

Development and Implementation of a Mobile Application for Real-Time Geolocation for University Transportation Management

Desarrollo e implementación de una aplicación móvil para geolocalización en tiempo real para la gestión del transporte universitario

Desenvolvimento e implementação de um aplicativo móvel para geolocalização em tempo real para gestão de transporte universitário

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Abstract

Introduction: this article is a product of the research "Development of a geolocation and seat availability system for the integrated mobility system of the University of Pamplona through a mobile application", developed at the University of Pamplona in 2024.

Objective: The research focuses on optimizing mobility, improving the user experience and ensuring real-time data-driven decision-making through the design, development, and implementation of a mobile application.

Method: Four stages are defined: identification, which is carried out through requirements analysis; selection with the use of development tools; development, which establishes the system design; and finally, validation, which verifies the process and its corresponding field validation.

Results: The final product is the integration of advanced tools such as Flutter, Firebase, and OpenStreetMap into an application that offers features such as real-time bus tracking, seat availability monitoring, and route management.

Conclusions: Finally, it is concluded that it is possible to build an efficient, scalable, and user-centered solution by addressing suggestions during the mobile application development process, using functional and usability testing to meet the requirements according to software evaluation standards and models.

Keywords: Geolocation, development, mobile application, transportation management, implementation.

Resumen

Introducción: Este artículo es producto de la investigación "Desarrollo de un sistema de geolocalización y disponibilidad de asientos para el sistema integrado de movilidad de la universidad de Pamplona por medio de una aplicación móvil", desarrollado en la Universidad de Pamplona en 2024.

Objetivo: La investigación se enfoca en optimizar la movilidad, mejorar la experiencia del usuario y asegurar una toma de decisiones basada en datos en tiempo real por medio del diseño, desarrollo e implementación de una aplicación móvil.

Método: Se definen cuatro etapas: identificación, se realiza mediante el análisis de requerimientos; la selección, con el uso de las herramientas de desarrollo; el desarrollo, que es donde se establece el diseño del sistema y finalmente, la validación, que es la verificación del proceso y su correspondiente validación en campo.

Resultados: El producto final es la integración de herramientas avanzadas como Flutter, Firebase, OpenStreetMap, en una aplicación que ofrece funcionalidades como seguimiento de buses en tiempo real, monitoreo de disponibilidad de asientos y gestión de rutas.

Conclusiones: Finalmente se infiere que es posible construir una solución eficiente, escalable y centrada en el usuario, atendiendo las sugerencias en el proceso del desarrollo de la aplicación móvil, por medio de pruebas funcionales y de usabilidad para cumplir con los requisitos de acuerdo a los estándares y modelos de evaluación de software.

Palabras clave: geolocalización, desarrollo, aplicación móvil, gestión de transporte, implementación.

Resumo

Introdução: Este artigo é produto do projeto de pesquisa "Desenvolvimento de um sistema de geolocalização e disponibilidade de assentos para o sistema integrado de mobilidade da Universidade de Pamplona por meio de um aplicativo móvel", realizado na Universidade de Pamplona em 2024.

Objetivo: A pesquisa concentra-se na otimização da mobilidade, na melhoria da experiência do usuário e na garantia da tomada de decisões em tempo real baseada em dados, por meio do projeto, desenvolvimento e implementação de um aplicativo móvel.

Método: Quatro etapas são definidas: identificação, realizada por meio da análise de requisitos; seleção, utilizando ferramentas de desenvolvimento; desenvolvimento, onde o projeto do sistema é estabelecido; e, finalmente, validação, que consiste na verificação do processo e sua respectiva validação em campo.

Resultados: O produto final é a integração de ferramentas avançadas como Flutter, Firebase e OpenStreetMap em um aplicativo que oferece funcionalidades como rastreamento de ônibus em tempo real, monitoramento da disponibilidade de assentos e gerenciamento de rotas.

Conclusões: Em conclusão, pode-se inferir que é possível construir uma solução eficiente, escalável e centrada no usuário, abordando as sugestões feitas durante o processo de desenvolvimento do aplicativo móvel, por meio de testes funcionais e de usabilidade, para atender aos requisitos de acordo com os padrões e modelos de avaliação de software.

Palavras-chave: geolocalização, desenvolvimento, aplicativo móvel, gestão de transporte, implementação.

1. INTRODUCTION

Mobility is a daily component for members of a university community, ensuring an efficient, reliable, accessible, and convenient transportation system. This research presents the design and development of the SIMUP mobile application, created to meet these needs by integrating real-time geolocation technologies and cloud services. The profiles of administrators, drivers, and students are included.

Urban mobility, understood as the way citizens move, is part of their social development and a growth factor that contributes sustainably to a good quality of life. Its impact on university environments is significant, according to a study by de [1]. They highlight the impact of smart systems and devices designed to optimize the operation, safety, monitoring, and experience of urban public transportation. Recent studies [2] have shown that the use of mobile applications as assistive technologies can significantly improve efficiency, safety, and the user experience.

When adopting mobile technologies, four determining factors must be considered: perceived usefulness, location accuracy, ease of use, and direct benefits to the mobility experience, as described by [3]. Applying these principles to the case study demonstrates a good practice aimed at modernizing university transportation systems through digital solutions.

This is where the application makes sense as an engineering response to a daily university problem, as a mobile application aimed at improving university mobility through advanced functions such as real-time bus geolocation, dynamic capacity control, and digital validation of access credentials according to user type. This proposal aligns with the vision of sustainability and efficiency proposed by [4], by reducing the inefficient use of resources, time, and travel so that the end user has accurate and timely information [1].

Implementing this type of system indirectly contributes to the Sustainable Development Goals (SDGs), particularly those related to sustainable cities (SDG 11) and responsible consumption (SDG 12). Its implementation not only modernizes the university transportation system but also positions the institution as a benchmark in technological innovation aimed at collective well-being and environmental responsibility [5].

2. RELATED WORK

The intelligent transportation system has been marked by the simultaneous advancement of communication technologies, digital platforms, and user-oriented solutions. In this case, [2] conducted a comprehensive review of the fundamental components of transportation management, focusing on the efficient use of parking space, the implementation of safety measures, and traffic optimization. Their analysis highlights the importance of connectivity protocols such as Wi-Fi, Bluetooth, and cellular networks to facilitate real-time data exchange between different infrastructures, vehicles, and users, all focused on the real needs of users.

Regarding on-demand mobility models, [3] propose a strategic approach that promotes operational efficiency and the expansion of transportation options through public-private partnerships. Their contributions include solutions for last-mile mobility and inclusive proposals for people with disabilities within a single platform, improving accessibility and trip personalization.

From an applied perspective, [4] developed a multiplatform system for the real-time visualization of specific urban transportation routes. This system incorporates technologies such as GPS, Google Maps API, Firebase, and Google Cloud, allowing users to view the precise location of vehicles on a map. Tests were conducted in Barranquilla. The system demonstrated an average accuracy of 4.13 meters in locating buses, validating its effectiveness as a tool for improving the efficiency of urban transportation.

Additionally, using a factor analysis model [5], they analyzed qualitative variables associated with user experience, such as service reliability, responsiveness, perception of safety, and staff empathy. These techniques provided a detailed characterization of the critical factors that affect the quality of urban transportation, generating an empirical basis for sound and planned decision-making.

In the study of substantial improvements in accessibility, service reliability, travel comfort, and perceived safety, [6] studied the impact of mobile applications integrated with GPS technologies and data collection systems on user satisfaction

and loyalty, reaffirming the value of mobile solutions as tools to increase the quality of transportation services.

In the case of technological development and the use of programming tools, Flutter is an efficient alternative for creating multiplatform mobile applications. [7] designed a framework using Flutter along with Firebase services, modeling the system using UML and adopting a waterfall development methodology. Validation tests, applying the black-box technique, confirmed the stability and reliability of the developed system. Similarly, [8] implemented a mobile application with Flutter, achieving significant improvements in efficiency, ease of interaction, security, and reduced operating costs in multiplatform environments.

Finally, [9] underline the consolidation of Flutter as a robust and adaptable tool for developing modern mobile applications, thanks to its ability to generate high-performance user interfaces compatible with multiple platforms, which positions it as a strategic solution in the current technological development ecosystem for urban mobility.

3. METHODOLOGY

The research development was based on a structured approach that encompassed the following phases [10]: identification through requirements analysis, selection of tools for mobile application development, development of the system design, and validation through process verification. The needs of stakeholders, especially students, were incorporated through surveys, with the aim of aligning the development and structure of the application with their expectations, as shown in Figure 1.

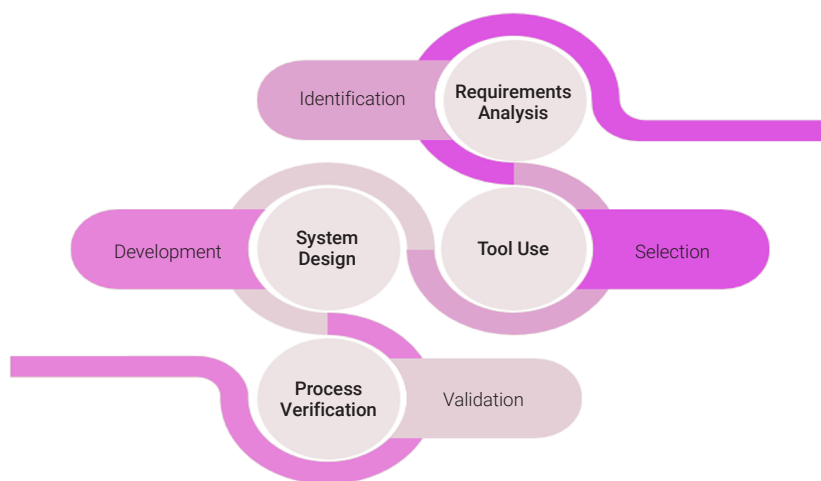


Fig. 1. Methodological process for the development of the SIMUP application.

Source: Own elaboration.

A. Identification: Requirements Analysis.

This is the phase of determining functional and non-functional requirements through surveys distributed among students on the University of Pamplona Villa del Rosario campus. The surveys highlighted key features such as real-time bus tracking, seat availability, route visualization, and intuitive navigation, as well as technical considerations regarding internet coverage and application scalability.

Functional requirements refer to specific features that meet user needs, such as real-time geolocation, seat availability display, and route management for administrators, drivers, and students [11]; Non-functional requirements encompass quality and performance attributes that improve the user experience through efficiency, responsiveness, ease of use, scalability, and data security. Aspects such as routes, travel schedules and frequency, technical infrastructure limitations, and the capabilities of the selected tools are also analyzed [12].

B. Selection: Use of development tools.

This phase focuses on designing the overall structure of the mobile application, including the choice of framework, Integrated Development Environment (IDE), map provider, and database management. Each subphase of the process is described [13].

Development Framework

Flutter was selected for its cross-platform compatibility, high performance, and broad support community [14]. To ensure the best choice, a comparative evaluation was conducted using a comparison table and a weighted matrix (Table 1), which allowed us to analyze the available options and justify the final decision [15].

Table 1. Framework Selection.

Criterion	Visual Studio Code	Android Studio	Xcode
Ease of use	High	Medium	Medium
Flutter compatibility	High	High	Low
Performance	High	Medium	High
Support community	High	High	Low
Resource consumption	Low	High	Medium
Flexibility	High	Medium	Low
Outcome	Selected	Not selected	Not selected

Source: Own elaboration.

Integrated Development Environment (IDE)

It is established through a weighted matrix for its compatibility with Flutter, high customization, ease of use, flexibility and access to resources. Visual Studio Code is selected [16]; compared to Android Studio and Xcode as shown in Table 2.

Table 2. Weighted matrix of IDEs according to the criteria.

Criterion	Weighting (%)	Visual Studio Code	Android Studio	Xcode
Ease of Use	20	4.5	3	3
Flutter Compatibility	25	5	5	4
Performance	15	5	3	4
Support Community	15	5	5	3
Resource Consumption	15	5	2	4
Flexibility	10	5	3	2
Total Score	100	4.9	3.65	3.45

Source: Own elaboration.

Map provider

Using the criteria established in Table 3, a comparative evaluation was conducted to match the system’s geolocation needs. The matrix analyzed various aspects, such as cost, ease of integration, level of customization, and system licensing. Based on this analysis, OpenStreetMap [17] was selected due to its high scores across all the evaluated criteria.

Table 3. Selection of the appropriate map provider for the application and weighted matrix by criteria.

Criterion	OpenStreetMap	Google Maps	Criterion	Weighting (%)	OpenStreetMap	Google Maps
Cost	Low	High	Cost	30	5	2
Ease of integration	High	High	Ease of Integration	25	5	5
Customization	High	Average	Customization	25	4.5	4
Licensing	Free	Paid	Licensing	20	5	3
Result	Selected	Discarded	Total Score	100	4.875	3.45

Source: Own elaboration.

Database Management: Various as-a-service (ASS) tools were considered [18], including Firebase, Appwrite, and Supabase, analyzing the criteria of scalability, ease of use, real-time updates, flexibility, associated costs, and security. Therefore, Firebase meets the requirements, also due to its real-time data capabilities, scalability, and integration with Flutter [19], as shown in Table 4.

Table 4. Map source classification and weighted matrix by criteria.

Criterion	Firebase	Appwrite	Supabase	Ponderación (%)	Firebase	Appwrite	Supabase
Ease of use	High	Medium	High	15%	5	3	5
Flutter compatibility	High	Medium	High	20%	5	3	5
Real-time updates	High	Medium	High	25%	5	3	5
Scalability	High	Medium	High	10%	5	3	5
Cost	Medium	Low	Medium	15%	4	5	4
Flexibility	High	High	Medium	15%	4	5	3
Outcome	Selected	Discarded	Discarded	100%	4.5	3.35	4.4

Source: Own elaboration.

This makes database management accessible and reliable, as well as scalable and compatible with mobile app integration due to its wide range of services.

C. Development: System Design.

The application architecture is modular, associated with three functions based on the user's role: administrator, driver, and student. The prototypes were created using Figma [20] to ensure a user-centered design through the following stages:

Initial Configuration

Enabling Firebase services for authentication and security management, and Cloud Firestore [21] for storing structured data in real time, and initializing the Flutter project [7].

Database Design

Firestore was structured with data collections for administrators, drivers, routes, students and vehicles, including fields and values detailing their specific attributes,

for the following activities: a) Use of the Flutter framework to build the interface in the Visual Studio Code development environment under the name "SIMUP"; b) organization of the project by features: this method allows for a clear separation of the functionalities associated with the different roles and the scalable application; and c) construction of the interface through the selection and use of UI Libraries and UI File Organization [22].

Feature Development

Features for geolocation, seat availability, and user role-based interfaces were developed.

Location API Integration

The flutter_map package was used to enable real-time geolocation and route visualization using OpenStreetMap [23] to establish communication between the driver's location and the student interface using Firebase, as shown in the following code snippet, which refers to "Importing Map Libraries and HTTP Requests in Flutter."

```
Code line 1: import 'package:dio/dio.dart';
```

```
Code line 2: import 'package:flutter_map/flutter_map.dart';
```

```
Code line 3: import 'package:latlong2/latlong.dart';
```

The instructions: a) on line one: HTTP requests are made, useful for interacting with external APIs, such as obtaining routes from the OSRM (Open Source Routing Machine) service; b) on line two: maps can be integrated with OpenStreetMap [24]; and c) and on line three: classes are provided for working with geographic coordinates.

For the geolocation API to work correctly and display the location in real time, the application must be connected to Firebase so that shared services can be exported in Flutter, as follows:

```
Code line 4: export 'package:simup/shared/services/firebase_service.dart';
```

```
Code line 5: export 'package:simup/shared/services/navigation_service.dart';
```

Line of code four initializes and manages the connection to Firebase [25], enabling real-time interaction with the database, storing and retrieving real-time location data, and line of code five facilitates navigation between different screens of the app without the need for a Build context, making navigation flexible and centralized.

Creating use cases

Descriptions of how users interact with the app to achieve specific goals are summarized in Figure 2. This captures functional requirements, models usage scenarios, and facilitates the design to identify and understand different user interactions with the app [26].

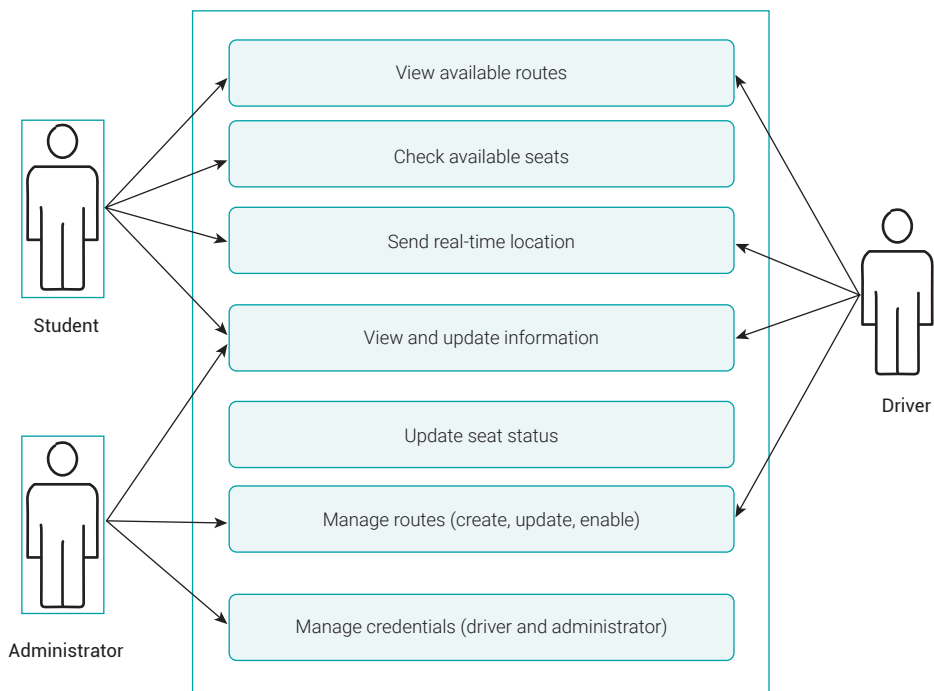


Fig. 2. Simplified use case diagram of the process.
Source: Own elaboration.

Testing and Debugging

Black-box testing was performed to validate functionality and usability. The Fake GPS Location application [26] was used, allowing locations to be simulated for both the driver and the test students, without the need for physical travel. The need was identified to centralize certain elements common to multiple features, such as use cases,

services, providers, and widgets, in a shared folder. A validation and registration system was implemented based on the institutional email domain name@unipamplona.edu.co, as shown in Figure 3.



Fig. 3. Email Validation.

Source: Mail report.

D. Validation: Process Verification.

This stage aims to ensure that the application offers a reliable and satisfactory user experience by systematically evaluating its performance. For the app analysis, a thorough review of each feature and functionality defined in the design phase was conducted, using a checklist based on the previously identified functional and non-functional requirements. As shown in Table 5, this evaluation was administered to a group of students, who assessed aspects such as user experience, functionality, navigation, usability, and compliance with expectations when managing mobile applications.

Table 5. Checklist based on requirements.

What is your level of experience with public transportation mobile apps?
What feature do you consider most important in a public transportation app?
How important is it to you to know seat availability before boarding a bus?
What are your expectations regarding the accuracy of the geolocation system?
How easy do you expect the app to be to navigate?
Do you find it useful to have the app inform you about bus schedules?
How long do you consider it acceptable to wait for real-time bus location updates?

Source: Own elaboration.

To ensure the system's proper functioning, black-box testing was proposed [27] focused on evaluating the application's functionalities without requiring knowledge of its internal implementation or source code. These tests verify that the system meets the established functionality and usability requirements. In addition, a usability test was conducted in a controlled environment using the University of Pamplona's Integrated Mobility System. In this phase, the user experience was validated in real time, potential errors were detected, and opportunities for usability improvement were identified, as detailed in Table 6.

Table 6. Satisfaction survey.

How easy was it to navigate the app?
How accurate did you find the real-time bus locations?
Was the seat availability information helpful in making decisions?
Which app feature did you find most useful?
Were the real-time location update times adequate?
Did you experience any technical issues while using the app?
How would you rate your overall satisfaction with the app?
Would you recommend this app to other users?
What would you improve about the app?

Source: Own elaboration.

To resolve errors, the code is reviewed, making the appropriate adjustments and retesting. If necessary, the process is repeated.

4. RESULTS AND DISCUSSION

Regarding the checklist, the following requirements were identified for building the application: functional requirements, including real-time geolocation, seat availability display, and route management; and non-functional requirements, including efficiency and response speed, ease of use, scalability, and data security. Based on these considerations and applying the research methodology, the user interface was designed, which is presented in Figure 4.



Fig. 4. SIMUP application login process.

In verifying the interaction between the application, Firebase, and OpenStreetMap, access is achieved through the API, which makes HTTP requests by querying map data. Based on the coordinates sent by the devices, images of the locations are generated on an interactive map, which connects to OpenStreetMap [28] using mapping compatible with flutter_map.

The geographic coordinates send the driver's current location (obtained from the device's GPS) and the data for each route. These are processed and updated in real time on the map, where the position of moving buses is observed to plan their location in real time. A checklist is run, and black-box testing identifies an error related to the navigation system, as shown in Figure 5.

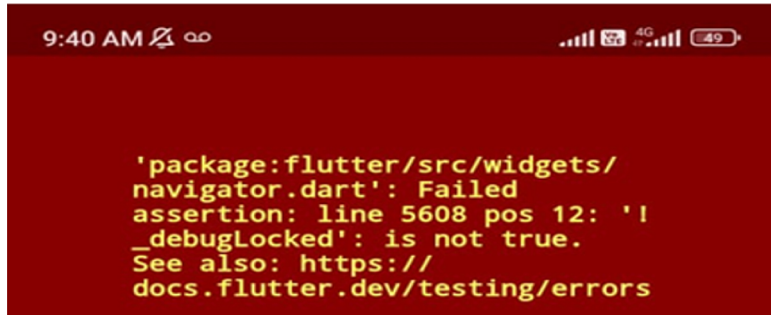


Fig. 5. Blocking error in the application's navigation system

This type of error is known as a “debugLocked assertion error.” It occurs when the system attempts to execute multiple navigation actions consecutively without waiting for the first action to complete. Specifically, the error message indicates a failure in the navigator.dart file, confirming that: ‘_debugLocked’: is not true, the error was not met. The error check shows that it occurs when multiple Navigator.push or Navigator.pop navigation instructions are executed. To resolve this, the navigation calls were reviewed, and additional verification was implemented to prevent multiple screen transitions from executing simultaneously. To do this, controls were added to the code to ensure that the navigation is completed before initiating another similar action, thus avoiding the application from crashing.

In the analysis of the results of the satisfaction survey on the use of the app, initially for on-site testing, it was observed (through a pretest) that some questions had very low or very high scores, indicating critical problems in the app when all combinations of questions are completely correlated, indicating the same direction. For example, if a user evaluates one aspect poorly, they are likely to also evaluate the others poorly. Conversely, if they evaluate one part of the app positively, they will also evaluate the rest poorly, indicating that the overall perception of the app influences all responses.

An inferential analysis shows that, according to Table 7, some key points.

Table 7. Satisfaction survey.

Metric	Value (%)	Interpretation
Mean	42.75	Average satisfaction is low.
Median	18.82	Most responses are in the low range.
Standard Deviation	42.46	There is a lot of variability in the responses.
Variance	1802.54	The responses are scattered, indicating widely divided opinions.
Range	74.12	There is a large gap between the best and worst ratings.

Source: Own elaboration.

According to the above, the average satisfaction rate is low (42.75%), while the median (18.82%) is even lower, indicating that the majority of users are dissatisfied, leading to a high level of dispersion in the data. Initial problems with geolocation and usability, strong correlation between responses, and low satisfaction with highly dispersed data are present. Therefore, the questions were reformulated and qualitative tests were conducted to identify the most dissatisfied users and prioritize their issues.

Based on the findings obtained, questions were formulated for the post-test. Key variables such as seat availability, real-time location, and recommendation for use of the app [29] were considered decisive for evaluating its functionality. The results of this stage are presented in Table 8.

Table 8. Determinants of app use.

Metric	Seat Availability	Real-Time Location	Recommend the App
Mean	83.53%	90.59%	95.29%
Median	100%	100%	100%
Standard Deviation	1.01	1.33	0.97
Variance	1.03	1.76	0.94

Source: Own elaboration.

From the table above, seat availability is 83.53%, real-time location is 90.59%, and recommendations to improve the app are significant at 95.29%. Therefore, the accuracy of the real-time update is improved, users are checked for specific GPS issues, and cases where the app is not recommended are analyzed. The standard deviation and variance are low, meaning the responses are consistent and there are no extreme variations.

A comparative exploratory analysis of the two surveys conducted, as shown in Table 9, showed an improvement in the case of whether the app was very accurate (16.7%). For the seat availability situation, whether it was very useful (a slight increase of 4.2%) in student perceptions. The app’s location update time decreased by 8.4%. The recommendation for app use increased by 16.6%. The satisfaction level increased by 8.3%, and finally, the recommendation for improvement increased by 2.7%.

Table 9. Comparison of results.

Question	Pretest	Posttest
How easy was it to navigate the app?	70.8% Very easy, 29.2% Moderately easy	83.3% Very easy, 16.7% Moderately easy
Is the real-time location accurate?	50% Very accurate, 37.5% Moderately accurate, 12.5% Not very accurate	66.7% Very accurate, 27.8% Moderately accurate, 5.6% Not very accurate
Was the seat availability information helpful?	45.8% Very useful, 45.8% Moderately useful, 8.3% Not very useful	50% Very useful, 44.4% Moderately useful, 5.6% Not very useful
Which feature did you find most useful?	50% All of the above, 20.8% View location, 16.7% View seats, 12.5% View routes	55.6% All of the above, 27.8% View location, 11.1% View seats, 5.6% View routes
Were the location update times adequate?	91.7% Yes, 8.3% No	83.3% Yes, 16.7% No
Did you experience any technical issues?	50% None, 16.7% Delays, 33.3% No	61.1% None, 22.2% Delays, 16.7% No
How would you rate your level of satisfaction?	41.7% Very satisfied, 50% Satisfied, 8.3% Indifferent	50% Very satisfied, 44.4% Satisfied, 5.6% Indifferent
Would you recommend the app?	66.7% Yes, 33.3% Maybe	83.3% Yes, 16.7% No
Do you suggest improvements to the app?	41.7% None, 29.2% Other, 16.7% Proximity to buses, 8.3% Accuracy, 4.2% Drivers	44.4% None, 27.8% Other, 16.7% Proximity to buses, 5.6% Accuracy, 5.6% Drivers

Source: Own elaboration.

Similarly, ease of navigation increased by 12.5%, recommendations were positive, and technical issues decreased by 11.6%.

Based on these results, a correlation matrix was constructed using the Pearson method (see Table 10), based on five premises: a) Ease of navigation (Scale: 1 = Not very easy, 2 = Moderately easy, 3 = Very easy), b) Location accuracy (Scale: 1 = Not very accurate, 2 = Moderately accurate, 3 = Very accurate), c) Usefulness of seat information (Scale: 1 = Not very useful, 2 = Moderately useful, 3 = Very useful), d) Overall satisfaction (Scale: 1 = Indifferent, 2 = Satisfied, 3 = Very satisfied), and e) Recommendation (Scale: 1 = No, 2 = Maybe, 3 = Yes).

Table 10. Correlation matrix de Pearson.

Variable	Ease	Accuracy	Usefulness	Satisfaction	Recommendation
Ease of navigation	1.00	0.75	0.68	0.82	0.79
Location accuracy	0.75	1.00	0.72	0.85	0.81
Usefulness of information	0.68	0.72	1.00	0.78	0.74
Overall satisfaction	0.82	0.85	0.78	1.00	0.88
Recommendation	0.79	0.81	0.74	0.88	1.00

Source: Own elaboration.

It is observed that: regarding ease of navigation, there is a strong correlation with overall satisfaction of 0.82 and recommendation of 0.79, suggesting that easy navigation increases satisfaction and the likelihood of recommending the app. Regarding location accuracy, the correlation is strong with overall satisfaction of 0.85 and recommendation of 0.81, indicating that an accurate location meets user needs. Finally, for overall satisfaction, the strongest correlation is with recommendation of 0.88, further confirming that satisfied users are more likely to recommend the app.

To verify the objectivity of the research, the evaluation model based on the ISO/IEC 25010 standard [30] was applied. This model allows determining quality characteristics by evaluating the functionality, usability, performance, reliability, and user satisfaction properties of the software product [31].

These properties are highlighted below:

- a) *Functionality*: *in accuracy: Location accuracy is high (66.7% "Very accurate"), compliant. *In interoperability: not evaluated; and *in security: partially compliant.
- b) *Performance*: *in response time: 83.3% consider update times adequate, but 16.7% report delays. Partially compliant. *In resource utilization: not evaluated.
- c) *Compatibility*: *in coexistence: No coexistence issues with other apps were reported.
- d) *Usability*: *in ease of use: 83.3% rate navigation as "Very easy," compliant. *In aesthetics: Users suggest improvements to aesthetics, partially compliant.
- e) *Reliability*: *in availability: No crashes were reported, compliant. *In fault tolerance: 61.1% reported no technical issues, but 22.2% mentioned delays, partially compliant.
- f) *Security*: *in confidentiality and integrity: No issues were reported, and it complies with the standard.
- g) *Maintainability*: *in modularity and reusability: Not evaluated.
- h) *Portability*: *in adaptability: Not evaluated, and *in installability: No installation issues were reported, and it complies.

5. CONCLUSIONS

An efficient, scalable, and user-centric solution was built, capable of adapting to the dynamic challenges of student mobility using Flutter, Firebase and OpenStreetMap as

technological pillars. Prioritizing not only functionality but also the human experience: ease of use, data security and the application's ability to grow.

The application complies with ISO/IEC 25010 software quality standards in most of the evaluated aspects. However, areas for improvement were identified: Interface aesthetics: Improve the visual design to increase clarity. Loading speed: Optimize performance to reduce delays. Proximity notifications: Implement this feature to increase usability.

During field testing and the SIMUP validation phase on campus, several critical conditions were identified to ensure the success of the deployment, such as: to mitigate weak signal areas, mobile devices are located in areas with good network coverage; strategies were implemented to reduce update times, error handling, and navigation; asynchronous management of the Navigator module in Flutter was strengthened by recalculating bus routes and, finally, in data management; read and write operations in Firestore are optimized.

The correlation analysis reflects a significant association between overall satisfaction and users' willingness to recommend the application, which refers to a positive experience on the part of users. Ease of navigation and location accuracy were also highlighted as key factors directly influencing the usefulness provided by the application. But it was observed that, the usefulness of the information had slightly lower values, which may be relevant within the set of data evaluated. Accordingly, it can be inferred that, the data suggests that the application meets the functional and emotional expectations of the users. These findings support its potential to be implemented and recommended in other similar contexts.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Jorge Enrique Herrera-Rubio: data interpretation, writing (review and validation).
Natalia: conceptualization, methodology, research, programming, field testing;
Francisco Velandia: supervision, administration, and code correction. All authors read and agreed to the published version of the manuscript.

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