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A Novel System Design for Optimizing Cloud-based Railway Cargo System (CBRCS) using Blockchain Technology

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ABSTRACT
Railway Cargo Systems (RCS) are often associated with issues such as data security, lack of transparency, and inefficiencies in terms of storage requirements and overall operability. This work proposes a novel technique combining blockchain technology with cloud computing to create a secure and streamlined railway cargo system. By leveraging the power of blockchain's distributed ledger and immutability, the system guarantees data integrity and fosters trust among all participants. Cloud computing, on the other hand, injects scalability, real-time data processing, and accessibility for every stakeholder involved in the network. The proposed integration promises significant improvements across various aspects of railway cargo operations. Firstly, enhanced security is achieved by storing transactions and cargo information permanently on the blockchain, significantly reducing the risk of fraud and unauthorized data alterations. Secondly, increased transparency is realized through a shared ledger accessible to all participants, enabling real-time tracking and clear visibility of cargo movement throughout the journey. Thirdly, streamlined processes through automated document handling and by implementing smart contracts on the blockchain lead to improved efficiency. Elimination of paper-based documentation and various intermediary parties achieves the desired cost savings. Finally, the potential benefits and challenges associated with the implementation of our proposed system in the railway cargo industry are assessed, which include the scalability limitations and seamless interoperability between different blockchain platforms.

Keywords
Blockchain, Cloud Computing, Cloud storage, CBRCS, Railway-Cargo

1. INTRODUCTION
The modern era has witnessed a surge in cloud computing as well as blockchain technology, with businesses worldwide adopting them for data storage and efficient data management. Both technologies offer similar functionalities, enabling participants in networks to store and access information or transactions. However, both cloud computing and blockchain face certain challenges. The first technology offers low-cost data storage and data access but is unable to provide due security needed to run various modern applications. Hence, blockchain technology combined with cloud storage can provide a secure low-cost system by complementing each other.

The decentralization, transparency, and security advancements of blockchain have prompted many information technology infrastructure providers to invest in innovative blockchain cloud services catering to a broad customer base. Integration of blockchain and cloud computing has the potential to address common issues in areas like compliance, data integrity, confidentiality handling, and interoperability.

A major drawback of cloud computing is its reliance on centralized servers for data management, making it vulnerable to hacking. Decentralized blockchain technology, on the other hand, distributes data storage across various computers. This eliminates the risk of system-wide failures due to a single server malfunction, as information is replicated across multiple servers. Organizations are also increasingly investing in Blockchain as a Service (BaaS) software. BaaS simplifies business development and facilitates hosting blockchain applications and smart contracts within the cloud-based blockchain ecosystem. In essence, BaaS enhances the accessibility of blockchain functionalities for businesses. For example, Amazon Web Services (AWS) provides a comprehensive cloud offering for those seeking to leverage blockchain technology. AWS offers services like Amazon Managed Blockchain, which allows users to effortlessly create a node on the public Ethereum blockchain and join the Hyperledger fabric network. Additionally, AWS offers an Amazon Quantum Ledger Database for users requiring immutable data chain tracking.

2. PRILIMINERIES
A Blockchain is a distributed ledger technology mainly used in cryptocurrencies, which can be decentralized, centralized, or distributed. It is a string of encrypted units of data blocks where the blocks have the information stored, with their previous block hash value. It is locked so that whoever has the hash value can access the information stored in that block in such a way that makes it difficult or impossible to change, hack, or cheat the system [6].

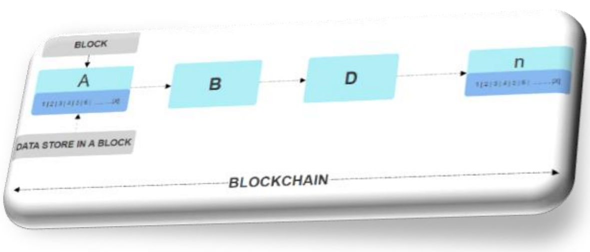

Fig. 1: The basic structure of a Blockchain

There can be ***n*** number of blocks in a single blockchain, and ***X*** be the maximum value of data stored [7] in a block which means a blockchain can store ***n.X*** number of data as represented in Fig.1 for a typical blockchain network.

2.1 Blockchain Mechanisms

There are various available techniques as of now associated with Blockchain Technology, which are used to model different supply chain networks are as follows:

2.1.1 Proof of Work (PoW): PoW is a suitable consensus mechanism when supply chain networks require a high level of security and trust. It ensures data immutability and tamper resistance, making it ideal for industries like pharmaceuticals or luxury goods, where maintaining the integrity of the supply chain is critical [6] [8].

2.1.2 Proof of Stake (PoS): PoS is a more energy-efficient consensus mechanism compared to PoW because it needs less computational power and relies on validators. It is suitable for supply chains that prioritize energy efficiency and involve known, trusted participants. This mechanism not only reduces energy consumption but also maintains trust among its members. With the current growth of Railway cargo transport, a more energy-efficient consensus mechanism is needed to make it more cost-efficient, and thus PoS comes into existence in implementing the RCS [8].

*2.1.3 Proof of Authority (PoA)***:** PoA is ideal for private or consortium-based supply chain networks where participants are known and trusted. It is well-suited for scenarios where high performance and scalability are crucial. For instance, a consortium of automotive manufacturers can utilize PoA to streamline the exchange of production and inventory data within their network, ensuring rapid transaction processing while maintaining a high level of trust among participants [9].

2.1.4 Hybrid Consensus Mechanisms: Some supply chain solutions benefit from a combination of consensus mechanisms. They can use PoW for data security and PoS for transaction processing efficiency. PoW could be employed to ensure cargo tracking security and the integrity of the data, while PoS to be used for rapid transaction processing, ensuring swift settlements and order confirmations [6] [8]. For instance, an international shipping company's supply chain might adopt a hybrid approach.

2.2 Blockchain Types

Various types of blockchain can be used at par the requirements to model different kinds of supply chain networks. According to their functionality and accessibility, the following types of blockchains can be developed.

2.2.1 Public or Permissionless Blockchain: Any node may join the peer-to-peer network via a consensus mechanism and take part in the block creation process, such as processing transactions, storing the block, and confirming and validating the transaction of data in the public blockchain. An open and decentralized ledger is maintained in this type of blockchain. Litecoin, Ethereum, and Bitcoin are a few examples of public blockchains.

2.2.2 Private or permission-based blockchain: Private blockchains are restricted since not everyone can join the network. To preserve accessibility, it is a centralized blockchain administered by a central authority. The public is therefore permitted case-by-case access to data on a private blockchain. Private blockchains benefit small businesses or industries the most. Private blockchains may be utilized for counting, digital identity, asset ownership, and supply chain management. Few instances of this type of blockchain are Multichain, Hyperledger, and Corda.

2.2.3 Consortium blockchain: A blockchain consortium is administered by a group as opposed to a single business. This technology is very similar to a private blockchain, with the added advantage of having more than one central authority to access the chain. Hence, such blockchains are more secure and versatile compared to a typical private blockchain. An example of a hybrid blockchain is Quorum [12].

2.2.4 Hybrid Blockchain: Both public and private blockchains simultaneously exist and use the same functionalities. Accordingly, there will be a system that requires private rights or one that does not. Using this hybrid network, the clients might control who has access to the blockchain's stored data. In addition to that, only a subset of the data or records stored in the blockchain may be made public. The remaining information is protected on the private network. An example of a hybrid blockchain is Dragonchain.

2.3 Cloud-based Storage System

Cloud storage is a way of storing data online instead of maintaining data on physical devices. It is like renting space in a massive off-site data center, accessed through the internet. This frees up space on individual devices and allows one to access files or data from anywhere in the world with an internet connection.

2.3.1 Cloud Computing Models:
Cloud computing provides on-demand access to computing resources, typically delivered through web applications. A public cloud offers these services to any business. In contrast, a private cloud is dedicated to a single organization and can be managed in-house or by a third-party provider. A hybrid cloud combines the two, allowing organizations to leverage public cloud benefits for non-critical tasks and maintain control over sensitive data on a private cloud, offering flexibility and adaptability. Cloud computing offers a wide range of advantages for businesses and individuals alike. Some of the key benefits include:

- **Cost savings:** Cloud computing eliminates the need for upfront investment in expensive hardware and software. Users only pay for the resources they actually use, following a pay-as-you-go model, which can lead to significant cost savings.
- **Scalability and flexibility:** Cloud resources can be easily scaled up or down to meet changing needs. This is particularly useful for businesses with fluctuating workloads. For instance, an e-commerce store can increase its server capacity during peak shopping seasons and then scale back down afterward.
- **Accessibility:** Cloud-based data and applications can be accessed from anywhere, at any time, with an internet connection. This allows for greater mobility and flexibility, enabling employees to work remotely or from different locations.
- **Improved collaboration:** Cloud storage enables teams to work together on documents and projects in real-time,

regardless of their location. This fosters better collaboration and higher productivity.

- **Automatic updates and security**: Cloud service providers are responsible for maintaining and updating their infrastructure. This ensures that users always have access to the latest security patches and features without worrying about manual updates.
- **Disaster recovery:** Cloud providers offer robust disaster recovery solutions. Data is stored in secure data centers, mitigating the risk of loss in case of a physical disaster at a local office.
- **Access to advanced technologies:** Cloud computing allows access to powerful computing resources and advanced technologies that may not be affordable or feasible to maintain in-house. This includes tools such as artificial intelligence, machine learning, Large Language Model (LLM), and big data analytics.

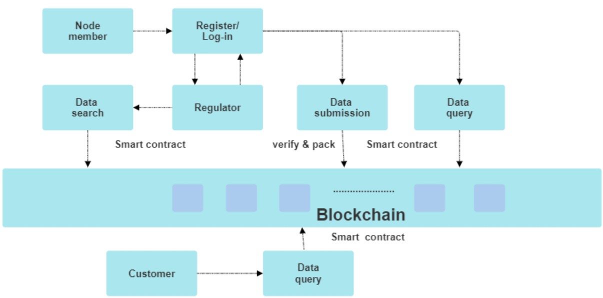

Fig. 2: Flow of data in a blockchain architecture

2.3.2 Cloud Service Models for Blockchain

The various cloud service models for Blockchains are used as of now. The proposed model has inspired and added such technologies to fulfill its scalability and commercial needs. The following models are taken into consideration and modified accordingly while designing the proposed ***C***loud-based ***R***ailway ***C***argo ***S***ystem **(*CBRCS*)** model.

2.3.2.1 Infrastructure as a Service (IaaS): In the Infrastructure as a Service (IaaS) model, consumers directly access and utilize fundamental computing resources like storage, networks, and other core functionalities. This allows them to deploy and run various services as needed. The service provider, on the other hand, is responsible for managing the underlying infrastructure, including servers, networks, virtualization, and data storage, all delivered through the Internet [13]. Examples of IaaS providers include Amazon EC2, Google Compute Engine, and OpenStack.

2.3.2.2 Platform as a Service (PaaS): In the Platform as a Service (PaaS) model, the focus is on application and data management by the consumer. The cloud service provider handles everything else, including the runtime environment, middleware, operating system, virtualization, servers, storage, and networking. This model is particularly popular among developers [13]. Examples of PaaS offerings include Google App Engine, AWS Elastic Beanstalk, QuickBase, and Adobe Commerce.

2.3.2.3 Software as a Service (SaaS): In the Software as a Service (SaaS) model, consumers leverage the applications provided by the cloud service provider. These applications are accessible via the internet or web browsers on various client devices. Consumers have minimal control over the underlying cloud infrastructure, which encompasses storage, network, operating systems, servers, databases, and the applications themselves. Examples of SaaS offerings include Salesforce.com, Google Apps, Office 365, and Dell EMC Syncplicity [13].

2.3.2.4 Blockchain as a Service (BaaS): Blockchain as a Service (BaaS) is a recent cloud service model where a third party takes care of installing and mainly training a blockchain network. Similar to Software as a Service (SaaS), BaaS allows businesses of any size to rapidly join a blockchain network. This eliminates the need for expensive in-house development, enabling companies to develop blockchain applications at minimal cost. Through BaaS, businesses can leverage the services provided by the blockchain provider. Combining cloud services with BaaS offers significant value. The adaptable nature of BaaS technology allows businesses to address challenges efficiently by adjusting integrations. In the financial sector, BaaS is particularly valuable for open banking initiatives within the banking industry. Additionally, BaaS plays a crucial role for lenders, facilitating smoother loan processes through instant transaction settlements. This helps mitigate risks like double-spending and fraud.

3. METHODOLOGY

The proposed method develops a cloud-based blockchain architecture for the Railway Cargo System with six distinct layers. Figure 3 describes different layers and its functionality on the cloud-based blockchain. This CBRCS architecture is modeled on Ethereum blockchain technology and integrated with a cloud server, which is introduced as a cloud layer on top of the application layer. The operational purpose of all the layers is given below.

1. Edge Layer: The edge layer serves as the foundational layer in cloud-based blockchain architecture, capturing and processing data at its source. Sensors, ranging from IoT devices to industrial equipment, generate vast amounts of data. Edge devices, equipped with computational capabilities, process this raw data locally to reduce network congestion and latency. Data preprocessing techniques, such as noise reduction and data normalization, enhance data quality before transmission. Security is paramount at the edge, with encryption, access controls, and intrusion detection systems protecting sensitive data.

ii) Data Layer (The Blockchain Foundation): The data layer is where the core blockchain technology is implemented. Data is organized into blocks, containing transactions, timestamps, and cryptographic hashes. Merkle trees are used for efficient data verification within blocks. The blockchain operates as a distributed ledger, with multiple nodes maintaining copies for data availability and resilience. Consensus mechanisms, such as Proof of Work or Proof of Stake, ensure agreement on the order of transactions and block validity. Smart contracts, defining rules and logic for data processing, are also integral to the data layer.

iii) Consensus Layer: The consensus layer is crucial for blockchain security and reliability. It employs algorithms like PoW or PoS to determine which nodes validate and add blocks. Byzantine Fault Tolerance ensures network operation even with compromised nodes. Incentive mechanisms reward honest behavior and penalize malicious actions, and the network topology influences consensus performance and security.

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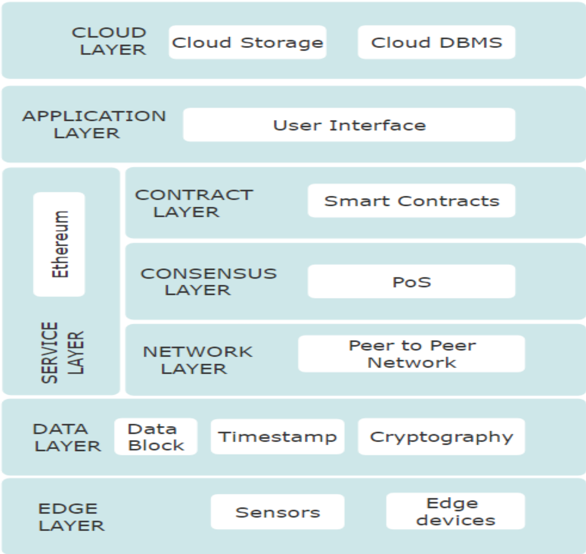

Fig. 3: Blockchain-based cloud architecture

iv) Contract Layer: The contract layer houses smart contracts, self-executing contracts with predefined terms and conditions. These contracts are written in programming languages like Solidity and deployed on the blockchain. Smart contracts can interact with oracles to access external data. They form the foundation of decentralized applications (dApps), enabling various blockchain-based solutions.

v) Service Layer: The service layer provides the underlying infrastructure for the blockchain system. It includes platforms like Ethereum, which support smart contracts and decentralized applications (dApps). Cloud storage and cloud database management systems are also crucial components, offering scalability, accessibility, and efficient data management.

vi) Application Layer: The topmost layer, the application layer, is the interface between users and the blockchain system. It provides user-friendly tools to interact with the blockchain, allowing users to view transactions, create smart contracts, and access data. This layer ensures that the complex underlying technology is presented in a user-understandable format.

The seamless operation of a cloud-based blockchain architecture depends on the interaction between these layers. Data collected by sensors is initially processed at the edge before being transferred to the data layer. Here, it is packaged into blocks and validated through the consensus layer. Smart contracts, executed on the contract layer, automate actions based on predefined conditions. The service layer provides the necessary computational resources and data storage, while the application layer facilitates user interaction.
This layered architecture, combined with the power of cloud computing, creates a robust and scalable platform for various applications, and used in the proposed CBRCS system.

3.1 System Setup for Cloud-based RCS:

In the proposed system, the cloud platform is first selected for its scalability and security features, with providers such as AWS, Microsoft Azure, or Google Cloud Platform being considered. The cloud infrastructure is established to host the application and store data securely. Depending on the specific needs of the model, either a relational or NoSQL cloud-based database is implemented to manage shipment information, participant details, and other records systematically.

To facilitate seamless communication between the mobile/web application, blockchain network, and backend services, an API gateway is designed, which ensures that all data communication is handled efficiently and securely, thereby maintaining the integrity and reliability of the system. The blockchain network is another critical component of the system, and the choice of platform is determined by factors such as scalability, security, and regulatory compliance. The platform Ethereum has been considered, depending on the model-specific requirements and its open-source availability. Fig. 4 represents the flow of operations via the CBRCS system.

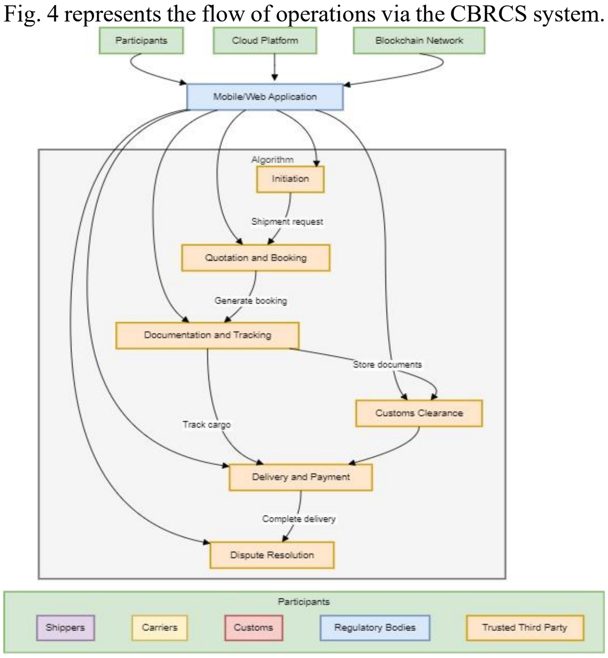

Fig. 4: Flow of operation via the RCS-Architecture

Ethereum uses a proof-of-stake consensus mechanism, which builds on ETH instead of energy to secure the network. Smart contracts are also developed to automate essential processes, such as booking confirmations, document verification, and payment execution, following predefined terms. To ensure the resilience of the network, blockchain nodes are deployed on geographically distributed servers, thus enhancing data integrity and overall system reliability.

The mobile/web application serves as the user interface for various participants in the system, including shippers, carriers, and others. It is designed to be user-friendly, offering features like shipment request creation and tracking, carrier selection, secure document uploads, and real-time cargo location track ing. Security measures are rigorously implemented throughout the system, including data encryption both at rest and in transit. Robust user authentication via multi-factor authentication, role-based access control to manage data access according to user roles, and comprehensive auditing and logging of system activities to ensure traceability and accountability.

Integration and deployment processes involve connecting the application with cloud platforms and blockchain network APIs. In this case, an IRCTC API [16] is used, and the JSON format of the API is given in Figure 5. Additionally, training and support are provided to participants to facilitate effective use of the system, ensuring smooth adoption and long-term success.

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```
JSON(API for Live location)
object    {4}
status :   true
message : Success
timestamp : 17231073132892024-08-08T08:55:13.289Z
 ▽ data     {49}
success :   true
user_id : 0
train_number  : 19038
train_name  : Avadh Cargo Express
gps_unable  :   true
train_start_date  : 2024-08-07
notification_date : 2024-08-08
at_src_dstn :   false
at_src  :   false
at_dstn :   false
is_run_day  :   true
source  : BJU
destination : BDTS
run_days  : MON,TUE,WED,THU,FRI,SAT,SUN
journey_time  : 2685
std : 2024-08-07 07:20
data_from : mntes
new_alert_id  : 19
new_alert_msg :
diverted_stations : null
instance_alert  : 0
related_alert : 0
late_update :   false
is_ry_eta :   true
update_time : 2024-08-08 14:25:00 +0530
distance_from_source  : 1027
total_distance  : 2256
avg_speed : 0
si_no : 166
current_station_code  : PTLI
current_station_name  : PATHAULI~
status  : T
eta : 14:23
etd : 14:23
delay : 454
ahead_distance  : 3
ahead_distance_text : 3 kms ahead
status_as_of  : As of few seconds ago
platform_number : 0
cur_stn_sta : 06:49
cur_stn_std : 06:49
stoppage_number : 0
a_day : 1
status_as_of_min  : 0
  dfp_carousel    {0}
  >upcoming_stations    [39]
  >previous_stations    [48]
  >current_location_info    [4]
spent_time  : 0.9225
```


Fig. 5: JSON format of API for train live location tracking

3.2 Proposed Algorithm

The proposed algorithm for a blockchain-based cargo transportation system aims to revolutionize the logistics industry by introducing transparency, efficiency, and security in railway freight management. It leverages modern technologies such as cloud computing, blockchain networks, and real-time GPS tracking to provide a seamless experience for shippers, carriers, customs officials, and regulatory bodies. The algorithm begins by enabling shippers to initiate shipment requests through a mobile or web application, providing essential cargo details such as origin, destination, weight, dimensions, and desired delivery timeframe. The system then employs an optimization algorithm to match shipment requests with available railway capacity and generates carrier quotes based on various factors like distance, cargo type, and current market rates. Shippers can review these quotes and select a carrier, which automatically triggers a smart contract on the blockchain to generate a booking confirmation, ensuring a secure and transparent transaction. The algorithm also addresses documentation and tracking by allowing shippers to upload necessary documents, such as invoices and customs declarations, to a secure cloud platform. These documents are cryptographically hashed and stored on the blockchain, providing a tamper-proof record that enhances security and traceability. Real-time cargo location tracking is facilitated through GPS integration, allowing participants to monitor shipments via the application. For international shipments, customs officials can access relevant documents directly from the blockchain, streamlining the clearance

Algorithm 1: System Setup for Cloud Platform and Blockchain Network

1. Cloud Platform Setup
- Select cloud provider as AWS, Azure, or Google Cloud.
- Setup cloudInfrastructure for application and data storage.
- Choose databaseType as relational or NoSQL.
- Initialize cloudDatabase with shipmentData, participantData, and systemRecords.
- Design APIGateway for secure communication between application, blockchain network, and backend services.

2 Blockchain Network Setup
- Select blockchain platform as HyperLedger or Ethereum.
- Choose a consensus mechanism as Proof of Authority or Byzantine Fault Tolerance.
- Develop smart contracts for booking confirmation, document verification, and payment execution.
- Deploy blockchain nodes on geographically distributed servers for network resilience.

3 Mobile/Web Application Design
- Design user-interface for shippers, carriers, and participants.
- Integrate features:
  - – Shipment request creation.
  - – Shipment tracking.
  - – Carrier selection.
  - – Quote management.
  - – Secure document upload (e.g., invoices, customs declarations)
  - – Real-time cargo location tracking (with GPS)
  - – Secure communication channels.

4 Security Measures
- Implement data encryption at rest and in transit for sensitive information.
- Enforce userAuthentication with multi-factor authentication.
- Implement accessControl using role-based access control.
- Maintain audit logs of all system activities for traceability.

5 Integration and Deployment
- Integrate application with cloud platform and blockchain network APIs.
- Conduct pilot testing with limited participants.
- Scale deployment based on usage patterns and transaction volume.

6 Additional Considerations
- Ensure standardization adheres to the UN/CEFACT Model for interoperability.
- Ensure regulatory compliance with GDPR, CCPA, and railway industry regulations.
- Provide training and support for participants.

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process and reducing delays. Upon successful delivery, the system automatically triggers payment from the shipper to the carrier via smart contracts, based on pre-defined terms set during booking. This automation reduces human intervention, minimizes errors, and accelerates the payment process. Furthermore, the algorithm incorporates a robust dispute resolution mechanism by leveraging the immutable transaction history stored on the blockchain. In case of any discrepancies or conflicts, participants can access a verifiable record of events, which simplifies the resolution process and fosters trust among stakeholders. Overall, this innovative approach offers significant benefits, including enhanced transparency, improved efficiency, reduced costs, and increased security, while also considering scalability, privacy, and regulatory compliance.

Algorithm 2: Define All Elements

1 Define Participants:
2 SET Shippers As Entities sending cargo;
3 SET Carriers AS Railway companies transporting cargo;
4 SET Customs As Optional For cargo;
5 SET Customs AS Optional for international shipments;
6 SET Regulatory Bodies AS Optional for overseeing railway operations;
7 SET Trusted Third Party AS Optional for managing user onboarding and system access;

8 DEFINE Cloud Platform AS Secure and scalable infrastructure for data storage and hosting;

9 DEFINE Blockchain Network AS a distributed ledger for secure record-keeping;

10 DEFINE Mobile Web Application AS a User interface for interaction;

3.3 Efficiency Measurement of the Proposed CBRCS Algorithm

The efficiency function for the Cargo Transportation System is designed to quantify the system's performance by integrating several critical factors that impact its effectiveness. The function is given by:

$$f(E) = \frac{\sum(i=1\ to\ n)\, W_i X_i}{\sum(i=1\ to\ n)\, W_i} \quad (1)$$

where i is the number of factors to be considered for a particular system design, Xi is the particular factor, and W_i is the respective weight for that factor. For the proposed system, the value of i = 5 is chosen, and the 5-factor efficiency of the CB-RCS system is measured as below.

$$f(E) = \frac{W_1T + W_2U + W_3S + W_4D + W_5P}{W_1 + W_2 + W_3 + W_4 + W_5} \quad (2)$$

Here, T represents the **Time Reduction** factor, which measures the decrease in processing and transportation time due to automation and optimization. U denotes **Utilization**, indicating how efficiently the available railway capacity is used. S and D represent **Security** and **Document Handling Efficiency**, respectively. Finally, P signifies **Payment Speed**, which assesses how swiftly and reliably payments are executed through smart contracts. The weights W_1 through W_5 are coefficients that assign relative importance to each factor, allowing for a tailored evaluation based on stakeholder priorities.

Algorithm 3: CBRCS System Design

1 Initiation:
Input: Shipment details from Shipper via Mobile Web Application;
Output: shipment Request to System;
2 Shipment details: origin, destination, cargoType, cargo Weight, cargoDimensions, deliveryTimeframe;

3Quotation And Booking:
4 Call optimization algorithm with shipment request;
5 Match shipment request with available Railway Capacity;
6 **if** match is found **then**
7 **foreach** Carrier in available Carriers **do**
8 Generate quote based on distance, cargoType, marketRates;
Output: quotes toShipper via MobileWebApplication;
Input: selectedCarrier from Shipper;

9 Create SmartContract on Blockchain Network;
10 Auto-generate bookingConfirmation on SmartContract;
11 **else**
Output: no Available Capacity Message;

12 Documentation and Tracking:
Input: necessary Documents from Shipper;

13 **documents:** invoices, customs declarations;
14 **Upload** documents to Cloud Platform;
15 Store hashed Documents on Blockchain Network;
16 Enable real-time tracking via GPS;
17 Display cargo Location on Mobile/Web Application;

18 Customs Clearance: if international shipment, **then**
19 Allow custom access to hashed documents on the blockchain network;

20 Delivery And Payment:
21 Wait until cargo arrives at the destination.
22 Mark delivery Complete on Mobile/Web Application;
23 Trigger payment Execution via Smart Contract;
24 Transfer payment from Shipper to Carrier based on predefined Terms;

25 DisputeResolution:

26 **if** discrepancies Detected **then**
27 Output immutable Transaction History from Blockchain Network;
28 Assist in resolution based on verified records;

The Equation No. (2) provides a measure of overall system efficiency by normalizing the weighted sum of these factors against the total weight. This approach allows stakeholders to prioritize specific areas based on their impact on system performance. For example, depending on the required system demand, we may introduce a dynamic system by increasing the weight of one or more factors, thereby giving more importance to certain factors. The equation helps identify which aspects of the system contribute most to efficiency and where adjustments can be made to optimize performance, ensuring that the system effectively meets its operational goals.

4. COST ANALYSIS OF CLOUD-BASED RAILWAY CARGO SYSTEM (CBRCS)

This section presents a comprehensive analysis of the cost of this architecture, where the system construction cost (C^{sc}), the construction cost of a blockchain-based supply chain system (C^{bsc}), overall environment development cost (C^{ed}), and overall development cost (C^{ad}). The following equation is a one-time input cost.

$$\sum_{n=1}^{m} C_n^{sc} + \sum_{n=1}^{m} C_n^{bsc} + C^{ed} + C^{ad} \tag{3}$$

$\sum_{k=1}^{q} C_k^{cspc}$ represents the standard connection generated by one blockchain operation.

$$\overline{\sum_{k=1}^{q} C_k^{cspc}} \tag{4}$$

$\sum_{k=1}^{q} C_k^{uc}$ represents the standard connection generated by requests from the users.

The following Fig. 5 and Fig. 6, respectively, represent the cost vs. time chart for loading and unloading activities on the CBRCS system and initial one-time cloud storage cost and daily recurring cost of the system assuming typical load calculations.

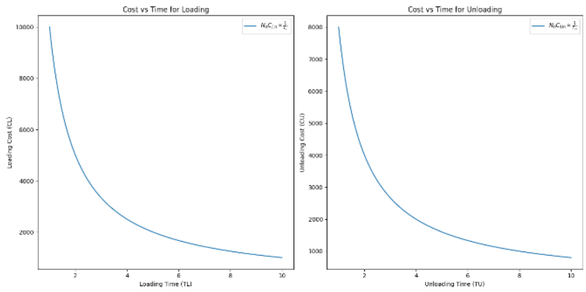


Fig. 5: Cost vs Time for Unloading and Loading

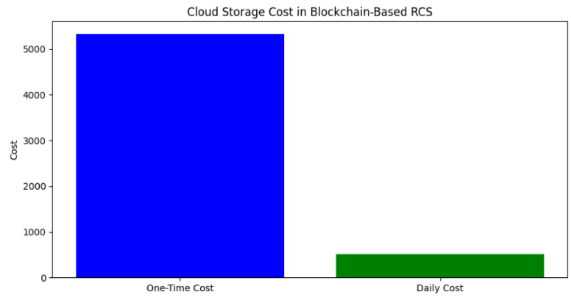


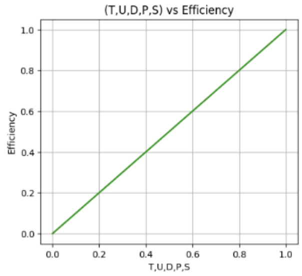
Fig. 6: Cloud Storage installation (5334 unit) and daily cost (518.2 unit)

4. EXPERIMENTAL RESULTS

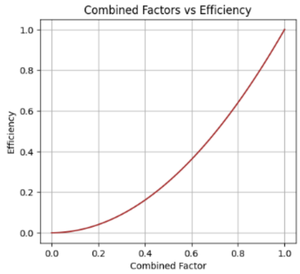
Figure **7** describes two different processes of the equation, where different values are taken for the given factors T=0.20, U=0.75, S=0.25, D=0.75, P=0.95(Fig. **7**c & **7**d) and T=0.90, U=0.20, S=0.95, D=0.20, P=0.25(Fig. **7e** & **7**f).

Two different operations are described, where System Efficiency is measured while the Weightage for T, S increases and U, D decreases and another is where the weightage for T, S increases and U, D, P decreases. From this process, the optimal threshold value for each factor can be found to optimize the CBRCS's system efficiency.

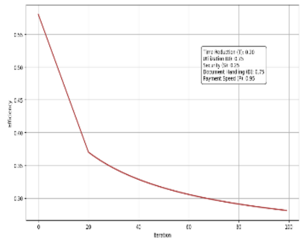
This also enhances the CBRCS transparency as all Participants have access to a shared ledger of information, improving trust and visibility across the supply chain.



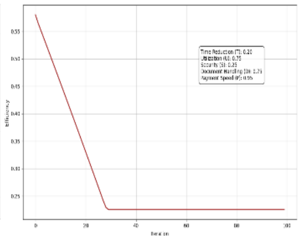
(a) System Efficiency Graph w.r.t. 5-Factors (T,U,S,D,P) considered in this model



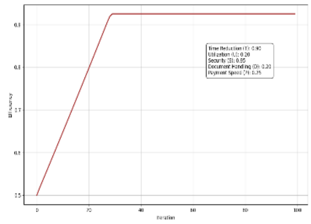
(b) System Efficiency Graph while 5-Factors having equal weights



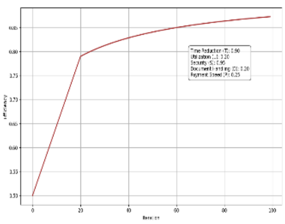
(c) System Efficiency while Weightage for T, S increasing and U, D decreasing



(d) System Efficiency while T, S increasing and U, D, P decreasing



(e) weightage for T, S increasing and U, D, P decreasing with high values of T,S



(f) T, S increasing, U, D decreasing with higher value of T,S

Fig. 7(a…f): Various System Efficiency Graphs w.r.t. Change of the Values of Different Factors and their respective weights

It streamlined processes through automation and real-time data sharing with proper cost optimization. The proposed Cloud-based Blockchain technology provides tamper-proof data storage and secure transactions. And simplified dispute resolution.

5. CONCLUSION

In essence, the marriage of blockchain and cloud computing- presents a paradigm shift for railway cargo systems. The immutable nature of blockchain transactions fosters an environment of trust and enhanced security. Data breaches and unauthorized modifications become relics of the past as cargo information and transactions reside permanently on the distributed ledger. Cloud computing, on the other hand, injects agility and accessibility into the proposed CBRCS system.

Real-time data processing and scalability ensure that everyone involved in the network can access the information on time without any delay. This translates to significant improvements across the board. In our proposed system different processes are Streamlined and facilitated by automated document handling and smart contracts, leading to increased efficiency. Visibility reigns supreme with real-time cargo tracking accessible to all participants through a shared ledger.

Furthermore, the elimination of paper-based documentation and intermediaries translates to potential cost savings. However, the journey towards a fully integrated system is not without its hurdles. Scalability limitations and ensuring seamless interoperability between different existing blockchain platforms require further research. Despite these challenges, the potential benefits are undeniable. By embracing this innovative approach, the railway cargo industry can pave the way for a future characterized by security, transparency, efficiency, and ultimately a more cost-effective transportation landscape.

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