



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 14, Issue 8, August 2025

Trace: Automated Public Transport System for Enhanced Passenger Safety and Fare Management

Sruthy K G, Jitha K, Muhammed Hamdhan C P, Sayuj M P, Shahinsh P, Shijah P S

Assistant Professor, Department of Computer Science & Engineering, MEA Engineering College, Perinthalmanna,
Malappuram, Kerala, India

Assistant Professor, Department of Computer Science & Engineering, MEA Engineering College, Perinthalmanna,
Malappuram, Kerala, India

Department of Computer Science & Engineering, MEA Engineering College, Perinthalmanna, Malappuram,
Kerala, India

Department of Computer Science & Engineering, MEA Engineering College, Perinthalmanna, Malappuram,
Kerala, India

Department of Computer Science & Engineering, MEA Engineering College, Perinthalmanna, Malappuram,
Kerala, India

Department of Computer Science & Engineering, MEA Engineering College, Perinthalmanna, Malappuram,
Kerala, India

ABSTRACT: The 'Trace: Automated Public Transport System' deals with the issues of urban transit by improving the safety of passengers and the operational efficiency of transport. Key features include real-time GPS tracking, image-based passenger verification using YOLOv8, SOS alerts, and contactless fare management. It includes IR sensors, Raspberry Pi for data processing, and 4G/Wi-Fi for real-time communication with data stored on the cloud for monitoring and analytics. This solution promises better safety, lower operational costs, and a more streamlined transit experience, which would pave the way for smarter, more secure urban transport. Future advancements could include predictive analytics and user feedback for further improvements.

KEYWORD: Intelligent Transportation Systems, Passenger Safety, Predictive Analytics, Real-Time Monitoring, Dynamic Fare Management, Edge Computing, AI-Powered Predictive Maintenance, Augmented Reality (AR), Smart City Integration, Intermodal Transport Systems, Traffic Management, Mobile Application Development, Firebase Integration, Machine Learning, Public Transportation Optimization, Resource Allocation, Behavioral Analysis, Demand Forecasting, Emergency Response Systems, Urban Planning Analytics, YOLOv8.

I. INTRODUCTION

Public transportation networks, especially bus services, form the backbone for easy mobility in the urban environment by providing affordable, environmentally friendly, and accessible travel options for vast sections of the population. Yet, such networks are fraught with numerous problems of efficiency, safety, and fare. The current paper provides a novel new answer to modernizing and improving bus transportation through embedding advanced technological applications. This system aims at addressing the more fundamental issues which exist in bus transport systems today by automating processes, passenger safety, and fare management among others.

A. Background and Motivation

In this regard, public buses are linked with the problems of operational delay, fare inequity, and poor security features. The overall passenger satisfaction and the overall operating efficiency of the system degrade, making the mode of transportation unattractive. The motivation behind the development of the system is primarily to solve such problems by incorporating modern technological advancements, such as GPS, infrared sensors, and automated fare systems.

Through eliminating those inefficiencies, the system wants to promote wider use while working toward public transportation that is reliable.

B. Problem Statement

Current bus transportation systems do not offer real-time monitoring, automatic collection of fares, and proactive measures of safety that cause inefficiency and inconvenience for passengers. This results in erroneous collection of fare, delay in payment, as well as scarce safety measures at times of crisis, putting the lives of the passengers at stake. In this regard, the project recommends the development of an Automated Public Transport System. The system encompasses real-time monitoring, contactless payments, and advanced safety mechanisms to improve operational efficiency and passenger safety.

II. LITERATURE SURVEY

Rapid technology development in public transportation has led to a series of innovations to ensure passengers' safety and proper management of fares and streamlining of services. Various studies have focused on integrating IoT, GPS, RFID, machine learning, and many more into the public transport systems to deal with issues like real-time tracking, automated fare collection, and passenger safety. This paper reviews recent literature, highlighting methods, benefits, and shortcomings of current systems, and also revealing areas left to be tackled by the proposed system.

A. Automated Public Transport Systems: A Comparative Analysis

K. Bhaskar et al. (2024) [1] have designed a system that monitors school buses using GPS and ESP32 camera module along with accident detection and generation of emergency alerts. The system can be used for the safety of passengers through real-time monitoring; however, its proper maintenance depends on stable network connectivity.

Kanwarpratap Singh Gill et al. (2023) [2] developed an RFID and GPS-based fare collection system for IoT. This system offers cashless payments and facilitates easier accessibility for passengers with visual impairment. However, the reliance on RFID and GPS hardware increases implementation costs, which leads to scalability issues.

Malte Bieler et al. (2022) [3] carried out a survey of automated fare collection systems using machine learning and mobile applications to increase the efficiency of service. Such systems enhance user experience but involve high technological investment and substantial infrastructure.

Hoang R. Oktorini et al. (2020) [4] have discussed the incorporation of public transportation in Jakarta's smart city strategy in order to tackle traffic congestion and achieve efficient and sustainable urban mobility. However, the system comes with a cost of high initial investment and needs proper coordination with the existing infrastructure.

Kazi et al. (2018) [5] discussed an intelligent e-ticketing system for mass transit, incorporating cashless tickets and automated bookings, which enables automatic seat allocation, thus optimizing boarding times; however, dependence on uninterrupted connectivity makes it inconvenient to use across networks with insufficient connectivity.

Sunitha Nandhini et al. (2017) [6] have presented an RFID-based bus fare collection system that automates the payment process and manages real-time data efficiently. However, this system has several drawbacks in the form of RFID's limited range, environmental interference, and privacy concerns.

Hoang J. T. Raj and J. Sankar (2017) [7] designed a monitoring system for smart school buses, using IoT and RFID technology to monitor students in real-time to alert parents. In the real world, the robustness of the RFID technology and stable internet connectivity contribute to challenges.

A method proposed by Antonio A. Nunes et al. (2016) [8] in order to estimate passenger destinations, using spatial validation of AFC data, improves travel pattern analysis. The method requires complex data processing and depends on the availability of good-quality data.

Rafael Mart'inez-Pelaez' et al. (2015) [9] put forward a mobile ticketing system that incorporates machine learning to facilitate adaptable and reusable ticketing solutions. Although the system enables effortless fare collection, its associated costs and intricacies could dissuade users with limited tech-nological proficiency.

Hoang Dat Pham et al., (2013), [10] developed a vehicle tracking system that uses GPS and GSM to provide real-time location updates across the world. Even though it is economically feasible, a network coverage and inconsistent

GPS signal in certain areas have already brought its success into question.

This study focuses on the necessity of a well-planned system that integrates the strengths of various technologies while removing their drawbacks. The proposed system aims to overcome these disadvantages by providing a single plat-form that promises the safety of passengers, ensures proper fare collection, and enhances the overall reliability of public transportation services.

III. METHODOLOGY

The system improves bus operations and ensures the safety of passengers by incorporating modules that capture data from cameras, sensors, GPS, and fare devices; preprocess it with accuracy; and analyze it against machine learning models trained on historic datasets. Models detect anomalies, such as overcrowding or inconsistent fares, and flag incidents in real-time according to their seriousness for prioritized review.

A centralized dashboard allows administrators to monitor flagged events, operational metrics, and take preventive measures. Incident reviews' feedback is integrated into the models such that the system can constantly learn and adapt according to real-world conditions.

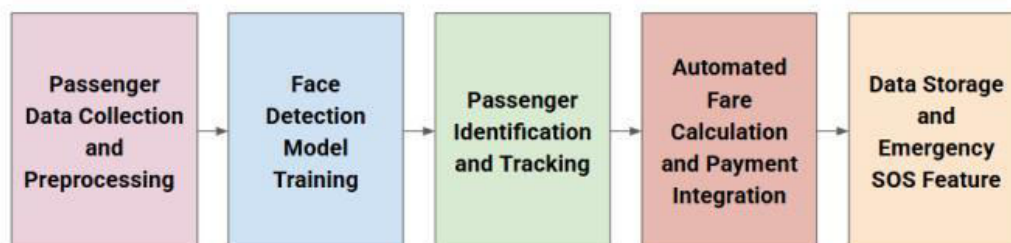


Fig. 1: Block Diagram for Trace

A. Passenger Data Collection and Preprocessing

Passenger data collection is the process of collecting images and location information for the purpose of forming a complete and diverse dataset. The images are normalized to keep them in the same range, thus ensuring uniformity regardless of the passengers involved. Each image has with it related location information for efficient tracking. All data are held securely in a well-arranged database so that it will be easily identified and computed and fares easily for access and for accuracy.

B. Face Detection Model Training

The YOLOv8 learns the face detection model on a labeled data set in order to accurately predict facial coordinates with low loss. To establish its effectiveness, the model is tested on the mean Average Precision (mAP) metric for ensuring its accuracy in face detection. It is exhaustively tested on an independent dataset before it is deployed for use to ascertain its accuracy and stability, and therefore its credibility for use.

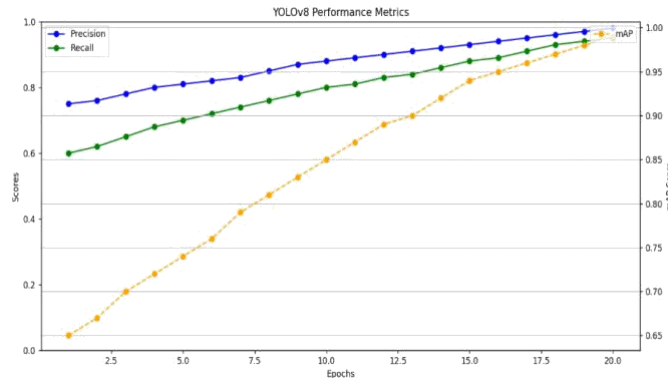


Fig. 2: YOLOv8 Performance Metrics

C. Passenger Tracking and Identification

Passenger tracking and identification are done in real-time with the help of an integrated system consisting of cameras and sensors. While boarding, their faces are scanned and uploaded into the database. At the same time, GPS sensors track their location and correlate it with the facial recognition data. The integration provides continuous monitoring, boosts security, and allows for easy running of the transportation system.

D. Automated Calculation and Payment Integration

Automated fare calculation increases transparency and pre-cision by calculating fares using real-time boarding and exit information. This removes human error and maintains a jus-tifiable price system. An admin panel provides a unified platform for monitoring in real-time, enabling administrators to observe incidents and oversee operations effectively. An approval/rejection workflow also supports utilizing admins to confirm suspicious incidents for increased system stability and passenger security.

E. Data Storage and Emergency SOS Feature

For security and data availability, passenger information, trip history, and fare records are stored securely in a cloud database. Effective monitoring, analysis, and maintaining proper records can be ensured due to this. Moreover, there is an in-built emergency SOS feature for enabling greater safety of passengers. For emergencies, an SOS alert may be initiated by the passengers that immediately sends out their location along with important information to the prescribed contacts and administrators, enabling quick assistance and increasing the safety factor while traveling.

IV. SYSTEM DESIGN

functionality and responsiveness to passenger needs while allowing for continuous improvement through data analysis insights.

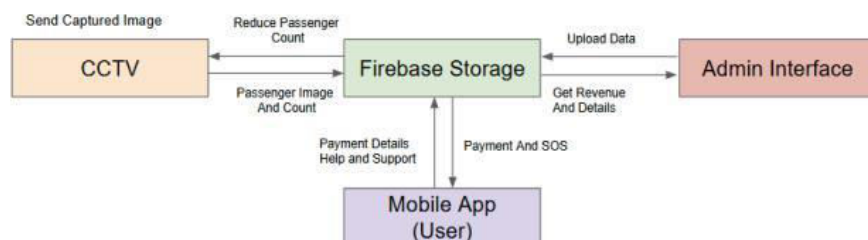


Fig. 3: System Diagram

The Intelligent Bus Transportation System underlines architectural frameworks that highlight the key elements that help in improving safety and managing fares. Real-Time Monitoring makes use of onboard cameras and sensors for monitoring passenger movement, emergency identification, and ensuring safety; meanwhile, Automated Fare Management assists in real-time fare collection with accuracy. A Mobile Application Interface gives the travelers direct access to real-time information about buses, alert services, and streamlined fare collection options. The Data Analytics Engine optimizes routes and maximizes overall efficiency for the system, whereas an Administrative Dashboard gives the authorities the power to monitor operations, analyze incidents, and manage the performance of the system efficiently. Altogether, all these parts come together to provide a safe and efficient public transport system.

A. CCTV System

The CCTV system is tasked with taking images of passengers and counting them. It keeps monitoring passenger movement and uploading the taken images to Firebase Storage for processing. Also, when a passenger leaves, the system up-dates Firebase Storage to decrease the number of passengers, providing real-time monitoring of occupancy.

B. Firebase Storage

The central component of the system is Firebase Storage, the central database and storage of the system where all the data collected is stored. It receives passenger images and count data from the CCTV system, verifies the payment details, and offers support and assistance functions. Apart from this, Firebase Storage transfers the revenue and passenger data to the admin panel so that all the data throughout the system is synchronized.

C. Mobile App (User Interface)

The Intelligent Bus Transportation System enhances the safety of passengers by the application of advanced sensor technologies, data analytics, and human-friendly interfaces in promoting engagement; it streamlines the management of fare collection through adoption of a comprehensive system that includes live surveillance, fully automated fare-collection mechanisms, as well as interaction through a mobile application. Every component is critical to ensuring effective

The mobile app is the primary interface for the passengers that offers multiple functionalities such as payment processing, assistance and support services, and SOS emergency notifications. It interacts with Firebase Storage to pick up payment information and offer real-time assistance to passengers. In times of emergencies, passengers can send an SOS alert, which immediately reaches Firebase Storage and is relayed to the concerned authorities or administrators for a prompt response.

D. Admin Interface

Admin interface provides system information to admins for observation and decision-making. It retrieves revenue and passenger information from Firebase Storage so that administrators can track fare collections and system performance. Admin interface also provides data uploads, which update the system and maintain it in its optimal condition.

E. System Workflow

The system efficiently monitors passengers, calculates fares, and ensures safety. When a passenger enters, the CCTV system captures his/her image and increments the Firebase Storage counter. The mobile app retrieves this data for fare computation and payment. Admins can see passenger details and earnings via the admin panel. When the user leaves, the CCTV system updates Firebase to decrement the counter. In case of emergencies, passengers can send an SOS alert, which is relayed to administrators for immediate action. This optimized process guarantees real-time monitoring, precise fare management, and improved safety.

V. IMPLEMENTATION

The Intelligent Bus Transportation System, at its core, combines state-of-the-art technologies that will ensure passengers' safety and proper management of fares and will provide real-time supervision. Such a system has been designed through the use of different modern frameworks and tools; for instance, Flutter for developing cross-platform applications, Firebase for safe storage of data and instant updates, and machine learning models directed toward anomaly detection. A critical part in the solution is its mobility via an application, an interface for administration, and a pipeline for data analytics, all working in concert to provide a comprehensive yet flexible solution. This chapter

describes techniques used in construction of the system; it covers application development, data integration, model training, and performance evaluation.

A. Flutter App Development

The reason for choosing Flutter was the cross-platform functionality, which would allow a single codebase to be served to both iOS and Android. User interface to the application is built using Flutter's widgets, therefore it would provide an adaptable design, irrespective of the varying screen dimensions. In terms of core functionalities, including live bus tracking, QR-based fare payments, and SOS emergencies in case an individual is a victim of the aforementioned, improved overall user experience. The libraries of tools and plugins in Flutter have made things really easy to add Firebase services related to real-time data and storing of data properly in a secured environment.

B. Firebase Storage Integration

Firebase Storage was used to store the data collected securely. All user and incident data, fare transaction logs, and captured images are sent to Firebase for real-time storage and retrieval. The Firebase real-time database was also used for rapid access to data. This is helpful in synchronized updates across devices. Firebase provides strong security features such as encryption of data and access management to ensure that sensitive data cannot be accessed by unauthorized people, thereby meeting the minimum security requirements.

C. Hardware Implementation

The Intelligent Bus Transportation System is built with a strong hardware infrastructure to support real-time tracking of passengers, security surveillance, and revenue collection. It employs an ESP32-CAM (OV2640) to take passenger images on detection, and an IR sensor to sense entry and exit activity. A GPS module (Neo 6M) offers real-time location, and a GSM module (SIM900) sends GPS coordinates and passenger data to Firebase for centralized monitoring. A USB-to-TTL converter also supports the programming of the ESP32-CAM for smooth operation. The integrated system improves public transportation efficiency, safety, and data-driven decision-making.

D. Admin Interface Development

The administrative interface was designed as a web application. This interface would provide an integrated platform for the monitoring and management of system activities. A framework like React or Angular would be used to design the dashboard, which would display real-time information about incidents reported, passenger movement, and performance metrics. The use of Firebase's real-time database would allow administrators to see the latest updates, thus enabling swift responses to incidents. Acceptance and rejection workflow in the administrative interface makes incident evaluation more efficient and allows operators to track flagged incidents and provide their feedback that can improve the detection model.

E. Data Collection and Preprocessing

Training data for the YOLOv8 model was collected using real images of passengers and coordinates. Preprocessing involved image normalization for consistency, resizing to the model's input dimension, and data augmentation to facilitate generalization. In addition, timestamp and GPS location meta-data were appended to the images to enable real-time tracking. The preprocessing made sure that the input data was high-quality, and this raised the accuracy and robustness of the model.

F. YOLOv8 Model Implementation

Real-time detection was performed by YOLOv8 due to its improved speed and high accuracy. Training for the detection and localization of faces of the onboard CCTV cameras was done to enable the identification and localization of the passengers. Face bounding box detection with low false positives was supported by robust object detection with YOLOv8. Integration with Firebase allowed real-time data processing so the model would operate smoothly within public transport.

G. Model Training

Training was done through a supervised learning approach in which YOLOv8 learned from labeled data sets that consisted of labeled facial images. Data was split into a training set (70%), a validation set (20%), and a test set (10%) to have optimal performance. During training, bounding box regression loss and the classification loss were optimized to increase the accuracy in face detection. Learning rate hyperparameters, batch size, and the confidence threshold were

also optimized to achieve improved performance. The obtained model was executed on cloud servers to provide the advantage of scalability and real-time processing.

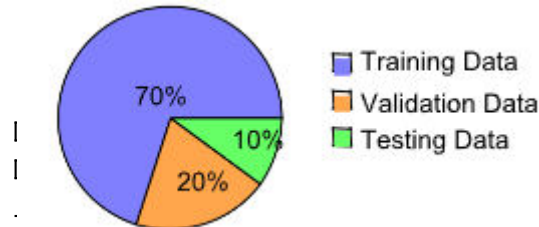


Fig. 4: Dataset Split for Model Training

H. Integration with Intelligent Bus Transportation System

The trained YOLOv8 model was incorporated into the Intelligent Bus Transportation System to improve passenger tracking and security. The ESP32-CAM module captures images of passengers, preprocessed and entered into the YOLOv8 model to detect faces. Upon detection, the system correlates it with an entry or exit event through an infrared sensor. The information is transmitted through the GSM module to Firebase, which is used to track in real-time, compute fares, and verify security.

VI. RESULTS AND DISCUSSION

Passenger Detection System is an essential element in implementing automated fare collection, passenger tracking, and security surveillance in smart transport. To evaluate its effectiveness, thorough testing under real operating conditions was conducted, measuring frame processing time and detection accuracy. The major aim was to validate that the system can run with high-speed processing, zero delays, and accurate passenger detection even in difficult operating conditions.

The performance of the Passenger Detection System was also validated with real measurements of processing time per frame and passenger detection accuracy. The system was aimed at delivering quick tracking of passengers, low delay in processing, and high accuracy of detection even in dynamic environments. Experiments were conducted under various conditions, including changing lighting conditions, multiple passengers, and occlusions, to test the robustness and responsiveness of the system. These tests provided valuable data about the ability of the system to recognize passengers properly, learn to adjust to changing conditions, and maintain uninterrupted real-time performance.

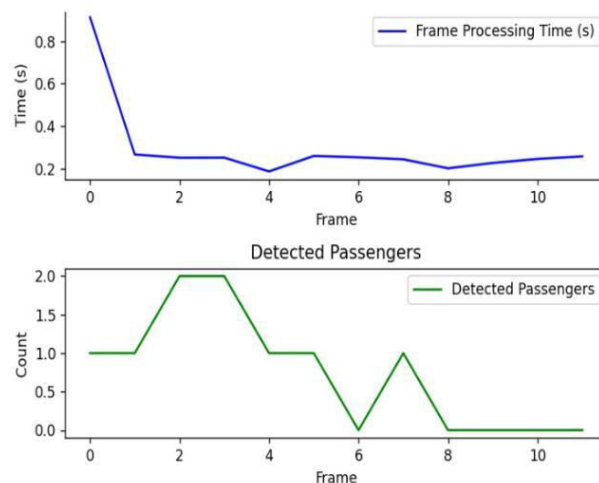


Fig. 5: Frame Processing Time and Passenger Detection

A. Frame Processing Time Analysis

The processing time of the frames varied between 0.2 and 0.8 seconds, averaging 0.3 to 0.4 seconds. The minimum processing times (0.2s) reflect an optimized system with fast processing of frames, whereas isolated spikes reflect computation complexity due to more than one face in a frame, occlusions, or system load variation. These fluctuations, although evident, are within acceptable limits, enabling real-time performance without considerable delay. The consistency of processing time is vital for smooth integration into transportation systems, where fast and precise detection is required for automated fare collection and security surveillance.

1) Passenger Detection Performance: The system successfully captures passenger movement, with the number of detected passengers oscillating between 0 and 2, precisely increasing as the passengers board and reducing when they alight. The tracking process exhibits real-time flexibility, providing consistent detection and logging of people. Minor inconsistency was, however, noted in some frames (e.g., frames 3 and 7), where detection accuracy varied. These inconsistencies are likely to be caused by occlusions, fast motion, or varying light, and can affect facial recognition performance in the short term.

The Passenger Detection System performs reasonably in real-time applications, maintaining an acceptable trade-off between detection precision and speed of processing. Although some variations in processing time and detection accuracy were observed, they are within acceptable limits. High system responsiveness renders it an ideal candidate for intelligent transportation systems, where automated passenger identification, fare calculation, and security monitoring are crucial. Further refinements in occlusion handling and lighting adjustments can enhance the robustness of the detection process, with even greater accuracy and reliability.

VII. FUTURE DIRECTION

Future developments of the Intelligent Bus Transportation System stress improvements in passenger safety, operational efficiency, and user satisfaction by advanced features and technologies. Planned augmentations are in the lines of predictive analytics in demand forecasting, AI-based safety mechanisms, personalized travel recommendations, and adaptive fare management. Among the advancements to be directed towards enhancing the system's responsiveness and usability include the incorporation of edge computing for real-time processing, AI-based predictive maintenance, and navigation through augmented reality. Integration into a comprehensive intermodal transport network, traffic management system, and urban infrastructures will allow fluid transit as well as data-informed city planning under dynamic circumstances that will thrive on the scalability of growth.

VIII. CONCLUSION

Altogether, the Intelligent Bus Transportation System represents an innovative approach to improve safety and efficiency in public transport through effective integration of advanced technology along with a solid ethical base. Success up to this point, along with a defined outline for future enhancements, make this paper a valid and visionary solution within the realm of public transport. Therefore, the Intelligent Bus Transportation System shall grow in tandem with technological advancements and societal needs to ensure a safer, more efficient journey for all by focusing on user trust, continuous improvement, and ethical considerations.

REFERENCES

- [1] K. Bhaskar, G. Sandeep, G. S. Srinivas, D. Keerthana, and D. Tejaswi, "A smart system for school bus accident detection and gps tracking," in 2024 International Conference on Emerging Systems and Intelligent Computing (ESIC), 2024, pp. 355–359.
- [2] K. S. Gill, A. Sharma, V. Anand, and S. Gupta, "Automated fare collection system for public transport using intelligent iot based system," in 2023 International Conference on Artificial Intelligence and Knowledge Discovery in Concurrent Engineering (ICECONF), 2023, pp. 1–7.
- [3] M. Bieler, A. Skretting, P. Budinger, and T.-M. Grønli, "Survey of automated fare collection solutions in public transportation," IEEE Transactions on Intelligent Transportation Systems, vol. 23, no. 9, pp. 14 248–14 266, 2022.
- [4] H. R. Oktorini and Others, "Integration of public transport in jakarta smart transportation system," in 2020 International Conference on Smart City and Emerging Technology (ICSCET), 2020, pp. 123–128.

- [5] H. S. Kazi and Others, "Smart e-ticketing system for public transport bus," in 2018 International Conference on Smart Technologies in Data Science and Communication (SmartData), 2018, pp. 1–5.
- [6] S. Nandhini and Others, "Automatic bus fare collection system using rfid," in 2017 International Conference on Advanced Communication Control and Computing Technologies (ICACCCT), 2017, pp. 1–5.
- [7] J. T. Raj and J. Sankar, "Iot based smart school bus monitoring and notification system," in 2017 IEEE Region 10 Humanitarian Technology Conference (R10-HTC), 2017, pp. 89–92.
- [8] A. A. Nunes, T. Galvao~ Dias, and J. Falcao~ e Cunha, "Passenger journey destination estimation from automated fare collection system data using spatial validation," IEEE Transactions on Intelligent Transportation Systems, vol. 17, no. 1, pp. 133–142, 2016.
- [9] R. Mart´mez-Pelaez, P. Romero-Navarro, A. Garc´ia-Molina, and J. Ruiz, "A flexible mobile ticket for intelligent public transportation," in 2015 12th International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE), 2015, pp. 1–6.
- [10] H. D. Pham, M. Driberg, and C. C. Nguyen, "Development of vehicle tracking system using gps and gsm modem," in 2013 IEEE Conference on Open Systems (ICOS), 2013, pp. 89–94.



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details