. This gap in knowledge highlights the need for further research to address evolving business needs in the MaaS field.

A. Data Management and Insurance

Several studies have focused on data management and insurance of smart contracts in transportation systems. Wang et al. [31] utilized smart contracts to establish an auditable payment and asset delivery protocol in transportation, ensuring transparent and secure transactions. This protocol enhances fairness, traceability, and security by leveraging blockchain technology, thereby addressing third-party payment and security issues. Balasubramaniam et al. [20] applied dimensionality reduction techniques and blockchain in transportation to present verifiable digital evidence while minimizing data for efficient storage on the blockchain. Smart contracts facilitate data sharing among insurance companies, enhancing data integrity within Intelligent Transportation Systems (ITS).

Furthermore, Quoc et al. [43] introduced the 'Safe Seller Safe Buyer' (SSSB) system in transportation, which eliminates intermediaries. Smart contracts include rules for conflict resolution and penalty enforcement, providing insurance-like protection. Lastly, Valencia-Payan et al. [28] applied smart contracts in goods transportation, with an emphasis on traceability and transparency in social selling.

However, these studies have focused on data management, insurance and safety in transportation systems without emphasizing on the global ecosystem interaction and collaboration. This gap in knowledge highlights the need for further research to address evolving business needs in the global ecosystem.

B. Real-Time Tracking and Decision-Making

Several studies have focused on role of smart contracts in transportation systems for real-time tracking and decision making. Arumugam et al. [34] applied smart contracts in transportation for advanced supply chain management and logistics, utilizing real-time IoT tracking and decision-making processes. These contracts allow users to establish trust and enforce conditions, ensuring visibility and traceability throughout the supply chain. Their proposed smart logistics system combines condition monitoring, logistics planning, and smart contracts to enhance accountability and efficiency in supply chain asset management. To enhance transportation management, Hasan et al. [35] employed smart contracts on the Ethereum blockchain for efficient supply chain management in transportation, with a focus on tracking and managing global trade shipments. These contracts govern stakeholder interactions, automate payments, and enforce predefined shipping conditions for IoT-equipped smart containers. This technology enhances transparency, security, and automation in complex logistics, with potential applications in vaccine supply chain management. Additionally, Arumugam et al. [42] used smart contracts in transportation to improve supply chain management and logistics through real-time tracking and decision-making with IoT devices. These contracts enable trust and enforceability, providing visibility and traceability throughout the supply chain. Their proposed smart logistics system integrates condition monitoring, logistics planning, and smart contracts to enhance accountability and efficiency in supply chain asset management. This streamlines document processing, reducing errors and manipulation, while enhancing efficiency and saving time and costs. Automation ensures the immutability, trust, and privacy of the blockchain, thereby improving the speed of the shipment process.

These studies have focused only on real-time tracking and decision making. This gap in knowledge highlights the need for further research to address other business needs in the transportation ecosystem.

C. Cargo Information and Traceability

Several studies have focused on role of smart contracts in transportation systems for tracking Cargo Information and Traceability. For example, Munari et al. [45] investigated smart contract usage in transportation, focusing on the Tradeless platform, a permissioned blockchain for real-time cargo data. Concerns arose regarding data transparency's anti-competitive effects and sensitive information exposure among competitors. The work explores blockchain and smart contracts' impact on transportation, highlighting changing transport patterns and reduced transmission of personal or sensitive data.

These studies have focused only on cargo information. This gap in knowledge highlights the need for further research to address other integrated business needs in the transportation ecosystem.

V. PROPOSED FRAMEWORK FOR SMART CONTRACTS BASED TRANSPORTATION

The transportation industry in the Arab World is one of the most lucrative sectors, with revenues increasing annually. Smart contracts have introduced new forms of interactions, such as the reliable logging of transit traffic, which was previously unmanageable with traditional systems. The conventional transportation system in Egypt and other countries is slow and cumbersome, relying heavily on multiple intermediaries. By integrating blockchain technology into the transportation sector, real-time tracking of transportation movements can be verified on a unified blockchain platform, ensuring transparency, high security, a decentralized environment, and a distributed ledger.

This paper proposes a formal method to ensure compliance with existing smart contract regulations and assign liability. The objective is to develop a distributed system that securely manages transactions to accelerate movement, streamline transfers, and address various transportation-related tasks. These tasks include supply chain management, safety, security, traceability, mobility-as-a-service ecosystems, data management, real-time tracking, and cargo information all without requiring vehicles to stop at toll plazas. This approach ensures data security, transparency, and privacy through the decentralized and transparent nature of blockchain. By authenticating vehicle data, smart contracts facilitate automatic toll collection without the need for stops, leading to fuel savings, improved time efficiency, and enhanced data security compared to traditional RFID-based systems.

Smart contracts, implemented on platforms such as NEAR and Ethereum, enable secure communication between parties and efficient tracking and tracing of RFID-tagged shipments using Internet of Things (IoT) and Ultra-High Frequency (UHF-RFID) sensors. This paper highlights an encouraging trend for the future development of Intelligent Transportation.

A. The Traditional Transportation System

In traditional transportation systems, customers typically visit the transport company in person to submit all necessary documents verifying their ownership of the goods. Afterward, the customer pays the required transportation fees and receives an invoice that includes the expected delivery date. One of the major drawbacks of traditional land transport is the lack of goods tracking, insufficient driver oversight, and inflexible scheduling. These issues can lead to damage to certain goods and increase the risk of theft due to the absence of tracking and a clear understanding of the different stages of the goods' journey, as illustrated in Fig. 3.

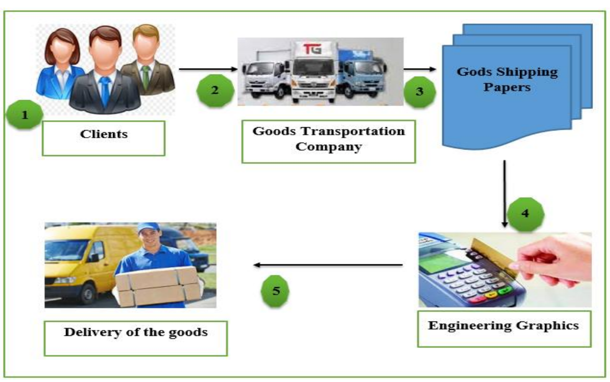

Fig. 3. Traditional transportation system in Egypt.

B. Smart Contract based Transportation System

This work proposes a framework for tracking transportation movements in Egypt using smart contracts and blockchain technology. The framework documents the transportation of goods through smart contracts facilitated by blockchain technology. Customers enter into an agreement with the transport company and provide all necessary documents verifying the ownership of the goods.

The shipping company then records the transaction on the smart contract, creating a new record and assigning a unique identifier to track the shipment. Blockchain technology simplifies shipping operations significantly by enabling direct and secure tracking of shipments at all stages. This is achieved through the integration of GPS (Global Positioning System, which provides positioning, navigation, and timing services) with sensors—electronic devices that monitor physical attributes such as temperature, pressure, distance, speed, torque, and acceleration.

The system consists of three chips: a space chip, a control chip, and a user chip, along with a mobile chip. These devices are attached to the goods cart, allowing precise monitoring of shipment details, tracking the status of shipments, and connecting the information to the smart contracts network. The proposed system aims to improve traceability, transparency, information security, and the immutability of data stored and exchanged during various operational processes in a decentralized manner, thereby eliminating the need for intermediaries or third parties, as illustrated in Fig. 4.

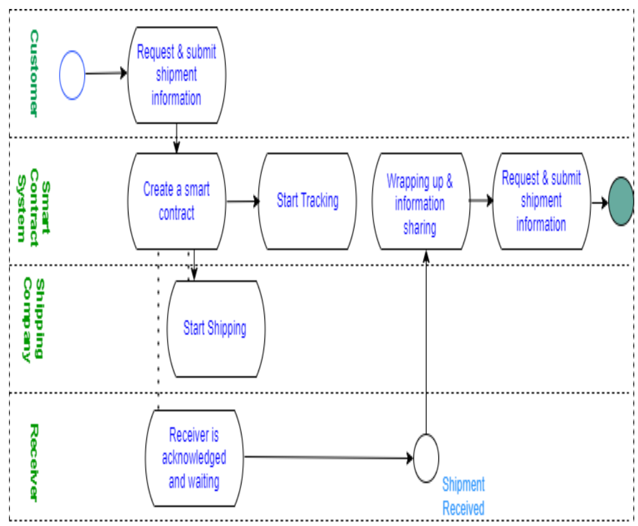

Fig. 4. The Proposed framework for tracking transportation in Egypt.

VI. Implementation

We will implement the proposed framework for smart contracts, designed to facilitate the registration and tracking of goods and commodities using blockchain technology. The protocol has been developed and executed on the NEAR platform. Smart contracts are integral in establishing a distributed, secure, and decentralized ledger to safely record all assets and transactions between parties. Our model is developed using Assembly Script and Rust programming languages and operates on the NEAR platform, a decentralized application based on blockchain technology, where it meticulously stores all transaction records related to the goods tracking process.

During the design phase, the necessary input forms are defined and translated into code programs. These screens include various functions such as user login, registration of buyer and seller information, payment processing, document review and validation, smart contract creation, TXN hash, and ID property generation. The NEAR platform is notable for offering the lowest transaction fees, approximately $0.0001 per transaction, and supports up to 100,000 transactions per second (TPS), outperforming many other platforms.

A. Testing and Assessment

This study addresses two types of assessments: statistical analysis and performance evaluation.

B. Statistical Analysis

The primary objective of the surveys is to examine the feasibility of adopting smart contracts based on blockchain technology as an alternative to the conventional shipment registration system in Egypt. This research employs a questionnaire study to validate the proposed model's effectiveness and a survey to assess the impact of various factors on the adoption of blockchain-integrated smart contracts within the Egyptian shipment registration system.

The questionnaire evaluates the influence of independent variables, such as data availability, location accessibility, ease of transaction verification, transaction comprehension, data accuracy, data immutability, cost reduction, affordable contract execution, and improvements in process efficiency, on the dependent variable: the integration of blockchain technology with the Egyptian cargo tracking infrastructure.

The research sample was carefully selected based on relevant criteria and included individuals with a keen interest in blockchain and smart contracts, IT specialists, and professionals involved in the shipping industry. The proposed framework was introduced and practically demonstrated to each member of the research sample, followed by initial testing to ensure the model's practical applicability.

The sample consisted of 127 participants interested in the study's subject matter. The study on hand categorized the sample into groups of questions concerning blockchain, smart contracts, the questionnaire format, and the total number of questions (15). This section presents the conclusions drawn from the survey data analysis, which was conducted using the Statistical Package Table II summarizes that.

Table I illustrates a Comparison of Some of the most popular Smart contract platforms.

This section discusses a comparison of the five most popular smart contract platforms Hyperledger Fabric, Ethereum, NEAR, Solana, and Cardano, highlighting their main characteristics like Transaction per second (TPS), Average transaction fee, Network type, Programming Language, Market Capital, and highlighting the importance of using the NEAR platform Table I summarizes that.

TABLE I. PLATFORM COMPARISON

Description	Ethereum	NEAR	Hyperledger Fabric	Solana	Cardano
Used Language	Solidity	Assembly Script, Rust	JavaScript, Go	C, Rust	Plutus
Foundation	Ethereum developers	NEAR foundation	Linux foundation	Solana foundation	Cardano foundation
Ledger type	Permissionless	Permissioned	Permissioned	Permissionless	Public
Cryptocurrency	ETH	NEAR	No Token	SOL	ADA
Coin market cap 5/2023	$ 1,08	$ 2.21	Not Applicable	$ 35.09	$ 0.48
Consensus algorithm	Proof of work (PoW)	proof of stake (PoS)	Crash Fault Tolerance (CFT)	Proof of stake (PoS-PoH)	Proof of stake(PoS)
Open Source	Yes	Yes	Yes	Yes	Yes
Using	Easy to use	Easy to use	Easy to use	Easy to use	Easy to use
Transactions per second (TPS)	27 / TPS	100,000 / TPS	3,500 / TPS	3,240 / TPS	250 / TPS
Average transaction fees	$ 0.7962	$ 0.0001	No transaction fees	$ 0.00025	$ 0.4
Network Type	Public Network	Public and Private Network	Private Network	Public Network	Public Network
Market Capital	$ 225,052,960	$ 1,756,564	$ 1,148,790	$ 8,532,436	$ 13,652,673
Date released	2013	2020	2016	2017	2013

Sciences (SPSS) as the analytical tool.

TABLE II. SUMMARY OF DEMOGRAPHIC PROFILE OF RESPONDENTS

Variable	Category	Frequency	Percentage (%)
Gender	Male	84	66%
	Female	43	34%
	Total	127	100%
Age	51 to 60	21	17%
	41 to 50	42	33%
	31 to 40	27	21%
	20 to 30	37	29%
	Total	127	100%
Specialty	Information Technology Specialists	37	29%
	Interested in buying and selling	29	23%
	Employees	31	24%
	Others	30	24%
	Total	127	100%

TABLE III. FREQUENCIES

Q	Strongly Agree (100%)		Agree (75%)		Strongly Agree	Neutral	Neither Agree nor Disagree (50%)		Disagree (25%)		Strongly Disagree (0%)	
	Frequency	Row N%	Frequency	Row N%			Frequency	Row N%	Frequency	Row N%	Frequency	Row N%
Q1	70	55%	50	39%	120	94%	94%	6%	7	6%	0	0%
Q2	68	54%	45	35%	113	89%	89%	11%	13	10%	0	0%
Q3	70	55%	44	35%	114	90%	90%	10%	13	10%	0	0%
Q4	50	39%	57	45%	107	84%	84%	16%	19	15%	1	1%
Q5	74	58%	48	38%	122	96%	96%	4%	5	4%	0	0%
Q6	35	28%	65	51%	100	79%	79%	21%	25	20%	1	1%
Q7	70	55%	47	37%	117	92%	92%	8%	8	6%	2	2%
Q8	51	40%	62	49%	113	89%	89%	11%	13	10%	1	1%
Q9	51	40%	67	53%	118	93%	93%	7%	7	6%	2	2%
Q10	11	9%	33	26%	44	35%	35%	65%	24	19%	35	28%
Q11	9	7%	29	23%	38	30%	30%	70%	46	36%	19	15%
Q12	29	23%	43	34%	72	57%	57%	43%	46	36%	7	6%
Q13	37	29%	15	12%	52	41%	41%	59%	60	47%	9	7%
Q14	7	6%	14	11%	21	17%	17%	83%	39	31%	37	29%
Q15	52	41%	60	47%	112	88%	88%	12%	9	7%	1	1%

VII. RESULTS AND FINDINGS

The survey findings reveal that a significant majority of respondents hold positive views regarding the adoption of smart contracts. Notably, 96% of participants found it convenient to access data and monitor shipments and logistics using smart contracts and cryptography. Additionally, 92% acknowledged that smart contracts enhance security and privacy for all stakeholders involved. A substantial 84% agreed that the integration of smart contracts eliminates intermediaries acting as third parties between sellers and buyers. Furthermore, 93% concurred that using Transportation in blockchain technology in conjunction with Supply chains and smart contracts helps mitigate tax evasion, as illustrated in Fig. 5.

The survey results indicate that 90% of respondents believe that smart contracts effectively regulate the shipping tracking process, while 89% agree that employing blockchain technology alongside smart contracts helps reduce tax evasion. Additionally, 79% observed significant changes in the electronic shipping registration process compared to traditional methods. Notably, 17% of respondents acknowledged the inefficiency and sluggishness of traditional contract registration procedures. The questionnaire results strongly support the notion that incorporating blockchain technology and smart contracts into the shipping registration process in Egypt would provide various benefits, including rapid access to transaction information, streamlined verification processes, improved data accuracy, increased reliability, and significant cost reduction.

The survey findings suggest that adopting blockchain technology in conjunction with smart contracts for shipping registration in Egypt, offers advantages such as fast access to shipment location data, simplified transaction verification, improved data precision, enhanced reliability, and substantial cost savings.

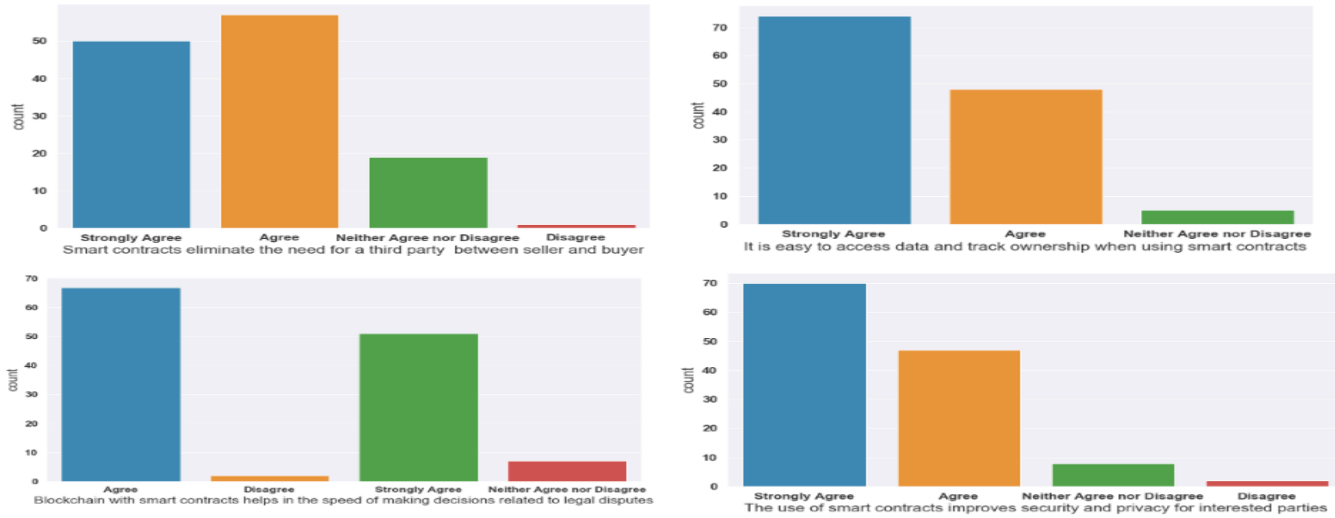

Fig. 5. Analysis results.

To further evaluate the model's performance, the proposed smart contract model was deployed on the NEAR platform, and its performance was compared to other smart contract platforms. The smart contract was written in Assembly Script on the NEAR Web3 platform. The model effectively addresses shipping registration challenges in Egypt and demonstrates superior attributes compared to Ethereum-based smart contracts. It successfully resolves issues related to registration time, sequencing characteristics, cost-efficiency, and transaction speed. While smart contract development can be performed on various blockchain platforms, the choice of platform is influenced by decentralized application storage techniques.

In our view, the positive response to smart contracts demonstrates the significant potential of this approach to transform Egypt's transportation sector. The high percentages in the results confirm the practicality of integrating smart contracts. Additionally, the reduction in tax evasion and the increased registration efficiency offer promising implications for economic governance and operational sustainability. However, challenges related to classical bureaucratic processes still need to be addressed Table III summarizes that.

VIII. Conclusion

This study demonstrates how smart contracts and blockchain technology can significantly improve transportation and logistics in Egypt. It addresses key challenges such as congestion, inefficiency, and a lack of transparency in conventional systems. Our smart contract framework, powered by blockchain technology, offers a secure and decentralized method for transportation management, streamlining processes and addressing logistical tasks such as supply chain management and real-time tracking. The framework, implemented on the NEAR platform, outperforms traditional methods by delivering improved information accessibility and enhanced privacy. The features of the framework include the integration of technologies, user-focused design, decentralization, and the scalability of the NEAR model. Survey results indicate a 96% increase in convenience for data access, a 92% improvement in privacy and security, and an 84% reduction in the need for intermediaries. Other results indicate a 93% increase in the mitigation of tax evasion and a 93% improvement in shipping registration. While the framework provides promising results, further research is needed to improve scalability and address potential regulatory challenges. Future work could recommend integrating analytics and machine learning to further optimize logistics or applying the model to other industries. In addition, further investigation can be conducted into IoT integration, regulatory frameworks, cross-border applications, environmental impact studies, blockchain scalability, and cybersecurity risk evaluation. In conclusion, smart contracts and blockchain technology hold significant potential for transforming transportation management, particularly in Egypt."

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