

RailLink - Enhanced Train Operations System for Sri Lanka Railways

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Abstract - RailLink, a comprehensive system designed for the Sri Lanka Railway Department, tackles the challenges faced in railway operations through four primary subsystems: the Self Ticketing System and Chatbot, Timetable Management and Passenger Demand Forecasting System, Driver Management System, and Fleet Management System. The Self Ticketing System and Chatbot enhance customer convenience by offering real-time ticket booking and information access through a user-friendly web application, reducing queues and improving satisfaction. The Timetable Management and Passenger Demand Forecasting System optimize resource allocation and train schedules, ensuring efficient resource use and improved passenger convenience through predictive modeling. The Driver Management System enhances safety and operational efficiency by considering driver health, previous journey data, and grades when allocating drivers. The Fleet Management System, using blockchain technology, ensures secure data sharing among sub-departments, safeguarding data integrity and confidentiality for effective fleet management. By harnessing advanced technologies, RailLink promises to modernize railway operations, resulting in increased efficiency, customer satisfaction, revenue, and overall network performance.

Keywords: RailLink, Railway Operations, Self-Ticketing System, Railway Modernization, Sri Lanka Railways

I. INTRODUCTION

Rail was introduced in Sri Lanka in 1864 since then, the Sri Lanka Railway Department has been providing its services to the public until today[1]. The British rulers introduced a railway service for the planters to bring the harvest of their plantations from the country's interior to the port of Colombo. Although the railway served as one of the most popular and fastest freight and passenger transport modes in the early decades, after the introduction of road-based public transport in the late 1940s, railway revenues declined, and it continues to operate at a loss [2]. Presently, Sri Lanka Railways daily

operates approximately 315 trains, facilitating the daily transportation of around 3.72 million passengers [3]. Unfortunately, the utilization of conventional operating methods has contributed to significant financial losses on an annual basis.

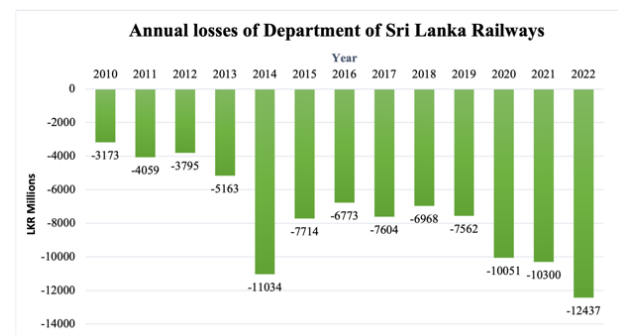


Figure 1: Annual losses of Department of Sri Lanka Railways

Source: Central Bank of Sri Lanka Annual Report 2010-2022

These circumstances emphasize the need for reforms and modernization within the Sri Lanka Railway Department to enhance efficiency and financial sustainability. Presently, this department finds itself in possession of a substantial volume of assets. However, regrettably, the department's utilization of outdated methodologies and the undue influence of political interference have impeded its ability to deliver its services in an efficient and effective manner.

RailLink consists of four primary subsystems powered by Natural Language Processing (NLP), Blockchain technology and Machine Learning (ML) to effectively address the domains. They are Self Ticketing System and Chatbot, Timetable Management and Passenger Demand Forecasting System, Driver Management System and Fleet Management System.

A) Background

The Sri Lanka Railways, with a remarkable history of over 165 years, has relied on the Edmondson ticket system since the 19th century. However, this manual system has led

to inconveniences for both passengers and ticket inspectors, including congestion at ticket counters during peak hours and difficulties in ticket verification. Additionally, the lack of a reliable information dissemination system has caused further inconvenience for passengers, as updates are communicated through media or letters. These issues have made it challenging for the railway department to accurately manage passenger demand and establish suitable train schedules, resulting in inconsistent passenger capacities.

Beyond passenger concerns, the railway department faces internal challenges, such as resource management, revenue optimization, operational efficiency, and ensuring the overall sustainability and success of the railway system. These problems are distributed among the department's various sub-departments, necessitating careful consideration and effective solutions.

Despite the crucial role played by these sub-departments in ensuring the success of a train journey, the inadequate availability of human resources has hindered the proper execution of related activities. Table I provides an overview of the department's employee count and the existing job vacancies as of 2019, highlighting the disparity between the required workforce and the actual number of staff available.

Table I: Manpower of sri lanka railways 2019[4]

	Approved number of employees	Existing Number of Employee	Vacancies / (Excess) **
Senior	212	25	87
Tertiary	415	125	290
Secondary	11,215	5,814	5,401
Primary	8,601	7,064	1,537
Total	20443	13028	7315

The shortage of employees within the railway department has had a direct impact on the operational aspects of train services. On a daily basis, numerous train cancellations occur as a result of insufficient train drivers available. Consequently, it becomes imperative to effectively manage the existing pool of train drivers within the department. Nevertheless, the existing system of manually scheduling train drivers gives rise to numerous challenges. These challenges stem from difficulties in exchanging information and issues in accurately and efficiently processing the required data.

Another critical aspect affecting train operations and passenger demand is the condition of train carriages and engines used by the Sri Lanka Railways. The department has a train fleet comprising over 1700 units (Table II). Unfortunately, a lack of proper maintenance is leading to frequent delays and cancellations of trains. In 2019, 46% of passenger trains reported delays exceeding 10 minutes, and

passengers faced many inconveniences and problems due to poorly maintained carriages.

Table II: Train fleet used in 2019[5]

Category	Nos.
Locomotives	79
Power Sets	92
Carriages	579
Wagons	1008

In a research study conducted by the University of Sabaragamuwa in 2019, an analysis of passenger feedback on the quality of service provided on the Colombo Fort to Badulla railway line revealed that passengers expressed dissatisfaction with the service provided by the Railway Department. The study utilized a 9-point Likert scale, ranging from 1 (least important) to 9 (highest important), to measure satisfaction levels. The analysis's lowest average value showed of 4.17, indicating a significant level of dissatisfaction among passengers[6].

This issue is attributed to the absence of a comprehensive system to manage train operations and maintenance as well as record losses and information changes that have led to this problem. "RailLink" aims to solve the above problems by providing the required online digital and secure platform to the departments.

II. LITERATURE REVIEW

According to a survey conducted in research conducted in 2021, 63% of the sample railway department employees agreed that the current system relies on files and is vulnerable to data alteration or destruction. According to research results, the current locomotive schedule record system in Sri Lanka Railways heavily relies on a traditional file system with manual methods for inserting and retrieving information. The findings indicate that the system's effectiveness is hindered by its reliance on manual processes, resulting in complex decision-making, increased budget allocation for paper and storage space, and slower inventory management and locomotive allocation. The research concludes that the prevailing system is not user-friendly and falls short when compared to information technology implementations in other government sectors. To enhance effectiveness, the recommendation is to transition from the current manual system to a computerized one, leveraging computers and the internet to automate basic functions and mitigate drawbacks [7].

The research conducted by Jinping et al. aims to address the critical requirements of safety, efficiency, and short maintenance time in China Railway High-speed (CRH) operations. Through the use of a virus genetic algorithm

(VEGA), they propose a novel approach for optimizing resource allocation and scheduling in the maintenance work order, overcoming the limitations of traditional genetic algorithms. The simulation results demonstrate the algorithm's effectiveness in quickly obtaining optimal engineering solutions, meeting the mission quality improvement and mission duration reduction objectives of CRH projects. This research contributes to the advancement of CRH maintenance planning by achieving an optimal configuration of human resources and ultimately enhancing the overall performance of CRH operations[8].

In their research conducted in 2007, Andrea et al. focus on the challenges of timetable perturbations during rail operations and propose an intelligent conflict detection and resolution system to proactively reduce consecutive delays. By accurately monitoring train positions and speeds, potential conflicts between trains can be predicted and resolved in real-time. The authors adopt a detailed alternative graph model for the train dispatching problem, effectively detecting and solving conflicts while considering safety constraints and speed coordination issues. Through an iterative rescheduling procedure, a conflict-free schedule that respects signaling and safety constraints is obtained. The research highlights the importance of considering dynamic speed profiles and advanced scheduling algorithms for improved real-time traffic management of rail networks[9].

A research report published in 2021 has introduced a blockchain-based CBTC Rail-ground communication platform for railways. The Communication Based Train Control (CBCT) system network instructure divides into three types logical network: Automatic Train Control (ATC) network, Automatic Train Supervision (ATS) network and maintain network. Based on blockchain technology, CBTC system information security testing environment is set up. The test results of this system show that the centralization method of railway-ground communication information security in the blockchain-based CBTC system can avoid the single-point failure vulnerability and improve the security of communication information[10].

In research conducted in 2019, the cryptographic procedure for railway ticketing systems has been used to increase the security of the system. Through this system, all the ticket information obtained by railway passengers will be stored in a blockchain network created by the Hyperledger Fabric ledger framework. It ensures the security and reliability of railway ticket information. This system avoids data centralization, avoiding the possibility of network downtime and redundancy of duplication. If one sales organization experiences a problem, a passenger's ticket can be obtained through any other participating organization[11].

Research conducted by Dhanushaet al. in 2019 addresses the need for a cashless and convenient ticketing system in India's transportation sector. Their proposed solution is an android application that utilizes existing electronic smart cards and replaces traditional paper tickets with paperless ticketing through QR codes. By scanning the QR code at the entrance, passengers can enter the train platform, and the ticket, containing journey details, is stored as a QR code. Upon reaching the destination station, the QR code is scanned again, and passengers can exit after paying the appropriate fare. The system allows users to add money to their wallet through card transactions and deducts the fare amount accordingly. However, the paper acknowledges a limitation in ticket booking, which can only be done if the user is within a certain distance from the railway track or station, leading to user frustration in urgent situations. The proposed architecture of the system involves a sign-in process, QR code scanning at the entrance and exit, fare calculation, wallet management, and transaction notifications[12].

The "TrainGo" mobile-based train ticketing system introduced in a research paper conducted in 2020 aims to address the inefficiencies of the traditional ticketing process in the Sri Lankan Railway Department. By leveraging QR code scanning technology, dynamic QR codes, an E-Wallet system, and ticket booking capabilities, the application provides a seamless and convenient ticketing experience for passengers, eliminating long queues and reducing waiting times. With the use of technologies such as the React framework, Vue-electron framework, and node.js, the "TrainGo" app offers an efficient and user-friendly solution that has the potential to improve service quality and enhance the overall perception of the railway service in Sri Lanka[13].

A) Research Gap

Previous research has predominantly focused on addressing challenges in railway passenger services, particularly by proposing mobile applications to streamline ticket issuance. However, it is essential to acknowledge the drawbacks of relying solely on mobile ticketing. Firstly, there is a lack of a robust communication mechanism for transmitting vital announcements and notices from the Railway Department to passengers. Secondly, assuming every passenger has access to modern mobile technology is unrealistic, excluding a significant portion of the population. Lastly, neglecting the importance of the existing railway station ticketing system creates a disparity between mobile and traditional users, impacting inclusivity and overall passenger experience. A balanced approach that integrates both mobile and station-based ticketing is necessary to cater to the needs of all passengers effectively.

Other studies have highlighted several challenges faced by the Railway Department, encompassing railway communication, resource management, train delay management, and fleet management. One critical issue is the lack of focus on train drivers, despite their vital role in ensuring safe and efficient operations. Additionally, comprehensive train delay management should consider train schedules, passenger demand, and revenue implications to avoid ineffective strategies and financial losses. Collaboration with external organizations responsible for fleet maintenance is often limited, hindering effective fleet management practices. Furthermore, relying solely on role-based access mechanisms for fleet management security may overlook vulnerabilities, necessitating the implementation of additional security measures and protocols to ensure data integrity and confidentiality.

The use of foreign railway services' solutions in surveys is noteworthy, overlooking the Sri Lanka Railway Department's specific framework and terms. Lack of alignment raises concerns about suitability and effectiveness. Crucial to consider Sri Lanka Railway's requirements and regulations for congruent and viable solutions that address distinct challenges and dynamics of the system.

To enhance efficiency, revenue generation, and passenger comfort in Sri Lanka Railways, the new system must prioritize four key areas. Firstly, focus on improving Ticketing and Information Management for a streamlined and user-friendly experience. Secondly, optimize Passenger Demand and Timetable Management to cater to passenger needs effectively. Thirdly, strengthen Human Resource Management to recognize the importance of employees, including train drivers, in ensuring smooth operations. Lastly, enhance Fleet Management practices by collaborating with external organizations for maintenance and implementing robust security measures. Emphasizing these areas will address previous shortcomings and weaknesses, leading to a more efficient and customer-centric railway system.

III. METHODOLOGY

The methodology section of this study outlines the systematic approach employed to investigate and address the research objectives and questions. "RailLink" is an innovative web-based application revolutionizing Sri Lanka's railway services using the MERN stack. It comprises four primary subsystems designed to enhance efficiency, customer experience, and profitability. The Self-Ticketing System and Chatbot utilize Natural Language Processing (NLP) to enable seamless ticketing and intelligent interactions. Meanwhile, Machine Learning (ML) powers Timetable Management and Passenger Demand Forecasting, optimizing resource

allocation and decision-making. The Driver Management System ensures skilled personnel allocation, improving safety and punctuality. Lastly, the Fleet Management System maintains and monitors the railway fleet for optimal performance. With cutting-edge technologies like NLP, ML, and Blockchain for data integrity, RailLink aims to offer a customer-centric, intelligent railway management system that drives growth and success for the Sri Lanka Railway Department.

A) Self-Ticketing System and Chatbot

The implementation of the self-ticketing system at railway stations has revolutionized the ticketing process, offering passengers a seamless and efficient way to acquire their journey tickets. Through the generation of individualized QR codes for each ticket, passengers can easily enter and exit stations, eliminating the need for traditional ticket counters and reducing overcrowding and fraudulent activities. This streamlined approach ensures convenience, security, and efficiency within the railway network.

Moreover, the integration of this system addresses the challenge of data collection for the Railway Department. Real-time passenger count data for each train throughout the day enables accurate monitoring and analysis of train occupancy. Armed with these insights, the Railway Department can make informed decisions on train scheduling, resource allocation, and service optimization. This data-driven approach enhances operational efficiency, passenger satisfaction, and strategic decision-making, leading to a better and more streamlined experience for railway passengers.

The inclusion of a Chatbot feature the system offers passengers easy access to train-related information and assistance with inquiries. Utilizing NLP, the Chatbot conversationally engages users, providing accurate and relevant responses in real-time. The Chatbot's extensive training with over 1000 questions from passengers and officials equips it to effectively handle a wide range of user queries, including Sri Lankan-specific language and unique aspects of English language usage in the country.

The Chatbot's algorithm follows 7 essential steps for efficient user query handling, ensuring a smooth experience.

- 1) Segmentation - Breaking down the user input into meaningful segments or units / parts.
- 2) Tokenizing - Dividing the segmented input into individual tokens or words.
- 3) Stop Word Removal: Filtering out stop words that do not carry significant meaning.
- 4) Stemming - Reducing words to their base or root form to normalize the vocabulary.

- 5) Lemmatization - Transforming words to their dictionary form to ensure accurate understanding.
- 6) Speech Tagging - Assigning part-of-speech tags to each word to determine their grammatical role.
- 7) Named Entity Tagging - Identifying and categorizing named entities. (Such as names, locations, organizations within the given input.

Let us consider the following problem to demonstrate the application of the algorithm: "How much does it cost to book a ticket from Colombo Fort to Waga? Provide the Maradana Stations phone number."

Table III: Table of results after applying the above steps to the given question

Step	Result
1	"How much does it cost to book a ticket from Colombo Fort to Waga?" "Provide the Maradana Stations phone number"
2	"How", "much", "does", "it", "cost", "to", "book", "a", "ticket", "from", "Colombo", "Fort", "to", "Waga", "?", "provide", "the", "Maradana", "Stations", "phone", "number"
3	"How", "much", "cost", "book", "ticket", "Colombo", "Fort", "Waga", "?", "provide", "Maradana", "Stations", "phone", "number"
4	"How", "much", "cost", "book", "ticket", "Colombo", "Fort", "Waga", "?", "provid", "Maradana", "Station", "phone", "number"
5	"How", "much", "cost", "book", "ticket", "Colombo", "Fort", "Waga", "?", "provid", "Maradana", "Station", "phone", "number"
6	("How", "WRB"), ("much", "JJ"), ("cost", "NN"), ("book", "VB"), ("ticket", "NN"), ("Colombo", "NNP"), ("Fort", "NNP"), ("Waga", "NNP"), ("?", "EN"), ("provide", "VB"), ("Maradana", "NNP"), ("Station", "NNP"), ("phone", "NN"), ("number", "NN")
7	"Colombo", "Fort", "Waga", "Maradana", "Station"

WRB - Wh-adverb, VB - Base form verb, NN - Noun, NNP - Proper noun / singular, JJ-Adjective, EN - End.

By applying these steps, the algorithm can process and analyze user queries more effectively, leading to accurate and relevant responses.

B) Timetable Management and Passenger Demand Forecasting System

The effectiveness of the Timetable Management and Passenger Demand Forecasting System (as illustrated in figure 2) lies in its ability to accurately predict passenger demand for each train journey. This is achieved through regression analysis and time series modelling, primarily utilizing the ARIMA model.

The system utilizes historical data, trends, and patterns to forecast passenger demand. To address increased demand, it suggests solutions like adding an additional train with the same destination or adjusting stops. However, the ultimate decision rests with the system manager, aligning with Railway Department guidelines.

The system's predictive capabilities are based on its extensive training using a dataset of approximately 5,000 real records obtained from the Railway Department. Through this rigorous training, the system has achieved an impressive accuracy rate of 98% in predicting passenger demand. This high accuracy enables the system to make reliable forecasts and optimize train schedules for maximum efficiency and resource utilization.

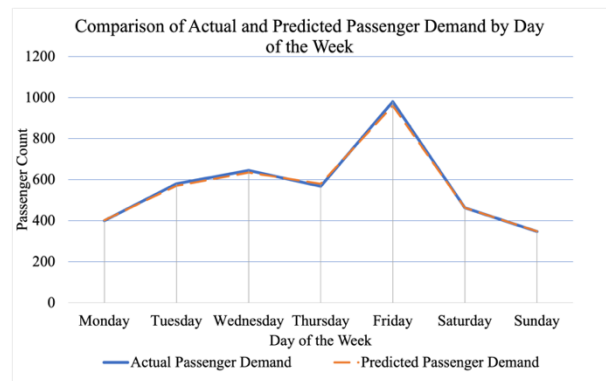


Figure 2: Comparison of Actual and Predicted Passenger Demand by Day of the Week

C) Train Driver Management System

The Train Driver Management System utilizes a classification model to optimize driver allocation for train journeys. It considers factors such as the driver's health, previous journey records, and driver grade to make data-driven decisions. By leveraging historical data and driver profiles, the system assigns drivers more effectively, prioritizing those with suitable health conditions and relevant experience for each journey.

The system enforces a minimum 2-hour break between a driver's consecutive train journeys, except for emergencies, to prioritize driver well-being, reduce fatigue, and enhance readiness for future operations. This approach emphasizes safety and operational efficiency, ultimately improving railway performance.

Furthermore, the system focuses on assigning drivers to train journeys starting from nearby stations. This minimizes delays, optimizes resource utilization, and ensures a smooth and efficient railway service, ultimately enhancing the overall passenger experience and railway department performance.

D) Fleet Management System

The Fleet Management System remains a pivotal component of the RailLink system, overseeing the efficient management and maintenance of the train fleet. It continues to achieve this through data-driven approaches and advanced technologies, ensuring optimal utilization, performance, and safety of the trains.

To uphold the confidentiality and immutability of system data for fleet manufacturers, blockchain technology is now employed using Ethereum and Solidity smart contracts, along with a private network. The network architecture comprises an initiating organization (the Railway Department) with components like a network policy, smart contracts, consensus mechanism, transaction pool, and ledger, ensuring decentralized data sharing with security and individual rights (figure 3).

1. Smart Contracts - These self-executing contracts facilitate automatic and trustless interactions between parties. They are programmed in Solidity and deployed on the Ethereum-based private network. Smart contracts enable various functions, including asset tracking, maintenance scheduling, and performance monitoring.
2. Consensus Mechanism - The private network relies on a consensus mechanism (e.g., Proof of Authority or Proof of Stake) to validate and finalize transactions. This ensures secure and efficient transaction processing while maintaining system integrity.
3. Transaction Pool - Transactions submitted to the network are temporarily held in a transaction pool before being included in a block. This pool helps manage the order and processing of transactions.
4. Ledger - The ledger records all transactions in a secure and immutable manner. Each participating organization maintains a copy of the ledger, enhancing reliability, integrity, and transparency throughout the Fleet Management System.

Additionally, channels are created within the network to incorporate additional organizations (fleet manufacturers). Each channel has its policies, enabling secure data sharing while maintaining privacy and autonomy for participating organizations. The system's distributed data storage mechanism ensures data redundancy, further enhancing reliability, integrity, and transparency throughout the Fleet Management System. This secure data environment remains vital for the Railway Department's sensitive transactions with bilateral governments related to national security.

IV. RESULTS

The "RailLink" Train Management System has successfully integrated machine learning (ML) and natural language processing (NLP) models, leading to significant improvements in performance and efficiency. The NLP chatbot interface achieved an impressive accuracy rate of 97%, enabling seamless interactions with users. The passenger demand forecasting model demonstrated remarkable precision with an accuracy of 98%, while the driver management model achieved a commendable accuracy of 97%, optimizing train operations efficiently.

The testing of the system in the Sri Lanka Railway Department resulted in notable benefits. Congestion at railway ticket windows reduced significantly, streamlining the ticketing process and enhancing customer experience. Train delays attributed to fleet and driver issues saw a remarkable 70% decrease, ensuring punctuality and efficiency. The train forecasting system's success allowed for the addition of special trains to meet increased demand, positively impacting passenger confidence. Without the mobile phone application, its overall performance and accuracy across subsystems remained outstanding. Despite some challenges faced by passengers due to this limitation, the "RailLink" Train Management System proved to be an innovative and transformative solution, significantly improving railway efficiency, safety, and passenger satisfaction.

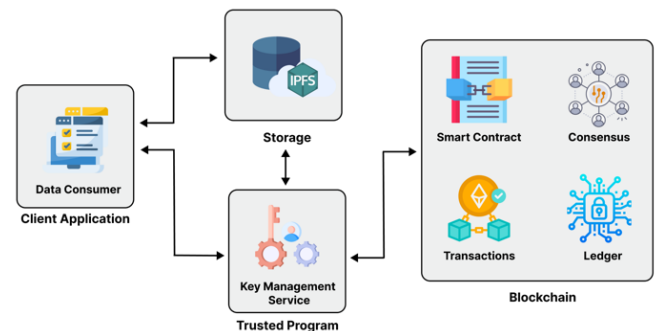


Figure 3: Fleet Management System Architecture

V. DISCUSSION

The "RailLink" Train Management System has proven to be an effective and transformative solution, addressing the challenges faced by the Sri Lanka Railway Department. By leveraging cutting-edge technologies like NLP, ML, and Blockchain, the system streamlines ticketing, optimizes train schedules, enhances driver allocation, and ensures efficient fleet management. This comprehensive approach leads to improved efficiency, customer satisfaction, and financial sustainability for the railway department.

Compared to existing railway management systems, "RailLink" stands out in several ways. It offers seamless information sharing between all sub-departments of the Railway Department, accessible through both mobile phones and computers as a web-based application. The complete automation of ticketing reduces congestion at ticket counters, while the train forecasting, driver management, and fleet management systems ensure proper resource utilization. Unlike some other systems that focus solely on passenger convenience, "RailLink" balances passenger needs and departmental efficiency. The use of blockchain technology in the fleet management system enhances the reliability of information exchange between the railway department and stakeholders.

However, the system's lack of a mobile phone application and the need for further attention to train seat reservations and goods transportation are notable weaknesses. Despite these shortcomings, the "RailLink" Train Management System demonstrates its capacity to revolutionize railway operations, benefiting both passengers and the railway department through enhanced efficiency, service quality, and overall performance.

VI. CONCLUSION

The RailLink system presented in this study offers a comprehensive solution to address the challenges faced by the Sri Lanka Railway Department. Through its four primary subsystems, namely Self-Ticketing System and Chatbot, Timetable Management and Passenger Demand Forecasting System, Driver Management System, and Fleet Management System, RailLink aims to enhance the overall efficiency, convenience, and security of railway operations. The Self-Ticketing System and Chatbot revolutionize the ticketing process by allowing passengers to book tickets through user-friendly self-ticketing pods, reducing congestion at ticket counters, and providing real-time information through an interactive chatbot. This streamlined approach enhances customer satisfaction and improves communication between passengers and the railway department.

The Timetable Management and Passenger Demand Forecasting System optimize train schedules and resource allocation by analyzing historical passenger data and using predictive modeling techniques to accurately forecast passenger demand for different train journeys. This proactive approach enables efficient utilization of resources and enhances passenger convenience. The Driver Management System focuses on assigning drivers for train journeys based on factors like health conditions, previous journey information, and driver grades, ensuring safe and efficient operations while minimizing driver fatigue. Additionally, the Fleet Management System utilizes blockchain technology to

facilitate secure data sharing among sub-departments, ensuring data integrity and confidentiality for effective fleet management. By leveraging advanced technologies, RailLink offers a transformative solution that has the potential to modernize and improve railway operations, resulting in enhanced efficiency, customer satisfaction, income, and overall performance of the railway network.

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