International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 05, IIRA 5.0 (2026)

Container Space Management and Tracking System: A Review

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***Abstract*— The global logistics industry is confronted with the critical issues of cargo handling, specifically shipping container usage optimization and efficient cargo tracking across the supply chain. Mitigation of these issues is imperative to greater operating efficiency, cost reduction, and loss from inefficient handling of cargo and tracking errors. These prevailing practices are vulnerable to inefficiencies such as the lack of adaptive algorithms, integration issues, and inadequate real-time data handling, which restrain efficient decision-making and operating responsiveness. This research proposes an AI-driven cargo management system, CargoTrack, based on the MERN stack (MongoDB, ExpressJS, ReactJS, NodeJS), to automate cargo booking for space and enhance shipment tracking with real-time visibility. Multi-step authentication, dynamic container provisioning and seamless integration of data from various sources are some of the salient features of this system. By leveraging the latest technologies like artificial intelligence and data analytics, CargoTrack greatly improves the efficiency of cargo handling, scalability of operations, and sustainability through optimal utilization of resources. The system proposed not only fills present gaps but also offers a unified approach to the improvement of supply chain visibility and thus the improvement of shipping, manufacturing, and retail logistics industries. Ultimately, CargoTrack is intended to play a role in an integrated and responsive logistics environment, promoting improved collaboration among the players and pushing for operational excellence in freight transportation.**

Keywords—Cargo Management, Space Optimization, Real-Time Tracking, Supply Chain Efficiency, MERN Stack, Logistics Technology

I. Introduction

Logistics and transportation sector is witnessing unprecedented expansion driven by globalism and the demand for efficient supply chain management. While the sector is expanding at a great pace, issues such as inefficient use of cargo space, no real-time monitoring and intricacy involved in integrating different technologies and sources of data remain to be addressed. These problems lead to operational inefficiencies, increased expense and an increased chance of errors during cargo handling and delivery, which can damage stakeholder confidence and indirectly influence customer satisfaction.

Addressing these issues is of global importance because they have direct impacts on the financial performance of businesses and the general efficiency of supply chain logistics. With e-commerce and international trade on the increase, the capacity to maximize cargo management is increasingly essential to the quest for competitive edge. But current solutions fall short in terms of inflexibility of algorithms that do not respond to changing conditions, poor integration of disparate tracking systems and insufficient real-time visibility that undermines timely decision-making. Such loopholes have created a pressing need for fresh ideas that can increase operational flexibility and reliability in logistics. The literature review identifies that while various methodologies have been proposed, the majority fail to leverage contemporary technologies like artificial intelligence and machine learning for predictive modelling and optimization.
In addition, traditional systems rarely integrate complete visibility throughout the entire supply chain, which restrains their efficiency and scalability.

As a response to the mentioned challenges, this paper presents CargoTrack, a new cargo management system based on the MERN stack. The system seeks to optimize cargo space allocation through dynamic tracking and solid data integration. The goals include increasing precision in the handling of cargo, facilitating sustainable utilization of resources and achieving greater stakeholder collaboration.

Through the resolution of the limitations found in existing solutions, CargoTrack aims to play an important role in the development of smart logistics and hence advance the operational excellence of global trade networks.

II. LITRATURE SURVEY

A systematic review of data-driven predictive models for track maintenance of railways, specifically focusing on geotechnical applications, is conducted in the study [1]. Studies on AI, machine learning, and statistical models used for track condition monitoring, for defects like rail geometry irregularities and missing components are categorized. The systematic review approach was adopted, and articles from 1999–2019 were downloaded from ScienceDirect, Scopus, and IEEE Xplore. Key challenges found are variability of data, complexity in model selection, integration across disciplines, scalability, uncertainty in prediction, and non-standardization. Strengths and limitations of various algorithms are illustrated, and recommendations for improving railway maintenance efficiency are provided. Results offer a guideline to optimize predictive maintenance strategy in transportation and civil engineering applications.

The SPD-Safe framework improves security, privacy, and reliability in railway cyber-physical systems by defending against cyber-attacks with AI-based real-time monitoring and enhancing network protection [2]. It proposes SecRoute is a secure routing protocol providing confidentiality, integrity, and authentication and incorporating Wireless Sensor Networks for data gathering. It showcases its solution in a cybersecurity-aware simulator (COSSIM). The main challenges are integrating security protocols into current systems, real-time data processing optimization, adequate simulation of cyber-attacks, security-performance tradeoff, regulatory compliance navigation, and stakeholder buy-in security. Through the improvement of the resilience of railway systems against cyber-attacks and incident management, the framework sets a benchmark for secure intelligent railway transportation systems, making railway operations safer and more reliable.

The study “Toward smart logistics: Engineering insights and emerging trends” is an extensive review of smart logistics, considering emerging technologies and practices to enhance logistics processes [3]. It synthesizes 108 research articles from databases like Springer, IEEE, and ScienceDirect in a logical order, determining eminent trends in IoT, AI, and Blockchain implementation. There are limitations on data access, heterogeneity of purpose of study, rapid technological progress, ambiguity of concepts, lack of empirical studies, and integration problems due to legacy systems and labor adaptation. The correlation between technology and sustainability, giving insights on emerging trends and practical implications. Closing the gap between theoretical and applied thinking improves the study aims to guide future developments in smart logistics and supply chain optimization.

H. hring examines the application of genetic algorithms (GA) to optimize container loading by stacking boxes in an efficient manner considering realistic constraints like weight distribution, stability, and orientation [4]. Two stages are employed in the approach: a greedy algorithm stacks the boxes into stable piles, and GA optimizes their placement inside the container. Promising as the approach is, it is plagued by issues like managing intricate constraints, balancing computation time and accuracy, rescaling to different loading conditions, tuning GA parameters, and comparing its performance objectively to traditional approaches. The study in general presents GA as a potential direction to optimize container utilization and streamline logistics, and therefore it is a viable substitute to traditional packing techniques.

The research by C. Zhang et. al will assist air cargo agents in better managing their cargo space, particularly in an uncertain market with volatile demand [5]. Through the creation of an optimization model, the research presents a structured method of space allocation by agents to hold long-term and short-term bookings in a manner that maximizes space purchase. Informed by a static stochastic programming methodology, the model forecasts demand from historical booking data and varies space purchase in response. Implementation is constrained by data accuracy, market uncertainty, heterogeneity of goods, and price variability. In spite of these challenges, the research presents practical recommendations for enhancing decision-making, profitability, and a more efficient and flexible air cargo management system.

Study optimize Less-than-Truckload (LTL) logistics cargo loading efficiency using space and weight distribution in the application [6]. A backtracking tree-based algorithm minimizes the number of vehicles and optimizes capacity and improve the performance. The process methodically explores a number of loading configurations through the use of sorting algorithms to select the most efficient loading. Difficulty in handling varied types of cargo, computational difficulty, and the presence of real-world constraints render optimization more complicated. BT-DVWBA is compared against the industry's NSGA-2 and CPLEX algorithms and finds itself more efficient and more accurate. This research presents a real-world solution to assist logistics companies in decreasing cost and increasing the use of cargo.

“Container tracking and tracing system to enhance global visibility” aims to enhance tracking of cargo through the development of a Container Tracking Service with use of real-time tracking of cargo [7]. Using LEO satellites, GPS. The system tracks container position, temperature, humidity, and door status with greater supply chain efficiency. Satellite communication, GPS receivers, RF modules, and a web platform are integrated to make CTS easily accessible to logistics players. A pilot test on cold containers proved its feasibility. Interference of signals, integration complexity, high expense, heterogeneity of regulations, and security of data were, however, faced. In spite of such drawbacks, the study offers an extensible solution for improving tracking, minimizing losses, and increasing transparency in international shipping.

The article presents an intelligent Air Cargo Loading Information System (ACLIS) that optimizes space and profitability for air freight operations [8]. Unlike traditional methods that optimize space alone, ACLIS uses heuristic iterative reasoning technology (HIRT) to integrate cargo placement and profitability. ACLIS processes shipments by size, weight and frequency, refining the configuration for greater efficiency. Data consistency challenges, variability of cargo attributes, real-time processing needs, and resistance to change, however, made implementation difficult. Despite these difficulties, ACLIS provides a systematic and intelligent method of cargo loading to allow logistics providers to maximize profitability and efficiency with ease of integration into existing practices.

International Journal of Engineering Research & Technology (IJERT)
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"Measures of supply chain collaboration in container logistics" examines supply chain collaboration (SCC) in seaport logistics between container terminals and their stakeholders [9]. It aims to measure SCC's impacts on operational efficiency through drivers like information exchange, decision-making, and joint performance measurement. The study uses literature reviews, expert interviews, questionnaire development, pilot surveys, and data sampling from 178 South Korean logistics professionals. Challenges encountered were diverse stakeholder views, measurement validity, translation, response bias, and limited generalizability to South Korea. In spite of such challenges, the study provides valuable insights to improve collaboration in seaport logistics to enable managers to optimize partnerships and performance.

"Optimization solution of equal dimension boxes in container loading problem using a permutation block algorithm" focused on maximizing the loading of similar-dimension boxes inside containers using the Permutation Block Algorithm (PBA) in order to utilize maximum space with minimal wastage [10]. Methodology follows a five-step process: initialization of parameters, main and secondary filling, evaluation of filling, and choice of optimal configuration. PBA accommodates flexible box orientations in order to pack effectively. Constraints are the nature of three-dimensional packing, computational complexities, randomness in space, logistical parameters, precision of data, and design of an interface that is user-friendly. Despite these constraints, the study demonstrates a systematic algorithmic solution maximizing container loading efficiency, which saves costs and optimizes logistics processes.

The study considers cargo space optimization techniques to enable more efficient air, rail, and road freight transport and also minimize cargo damage [11]. It discusses techniques like linear programming, genetic algorithms, and dynamic programming and also optimization software. Challenges are tough cargo configurations, fluctuating demand, computational limitations, data reliability, regulatory compliance, and environmental conditions. Drawing from the comparison between stochastic and deterministic models, the study identifies best practices and areas of future research in cargo optimization. It aims to improve the efficiency and cost reduction in logistics operations, with useful information for scholars and practitioners.

In the research by X. Shi et. al [12], RFID technology is tested for its value in container cargo logistics within port environments and in its capability of automating information collection, speed of identification for cargo, increased inventory tracking capabilities, and decreasing costs. Using a review of literature, case studies, quantitative comparison with regular barcode-based technologies, questionnaires, and in-depth interviews as data gathering means, provides rich qualitative input for logistics managers and experts. Challenges to adoption are integration complexity, high upfront costs, data management, non-standardization, training of the workforce, and global regulatory barriers. The research is designed to offer an in-depth perspective on RFID's application in contemporary logistics and its future prospects.

The research examines container shipping management with an emphasis on maximizing empty container logistics through a gravity model approach. The study seeks to enhance efficiency in container movement and create algorithms for solving constraints in transportation planning. The method of analysis entails representing the transportation network as a weighted graph, using optimization methods to assign containers efficiently with the least empty trips. Critical issues involve network transport complexity, accuracy of data, imbalances in international trade, limitations of models, obstacles to algorithm implementation, and coordinating stakeholders [13]. This research adds value to improving container logistics strategy development and maximizing utilization of transport capacity.

V. Francis discusses supply chain visibility (SCV), explaining its definition, nature, and implication for logistics effectiveness [14]. It bridges the prevalent communication gap among suppliers and experts and focuses on how SCV promotes integration and operating performance. The method entails literature review of more than 348,000 articles and articles with discrepancies, outlining an enhanced definition. The major challenges are from the absence of a unified definition, varying terminologies, information overload, subjective understanding, technological limitations, and integration problems. The research is the importance of standardized SCV frameworks to enhance communication and the implementation. Through conceptual insights, it enhances theoretical knowledge as well as practical, aiding future research and industry uptake.

The research "Supply chain visibility and security–the SMART-CM project solution" investigates supply chain security and visibility in the SMART CM project, with a focus on their importance for efficiency. It investigates technological solutions to fill visibility gaps and address stakeholder requirements with their demands. It employs literature reviews, stakeholder questions, KPI-based evaluations and prototype testing of tracking systems. Main challenges are data gaps, stakeholder participation, technological integration, compliance with regulation, and testing technology adoption [15]. Supply chain complexity also adds to the challenges of standardization. Results point towards the importance of combining visibility and security technologies in order to drive operational performance. The research presents a complete analysis of the effect of SMART-CM, and it adds both theoretical insights and real-world solutions to contemporary supply chain management.

Th research investigates the use of real-time tracking technology in railway transportation, with special reference to the UK FMCG industry [16]. They assess their contributions to logistics effectiveness, delivery efficiency and supply chain transparency. The case is presented of three manufacturers implementing vehicle telematics through structured interviews, system walks, and historical analysis. Key challenges are technology adoption gaps, cost allocation disputes, asymmetric benefits to shippers, data management inefficiencies, scalability issues, and infrastructure limitations. Findings emphasize seamless integration, collaboration, and investment to achieve maximum benefits. The study offers useful insights into the technical and managerial dimensions of real-time tracking for its successful implementation in freight transport in modern times.

III. Methodology

A. System Overview

CargoTrack is an innovative cargo booking and management system, built on the MERN (MongoDB, ExpressJS, ReactJS, and NodeJS) stack, to simplify cargo space allocation, shipment tracking, and container

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management. The system offers a solid foundation for real-time cargo tracking, secure transactions, and most efficient space utilization in freight logistics. The most important functionalities are multi-step authentication, authorization mechanisms, and dynamic container allocation. Besides, real-time tracking functionality and user notifications help increase operational effectiveness and visibility in the logistics network.

B. System Architecture

As seen in Fig 1 the system proposed has four main components: the user interface, backend services, database management layer, and security infrastructure.

The user interface is built on top of ReactJS to provide a responsive and interactive experience. The interface enables exporters and logistics operators to look up available cargo capacity, place bookings, track shipments, and make payment transactions. The backend, built with NodeJS using ExpressJS, supports secure API interactions, real-time data syncing, and processing authentication and transaction requests.

The database layer is organized using MongoDB with the use of Mongoose ORM so that efficient storing and retrieval of crucial records like user information, container assignments, booking history and financial information can be obtained. The entity-relationship model preserves optimized links between data to provide structured and trustworthy space administration.

Authentication is controlled via JSON Web Tokens (JWT) for system security supported by multi-factor authentication via OTP verification using Nodemailer. Security of data is ensured via bcrypt-based password hashing and Secure Sockets Layer/Transport Layer Security encryption to keep unauthorized parties out and protect user confidentiality.

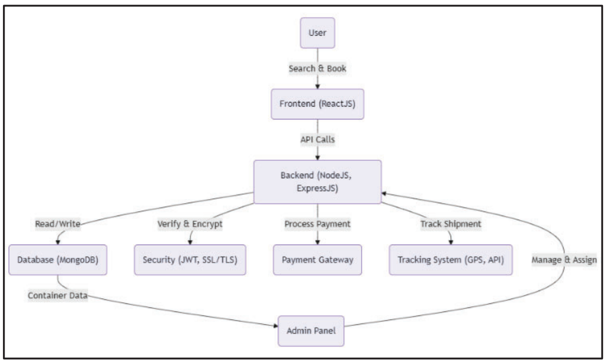

Fig. 1. System Architecture

C. System Workflow

The flowchart illustrates the process and simplification of the tracking and management of the container space and railway cargo booking for the users. The system begins with the login of the users whereby they are routed to the admin or customer dashboard, based on whether they are an admin or customer.

The customers begin with inputting parcel details like weight and destination on which transport charge is automatically calculated by the system. If the customer goes on to pay and

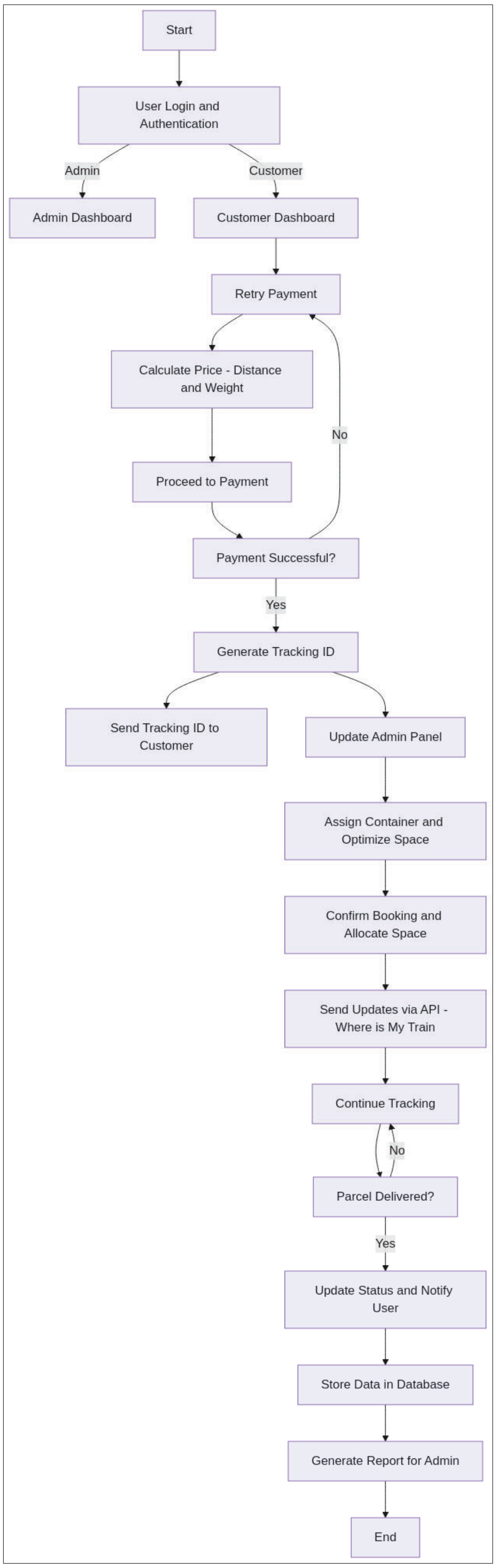

Fig. 2. System Workflow

that is successful, a tracking ID is created. The customer is provided with the tracking ID and, simultaneously, the admin panel is updated so that container allocation is initiated.

On the admin side, the website allocates space in containers by an algorithm that makes the best use of available rail containers. When the parcel is allocated to a container, booking is reserved and real-time tracking is enabled. The tracking module, combined with the "Where is My Train" API, enables customers to view their shipment in real time.

In the course of shipping, customers receive status updates until the package reaches the destination. When the package is delivered, the system updates the status, notifies the recipient, and securely keeps the shipping details in the database. These details are then used later for generating reports and system performance analysis to improve efficiency.

With automation of bookings, space utilization and real-time monitoring, the system eliminates prevalent inefficiencies in rail freight management. It increases transparency, enhances the user experience, and simplifies coordination between customers and administrators, making rail freight services more convenient and dependable.

D. Data Managment and Storage

The database design is geared towards managing structured data for users, cargo bookings, shipments, and financial transactions. The booking-user relationship keeps multiple bookings in relation to a registered user. The container-cargo relationship supports efficient space allocation, where one container contains multiple cargo items with respect to predetermined constraints. The admin-container relationship supports container management where administrators can manage allocations and monitor container status.

Schema constraints are utilized to check route selections, cargo size limitations and space computations, thus improving accuracy and system dependability.

E. Secuirity

Data integrity and unauthorized access are at the core of the system design. Communication is encrypted using SSL/TLS for all communication, which is not accessible when transmitted. Role-Based Access Control (RBAC) is enforced to demarcate user permissions, allowing administrative activities only by authorized personnel. Fraud detection features are in place that continuously track patterns in bookings and transaction flows to detect and minimize likely risks.

F. System Deployment and Execution

The system is installed after a formal installation procedure. The backend services are started using the commands npm install && npm start, while the frontend is started using npm install && npm run dev.

Configuration parameters such as MongoDB connection strings, JWT secrets, and email credentials are stored securely in an environment variables (.env) file.NodeJS cluster mode for load balancing is implemented to scale up the system and allow the application to efficiently process high traffic. Database indexing techniques are implemented to accelerate query efficiency and offer quick retrieval of cargo availability records.

IV. Future Scope

The web platform as envisioned has enormous scope for expansion and growth in the global logistics industry. Geographical expansion is one of the key areas of expansion where the platform can expand beyond the initial geography by partnering with railway operators and logistics operators in other geographies. It would expand market coverage and increase the platform's user base so that exporters can utilize a wider network of freight transportation services.

The second key area of future growth is the integration of multimodal transportation. Though the platform starts with rail freight containers, sea and road freight integration would complete the multimodal logistics solution. This would enable exporters to use the lowest-cost and most desirable mode of transportation for their individual shipping requirements, improving supply-chain agility.

As the world witnesses more global trade, the need for seamless cross-border logistics is essential. The future releases of the platform may incorporate integration with international rail networks to make cross-border trade as well as customs clearance easier. With real-time tracking and optimization of routes across the borders, the platform may even reduce transit time and make trade more efficient.

Sustainability is also a key feature of contemporary logistics. The platform can help advance green transport programs by giving exporters a live carbon footprint of their cargo. Further, offering incentives for green modes of transport, e.g., priority booking for green cargo transport, would encourage companies to utilize green options. Such programs would bring the platform in line with international sustainability objectives, enhancing the carbon footprint of freight transport and encouraging sustainable business. Additionally, the platform would be able to facilitate strategic collaborations and alliances with critical players in the supply chain, such as customs, freight forwarders, and trade associations. The alliances would be aimed at promoting efficiency in operations by facilitating ease in customs clearance procedures and maximizing coordination between the various segments in the supply chain. Alliance with a broader base of logistics service providers would present exporters with access to a broad scope of services, which would increase the level of customer experience.

Overall, the new system has a great deal of room for development and innovation. Through expansion into new markets, further addition of transport modes, enhanced connectivity of cross-border trade, prioritization of sustainability, and the formation of strategic alliances, the system can become a leading global logistics solution.

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CONCLUSION

The CargoTrack system concept responds to major issues in the logistics and transportation industry through the use of dynamic MERN stack-based architecture. It improves cargo management through space allocation optimization algorithms and real-time data processing for accurate cargo condition and position monitoring. Timely responses to environmental fluctuation as well as transportation route disruptions are achieved. The integrated data analytics framework of CargoTrack supports scalability, thus enabling easy configuration to support various types of cargo and operational conditions without affecting performance. Through enhancing operational effectiveness, lowering costs and improving supply chain transparency, CargoTrack is of immense benefit to logistics stakeholders. Through its facilitation of bridging the gaps in conventional cargo management approaches, CargoTrack is a progressive solution to sustainable and smart logistics. In this way, CargoTrack is part of the global initiative towards smarter supply chain management, preparing the logistics industry to respond to changing market needs with speed and accuracy.

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