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Cloud-Integrated Fleet Management for Intelligent Maintenance and Operational Monitoring

Ramesh Kumar Panneerselvam[1], K.L. Sailaja[1], Yasaswini Venuturumilli[1], Pujitha Vaka[1]
[1]Dept. of Computer Science and Engineering, Siddhartha Academy of Higher Education (Deemed to be University)
Vijayawada-520007, India

***Abstract*—Transport organizations use fleet management applications to achieve better vehicle maintenance results and maintain regulatory compliance. Fleet operators still use manual tracking methods because they do not have effective solutions to handle their service schedules and renewal processes and their operating costs remain untracked. The paper introduces Fleet Symphony which is a cloud-based mobile fleet management solution that enables secure user access through vehicle-specific dashboards and document storage and cost management and maintenance record systems. Service templates create automatic service reminders that begin vehicle onboarding process and subsequent service work creates updates for upcoming maintenance tasks which synchronize with both activity logs and cost records. The system creates analytics-based insights and a vehicle health score through service status information and upcoming service reminders and document validity records and spending history data. The system testing process shows that all modules synchronize correctly while reminder notifications schedule accurately. The proposed system enables better operational visibility and maintenance planning capabilities than existing manual methods.**

***Index Terms*—Fleet Management, Automated Service Scheduling, Maintenance Logs, Cost Tracking, Vehicle Health Score.**

I. Introduction and Related Works

Fleet management has undergone a transformation from tedious, manual, and prone to errors operations to smart systems that have been supported by IoT, cloud computing, AI, and secure blockchain protocols. Nowadays the fleets need constant monitoring and Hussain et al. [1] were able to provide such a service using an IoT-based GPS and sensor platform that gives non-stop tracking and health alerts to support the reduction of downtime. Access to data in a secure manner is also key; Khambam and Kaluvakuri [2] put forward a multicloud identity and access management system to facilitate the data handling that is scalable and meets privacy requirements. AI has the potential to make operations even smarter. Dai et al. [3] utilized deep reinforcement learning to identify the maintenance needs by analyzing the sensor histories, thus scheduling and disruptions have been optimized and minimized, respectively. To reinforce the security of cloud systems, Mishra [4] has introduced a multi-layer data-encoding framework for safeguarding maintenance logs, sensor data, and driver credentials. Real-time analytics and energy management are the areas in the study of Gheni et al. [5] where improved shared mobility and electric fleet operations are achieved through the ways that reduce idle time and optimize charging cycles. Tracking systems with high accuracy such as GPS and GLONASS presented by Ahmad [6] allow for the location monitoring, giving insights into fuel usage and performance analytics. A zero-trust authentication model was also proposed by Ahmad that non-stop verifies user and vehicle permissions which is vital for fleets operating in autonomous or semi-autonomous modes. Regarding secure inter-vehicle communication, Li et al. [7] have devised a blockchain-based authentication system along with zero-knowledge proofs that would enable secure and coordinated communication in applications like truck platooning. The privacy-preserving federated learning models introduced by Azmoudeh Afshar et al. [8] provide an opportunity for vehicles to work together on authentication without the necessity of revealing the raw data. The cloud infrastructure designed by Deng et al. [9] allows for real-time advisory services such as traffic updates, speed guidance, and route optimization through the use of distributed processing. The current research develops Fleet Symphony which functions as a cloud-based fleet management system that enables secure authentication together with vehicle-based data organization and automatic service scheduling and manual compliance alerts and document control and expense management and maintenance record tracking. The system uses existing fleet data to generate operational insights and vehicle health scores which help maintenance planning and decision-making processes without needing any extra IoT devices. Table I compares traditional fleet management practices, existing mobile applications, and the proposed system.

TABLE I
Comparison of Fleet Management System Approaches

Aspect	Traditional	Existing Apps	Proposed System
Record Keeping	Manual logs	Digital records	Cloud-based storage
Maintenance Scheduling	Manual tracking	Reminder based	Automated scheduling
Data Organization	Registers	Module based	Vehicle-centric structure
Cost Monitoring	Manual calculation	Basic tracking	Analytics summary
Document Handling	Physical storage	Digital storage	Centralized repository
Operational Visibility	Very limited	Moderate	Dashboard insights
Decision Support	None	Limited reports	Insights + health score

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A. Motivation

Fleet operators need a single platform which allows them to control all their vehicles while reducing both operational downtime and compliance violations. The organization incurs higher operational expenses because manual record-keeping causes them to miss servicing dates and delays their insurance and permit and fitness renewals and they cannot track their expenses. The mobile-first cloud solution enhances data consistency and accessibility and monitoring capabilities by storing vehicle servicing records and reminders and documents and costs through secure authentication in an organized system.

B. Objective

To develop a secure cloud-based fleet management system with Firebase Authentication and vehicle-wise data storage. To implement automatic service scheduling using predefined service templates along with manual compliance reminders for renewals and expiries. To provide integrated cost management and maintenance history logging, ensuring service completion updates are recorded consistently. To generate data-driven insights and a vehicle health score to support better fleet monitoring and decision-making.

II. Literature Review

A. Existing Fleet Management Systems

The investigation of fleet management systems has covered the topics of real-time monitoring, predictive maintenance, data interoperability, and security. The work of Meenambika et al. [10] presented a system called Fleet Guard that used sensors for keeping track and doing maintenance beforehand whereas Chukwudi et al. [11] improved the prediction of engine health through an ensemble of deep learning methods. Sterk et al. [12] not only tackled the issue of integrating multi-brand data but also claimed that there was still no user-friendly mobile platform that provided document management or automated workflows when delivery was considered. Scheduling, mobile integration, and authentication were the areas covered by Tan et al. [13], who discussed fleet scheduling and resource optimization; Saghaei [14], who presented Android-based GPS/GLONASS tracking without document and cost modules; and Enem [15], who made IoT-based authentication more efficient but did not automate reminders or cost aggregation. Studies that focus on cloud integration and predictive maintenance, such as those by Tuyambaze et al. [16] and Mittal et al. [17], demonstrate the maturity of cloud-mobile architectures while Machaba and Ndou [18] point out real-world problems like fragmented data and inadequate planning-thus, the need for centralized automated solutions is reaffirmed. Research that prioritizes security through blockchain and reliable AI techniques is conducted by Sehar et al. [19], Ucar et al. [20], Saad et al. [21], and Yuan and Xiao [22], who examine secure data sharing, trustworthiness in PdM, security in VANET, and PUF-based authentication. These works, though, while being a great support to tracking, PdM, and secure authentication as separate parts, do not bring those elements together in a mobile-first unified system. Fleetio Go is a commercial mobile fleet management application that supports inspections and maintenance tracking for fleet operators [23].Fig 1 is the sample of the Fleetio application.

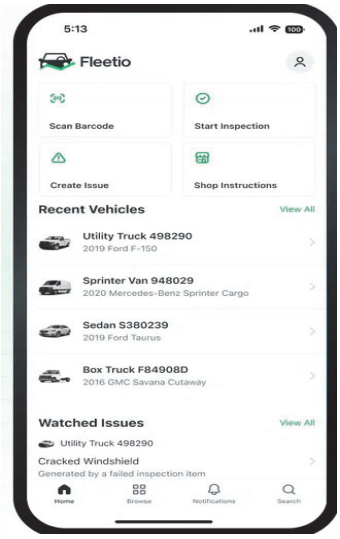

Fig. 1. Fleetio Application[23]

The Fleet Symphony system which our proposal presents requires secure authentication together with vehicle master data management and vehicle-wise dashboard display and automatic service reminders through template system and manual compliance reminders and document management and cost aggregation and maintenance history logs and activity tracking and health scoring with data-driven insights all developed as a single mobile application which operates through cloud technology.

B. Research Outcomes

Present fleet systems deliver incomplete operational capabilities which need human personnel to monitor their repair work and regulatory adherence activities. The cloud-based mobile application of Fleet Symphony enables users to handle vehicle data through its automated service scheduling system. The system provides standard activity tracking capabilities which deliver essential data to assist fleet operations.

III. Architecture

Fleet Symphony functions as a secure and scalable fleet management system which operates through a three-level hybrid system that includes a mobile application and its cloud infrastructure and data control segment. The system architecture enables organizations to add new features while they manage vehicles and maintain synchronized operation of their different system components. The complete system design appears in Fig 2.

An Android application serves as the main mobile client interface through which fleet operators manage their operations. The application provides key modules such as user authentication, vehicle master data management, vehicle-wise dashboard navigation, automatic service reminders, manual

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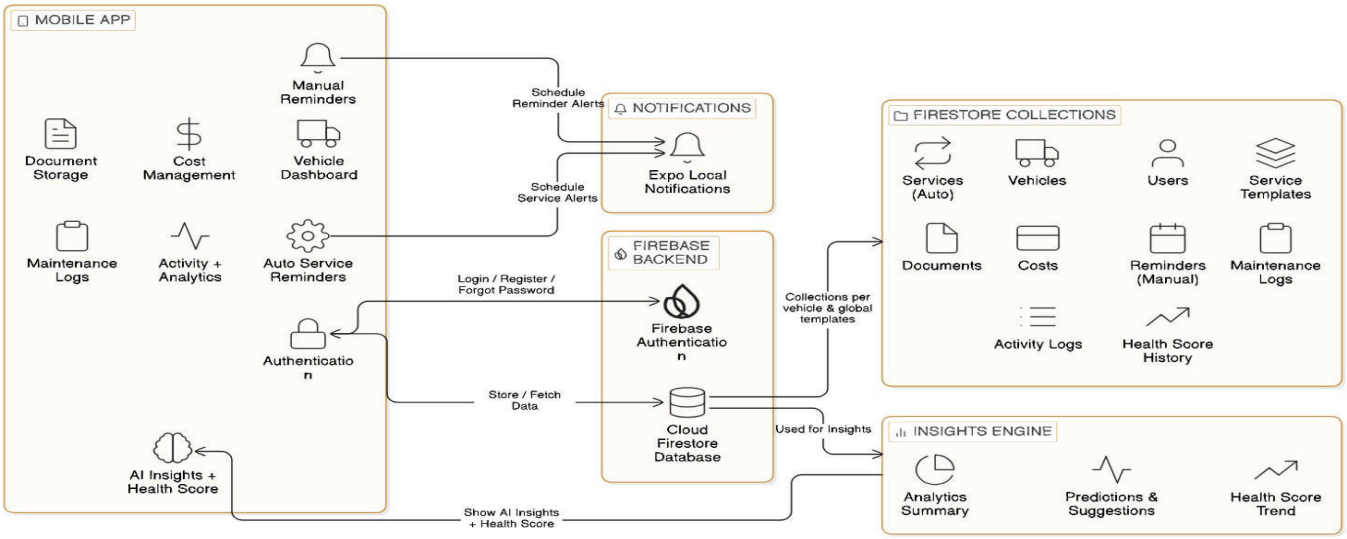

Fig. 2. Architecture of the proposed Fleet Symphony system.

compliance reminders, document management, cost management, and maintenance history logs. Firebase Authentication provides secure access protection while vehicle entities function as main objects which store all associated data related to services and reminders and documents and costs and logs.

The cloud backend uses Firebase services to manage all mobile client and database interactions. It manages user identification processes and maintains real-time data updates while executing backend functions needed to schedule services and store reminders and update records. The system provides users with notifications and time-based alerts through Firebase services and email integration which keeps users updated about their upcoming or overdue tasks.

The data management layer utilizes Firebase Cloud Firestore to organize all fleet records which include vehicles and service schedules and reminders and document entries and cost transactions and maintenance logs and activity logs. The system creates automatic service reminders based on service templates which get stored under each vehicle to maintain regular servicing schedules. The architecture enables organizations to create data-driven insights through its operational data analysis capabilities, which include overdue service records and expiring item data and spending patterns analysis.

The Fleet Symphony system uses its layered architecture to provide secure access control and modular system expansion capabilities, which enable maintenance of existing fleet modules while supporting the addition of new modules needed for real-world operational testing with multiple vehicles.

IV. Methodology

The methodology followed to design and develop Fleet Symphony, a modular fleet management mobile application, is presented in this section. The system integrates multiple fleet modules which include authentication and vehicle management and automatic service reminders and manual reminders and document tracking and cost management and maintenance logs and activity analytics and AI-based health insights. The modules establish connections with Firebase Authentication and Cloud Firestore which deliver secure access control and structured cloud-based data management. The overall operational flow of the system is illustrated in Fig 3.

A. Development Environment

Fleet Symphony was implemented using React Native (Expo) with Expo Router for navigation. Firebase services were used for backend integration, where Firebase Authentication supports login, registration, and password reset, while Cloud Firestore stores all fleet-related data. Firestore structures its data through user accounts which enable each vehicle to create different collections that include services, reminders, documents, costs, maintenance logs, and activity logs. The system enables users to track multiple vehicles simultaneously while mobile application users receive live updates.

B. Authentication Module

The authentication module serves as the access control system for Fleet Symphony which enables only registered users to access the fleet dashboard. Users can register and log in securely and recover their passwords through email with the help of Firebase Authentication system. The application first checks user session validation after successful login before it shows the vehicle list screen which displays fleet data from Firestore based on the authenticated user. The module stops people from accessing the system without permission while it protects all vehicle and service records which belong to the specific account.

C. Vehicle Management and Auto Service Creation

The feature for vehicle management in Fleet Symphony allows fleet managers to register vehicles in the system by

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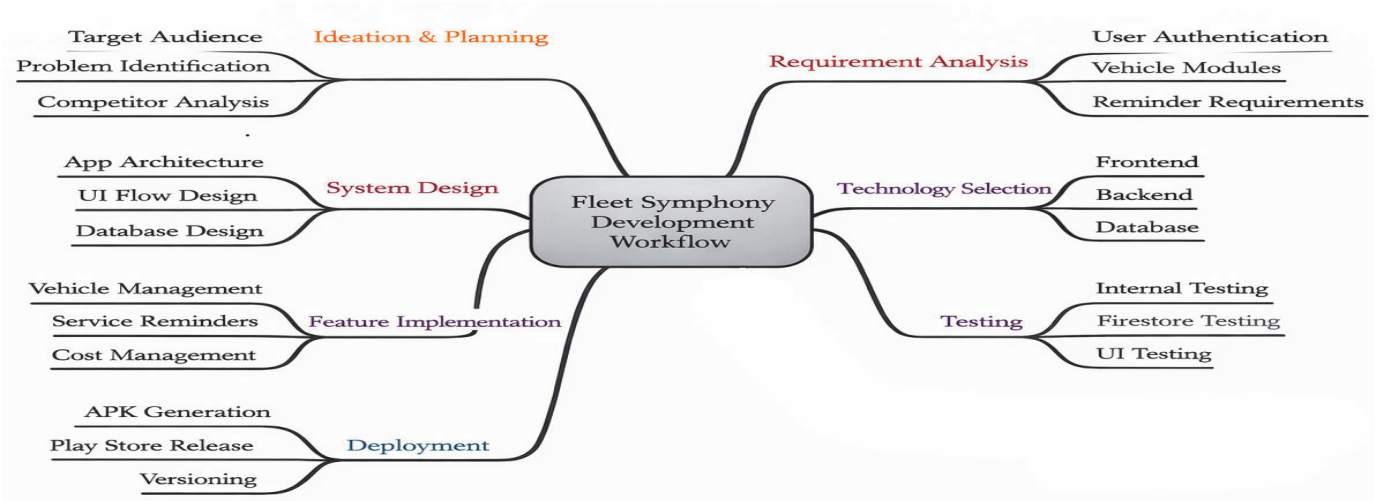

Fig. 3. Workflow of the Fleet Symphony system.

storing the vehicle number, chassis number, and type of vehicle

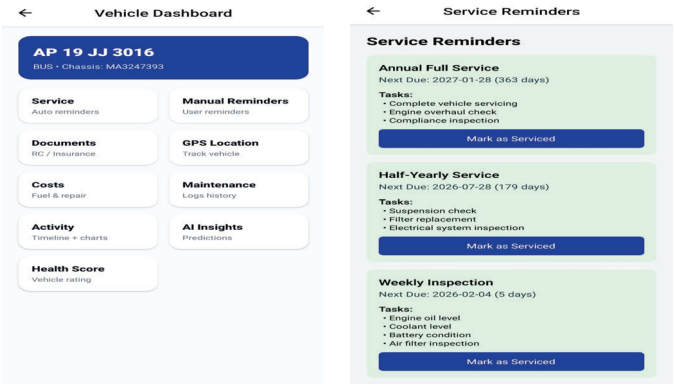

Fig. 4. (A) Vehicle Dashboard (B) Service Reminders Screens

separately as different documents in Cloud Firestore. Fig 4(A) and Fig 4(B) shows the screens of vehicle dashboard and service reminders.

At the same time, reminders for vehicle maintenance services are created. Service templates pre-set in Firestore are stored in the services collection of the newly added vehicle. The algorithm for creating service templates directly after vehicle registration is given in Algorithm 1.

D. Document Management Module

Document Tracking by the fleet manager helps in storing all vehicle-related documents such as RC, insurance, permits, and compliance records in an organized manner. Document details are maintained at the individual vehicle level; it is realized by a Firestore subcollection, with fields for document name, document type, date of expiry, and reference URL. Quick access to key vehicle documents from the dashboard. The system also monitors document expiry dates to ensure compliance requirements are met. Since only free-tier cloud resources will be used, documents will be accessed by using external links rather than storing binary files in the system.

Algorithm 1 Auto Service Creation After Vehicle Registration

Input: userId, vehicleId
Output: Auto service reminders stored in Firestore
Fetch all service templates from */serviceTemplates*
Set $D_{today} \leftarrow$ current date
for each template in serviceTemplates **do**
  Read frequencyType, interval, tasks
  Compute next due date:
    $D_{next} \leftarrow D_{today} + interval$
  Create service record in
    /users/userId/vehicles/vehicleId/services
  Store {serviceName, tasks, frequencyType, interval, D_{today}, D_{next}}
end for

E. Reminder Scheduling and Notification Module

It supports two types of reminders: manual reminders and automatic service reminders. Manual reminders will be created by the users themselves for events like insurance expiry, permit renewal, and license expiration. Fig 5 shows the sample reminder notification.

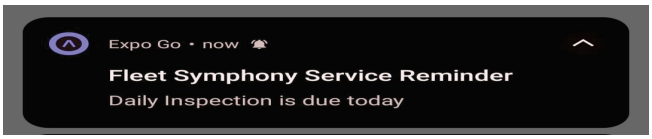

Fig. 5. FleetSymphony remainder notification

Automatic service reminders will be created at the time of vehicle registration using predefined templates and stored in the service collection of a vehicle with precalculated due dates. The system will schedule a local notification on the device using Expo Notifications at a fixed time-for example, 9:00 AM-on the due date. Each notification ID is stored in Firestore in order to avoid duplicates and support further updates.

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$$C_d \geq D_{due} \Rightarrow \text{Trigger Notification} \quad (1)$$

Algorithm 2 Scheduling Reminder Notification

1: **Input:** dueDate, reminderTitle
2: **Output:** notificationId stored in Firestore
3: Set triggerTime ← 9:00 AM on dueDate
4: Schedule a local notification using Expo Notifications
5: Receive notificationId from the scheduler
6: Store notificationId in Firestore under the reminder/service document

F. Cost Management Module

Within the cost management module, the cost management module accumulates and records all expenses incurred, such as fuel, servicing, repairs, and other costs, and links these costs to the vehicle using the Firestore database cost sub-collection of the relevant vehicle document. Algorithm 2 describes how scheduling of reminder notification is done. Servicing costs are also entered into the cost collection under the vehicle's maintenance category to aid in analysis, and the overall operational costs for the vehicles are calculated using Equation 2:

$$T_c = \sum_{i=1}^{n} Cost_i \quad (2)$$

G. Maintenance Logs and History Module

The module for maintaining logs of servicing and repairing activities for all vehicles is named "Maintenance Logs." Fleet Symphony offers both manual log entries by users and automatic log entries upon completing an auto service. Each log comprises different details including title, dates, odometer readings, cost, checklist of tasks involved, etc.

H. Activity Logging and Analytics Module

Activity logging is maintained by the Fleet Symphony application. Activity logging is designed to store vehicle operations under a unified timeline. Activities such as service completion, cost addition, document addition, and maintenance log records are stored in the Firestore service under the vehicle activity collection. Each activity record contains the type of activity, date, and cost.

Algorithm 3 Monthly Cost Summary Using Activity Logs

1: **Input:** ActivityLogs, month m
2: **Output:** Monthly cost total C_m
3: $C_m \leftarrow 0$
4: **for** each log in ActivityLogs **do**
5: **if** month(log.date) = m **and** log.cost > 0 **then**
6: $C_m \leftarrow C_m + log.cost$
7: **end if**
8: **end for**
9: Return C_m

Algorithm 3 describes the monthly cost calculation using activity logs. To produce cost analytics, it aggregates activity records containing cost values; it also derives monthly vehicle expenditure to create a dashboard visualization. Fig 6 shows the screen of activity & analytics.

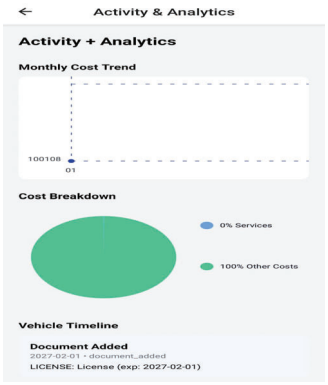

Fig. 6. Activity and analytics screen

I. AI Insights and Vehicle Health Score Module

Fleet Symphony derives AI-based insights on historical vehicle records such as vehicle servicing completed, maintenance logs, and expense trends. The purpose of this module is to provide a simplified vehicle condition summary and predictive suggestions without requiring hardware sensors. The The system determines vehicle health score based on various parameters, which are combined by the "system operational indicators like service punctuality and maintenance frequency, and cost burden.

$$H = 100 - (w_1 R + w_2 M + w_3 C) \quad (3)$$

where H is health score (0-100), R is reminder overdue count, M is recent maintenance count, and C is normalized monthly maintenance cost. The weights w1, w2, w3 determine the contribution of each factor. Fig 7(A) shows the AI Insights and Fig 7(B) shows Vehicle health score screens.

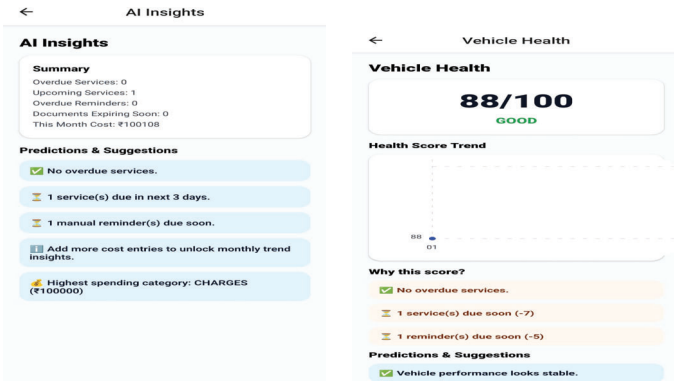

Fig. 7. (A) AI Insights (B) Vehicle Health Screens

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Algorithm 4 Health-Based Vehicle Risk Prediction

Input: Health score H
Output: Vehicle status and AI suggestions
if $H \geq 80$ **then**
    Status $\leftarrow$ Healthy
else if $50 \leq H < 80$ **then**
    Status $\leftarrow$ Moderate Risk
else
    Status $\leftarrow$ High Risk
end if
Return Status and corresponding suggestions

J. GPS Location Tracking

The application tracks vehicle movements by storing their geographical coordinates which include latitude and longitude information together with time-stamped data. The application provides basic tracking functions which enable users to verify movements and see their previous locations. The system maintains location records for each vehicle which allows for organized tracking and future expansion of map display capabilities.

V. Results and Verification

The functional testing of all application modules which included authentication, vehicle creation, automatic service reminder generation, manual reminder creation, document tracking, cost logging, and maintenance history recording confirmed the operational capabilities of the Fleet Symphony application. The validation of data persistence and synchronization processes was achieved through testing Cloud Firestore to confirm that vehicle collection updates occurred correctly. The testing process validated the notification scheduling system through tests which used local reminder triggers on their scheduled due dates. The application demonstrates its ability to manage vehicles throughout their operational lifecycle because it maintains accurate records of all operational data.

VI. Conclusion

The mobile application Fleet Symphony serves as a modular fleet management solution which enables users to access their vehicles through secure authentication while receiving automated service alerts and manual reminder functions and document management and expense tracking and maintenance recordkeeping. Secure user authentication together with centralized data management operates through Firebase Authentication and Cloud Firestore. The activity log and analytics features enable fleet operations monitoring which supports better decision-making processes.

VII. Future Work

The research will progress toward developing real-time GPS tracking which includes driver assignments and map displays and route tracking of previous movements. The system will achieve better notification accuracy through the use of production builds and user-defined reminder intervals. The system will extend AI insights through predictive maintenance and cost estimation based on maintenance records and operational patterns.

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