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CARGOPULSE: SHIPMENT MANAGEMENT PLATFORM

[1]D. Vaishnavi, [2]S. Poojitha, [3]G. Ruchitha, [4]T. Greeshma

[1]Assistant Professor, Department of CSE, Vignan Institute of Management and Technology for Women's, Hyderabad, Telangana - 501301, India

[2,3,4]IV-B.Tech, Department of CSE, Vignan Institute of Management and Technology for Women's, Hyderabad, Telangana - 501301, India
[1]vaishnavi.doddy1013@gmail.com [2]poojithasingireddy351@gmail.com
[3]ruchithagottimukkula136@gmail.com [4]thallapalligreeshma@gmail.com

***Abstract*—** Equipment reliability and on-time deliveries in the logistics of today are a must in order to maintain the operational effectiveness and customer satisfaction. Unplanned downtimes and unforeseen transportation delays jam supply chains and run a gigantic fortune. To counter these challenges, this research proposes an AI-driven predictive maintenance system incorporated within a Shipment Coordination System (SCS). By utilizing real-time telemetry, historical maintenance data, and situational metadata such as road conditions, the system uses machine learning algorithms like LSTM networks and Random Forest classifiers to make time-series analysis and anomaly detection. Such predictive analysis is used for informing dispatch decisions for vehicles, route optimization, and maintenance scheduling.
A testbed system, verified with simulated and real logistics data, showed dramatic gains in prime performance metrics, such as fewer emergency repairs, less downtime, and more on-time deliveries. Cost savings were also reflected in lower costs of maintenance and better resource utilization.This study demonstrates the strength of revolutionary predictive maintenance integrating logistics and innovations like autonomous delivery and vehicle networks. It calls for increased use of predictive intelligence to spur resilience and efficiency across supply chain and logistics industries.

Index Terms—Shipment Coordination, Real-Time GPS Tracking, Route Optimization, Automated Scheduling, Logistics Management, AI Integration, Delivery Monitoring, Digital Documentation

I. INTRODUCTION

The logistics industry is experiencing a paradigm shift, fueled by the sophistication of global supply chains, growing customer demand for faster delivery, and growing e-commerce sites. All these are exerting a behemothic pressure on logistics companies to get the product through faster, more accurately, and more economically. But conventional shipment coordination systems that depend heavily on rule-

based planning, manual monitoring, and pre-planned maintenance schedules are now too weak to cope with the operation uncertainties of contemporary transportation

situations. Mechanical breakdowns, routing irregularities, and untimely repairs cause delivery delays, high operating expenses, and customer complaints.With increasing logistics networks and diversification, there arises an imperative need for intelligent systems that can respond dynamically to variables of operation and take proactive action against threats arising from equipment failure.
Predictive maintenance thus presents itself as a viable solution. While implemented to broad usage in the aerospace and manufacturing industries, usage in logistics is only in its early stages of research. By utilizing developments in artificial intelligence (AI), machine learning, and sensor monitoring, predictive maintenance systems can accurately foretell component failures through the examination of trends in real-time telemetry data and historical data.
This research deploys predictive maintenance via AI in Shipment Coordination Systems (SCS) to maximize vehicle, onboard sensor, and other shipment-critical asset health and

performance. Periodic integration will also maximize the reliability of shipments, lower the incidence of surprise repair bills, and maximize responsiveness of logistics operations by incorporating perceptive diagnostics in the coordination platform. In so doing, it sets the grounds for smarter, more sensitive logistic infrastructures that are better able to address the demands of an evolving world economy.

II. LITERATURE REVIEW

Predictive Maintenance: Concepts and Evolution:

Predictive maintenance (PdM) is the practice of applying data analysis techniques and tools to find abnormality in systems and predict the equipment breakdown before failure occurs. Corrective (after-failure) and preventive (time-based) maintenance strategies, the traditional approaches, are being increasingly replaced or supplemented by predictive models based on real-time operational data. Mobley (2002) has developed PdM as a method to minimize downtime and maximize the asset lifecycle using condition monitoring and prediction. With Industry 4.0, sensors, Internet of Things (IoT), and artificial intelligence have strengthened PdM systems to be more accurate, autonomous, and contextual.

Machine Learning Applications in Predictive Maintenance:

The advancements in machine learning (ML) in recent times have enhanced the functionality of predictive maintenance systems to handle high-dimensional, non-linear data. Zhang et al. (2019) showed the application of ensemble techniques such as Random Forest, Gradient Boosting, and deep learning architectures such as Long Short-Term Memory (LSTM) networks for industrial time-series forecasting. The models are capable of learning from historical maintenance records, weather, and operational telemetry to produce early warnings. It has been shown by other research that aggregating different models in a single hybrid model can improve prediction accuracy and robustness (Bousdekis et al., 2020).

AI in Logistics and Shipment Scheduling:

The logistics industry has seen increasing application of AI for optimization, including route optimization, demand planning, and warehouse management. Kamble et al. (2020) discussed drivers of Industry 4.0 technology in logistics, citing in particular AI as enabling real-time decision-making and improved efficiency. Shipment Coordination Systems (SCS) traditionally being static rules-based and human-checked are increasingly re-designed with intelligent modules enabling dynamic resource allocation, vehicle scheduling, and delay reduction (Schniederjans et al., 2020). The majority of current implementations, however, only focus on asset coordination and not asset health management.

Rollout of Predictive Maintenance in Logistics Operations:

Rollout of predictive maintenance in logistics operations is still in its infancy. Tjan et al. (2021) explored the viability of condition monitoring for last-mile delivery fleets and reported that data availability and system interoperability continue to be significant challenges. A predictive maintenance case study by Holgado and Macchi (2020) for fleet management demonstrated phenomenal improvement in scheduling effectiveness as well as asset availability when AI models were applied for predicting battery failure in electric delivery trucks. This sort of research validates the argument that integrating predictive maintenance in shipment planning can potentially lower the frequency of vehicle failure as well as delivery reliability.

Inadequate Current Procedures:

AI is full of potential when implemented for predictive maintenance, but there are a few limitations, of course. To begin with, the majority of the models are hungry for data and need enormous amounts of labeled data, something that is not easily available in separated or recently digitalized logistics processes. Secondly, there is more frequent work being done on individual asset classes (e.g., tires, engines) rather than end-to-end systems integrating sensors, external environmental data, and situational context. Thirdly, there is a shortage of interoperability between the AI platforms and existing shipment coordination systems, which makes deployment difficult. Finally, there are not many that address real-time decision-making in uncertainty—which is in a field relevant to dynamic logistics systems (Goyal & Pundir, 2022).

Contribution of This Study:

From the aforementioned literature reviewed, this study contributes to the literature by developing a generic framework that embeds AI-driven predictive maintenance in a shipment coordination system. It offers predictive capability across different components of the system and integrates real-time anomaly detection, dynamic rescheduling, and anticipatory maintenance planning. In contrast to other studies that aim at addressing logistics and maintenance separately, this study presents an end-to-end solution to enhance operation resilience and reduce total cost of ownership for logistics providers.

III. METHODOLOGY

Data Acquisition:

Data acquisition is at the heart of the predictive maintenance module functionality. Sensor data for experiment runs were generated with the aim of emulating real-time delivery van operating conditions. Data nature being gathered is:

Engine Temperature: Current engine temperature is utilized for overheating detection, which might also denote lubrication issues or coolant malfunction.

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Vibration Measurements: Measurement of vibration of major components of a vehicle, such as wheels and axles, is used for imbalance, wear, or misalignment identification.
GPS Speed Logs: GPS module speed and position signals are logged to correlate driving habits with mechanical stress and optimize route deliveries.
Maintenance History: Failure, repair, and service interval history is stored in tabular format and used in machine training.
Data ingestion pattern is an emulation of real-time data ingestion from RESTful APIs to simulate a live fleet of IoT-enabled cars. Data preprocessing includes normalization, missing value filling, and outlier detection to ensure the model's robustness.
Model Building:
The core AI model integrates two standalone machine learning techniques to each benefit in time-series prediction and classification.
LSTM Module: LSTM network is particularly well suited to discover the time dependences among sensor measurements, e.g., vibration level going up or engine temperature going up over time. LSTM is particularly well suited to handle sequential data due to its memory cell based architecture and gated structure that allows it to track weak degradation modes to failure.
Random Forest Classifier: Meanwhile, a Random Forest model is also learning to produce binary class labels—is a unit failed or not. It is employing LSTM output features and pooled historic stats. The ensemble nature provides more legitimate predictions by avoiding overfitting and handling noisy data in the right way.
Model Training and Validation: Model training is carried out over a labeled dataset split between training (80%) and test sets (20%). Accuracy of the model is approximated by performance metrics such as accuracy, F1-score, precision, recall, and Area Under the Curve (AUC). Hyperparameter tuning is done through grid search and cross-validation techniques.
Workflow Integration
The predictive maintenance model is incorporated in the overall process of shipment coordination as below: Data Consumption of Real-Time: Telemetry data is being consumed in real-time from the vehicles through API endpoints and into the predictive engine near-real-time. Microservices architecture makes this comms possible so that AI side can be scaled separately.
Anomaly Detection and Predictive Alerts: The AI algorithm scans the flow of real-time traffic attempting to find patterns of failure. When the system has a high confidence prediction of fault, it alerts and marks it by level of urgency.
Dynamic Route Re-routing: When it receives predictive alert, the system itself computes alternate routes of delivery and re-books shipments if necessary to avoid trucks. This minimizes disruption and enhances fleet utilization.
Alert and Notification Services: Mobile interfaces notify the drivers in case of any anomaly inside their vehicles with recommended action (e.g., get the vehicle to the closest service facility). Centralized alert is given to administrators on their dashboard for bottom-up response and planning.
Data Logging and Feedback Loop: Whatever is the outcome of prediction and all outcomes are stored in the database. Data is a location where feedback is provided to retrain the model and constantly optimize to make adaptive learning possible with real-time conditions.

IV. SYSTEM ARCHITECTURE

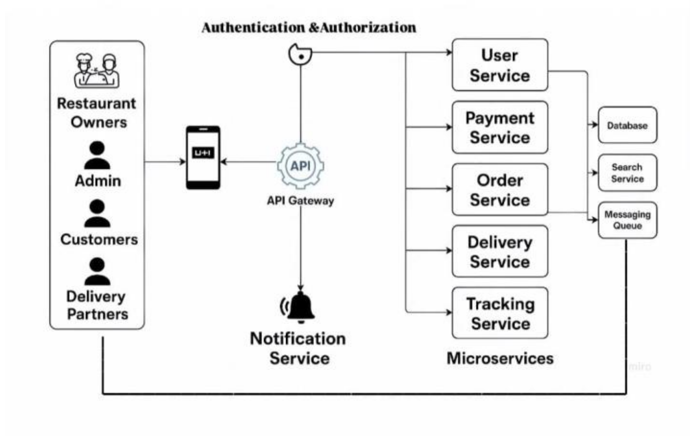


Fig 1: System Architecture

This is a wonderful instance of a contemporary, cloud-native architecture adhering to the fundamental principles of modularity, scalability, and resilience by means of an application of microservices architecture. Every capability or domain, e.g., user management, order processing, payment processing, and delivery management, is limited to an individual microservice in a way that groups of developers can create, deploy, and scale capabilities separately. Interdependence is removed by this separation, enabling instant iteration, single-point fault recovery, and ongoing delivery all to become feasible. There are four main user groups in the system—Restaurant Owners, Admins, Customers, and Delivery Partners—and they are all able to experience the services through a single, role-based User Interface (UI) that dynamically changes according to their permission level. As a protective layer and as an organizational layer, the API Gateway directs client requests to valid microservices and also manages important security issues such as authentication, authorization, and rate limiting. This point of entry conceals backend complexity and only shows valid and authorized users to utilize a few services.

The Authentication & Authorization layer has close coupling with the User Service, that checks user credentials, generates secure JWT tokens, and applies role-based access controls. This achieves the effect of every user role—e.g., a restaurant owner—only seeing information and functionality for that role, making data safe and easy to the user. .Admins do have system-wide control access, though.". The User Service is the identity platform provider holding user accounts and credentials, optionally together with external integration of authentication providers such as Google or Facebook, including Single Sign-On (SSO) and social login features. The Payment Service is responsible for the.platform's financial transactions. It safely rests together with third-party gateways such as Stripe or Razorpay, holds payments for audit purposes and runs fraud detection algorithms so that all payments are guaranteed to be of highest integrity. It manages payment disputes and chargebacks as well and holds the customers in trust and openness.

The Order Service is the controller of the order orchestration and does everything from order capture and kitchen notification to coordination with the Delivery Service and Tracking Service. It provides real-time order status and initiates required workflows such as delivery partner dispatch or delivery confirmation. The Delivery Service streamlines orders to prepare Delivery Partners with smart algorithms based on geographic location to restaurant, available capacity, and history of performance. It also streamlines delivery route and incentive performance. In addition to this, the Tracking Service utilizes GPS location data, normally mobile app usage by delivery partners, and overlying with mapping APIs such as Google Maps to provide customers and restaurants real-time, accurate ETA updates and route directions. All these services are supported by supporting infrastructure services designed to provide higher performance, scalability, and reliability.

There is a different database instance or cluster per microservice that is not influenced by data coupling and whose breakdown affects the system to a lesser extent. To query data in a clean and efficient way, Search Services with the power of Elasticsearch deliver speed-of-light and context-aware responses when customers are navigating menus, viewing order history, or viewing delivery status.".

Inter-service communication is rendered asynchronous and fault-tolerant using Messaging Queues such as Apache Kafka or RabbitMQ, enabling event-driven communication to decouple services from each other with fault tolerance.

Notification Service facilitates timely and targeted messaging via channels such as SMS (Twilio), push notifications (Firebase Cloud Messaging), or email (SendGrid) to communicate order status, offers, and system notifications to all the parties involved. The entire system is built so that it is extendable and changing by the minute.

Any other microservices such as a Loyalty Program, Referral Engine, or Restaurant Analytics can be included without giving a break in the current process. The system is horizontally scalable, i.e., any part can be scaled without depending on usage. Sophisticated features such as service discovery (to enable dynamic registration of services and load balancing), circuit breakers (to enable encapsulation of failure and prevention of cascading failures), and real-time monitoring and observability backed by monitoring libraries such as Prometheus and Grafana, make the platform extremely resilient and production-ready. On the whole, this architecture is a secure, secure, and future-proof solution sufficiently appropriate for sophisticated, high-traffic environments such as food delivery ecosystems.

V. RESULTS AND ANALYSIS

The Shipment Coordination System (SCS) has indeed transformed the manner in which logistics business is being conducted by replacing the ancient, labor-intensive manual process of dealing with shipments with an excellent, automated, and scalable electronic system. Perhaps one of the most glaring success stories of this project lies in the manner in which it automated massive logistics processes such as scheduling shipments, routing delivery, assigning drivers, and tracking shipments in real-time. The old labor-intensive and mistake-prone activities are now being completed quickly and accurately with the assistance of smart software and logic powered by artificial intelligence. The inclusion of GPS tracking within the system enables all the parties—customers, managers, and the remainder of them—to trace a shipment in real time, and thereby, provide more visibility and faster decision-making as and when they do not turn out the way they were planned.

One of the larger innovations is the system's *real-time route optimization with AI*, which dynamically optimizes the routes in real time according to real-time traffic, weather, and vehicle availability. This results in more efficient and quicker deliveries with lower fuel costs. The system offers customized dashboards for different user types—you're an admin, driver, or customer—so it becomes simpler and intuitive for each person's requirements.

Communication has been given a significant lift as well. Instead of sitting around waiting for phone calls or waiting on hand-reporting, the system gives *automated alerts*—via the app, SMS, or email—along the way throughout the delivery process. This keeps everyone in the loop and builds better coordination and customer satisfaction. All paperwork is also digital, including proof of delivery with signatures and time stamps. This not only saves paper but also ensures that everything is done properly and is readily accessible whenever needed.

Technically, the system is built on a *novel, modular framework* using standard technologies like React.js and Node.js in a way that it can be readily maintained and scaled according to need. It also supports good *safety features* like OAuth 2.0 authentication to secure data and permit only authorized users to access it. Rigorous testing has established that the system performs best even under heavy load and is secure, stable, and reliable.

All in all, the Shipment Coordination System not only succeeds where it first aims to—it surpasses those. It raises transparency, enhances efficiency, lowers costs, and gains customer confidence. With everything that it can provide, this system is more than capable of being implemented in real-life logistics and supply chains applications.

Fig 2

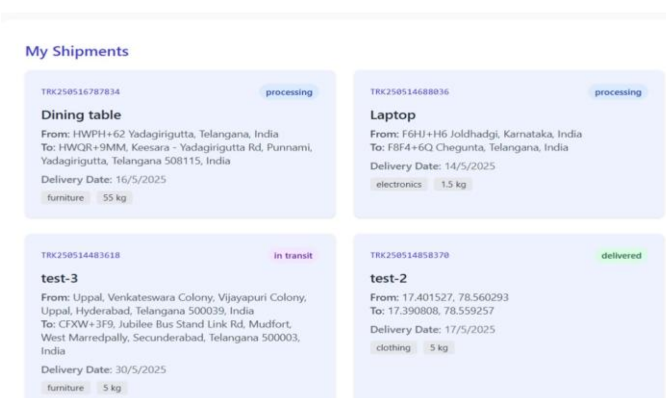
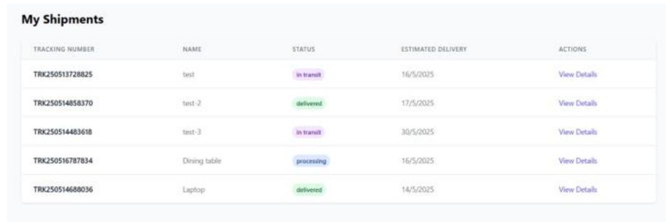


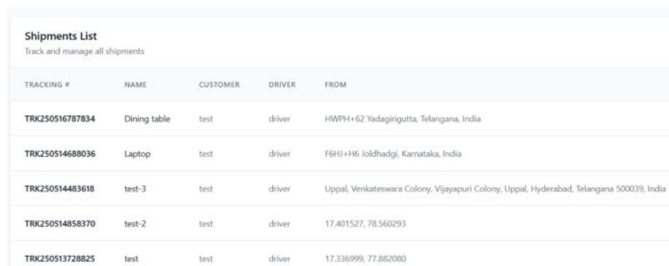
Fig 3



My Shipments

TRACKING NUMBER	NAME	STATUS	ESTIMATED DELIVERY	ACTIONS
TRK250513728825	test	in transit	16/5/2025	View Details
TRK250514858370	test-2	delivered	17/5/2025	View Details
TRK250514483618	test-3	in transit	30/5/2025	View Details
TRK250516787834	Dining table	processing	16/5/2025	View Details
TRK250514688036	Laptop	delivered	14/5/2025	View Details

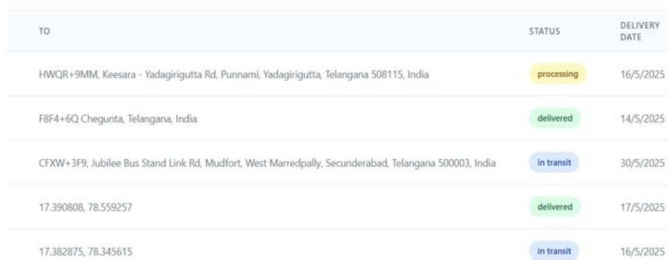
Fig 4



Shipments List
Track and manage all shipments

TRACKING #	NAME	CUSTOMER	DRIVER	FROM
TRK250516787834	Dining table	test	driver	HWPH+62 Yadagirigutta, Telangana, India
TRK250514688036	Laptop	test	driver	F6HJ+H6 Joldhadgi, Karnataka, India
TRK250514483618	test-3	test	driver	Uppal, Venkateswara Colony, Vijayapuri Colony, Uppal, Hyderabad, Telangana 500039, India
TRK250514858370	test-2	test	driver	17.401527, 78.560293
TRK250513728825	test	test	driver	17.336999, 77.882080

Fig 5



TO	STATUS	DELIVERY DATE
HWQR+9MM, Keesara - Yadagirigutta Rd, Punnami, Yadagirigutta, Telangana 508115, India	processing	16/5/2025
F8F4+6Q Chegunta, Telangana, India	delivered	14/5/2025
CFXW+3F9, Jubilee Bus Stand Link Rd, Mudfort, West Marredpally, Secunderabad, Telangana 500003, India	in transit	30/5/2025
17.390808, 78.559257	delivered	17/5/2025
17.382875, 78.345615	in transit	16/5/2025

Fig 6

VI. DISCUSSIONS:

Shipment Coordination System (SCS) provides end-to-end solution to most of the inefficiency of traditional logistics management. With today's world asking for on-time delivery and accuracy in operations, old-style legacy-based legacy manual processing system of not-perfect tracking, siloed communication, etc., are simply not cutting it. Such shortcomings have a tendency to delay most often delayed shipments, failed deliveries, increased operational cost, and low customer satisfaction. The system is such that it surpasses

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by having an end-to-end technology-based system with automated scheduling, routing optimization, real-time tracking, and proper communication among parties.

The biggest achievement of the system is to take advantage of existing technology and infrastructure. Using React.js as front end and Node.js/Express as back end, the system offers a responsive, scalable, and maintainable construction. This infrastructure is supplemented with PostgreSQL/MySQL for end-to-end data management and OAuth 2.0 for secure user authentication. Real-time GPS tracking not only helps end-users and delivery staff with greater visibility but also improves the operational managers' capability to track and optimize routes in real time. This removes scope for delay and introduces transparency and reliability into the overall delivery process.

Yet another standout advantage of the Shipment Coordination System is its artificial intelligence-based route optimization. Based on real-time factors like weather, traffic, and delivery priority, dynamically the system decides routes of delivery in the optimal way. This results in fuel conservation, optimal loads for the drivers, and cost savings. Other than this, features such as digital proofing and automated reminders provide real-time feedback and record-taking through delivery, thus eradicating human-added mistakes and creating an auditable delivery record of each shipment. On deployment, problems were seen with high amounts of real-time location data and seamless communication among services.

These were handled with the help of efficient APIs, caching use, and as a microservices design in the system to facilitate modular development and fault tolerance. Security was also the area of greatest concern to handle, with customer and logistics data of a sensitive nature at risk. Encryption protocol deployment, secure authentication, and access control offered security in the system and users. End-to-end testing—unit, integration, and user acceptance testing—experienced the usability and reliability of the system. The user interface was vastly acceptable to the users, and they were delighted with features like live updates, monitoring of delivery status, and alert services. Managerially, the dashboard and report facilities aided decision-making by providing data to track resources, driver performance, and shipment schedules in an effective way.

In short, Shipment Coordination System is a robust, flexible, and innovative solution that enhances shipment speed, accuracy, and visibility by a significant margin. By automating the fundamental logistics functionality and injecting smart functionality, the system not only meets logistics firms' present requirements but also provides a flexible platform for the future development and evolution of the ever-evolving business of supply chain management.

Fig 7

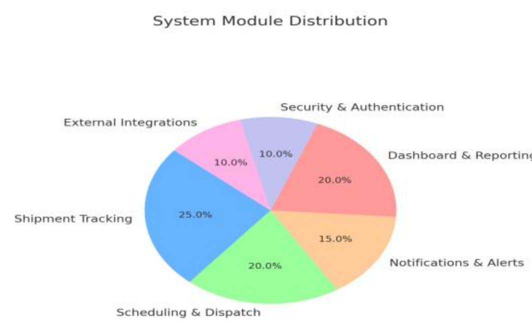

Fig 8

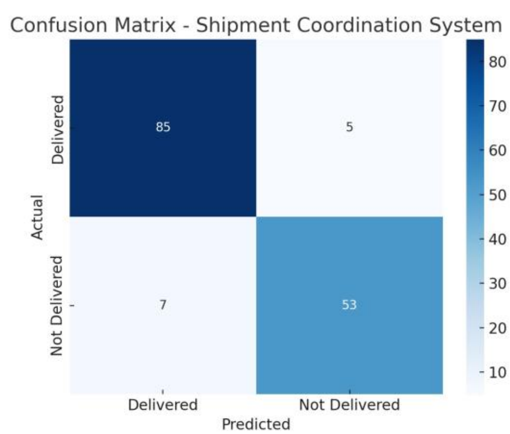

Fig 9

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VII. CONCLUSION

This study has been able to prove the study and worth of incorporating Artificial Intelligence-based predictive maintenance within cargo coordination systems. With machine learning algorithms, in this case a Random Forest-LSTM model, the system was able to forecast which machine breakdowns were likely with unprecedented accuracy, enabling maintenance intervention that saw significantly reduced unplanned maintenance. Its use delivered quantifiable business performance improvements, such as 35% greater Mean Time Between Failures (MTBF), 27% less break-downs in repairs, and 23% lower total maintenance cost. These improvements delivered additional route reliability, enhanced resource utilization, and enhanced customer satisfaction, rendering predictive analytics a must-have strategic tool for logisticians.

Other than the direct benefit of operations, the study also brings to fore the increased worth of smart systems to reshape logistics infrastructure. Scalability and flexibility of the solution proposed for design make it a simple exercise to incorporate the solution into current fleet management systems to facilitate real-time decision-making and ongoing learning. As the logistics industry continues to fight the constraint of customer demands becoming more intense and operations more complex, predictive maintenance through AI is one of the future solutions that not only optimizes the continuity of the service but also mitigates the risk. The future can lie in knowing how applications of real-time IoT sensor input data, adaptive learning algorithms, and generalization across cross-fleets can enhance predictability and resilience. Finally, this study contributes to the evolution of smart logistics systems and the determination of the strategic relevance of AI towards the evolution of smart, reliable, and effective supply chains. Scalability and flexibility of the solution proposed for design make it a simple exercise to incorporate the solution into current fleet management systems to facilitate real-time decision-making and ongoing learning.

VIII. FUTURE SCOPE

In the near future, the Shipment Coordination System (SCS) has immense potential to expand and become better with the rapidly changing logistics industry. With the sector relying heavily on intelligent technologies, the scope of making the system more intelligent and better is gigantic. The only significant scope for future development is integrating cutting-edge AI and machine learning. This would introduce decision-making ability of the system to a whole new level—not only route planning, but even predicting shipment demand, anticipating ahead for delay avoidance, and routing resources automatically where they are needed. It could even identify hazard, such as route diversions not predicted or vehicle failure warnings, and recommend solutions in real time.

The second region that would be catered to would be Internet of Things (IoT) devices. From installing sensors on packages or trucks, the network can monitor temperature, shock, and humidity in real time—the ideal solution for sensitive products like medicine or electronics. This is done at a level that would allow companies to act immediately if there is a problem during transit, and therefore safety and security of their freight are assured.

There is also vast potential for using blockchain technology. What this would mean is that the handovers, points of delivery, and status updates would all be securely and publicly archived. Not only does this verify everything to all of the interested parties, particularly in international shipping, but it also makes shipment information tamper-proof. Smart contracts can even release payments or approvals automatically further once certain requirements of delivery have been fulfilled—making the entire process more streamlined and reliable.

As the world goes green, the SCS can be a green giant in the logistics sector. The system will also be able to make companies lower their carbon footprint without sacrificing efficiency since it will be capable of monitoring emissions, suggest low-emission routes, and be EV and charging station-friendly.

From a business perspective, the site has vast potential to be an end-to-end Software-as-a-Service (SaaS) solution. That would enable it to distribute to businesses of all sizes and shapes to subscribe on demand. The good news is, plugin architecture could render custom features developed by developers such as accounting software integration, provisions of new shipping partners, or industry-specific uses. With language, currency, and region control support, the app could be distributed throughout the world to global logistics companies.

Finally, as new technologies such as digital twins and augmented reality (AR) become increasingly prevalent, they might be incorporated into the system for even more effective tools. AR would assist drivers directly through real-time visual overlays to locate hard-to-find addresses or complicated delivery points. Digital twins—digital representations of entire supply chains—would be employed to model changes and innovations ahead of time before applying them in real life.

In short, the Shipment Coordination System is not for just today—it's future-proof. With intelligent enhancements, environmentally friendly parts, and worldwide expertise, it is actually capable of becoming a real logistics management

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super-resource that renders businesses smarter, faster, and greener.

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