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Automated Bus Scheduling and Route Optimization Platform

Chetan Vilas Pawar
Department of Computer Engineering
R. C. Patel Institute of Technology
Shirpur, India

Darshan Yashawant Jadhav
Department of E&TC Engineering
R. C. Patel Institute of Technology
Shirpur, India

Mohit Bhaiyyasaheb Patil
Department of Computer Engineering
R. C. Patel Institute of Technology
Shirpur, India

Dr. S. S. Sonawane
Department of Computer Engineering
R. C. Patel Institute of Technology
Shirpur, India

Jaydeep Pramod Mahajan
Department of Computer Engineering
R. C. Patel Institute of Technology
Shirpur, India

Chetan Dipak Patil
Department of Computer Engineering
R. C. Patel Institute of Technology
Shirpur, India

Abstract - **Public bus transportation systems are an important part of urban mobility; however, conventional scheduling and route planning approaches are for the most part static, and rely greatly on manual intervention. These methods are not good enough for dealing with real time traffic fluctuations and dynamic passenger demands, often leading to service delays and inefficient fleet utilization and increased operational costs. Recent research shows the importance of dynamical scheduling and data-driven optimization techniques to increase the efficiency of public transportation systems in smart cities. This paper proposes about Automated Bus Scheduling and Route Optimization Platform that generates optimized bus schedules based on consideration of important operational factors such as fleet availability, route assignments and predefined time windows. The system incorporates data from a Geographic Information System (GIS) to find efficient path in congested urban environment, thereby reducing the travel time and making service more reliable. Real time monitoring is made possible using GPS based vehicle tracking, enabling transport administrators to see bus movements and address delays or problems at the operation level. The platform is implemented as a web-based application employing a scalable client server architecture. Backend services are managed using Spring Framework, while MySQL is used for reliable data storage. In addition, role-based access control ensures safe and structured interaction between administrators, drivers, conductors, consistent with assuring security today requirements for smart transportation systems. Experimental evaluations show that the proposed system provides substantial lessening of manual scheduling efforts, enhances operational transparency, and enhances fleet use when as compared to traditional methods. The platform is designed to support the smart city initiatives and provides a basis for future improvements, including demand learning based on machine learning predicting and transportation services using IoT.**

Keywords - Automated Bus Scheduling, Route Optimization, Intelligent Transportation Systems, Geographic information System (GIS), Global Positioning System (GPS) based Real Time Monitoring, Smart City Mobility, Web Based Transportation Platform

I. INTRODUCTION

Urban centers greatly depend on public transportation systems. This is especially so in less developed countries where, thanks to a combination of rapid urbanization and population growth with worsening congestions, there is a heavy dependence on bus services as an affordable and easily accessible means of both mass transport and mass transportation. This has resulted in a major burden on the infrastructure of existing public transportation systems. Many of the traditional means of scheduling and planning bus routes involving use of static, manual techniques to develop timetables that are unable to respond to variation in demand for services or to changes in traffic conditions. The results of this lack of flexibility include delays in service delivery, ineffective fleet management, excessive consumption of fuel and reduced customer satisfaction [1], [2].

The development of smart city projects has in the last several years saw the interest expanded in how intelligent technology and data analytics can be used for improved urban mobility through means of providing better transportation solutions. The Intelligent Transportation Systems (ITS) employ advanced technologies such as cloud computing, internet of Things (IoT), in the World Wide Web (WWW), GPS and Geographic Information Systems (GIS) to enable greater efficiency, reliability, and sustainability in the provision of public transit services . An important part of the ITS system is automated scheduling and routes for the bus, which are fundamental for effective planning, monitoring in real time and adaptive decision making about transit operations and service delivery [3].

A manual scheduling method requires a lot of time, are vulnerable to human error, and lacks a sense of transparency into operations. Due to those reasons and many additional challenges, it cannot effectively deal with unexpected events such as closing of road, emergency repairs, breakdowns of

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vehicles, and the fluctuation of demand. Additionally, a static method of defining routes does not take into account live traffic; hence, it will lead to excessive traveling time and ultimately increased costs of running an operation [6]. Recent studies emphasize that Geographic Information Systems (GIS) driven and real time data-based optimization techniques to increase punctuality dramatically and overall urban bus transportation service performance systems [3], [7].

The research comprises of Automated Bus Scheduling and Route Optimization Platform that tries to resolve the limitations of existing systems of public transport by incorporating an automated timetable generator which will allow to the management of operational constraints such as the availability of the fleet, the assignation of routes, as well as preset service times for each route. The platform will also have a route optimization solution (based on GIS) using real time GPS tracking and IoT enabled hardware that is built into buses. The platform's web-based interface is based upon a distributed client server model where the Spring Framework is used for backend services and MySQL are used for persistent storage of data. Access to the platform is secured, and structured according to the roles of the user i.e. administrators, drivers and conductors [5].

This work's mission statement is to increase operational effectiveness, minimize delay in transportation service, maximize use of fleet vehicles, and create much more visibility of managing the public transportation. The proposed solution incorporates an automated system as well as real time processing of data in order to comply with 'smart city' goals for mobility. In addition, the proposed solution can be used as a base for further developments such as predictive modelling using machine learning, the Internet of Things to help in sensing, as well as mobile applications that support commuters [4], [8].

II. LITERATURE SURVEY

The study of bus schedules and routes optimization can be traced back to transportation engineering and researching ITS. Early studies used mostly static optimization techniques linear programming, network flow modelling or integer programming) preeminently to reduce operational costs or travel times with limited by fixed parameters while successful in predictable and controlled situations, these ways do not meet the today's demands of multiple variables affecting urban transportation (e.g., continuous changes in traffic conditions, passenger demand) [1].

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These approaches had added incremental benefits for scalability and flexibility of solutions when compared to classical optimization methods. However, the majority of such models make extensive use of historical datasets and offline calculation which restricts their capability to adapt dynamically with operational change during time of real time. The inclusion of Global Positioning Systems (GPS) was a major improvement in the public transport management. Several studies proposed the use of GPS based vehicle tracking effective systems to monitor real time bus locations, improve schedule adherence, and better operational visibility [6]. Real time tracking enabled transport authorities to detect delays and analyze fleet movement patterns more efficiently. Nevertheless, many GPS enabled systems primarily function as monitoring tools and provide limited support for automated decision making, dynamic rescheduling, or route reconfiguration.

Real time tracking allowed transport authorities to recognize delays and analyze patterns of fleet movement more efficiently. Nevertheless, GPS enabled systems mainly operate as monitoring support and limited support for automated decision making, dynamic rescheduling or route reconfiguration. There has been a recent emphasis in research on the use of Geographic Information Systems (GIS) and real time traffic information for the better urban route planning. GIS based approaches facilitate correct computation of distances, spatial analysis, and route visualization, allowing more informed decisions about routing under congested traffic condition [3]. Some studies integrated live traffic data to adaptively plan routes, leading to decreases in travel time, also for fuel consumption. Despite These benefits, such solutions often tend to focus only on route optimization and not include scheduling automation, and user management, or operational monitoring in a unified framework [1], [7].

In parallel, web-based transportation management platforms have been proposed to enhance accessibility, transparency, and administrative control. These systems typically offer centralized dashboards for schedule management and online access for users [4]. In parallel, transportation management platforms, web based have been proposed to increase access, openness and administrative control. Such systems usually provide central online access to and individualized dashboards for schedule management for users [4]. While web-based solutions are better usability, a lot of existing implementations have no intelligent automation, real-time data processing, and robust role-based access control, troll mechanisms. Furthermore, there is scalability and security critical problems with large scale public transportation deployments [5].

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In sum, current research covers single components of public bus transportation, including scheduling of locomotion, routing, tracking, or visualization. However, there is a significant absence of combined automated scheduling platforms, GIS based route optimization, real time monitoring, secure web-based access in one system. The proposed *Automated Bus Scheduling and Route Optimization Platform* aims to fill this breach of research by providing an end-to-end solution that makes use of modern web technologies and real-time data to enhance the efficiency, reliability and transparency of public transport operations [2], [8].

III. PROBLEM STATEMENT

Public bus transportation systems traditionally have relied on static schedules and predefined routes that are manually planned on the basis of presumed traffic conditions and uniform passenger demand. Such assumptions are not often valid in the real urban environments, where there will be traffic congestion, road diversions, vehicle breakdowns, and variable passenger volumes are common occurrences. As urban populations increase and road networks become more and more congested rigid scheduling approaches do not keep the service reliable and operational efficiency [1], [2].

Manual bus scheduling is by its very nature complicated and time intensive requiring co-ordination of multiple operational constraints including fleet availability, routes allocation, driver duty regulations, as well as fixed service time windows Human involvement in this process will often introduce scheduling nonflights, inefficient use of resources, and low level of operations transparency. In addition, manually generated schedules lack flexibility and are difficult to modify in real time making it difficult feeding for transport authorities to react in time to unexpected disruptions [4].

Another major drawback with conventional public transportation systems is the absence of the intelligent decision support mechanisms. Although tracking vehicles based on GPS data has been adopted by several transport agencies to track the location of buses, such systems are mostly used for a visualization purpose about and do not support auto rescheduling or dynamic route optimization [6]. As a result, the delays in one segment of the network tend to propagate in terms of routes, negatively impacting punctuality and satisfaction of the passengers. Furthermore, many transportation management systems do not have centralized, secure and scalable platforms that support role-based access for important stakeholders such as administrators, drivers and conductors. This fragmented approach increases operational costs, decreases responsiveness of the system, and limits one's ability to scale services efficiently in smart city environments [5].

Therefore, there is critical need for an automated, smart, and real-time capable bus scheduling and route management platform. Such a system must be able to dynamically generating schedules, optimizing routes and routes using GIS and real-time traffic data, as well as providing continuous monitoring through a centralized web-based interface. Addressing these challenges is vital to the improvement of operational efficiency, service reliability, and overall sustainability of public transportation systems in the modern urban environment [3], [7], [8].

IV. SYSTEM ARCHITECTURE

The Automated Bus Scheduling and Route Optimization Platform is designed based on the layered and modular architecture to provide scalability, reliability, maintainability, and ease of integration of emerging smart city technologies. The proposed system is based on the client-server model, where centralized backend services manage important processing and data management whereas users interact with system through a secure web-based interface. In addition to the software components, embedded hardware-based tracking unit is deployed on each bus to allow real-time location monitoring. Such architecture patterns are rampantly used in the modern intelligent transportation systems thanks to their flexibility and scalability [2], [4].

There are four main layers of architecture: User Interface Layer, Application Layer, Optimization Layer, and Data Layer. A hardware based IoT tracking module consisting of ESP32 microcontroller, GPS module and GSM communication module works at the external data source and Integrating with the backend system. Each layer is responsible for a set of specific functionalities and communicates with adjacent to each other through well-defined and secure interfaces. This separation of concerns helps make the system more robust and eases maintenance and upgrading in the future [5].

A. Architectural Layers

1) User Interface Layer: User Interface Layer: User Interface (UI) Layer provides role-based access to different stakeholders including administrators, drivers, and conductors. Administrators can manage buses, routes and schedule, and system configurations, while drivers and conductors can view assigned routes, schedules, operational updates. The implementation of the interface is using web technologies in order to ensure platform independence, ease of access, and better user experience [4].

2) Application Layer: The Application Layer is used as the core of the system and is implemented using Java Spring Framework. It handles the business logic and request handling, user authentication, authorization and communication between the frontend and backend components. REST APIs are employed to facilitate data exchange and seamless integration with external services e.g. GIS platforms, hardware-based GPS Tracking units installed in buses [5], [8].

3) Optimization Layer: The Optimization Layer is responded to be possible to automatically generate bus schedule and route optimization. It processes operational constraints

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such as fleet availability, route assignments, and duty regulations, and predefined service windows. In addition, it makes use of geographical information and real time location data received from GPS allowed hardware devices to know efficient routes, thereby reduction in travel time and operational costs and improve punctuality [1], [3], [7].

4) Data Layer: The Data Layer comprises of a centralized MySQL database that contains all the system related information, such as user credentials, bus information, route information, schedules, and real time tracking logs. Location data transmitted from the hardware units on board via GSM networks is stored and processed in this layer. Centralized data storage insures consistency, security and efficient retrieval. External services e.g. GIS APIs, Traffic data providers, GPS enabled IoT devices communicate with this layer for supporting real-time monitor and data driven decision making [6], [8].

B. System Architecture Diagram

The overall system architecture of the proposed system platform is shown in Fig. 1 which exhibits the interaction between users, software layers, external services and the onboard hardware-based tracking unit. The hardware setup used for real-time tracking of the bus (consists of ESP32 microcontroller) integrated with a GPS module and a GSM communication Of the latter, module, is shown separately in Fig. 2.

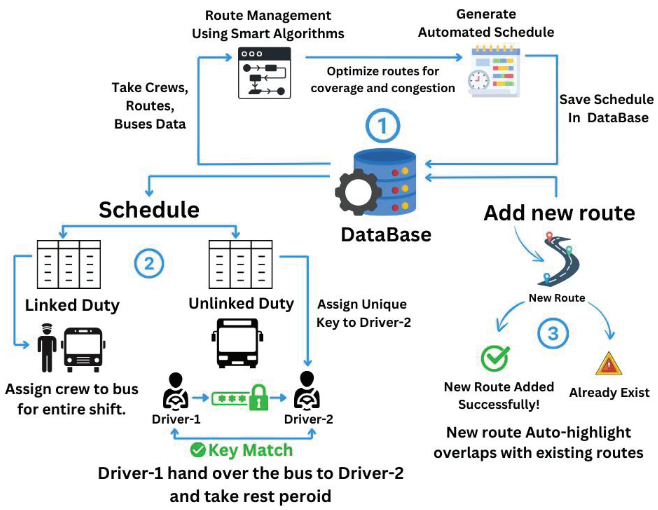

Fig. 1. Overall System Architecture of the Automated Bus Scheduling and Route Optimization Platform

C. Component Description

Table I summarizes the key components of the proposed system architecture and their respective functionalities.

D. Architectural Advantages

The proposed system architecture ensures modularity, scalability, and robustness through close collaboration between software services using embedded hardware-based tracking units. Each layer and component can be independently improved or replaced without affecting the system as a whole. The architecture supports as well as future extensions, e.g., mobile applications for commuters, and IoT based Sensor integration, Machine Learning based demand prediction, as well as interoperability with other smart city platforms [2], [7]. This makes the proposed platform appropriate for large scale implementation in contemporary urban transportation systems.

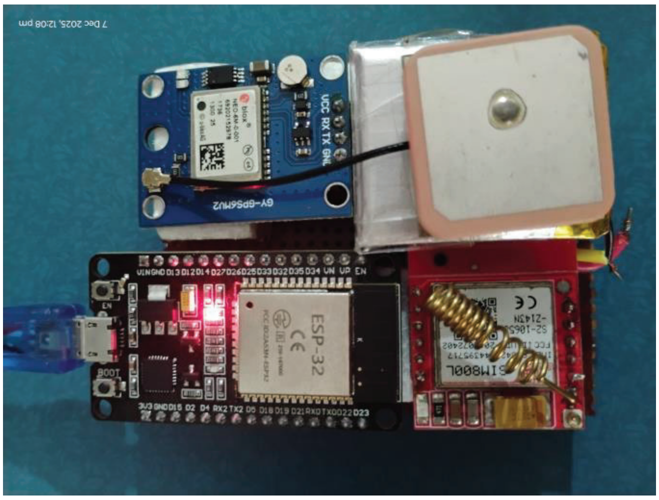

Fig. 2. Hardware Setup for GPS-Based Real-Time Bus Tracking

TABLE I. System Architecture Components

Component	Description
User Interface Layer	Web-based interface providing role-based access for administrators, drivers, and conductors.
Application Layer	Handles business logic, authentication, authorization, and RESTful API communication using Spring Framework.
Optimization Layer	Performs automated scheduling and GIS-based route optimization using operational and real-time data.
Data Layer	Centralized MySQL database for storing user, route, schedule, and tracking information.
Hardware Tracking Unit	ESP32-based embedded system with GPS and GSM modules for real-time bus location tracking.
External Services	GIS APIs, traffic data providers, and GSM networks for real-time monitoring and optimization.

V. METHODOLOGY

In devising the Automated Bus Scheduling and Route Optimization Platform's method, order, data-driven, and modular approaches will be employed in order to improve the efficiency and reliability of public bus systems. Automatic timetable generation, optimized bus routes with taking into account of geographical and traffic data, and ongoing, real time monitoring fleet activity, whilst, at the same time, maintaining

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the capability of being easily expanded and having a high-quality service [1], [2].

Data Acquisition Using Performance And Real-time Visualization, are aspects of the Workflow as defined in the above sequence (Staged Workflows). While each stage has a particular function tomorrow that is possibly performed independent of other stages, the use of defined interfaces on each stage of the Workflow improves the interaction between all the components of the Workflow and creates opportunities for both integrations and improved maintenance and greater capability of Workflow extension [5].

A. Data Collection and Input Management

The first part of the methodology is based on obtaining and organizing operational information so as to effectively schedule and route buses. This information is made up of the following: (1) Information about buses: the id of the bus, seating capacity and available buses. (2) Route Information: source destination, intermediate stop(s), and service times. (3) User Information: if role-based access control is used for role-based access control for admin, drivers, and conductors. (4) To produce informed scheduling and optimization scheduling and optimize the routes, the archives of historical schedules of the routes and route performance data is used [4], [6]

B. Automated Schedule Generation

The Automated Scheduling System works to create a daily or periodic bus schedule after validation of data. Automation of scheduling process eliminates the reliance on manual planning, reduce the occurrence of conflicts and improvement of overall efficiency of how available resources are harnessed. Previous studies have found that implementing Automated Scheduler can greatly increase efficiency and transparency of Intelligent Transportation Systems [1], [7].

C. Route Optimization

In the Optimization Route phase of the Intelligent transportation Systems Process, Geographical Information Systems (GIS) are being used to provide the routing information of how best to get from point A to Point B in the most efficient way possible using traffic-related data. All of the routing parameters including Route Distance, Estimated Travel Time and Congestion Levels, are evaluated in order to choose an optimal route. This data driven decision making process decreases travel time, decreases amount of fuel consumed reduces operational costs, and ensures the reliability and punctuality of services [3], [7].

D. Real-Time Monitoring and Adaptive Updates

Monitoring of bus movements on a real time basis this is achieved using GPS technology (GPS tracks in real time the location of the buses) The Automated Scheduling System is continuously checking and compares the locations of buses compared to their planned schedule. As a result of this monitoring system, should there be delay to, deviations in routes or other unforeseen interruptions, the Automated Scheduling System is used to create alerts for the transportation administrator(s) and provides them with actionable insights are provided about disruption [6], [8].

E. Visualization and Reporting

At the end of the methodology, the results of visualizations are interpretations and reporting are shown using a centralized online dashboard on the internet. Map viewer is available to schedulers types for visualizing generated schedules, optimized routes and real-time information of bus positions. Reports are produced to provide analysis for fleet use, delay patterns and operational performance, thus enabling the capacity to make data based decision and professional long-term planning [2], [4].

F. Methodology Workflow Diagram

The general workflow used in the proposed methodology is illustrated in Fig. 3, in terms of the interaction between data collection, scheduling, optimization, monitoring, and visualization modules

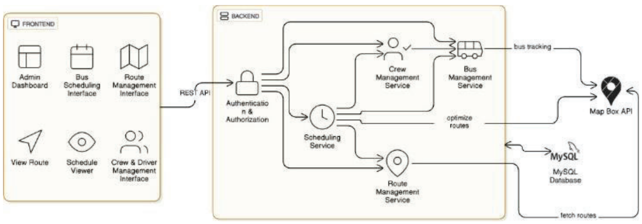

Fig. 3. Workflow of the Automated Bus Scheduling and Route Optimization Methodology

G. Methodology Summary

Table II summarizes the major stages of the proposed methodology and their corresponding functionalities.

TABLE II. Summary of Proposed Methodology

Stage	Description
Data Collection	Acquisition of bus, route, user, and historical operational data.
Schedule Generation	Automated creation of schedules based on operational constraints.
Route Optimization	GIS-based selection of efficient routes using traffic and distance data.
Real-Time Monitoring	GPS-based tracking and detection of delays or deviations.
Visualization & Reporting	Web dashboards and analytical reports for decision-making.

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The proposed methodology provides an integrated and adaptive approach to managing public transportation systems. Its modular design supports future enhancements such as machine learning-based demand prediction, IoT-enabled sensing, and integration with broader smart city platforms, making it suit- able for large scale urban deployments [2], [8].

VI. IMPLEMENTATION

Automated Bus Scheduling and Route Optimization Plat- form is a web application that has been developed by using several modern, reliable, and widely used software technologies. Implementation steals power from the modular design and development, security, scalability and ease of maintenance. The platform is based on a client server architecture that offers a separation of presentation layer and business logic, and data management. This is suggested in the Intelligent Transportation System platform [2], [5].

A. Backend Implementation

The backend development is performed using the Java Spring Framework. Java Spring Framework helps to develop robust and scalable enterprise web applications. Java Spring MVC handles the processing of the requests and responses in the case of the client, while Hibernate component to provide a structured way for developers to work with a MySQL database. The main business logic to generate and manage schedules, separating authentication of users, and configuration of system into dedicated service layer(s) to improve maintainability and provide to clean separation of concerns [4], [8].

In order to support secure access, Spring Security provides support for role-based access control (RBAC) to ensure that in persons who in the organization have specific role (administrators, drivers and conductors) to have access to the system. RESTful APIs give a way for the frontend and backend to communicate with each other and can be used to expand the platform in the future [5].

B. Hardware Implementation

To facilitate real-time location tracking of the bus, an IOT-based embedded hardware unit is installed in each vehicle. The hardware setup (ESP32 microcontroller, GPS) module for obtaining the geographical coordinates in real time, and GSM communication module to communicate with the centralized server connected with cellular network. The ESP32 is the central processing unit which interfaces using the GPS module to continuously acquire latitude and longitude information. The location data thus collected is periodically sent to backend server using GSM module via GSM utilizing lightweight data communications protocols. This setup ensures dependable real-time tracking even in environments where Wi-Fi There is no connectivity available. The hardware setup employed for the real time data acquisition and transmission is shown in Fig. 2.

C. Database Implementation

As relational database management system, MySQL will work best for this system due to its reliable performance and support for complex relational queries. The schema is designed in the User Credentials, Bus Details and Route Configurations Schedules and Tracking Logs The proper use of normalization techniques will help to get rid of data redundancy while at the same time upholding the integrity of stored data. The structure of the database is such that manner that it brings about a common place to store and retrieve reliable data from all the modules in the and efficiently from every module in the system [6].

D. Frontend Implementation

The Front-End Interface will be developed using the latest version of the internet programming language, the more recent version of html5 and CSS3, giving users a clean and easy to use and responsive User Experience. The UX will contain separate Dashboard for Administrators, Drivers and Conductors, and the appropriate functionality will be built into each Dashboard based on each user’s role. For example, Administrators will handle Buses, Routes and Schedules, while Drivers and Conductors will only be able to see their allocated Schedules and Routes. The Front End communicates with the Back End via the Help of the restful APIs to access real-time Schedule and Tracking data of Back End [4].

E. Deployment Environment

The application has been deployed on an Apache Tom- cat Server that has the Spring Framework Back End and processing Client Requests. The system can be deployed to Cloud Based environments like AWS and Digital Ocean with a higher degree of Scalability, High Availability and Ease of Maintenance. As well as the modularity of the system design enables easy integrations with other services, such as GPS Devices based on Internet of Things (IoT), mobile applications and Advanced Analytics [8].

Overall, the implementation does a good job of translating the proposed system architecture into a functional and reliable platform that can be used to automate the bus scheduling and optimize paths under real world operating conditions.

VII. RESULTS AND DISCUSSION

The Automated Scheduling and Route Optimization of Buses Platform was tested based on representative datasets designed to simulate the real world on public transportation scenarios. The evaluation concerned the assessment of the effectiveness

automated scheduling, routing optimization (GIS based) and hardware-based real time monitoring. Performance was analyzed according to scheduling efficiency, routes adaptability, tracking reliability, responsiveness of the systems and overall ease of use.

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A. Schedule Generation Results

The automated scheduling module was able to generate daily bus schedules by taking into consideration fleet availability, route constraints jacket, and predefined service time windows. Compared to manual scheduling methods - the system reduced significantly First, scheduling conflicts and administrative leftovers are a burden. Administrators were able to create and update schedules efficiently through the interface via the web, improving transparency of operation, A schedule output thus generated is shown in fig. 4, which showing routes- wise and time-wise allotment of buses.

The generated schedule output is illustrated in Fig. 4, which displays route-wise and time-wise allocation of buses.

B. Route Optimization and Monitoring Results

The GIS based route optimization module effectively identified efficient ways by analyzing spatial data and traffic-related parameters. The integration of IoT based hardware tracking units installed on buses allowed continuous real time monitoring of the movement of vehicles. GPS data collected

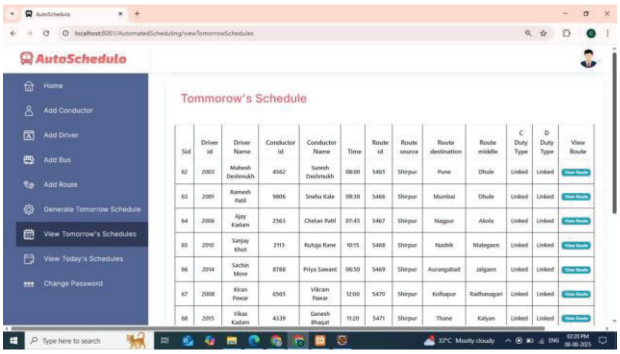

Fig. 4. Generated Bus Schedule Output

by the board hardware units were transmitted to the backend server through GSM networks and visualized on the administrative dashboard. The real-time tracking capability enabled administrators to timely identify delays, detouring routes and unexpected disruptions. Timely corrective Actions such as schedule adjustments or route reassignment, were done to minimize delay propagation in the network. This resulted in better reliability and punctuality of service consistent with recent research to do with GPS-enabled public transport monitoring systems [3], [8].

Fig. 5 illustrates the route visualization and live bus tracking functionality enabled by the hardware-based tracking system.

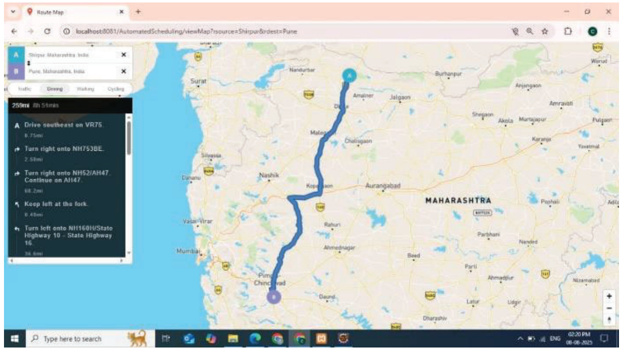

Fig. 5. Route Visualization and Real-Time Bus Tracking

C. Hardware Performance Analysis

The performance of the hardware-based tracking unit was evaluated in terms of consistency of location update, data transmission reliability, integration with backend system. The ESP32 based module acquired GPS coordinates and sent location updates periodically with little delay in communication. The GSM-based communication ensured stable data transmission in urban environment, including areas which have poor availability of Wi-Fi. The combination of hardware and software components demonstrated met reliable end-to-end data flow from buses to the centralized server. This real- time data improved considerably system responsiveness and supported informed decision not making during operational disruptions.

D. System Performance Analysis

Table III summarizes the comparative performance of the proposed system against traditional manual approaches.

TABLE III. Performance Comparison

Parameter	Manual System	Proposed System
Scheduling Time	High	Significantly Reduced
Scheduling Conflicts	Frequent	Minimal
Route Adaptability	Static	Dynamic (GIS-Based)
Real-Time Monitoring	Limited / None	Hardware-Based GPS Tracking
Operational Transparency	Low	High
Scalability	Limited	High

E. Discussion

From the experimental results, it can be shown that the proposed platform has a significantly improved operation efficiency comparison to traditional manual systems. Automated scheduling cuts back on administrative tasks and reduces hu- man error, while GIS-based route optimization makes travels more efficient and resource utilization. The inclusion of IoT- based hardware tracking allows continuous real-time tracking, improving operational visibility and enabling timely response to service, disruptions [1], [7].

These findings are in accordance with recent research in intelligent transportation systems, which emphasizes the importance of combining automation, GIS and real-time hardware- enabled data acquisition to enhance performance of public transport [1], [7]. The proposed system, overall, provides a practical, scalable, and reliable solutions to modern public bus transportation systems provides and lays solid foundation for smart city mobility applications of the future.

VIII. CONCLUSION AND FUTURE WORK

This paper presented an Automated Bus Scheduling and Route Optimization Platform aimed at addressing the limitations of traditional management of public transportation systems. Traditional bus scheduling approaches include a lot of static timetables, and manual planning, which is not adequate for processing dynamic traffic conditions in urban areas and fluctuating passenger demand. To overcome these challenges the suggested system combines automated scheduling, GIS-based route optimization, real time fleet monitoring within a web-based centralized platform. By using modern net technologies, Geographic Information Systems (GIS), real-time data processing, the platform enables operation efficiency and reduces scheduling conflicts, and uses the fleet overall bet- ter. The implementation of role-based access control ensures secure and structured interaction between the administrators, drivers, and conductors. Furthermore, the modular and layered system. architecture supports scalability and easy maintenance, making platform suitable for deploying in large scale urban transportation environments.

Experimental evaluation proved that the automated scheduling mechanism cuts down manual effort to a significant level while improving accuracy of schedule and punctuality. The integration of real time GPS based monitoring improve the operational transparency and facilitates early response of delays, route deviations, and unexpected interruptions. These outcomes test the effectiveness of the proposed platform in im- prove portraying service reliability and operational performance in public bus transportation systems, in consonance with recent advancements in the research on intelligent transportation systems

Future work will involve expanding the capabilities of the platform by having machine learning-based passenger demand forecasting models to allow proactive and adaptive scheduling. Integration of IoT enabled embedded tracking devices can further increase the accuracy of real-time monitoring. In addition, development of mobile applications for commuters can provide improved user engagement with live tracking, arrival predictions and service notifications. Future enhancements may also include integration with the multimodal transportation systems like metro, rail etc., real-time ticketing and digital payment systems, and advanced predictive analysis to enable smart city initiatives and sustainable urban mobility solutions.

REFERENCES

[1] Anandu, R., et al. “Automated Bus Scheduling and Travel Companion”, International Journal of Innovative Science and Research Technology, Vol. 6, No. 6, pp. 787–795, 2021.

[2] Wang, M., Guo, B., Zhang, Z., and Zhang, Y. “Research on Bus Scheduling Optimization Considering Exhaust Emission Based on Genetic Algorithm: Taking a Route in Nanjing City as an Example”, Applied Sciences, Vol. 14, Article 4126, 2024.

[3] Deng, S., He, Z., Zhong, J., and Xie, J. “Bus Rescheduling for Long- Term Benefits: An Integrated Model Focusing on Service Capability and Regularity”, Applied Sciences, Vol. 14, Article 1872, 2024.

[4] Jiang, M., Zhang, Y., and Zhang, Y. “A Branch-and-Price Algorithm for Large-Scale Multidepot Electric Bus Scheduling”, IEEE Transactions on Intelligent Transportation Systems, Vol. 24, pp. 15355–15368, 2023.

[5] Alamatsaz, K., Hussain, S., Lai, C., and Eicker, U. “Electric Bus Scheduling and Timetabling, Fast Charging Infrastructure Planning, and Their Impact on the Grid: A Review”, Energies, Vol. 15, Article 7919, 2022.

[6] Li, B., Chen, Y., Wei, W., Huang, S., and Zhang, M. “Resilient Restoration of Distribution Systems in Coordination with Electric Bus Scheduling”, IEEE Transactions on Smart Grid, Vol. 12, pp. 3314–3325, 2021.

[7] Ji, Y., Liu, B., Shen, Y., and Du, Y. “Scheduling Strategy for Transit Routes with Modular Autonomous Vehicles”, International Journal of Transportation Science and Technology, Vol. 10, pp. 121–135, 2021.

[8] J. S. P, J. D, B. Sandhiya, M. Vanathi and J. Karthika, ”Bus Tracking System using Mobile GPS Technology,” 2024 International Conference on Inventive Computation Technologies (ICICT), Lalitpur, Nepal, pp. 1811-1813, doi: 10.1109/ICICT60155.2024.10544750, 2024.