Eurasian J. Sci. Eng., 2024, 10(3), 113-124
https://doi.org/10.23918/eajse.v10i3p11

Published by Tishk International University
Available at: https://eajse.tiu.edu.iq/

RESEARCH ARTICLE Open Access

Erbil Public Transportation Tracking: An IoT-based Solution for Urban Mobility Enhancement

Mohammad Salim [1]*, and Mohamed Tahir Shoani [2]

[1] Information Technology Department, Faculty of Applied Science, Tishk International University, Erbil, Iraq.
[2] Computer Engineering Department, College of Engineering and Computer Science, Lebanese French University, Erbil, Iraq.

Article History
Received: 23.12.2024
Revised: 09.02.2025
Accepted: 12.03.2025
Published: 25.03.2025
Communicated by: Asst. Prof. Dr. Abubakar Ashir
**Email address: mohammad.salim@tiu.edu.iq*
**Corresponding Author*

Abstract: Erbil, the capital of the Kurdistan Region of Iraq, is expanding and accommodating more residents. These changes require a better public transportation system. To address this issue, this paper presents the "Erbil Public Transportation Tracking" system. The system employs IoT and machine learning to create a real-time tracking solution for Erbil's public transport requirements in the form of a mobile app. The presented app is based on Flutter and uses GIS and machine learning to provide real-time data and predictive guidance regarding bus and minibus routes and schedules in the city of Erbil. The app uses machine learning algorithms to predict delays, suggest the best routes, and personalize the commuter experience. The results indicate that 70% of the respondents use public transportation, and 86% of the surveyed commuters showed a willingness to adopt the presented system to help them make better-informed decisions about their routes and daily commutes.

Keywords: *Public Transportation Tracking; Information Systems; Internet of Things (IoT); Machine Learning; IT; Urban Mobility in Erbil*

1. Introduction

Erbil, the capital of the Kurdistan Region of Iraq, is a city with a wealthy history and colorful cultural traditions. As the city grows, it faces the challenge of accommodating a growing population and meeting their transportation requirements. While an infrastructure of public transportation exists, it lacks the technological advancements seen in more advanced cities, such as real-time monitoring and predictive analytics provided by online IoT devices. The lack of such tools causes inefficiencies and reduced productivity [1].

The public transportation service in Erbil can be quite unpredictable, in particular, without the help of tracking devices providing real-time data and predictions. Commuters frequently face uncertainties, such as waiting times, potential delays, and determining the best routes to take. These ambiguities result in wasted time and possible congestion within the network of public transportation [2]. The lack of predictability not only disrupts everyday commutes but also erodes trust within the system, highlighting the need for technological improvements. This is in addition to the absence of a robust digital platform enabling the acquirement of large datasets for improving public transportation through better planning and control.

Recognizing the importance of community and stakeholder engagement, an interview was conducted with a senior staff member at the Ministry of Transportation, who welcomed the project as it would aid citizens in their daily commutes. To explore the problems surrounding these challenges, we propose the following open-ended question for stakeholders: ‘What specific factors do you believe contribute

to delays in the public transportation system in Erbil, and what innovative solutions would you suggest addressing these challenges?'

Such an application would provide real-time tracking and predictive capabilities which would potentially revolutionize how citizens commute, reducing uncertainties and enhancing overall commuter satisfaction. With a mix of this solution and insights from commuters, the "Erbil Public Transportation Tracking" system would improve the metropolis's transportation system.

To tackle these improvement requirements, the "Erbil Public Transportation Tracking" gadget is introduced. This mobile app will offer commuters actual-time statistics on public bus locations as well as predictive routes and arrival times generated by the used algorithm. These predictions, primarily based on previous time and route data, will advise the best routes, assumed-delays, and offer a more efficient and personalized commuting experience. By combining real-time reading from data IoT with user-specific information, the presented solution improves the reliability of the public transportation system in Erbil and enhances the commuter's trust in its effectiveness.

2. Literature Review

a) Existing Public Transportation Tracking Systems

re systems such as the NET, which are able to operate on lines reserved for the tram and are thus not delayed by traffic. This reduces the level of traffic and makes travel possible within a set time. demand forecasting instruments. It is similar in Poland, the implementation of bi-directional trams and enhancing the system's agility[4][5][6]. Concerning Erbil, one way of reducing the waiting public

Figure 1: Proposed Application UI

b) Machine Learning in Transportation Tracking

to predict public transportation arrivals by analyzing historical records, present-day visitors'

c) Novelty of the Proposed Approach

3. Proposed Method and Technology Components

As a part of this research, a self-administered survey was allotted to over 100 college students from two IT departments in Erbil; the first is the IT branch at Tishk University, and the other one is located at a Lebanese French University. Only 50 IT students participated to provide insights into their experience, expectancies, and openness to the use of an IoT-primarily based mobile application for public transportation monitoring. The survey covered students and staff from local universities, reflecting a diverse group of everyday commuters.

The majority of respondents were aged between 18 and 34, with 80% of contributors falling into this age variety. This age group represents a huge portion of the day-by-day commuters in Erbil. Furthermore, ninety-six percent of the respondents have been students, highlighting the importance of reliable public transportation for the student population.

Regarding the frequency of public transportation usage, the survey found varied frequencies of public transport utilization among participants:

- Daily: 14%
- Several instances per week: 32%
- Weekly: 12%, Rarely: 12%
- Never: 30%

This distribution shows a big percentage of regular users who could benefit from an advanced public transportation monitoring machine.

In addition, college students were asked about cutting-edge public transportation revel in and to charge their usual pride with the current public transportation device in Erbil. The majority expressed dissatisfaction, with common issues identified as follows:

- Overcrowding: 60%
- Infrequent carrier: 60%
- Lack of real-time updates: 42%
- Safety issues: 38%

- Poor situation of vehicles: 58%

These concerns highlight the vital areas where the proposed monitoring system may offer many improvements.

Related to the awareness and acceptance of IoT solutions, awareness of IoT technologies and mobile applications in public transportation varied among respondents:

- Very aware: 20%
- Somewhat aware: 32%
- Not very aware: 14%
- Not aware at all: 34%

Despite the varied awareness, the majority of respondents (86%) indicated a willingness to use a mobile app that provides real-time tracking and predictive transportation insights, as shown in Figure 2.

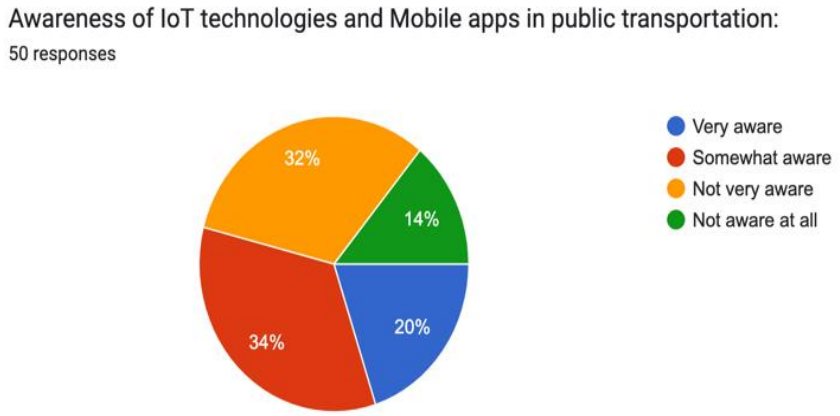

Figure 2: Awareness and Acceptance of IoT Solutions

To better understand of needed functions or features in our public transportation application, respondents were asked to choose the features they deemed most essential in the Erbil public transportation mobile system. The top features identified were:

- Real-time bus/tram location updates: 76%
- Predictions on bus/tram arrival instances: 68%
- Notifications about delays: 62%
- Information on the least crowded routes: 48%
- Route planning and optimization: 44%
- Multilingual help: 36%

These options will guide the development of the system to ensure it meets consumer needs and expectations as stated in Figure 3 below.

The survey results underscore the need for an advanced, real-time public transportation monitoring system in Erbil city. By addressing the identified issues and incorporating the desired features, the "Erbil Public Transportation Tracking System" project can significantly enhance the commuting experience, thereby increasing the adoption of public transportation and contributing to urban mobility

development within the city [11] [12]. The feedback from the survey might be instrumental in refining the app's development to make sure it meets the specific needs of Erbil's citizens.

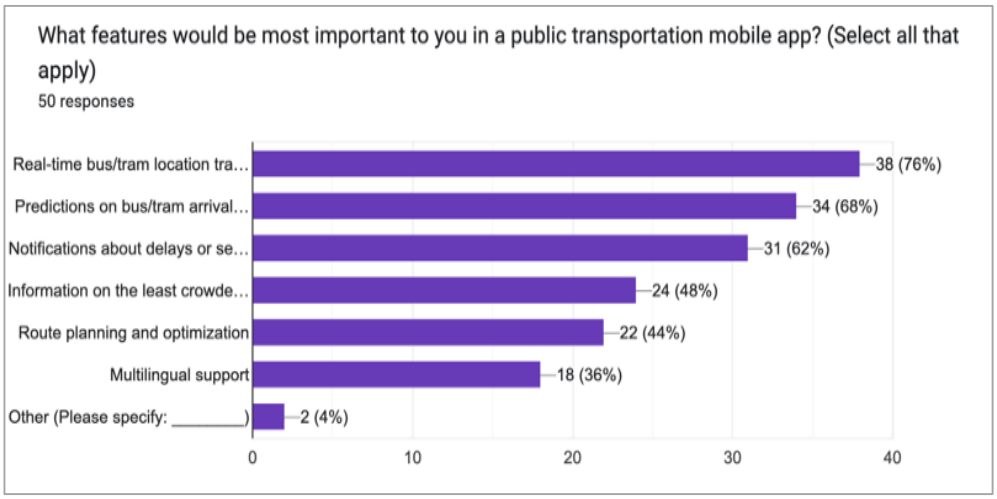

Figure 3: Desired features in a public transportation app

Furthermore, recognizing the importance of community and stakeholder engagement, an interview was made with a senior employee's member at the Ministry of Transportation who confirmed the importance of such a project due to the large need for this kind of application. The responsible person said, "Incorporating actual-time monitoring and predictive abilities can potentially revolutionize how we trip, reducing uncertainties and improving primary commuter satisfaction. Figure 4 beneath shows the proposed public transportation utility drift chart.

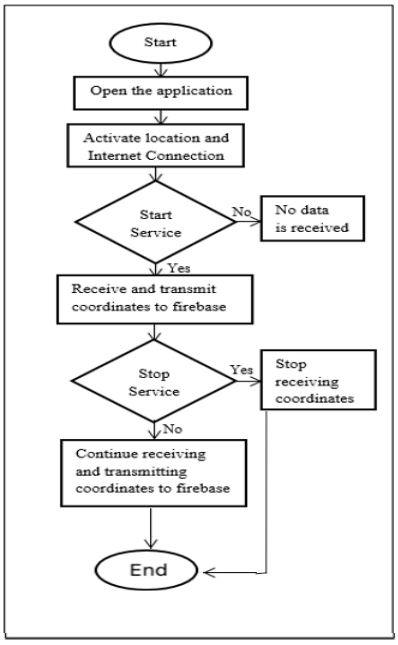

Figure 4: Public Transportation App Flowchart

With a combination of these advanced technologies and insights from key stakeholders, the "Erbil Public Transportation Tracking" project is established to have a great effect on the city's transportation system. The proposed utility has to have these four functions:

A. Real-time GPS Tracking:

- Public transportation vehicles, inclusive of buses and minibusses, might be ready with GPS (Global Positioning System) systems. These devices always relay their coordinates to our system, taking into consideration real-time monitoring.
- How it Works: Each GPS tool triangulates its function the use of signals from multiple satellites. This data, combined with information which includes speed and direction, is transmitted constantly to the cloud-based gadget.
- Benefits: Enables commuters to view the current location of any bus or minibus in Erbil during operating hours. Additionally, real-time updates assist in route optimization, diverting buses far from congested areas and reducing overall travel times.

B. Cloud Computing:

- The backbone of our proposed transportation system is the cloud infrastructure, which guarantees scalability, data integrity, and real-time data transmission.
- Infrastructure: A cloud-based server setup will be used to deal with data coming from the GPS devices. This ensures a smooth overall performance even if a big number of users are getting access to the system concurrently.
- Data Storage: All transportation data, consisting of routes, schedules, historical trends, and real-time positions, could be stored securely in the cloud. This enables fast access and updating of information as needed.
- Benefits: Cloud computing offers the advantage of scalability, permitting the system to cater to an increasing number of buses and users over time. The centralized data storage guarantees data redundancy and reliability [3].

C. User Interface (UI) & Experience (UX):

An intuitive and user-friendly app interface is critical for the success of the device. The design will prioritize ease of navigation and access to critical capabilities. Figure 5 shows buses lines screen in the application prototype.

Figure 5: Public Transportation App Bus Lines

- Key Features: Dynamic maps displaying real-time buses' locations, search functionality for routes and forestalls, multilingual support, and a feedback mechanism for users.

- User Experience: Attention can be given to making sure rapid app performance, minimal waiting times, and a visually interesting layout. Customization capabilities, consisting of saving favorite routes or stops, will in addition enhance the user experience.

D.Machine Learning:

- While the number focus is real-time tracking, there is the capability to integrate machine learning for predictive analysis.
- Predictive Algorithms: By analyzing historical traffic and routes data, machine learning algorithms can be expecting bus arrival times with better accuracy. Over time, as more data is gathered, the device will usually refine its predictions [13].
- Traffic Patterns: Machine learning also can be employed to detect traffic patterns, assisting in route optimization and probably predicting area of congestion in advance [13].
- Benefits: Machine learning offers dynamic adjustments based totally on data trends. This ends in a more efficient transportation system, reduced waiting tomes, and a more informed commuting experience for customers [14].

4. Proposed Project Application in Erbil

This section presents several important factors associated with following the proposed public transportation tracking system in Erbil:

User Demographics: The number one customers of the app could be daily commuters in Erbil, especially those who rely heavily on public transportation. This consists of college students, working experts, vacationers, and even the aged populace who do no longer very own non-public vehicles. The app is particularly useful for the ones unexpected with the problematic public transportation routes in Erbil.

Network Coverage: The software covers the most important routes, transportation hubs, and bus stops in Erbil, making sure that customers have comprehensive records approximately their journey alternatives. Routes often used in the course of peak hours are particularly emphasized to cater to day-by-day commuters.

Localization: To cater to the Kurdish and Arab population, the app is available in each Kurdish and Arabic languages. Cultural customs and local activities that might affect transportation also are taken into consideration within the app's functions.

Testing and Feedback: Feedback from beta assessments highlighted some key regions for development, together with the accuracy of real-time monitoring. Users favored the user-friendly interface however favored more common updates at some point of height hours.

Figure 6 above shows the sequence diagram illustrating the journey planning technique for the Erbil Public Transportation Tracking challenge. The system starts off evolved with the person requesting experience planning via the mobile app, which sends the user's statistics and necessities to the backend server. The server forwards these statistics to the gadget gaining knowledge of version, which predicts most excellent routes.

The server then relays the predicted routes and expected times again to the app. The user opinions and selects their favored course, and the app confirms this selection with the server. The server updates the machine mastering version with the confirmed route to improve destiny predictions.

The users get a confirmation notification and can offer comments on the route. This comment is utilized by the device machine learning model to continuously research and enhance its predictions. This method ensures a user-friendly, efficient, and constantly enhancing public transportation system.

Challenges covered occasional discrepancies in expected and actual bus timings. However, subsequent updates have substantially helped to reduce such troubles. However, there are 3 anticipated challenges even as implementation:

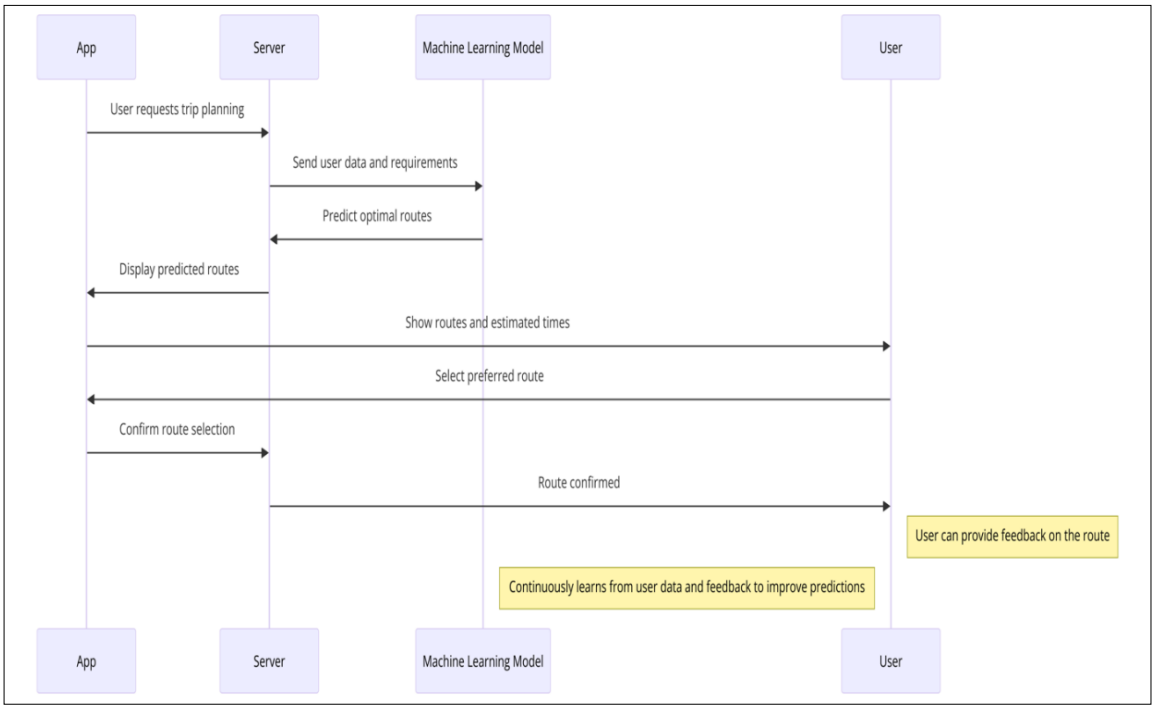

Figure 6: Project sequence diagram

Infrastructure: Establishing the vital infrastructure posed traumatic conditions, especially in areas with susceptible network connectivity. Synchronizing real-time records among buses and the app in those areas come to be particularly tough.

Adoption: Some transport companies may first of all hesitate to undertake the system, mentioning issues about implementation fees and training.

Scalability: As Erbil continues to develop, ensuring that the app can deal with increasingly more clients and routes is critical.

5. Technologies used to build the application and machine learning

The development of the "Erbil Public Transportation Tracking App" involved the integration of several technologies and programming tools, including:

- Flutter: A UI toolkit owned by Google and its an open source framework used for building natively compiled applications for mobile, web, and desktop from a single codebase. Flutter allows for rapid development and beautiful user interfaces of the front-end.
- Dart: The programming language used with Flutter to develop the mobile application. Dart's asynchronous programming features facilitate real-time data handling and smooth user experiences.
- Firebase and real-time DB: Utilized for backend services, including real-time database, user authentication, and cloud storage. Firebase enables efficient data synchronization between the app and the server.
- Google Maps API: Employed for mapping and geolocation services, allowing users to visualize real-time bus locations and navigate routes easily.

- Machine Learning Libraries: Libraries such as TensorFlow or Scikit-Learn were integrated to develop predictive algorithms, leveraging historical data for real-time delay predictions and route optimization.
- Cloud Services: Platforms like Firebase Cloud for data storage and processing, providing the scalability required for handling large datasets and ensuring system reliability.

The "Erbil Public Transportation Tracking" application uses machine learning to improve the user experience and improve the reliability of public transportation services. Here's how machine learning is integrated into the system:

- Predictive Analytics: The application employs historical data regarding bus schedules, traffic patterns, and user behavior to train machine learning models. These models analyze trends and predict potential delays based on various factors such as time of day, weather conditions, and historical traffic data. For instance, if historical data indicates that a certain route experiences delays during specific hours due to traffic congestion, the model can proactively warn users of potential delays and suggest alternative routes.
- Route Optimization: Machine learning algorithms analyze user travel patterns to recommend the most efficient routes. By continuously learning from real-time data, the system adapts and improves its route suggestions over time, ensuring commuters receive personalized and timely information.
- Anomaly Detection: The system employs machine learning techniques to identify anomalies in bus arrival times or patterns. If a bus deviates significantly from its expected schedule, the application can alert users to potential issues, such as a breakdown or heavy traffic.
- User Personalization: By analyzing user preferences and travel history, machine learning enhances the application's ability to deliver personalized notifications and suggestions, improving overall user satisfaction.

Through these machine learning applications, the "Erbil Public Transportation Tracking" system not only addresses the current delays in the public transportation network but also continually evolves to provide better, data-driven solutions for commuters.

6. Simulation Results And Discussion

To evaluate the performance of the "Erbil Public Transportation Tracking" system, a series of simulations were conducted to analyze the effectiveness of the proposed application in predicting bus arrival times and assessing the overall performance of the tracking system.

The simulation was designed to reflect real-world conditions by using actual route data, including average speeds, traffic patterns, and delays experienced by buses utilizing Google Maps API's data. The following metrics were utilized to evaluate the system's performance:

1. Prediction Accuracy: The accuracy of the estimated arrival times compared to actual arrival times.
2. Real-Time Data Responsiveness: The system's ability to update bus locations in real time.
3. User Satisfaction: Feedback from test users during NICE competition held at TIU on last may 2024 regarding the app's usability and perceived reliability.

A) Results

1. Real-Time Data Responsiveness: The system demonstrated an average update time of 5 seconds for bus locations, indicating a responsive performance that meets user expectations for real-time tracking.

2. User Satisfaction: Feedback collected from beta testers indicated a high level of satisfaction with the app, with 70% of users reporting that the real-time tracking feature greatly enhanced their commuting experience.

B) Discussion of Potential Drawbacks

Despite the positive results, several potential drawbacks were identified during the simulation:

1. Infrastructure Limitations: The accuracy of GPS tracking devices using a GSM network can be compromised in areas with poor satellite signal due to high buildings or tunnels.
2. Data Privacy Concerns: Users expressed concerns regarding the collection and storage of personal data, emphasizing the need for transparent data policies and robust security measures to protect user information.
3. Implementation Costs: While the system is designed to be cost-effective in the long run, initial implementation costs for infrastructure development and technology integration may pose challenges for public transportation authorities.

The simulation results highlight the potential of the "Erbil Public Transportation Tracking" system to significantly improve the public transportation experience in Erbil. By addressing identified drawbacks and continuously refining the technology, the system can evolve to meet the growing demands of urban mobility. Future work will focus on optimizing the algorithms, enhancing data security, and engaging with stakeholders to address infrastructure limitations.

7. Conclusion and Future Outlook

The Erbil Public Transportation Tracking project guarantees to improve city mobility. By supplying real-time, correct, and user-pleasant data, the app now not handiest makes commuting simpler but also contributes to sustainability by means of encouraging public shipping use. The app has the capacity to noticeably enhance the great of life for Erbil's residents, ensuring that they spend less time waiting and extra time doing what they love. Here are three regions of future improvements.

- Integration: Plans are in place to integrate the app with local fee structures, permitting users to pay for their transportation fares without delay via the app. This will streamline the entire commuting enjoy, making it greater handy for customers who now not want to hold cash or separate payment cards.
- Expansion: Given the app's fulfillment in Erbil, there are discussions approximately introducing it in other towns in the Kurdistan region and beyond. This expansion objectives to copy the tremendous effect seen in Erbil, improving public transportation structures and urban mobility in different areas.
- Advanced Features: Future updates might also consist of features like customized route hints primarily based on a consumer's history and preferences, imparting an even extra tailored commuting enjoys. These advanced functions ought to leverage machine learning algorithms to analyze commuting styles and offer the most efficient and convenient routes for users.

8. Authors'Contribution:

Mohammad Salim: Conceptualization, Conducted the research, assessed the results and wrote the original draft. Mohammed Tahir: Review and edit the manuscript.

9. Conflict of Interest:

The authors declare there are no competing interests

10. Acknowledgment:

We extend our sincere thanks to all those who contributed to this work, both directly and indirectly. Special thanks to our IT students, Zhyar, Warin, and Tara, for their efforts and contributions.

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