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Methodology for Improving Passenger Applications in Public Transport

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Abstract

Public transport plays a key role in the mobility of the population and in the efficient functioning of both urban and suburban areas. Continuous technological advancement and the changing needs of passengers create new challenges and opportunities in the development of digital solutions for public transport. Mobile applications have become an integral part of travel, enabling users' easier access to transport information, route planning, and ticket purchase. The aim of this article is to propose a methodology that systematically analyses existing digital solutions, identifies their shortcomings, and suggests new functionalities that will enhance the comfort and efficiency of public transport. The process includes a comprehensive approach ranging from the analysis of passenger behaviour and evaluation of existing applications to the proposal of innovative solutions, followed by their development, testing, and implementation. This systematic approach ensures that new technological solutions will be optimized for a wide range of users – from daily commuters to tourists and individuals with specific needs. The proposed solution is necessary in the context of future implementation of EU directives, and its results can contribute to increasing the competitiveness of public transport and its efficient use. The article provides a comprehensive methodology that serves as a key tool for innovation in public transport applications. This methodology contributes to improving the user experience, increasing the efficiency of transport services, and supporting the overall development of public transport.

Keywords

passengers' applications, public passenger transport, innovations, transport services

1 Introduction

The development and digitalization of public transport represent a significant step towards more efficient and environmentally friendly mobility. With the advancement of technology and the constantly changing demands of passengers, there is a growing need to continuously improve digital solutions in public transport (Dolinayová et al., 2018). However, for these tools to genuinely enhance the user experience, they must reflect the real needs of passengers and provide relevant functionalities (Stopka, 2014). In addition to user-friendliness, it is also essential to focus on the sustainability and long-term effectiveness of the proposed solutions (Bian et al., 2022). These solutions must be sufficiently flexible to respond to the ever-changing conditions in the fields of transport and digitalization (Ambrosino et al., 2015; Nelson and Mulley, 2013).

Through a systematic integration of customer behavior analysis, developments in the IT sector, and the evolution of services in public passenger transport, the article focuses on addressing existing problems, including insufficient information and the complicated use of applications, with the aim of providing passengers with more efficient and pleasant experiences with public transport. The comprehensive approach goes beyond current solutions by integrating multiple aspects and innovative elements, thus creating a holistic methodology. It adds value to existing public transport solutions by combining methods of monitoring customer travel behavior with the latest trends in the IT sector and the specific needs of public passenger transport. Its innovative approach strengthens the efficiency and sustainability of the transport system. The research is therefore focused on acquiring new knowledge and skills for the development of new services. The contribution lies in a comprehensive methodology with the potential for further development.

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The rapid advancement of smart devices and digitalization has significantly influenced public transport applications, improving user experience and operational efficiency. Several studies highlight key aspects such as usability, functionality, technological advancements, and sustainability of indicators of surface public transportation (Al-lami and Török, 2023). User involvement is crucial in app development to enhance usability. Habermann et al. (2016) studied the Mobility Broker project, emphasizing user integration in all development stages for better interface design. Similarly, Strenitzerova and Stalmachova (2021) found that COVID-19 changed passenger expectations, increasing demand for digital ticketing and real-time updates. Górniak (2022) categorized mobile transport apps into ticket purchasing and route planning tools, analyzing their features in Poland. Pawełoszek and Wieczorkowski (2023) conducted a case study on the "JakDojade" app, using sentiment analysis to identify key user concerns, highlighting the need for continuous feedback-driven improvements. Emerging technologies such as AI and machine learning enhance transport applications. Joseph and Kumar (2024) reviewed how deep learning and natural language processing improve functionality. Selivestov et al. (2020) detailed the technical development of a transport monitoring app, emphasizing structured frameworks like Clean Swift and Python-based data analysis. Mobile apps contribute to sustainable mobility by improving efficiency. Melo and Alturas (2022) analyzed public transport applications in Lisbon and Porto, identifying their role in reducing emissions and enhancing urban mobility. Casquero et al. (2022) reviewed how persuasive strategies, such as eco-feedback and multimodal travel packages, increase public transport use while decreasing car dependency.

The development and research in creating new modern applications with new functionalities for public transport are becoming not only a practical tool for everyday travel but also an essential element of a sustainable and efficient transport system (Sunio and Schmöcker, 2017). Their further advancement is necessary to achieve the goals of smart mobility, reduce traffic congestion, and support more environmentally friendly modes of transport (Beul-Leusmann et al., 2014).

2 Service-oriented functionalities in mobile applications

Public transport services are most effective in urban and developed areas, where integrated systems and modern technologies are in place (Stopka et al., 2019). To improve their user-friendliness, it is necessary to eliminate language barriers, increase the availability of real-time data, and support better integration between different transport providers (Bubelíny and Kubina, 2021). A broader adoption of technological solutions could also ensure better access in less developed regions (Foth and Schroeter, 2010).

When analyzing key passenger requirements for mobile applications and their functionalities, data were collected from various sources. In the first step, face-to-face interviews were conducted with passengers using public transport. The second source of data collection consisted of information provided directly by transport operators and their available information systems. Personal surveys were conducted with passengers of different ages and social groups to obtain a comprehensive view of their needs and expectations regarding public transport mobile applications. The distribution of respondents by age is shown in the graphical representation below. The largest group of respondents were individuals aged 18 to 30.

The main objective of these questionnaires was to identify which functionalities are most important to passengers in motivating them to use public transport. Passengers could select from the following functionalities, with the right-hand column indicating how many of the 100 respondents expressed interest in using each one. Table 1 presents

Table 1 Respondent preferences for mobile application functionalities in public transport

Functionality	Number of respondents
Ticket purchase and payment	91
Connection search	80
Service quality rating	77
Real time data	77
Map and navigation	75
Notifications	75
Detailed connection information	72
Fare information	70
Profile personalization and cloud wallet	67
Search personalization	55
Offline access to tickets	51
Offline maps and timetables	51
Trip sharing	32
Customer support	17
Integrated timetable	12
Virtual transport card	12
Special offers and promotions	11
Calendar integration	11
Check-in and self-check-in	10
Accessible interface for people with reduced mobility	3
Booking	3

the analysis of mobile application functionality preferences in public transport.

The analysis of existing services in public passenger transport and their efficiency and user-friendliness can be divided into several categories, with each service evaluated in terms of its availability, functionality, and user satisfaction (Al-lami and Török, 2025). Based on the key requirements of passengers for mobile applications and their functionalities, as well as consultations with transport service providers, it was possible to define the set of functionalities that can effectively bring essential services closer to passengers. Table 2 presents a matrix of selected functionalities. The first column and the first row of the matrix indicate the most important services provided in public passenger transport.

Based on the matrix presented above, it is possible to define the most important functionalities that every application should include—those directly related to the essential services of public passenger transport. The key functionality identified is Real-Time Data, as it is associated with as many as five core services. Of course, any functionality that appears at least once in the matrix is considered essential for ensuring high-quality services in public transport (Živković and Abramović, 2025).

Based on the analysis, the most important services contributing to a positive passenger experience include clear stop labelling, availability of real-time information, and the ability to easily plan trips via mobile applications. Personalization of services also plays a significant role, allowing passengers to tailor their travel experience according to their individual needs and preferences. Additionally, even functionalities that are not directly linked to the key services listed can still offer added value to end users. Table 3 presents the ranking of functionalities based on their relevance to core services in public passenger transport.

3 Methodology

The proposed methodology is a key tool for driving innovation in public transport applications. It contributes to

Table 2 Matrix of selected functionalities

Functionality/services	Timetable information	Real-time information	Navigation and interactive maps	Ticket purchase	Service personalization	Notifications	Integration with other modes of transport
Connection search	x	x			x		x
Real time data	x	x	x		x	x	
Map and navigation	x		x		x	x	
Ticket purchase and payment				x	x		
Search personalization					x		
Trip sharing							
Profile personalization and cloud wallet					x		
Integrated timetable	x						
Virtual transport card							
Notifications		x				x	
Detailed connection information	x	x	x		x		
Booking							
Offline access to tickets							
Special offers and promotions							
Accessible interface for people with reduced mobility							
Fare information							
Service quality rating					x		
Calendar integration							
Offline maps and timetables	x		x				
Customer support							
Check-in and self-check-in							

Table 3 Functionalities ranked by importance

Functionality	Occurrence
Real-time data	5
Detailed trip information	4
Map and navigation	4
Connection search	4
Ticket purchase and payment	2
Notifications	2
Offline maps and timetables	2
Service quality rating	1
Integrated timetable	1
Profile personalization and Cloud wallet	1
Personalized search	1
Booking	0
Check-in and self-check-in	0
Fare information	0
Calendar integration	0
Offline ticket access	0
Accessible interface for people with reduced mobility	0
Special offers and promotions	0
Virtual transport card	0
Customer support	0
Trip sharing	0

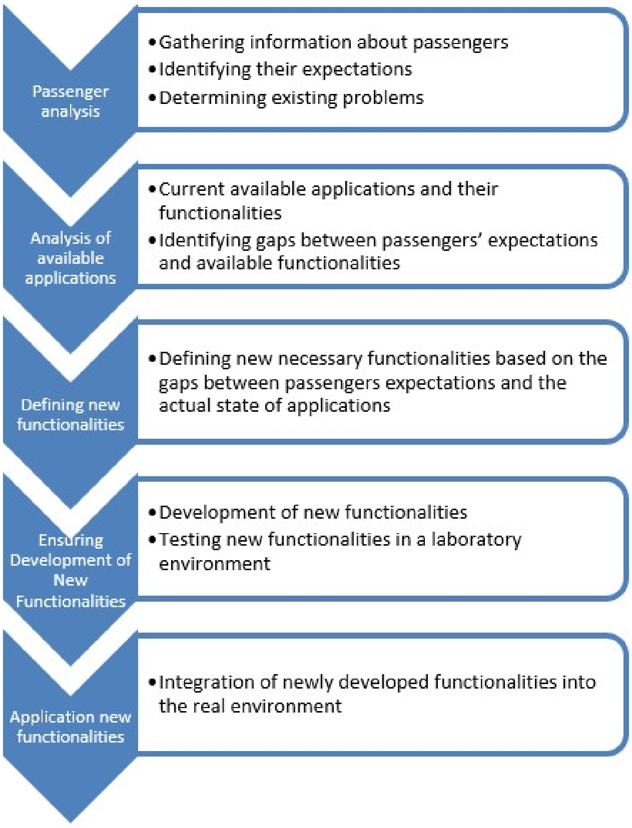

Fig. 1 Methodology for improving passenger applications in public transport

improving the user experience, increasing the efficiency of transport services, and supporting the overall development of public passenger transport. This methodology provides a systematic approach to enhancing mobile applications for passengers in public transport. It includes steps ranging from the analysis of the current state to the implementation of improvements and feedback collection. Fig. 1 illustrates the methodology for improving applications in public transport.

The methodology for improving passenger applications includes the following steps.

3.1 Step 1. Analysis of passengers and their needs

The first and most essential step in improving services in public transport is a thorough analysis of passengers and their needs. This process involves not only identifying the main categories of passengers but also understanding their expectations, preferences, and the problems they encounter during travel. The results of this analysis are crucial for designing modern solutions in the field of public transport, especially when implementing mobile applications that should reflect the real needs of users.

Public transport is used by a wide range of passengers, each with specific requirements. The main passenger categories include commuters who travel to work daily, students commuting regularly between school and home, seniors who often use transport for medical appointments or routine errands, and tourists who need to easily navigate unfamiliar environments. In addition, there are specific groups such as persons with reduced mobility, parents with small children, and international travelers who require multilingual information systems.

To ensure that mobile applications truly meet passenger expectations, it is essential to understand the key problems they face. Among the most frequently identified needs is accurate and up-to-date information on timetables, which includes not only scheduled departures but also delays and service disruptions. Passengers also demand clear and intuitive navigation that allows them to quickly orient themselves in unfamiliar environments and transfer seamlessly between different modes of transport. For many, the option to purchase tickets online is crucial, as it eliminates the need for physical sales points and allows for convenient and efficient boarding.

In addition to basic features, passengers have other expectations of modern transport applications. Service personalization is among the most frequently requested functionalities–users want the ability to save favourite routes, set notifications for their regular journeys, and customize the visual appearance of the application according to their preferences.

To gain a detailed understanding of passengers' needs, it is essential to conduct surveys and user behavior analyses. These can be carried out through questionnaires, interviews with passengers, or data analysis from existing applications. An important method is also monitoring user feedback, which helps identify weaknesses in current solutions and pinpoint areas where improvements can be made. A comprehensive analysis of passengers and their needs is a necessary foundation for further steps in modernizing public transport. Only based on real data and specific user requirements is it possible to develop effective, practical, and intuitive solutions that improve travel comfort and contribute to higher passenger satisfaction.

Passenger satisfaction is a key indicator of the success of implementing new digital solutions. To measure it, we can use the average satisfaction rating before and after the implementation of improved functionalities, calculated using Eqs. (1) and (2):

$$S_{\text{after}} = \frac{\sum_{i=1}^{n} R_{\text{after},i}}{n}, \quad (1)$$

$$S_{\text{before}} = \frac{\sum_{i=1}^{n} R_{\text{before},i}}{n}, \quad (2)$$

where:

- S_{after}: the average passenger satisfaction after the implementation of new functionalities;
- S_{before}: the average passenger satisfaction before the implementation of new functionalities;
- $R_{\text{after},i}$: individual satisfaction ratings from respondents on a scale (e.g., 1–10);
- n: the number of respondents participating in the evaluation.

By comparing the difference between Safter and Sbefore, we can quantify the impact of the new functionalities using Eq. (3):

$$\text{change in satisfaction} = \frac{S_{\text{after}} - S_{\text{before}}}{S_{\text{before}}} \times 100\% \quad (3)$$

If this value is positive, it indicates that the new functionalities have improved the user experience. On the other hand, if the value is negative, the implemented solutions were not sufficiently effective and need to be reconsidered.

3.2 Step 2. Analysis of available applications

After identifying the expectations and needs of passengers, it is essential to examine the functionalities currently offered by existing mobile applications in public transport. This step allows for a comparison between user requirements and the actual features provided by digital tools, highlighting gaps that should be addressed in future development.

Currently, passengers have access to various applications that differ by region and transport operator. Among the most common features are connection search and timetable information, which are offered by all applications aimed at public transport. Some apps also allow for ticket purchasing, which eliminates the need for physical sales points and enables faster and more convenient passenger processing.

Based on this analysis, it is possible to determine which functionalities are already present and which should be added to better meet the needs of passengers. This step is a critical foundation for the continued development of digital solutions in public transport.

An important part of the methodology is comparing the functionalities available in existing applications with the expectations of users. To evaluate the match between offered features and passenger needs more precisely, we can define a functionality match indicator using Eq. (4):

$$F_{\text{match}} = \frac{F_{\text{existing}}}{F_{\text{expected}}} \times 100\% \quad (4)$$

where:

- F_{existing}: the number of functionalities currently offered by the application;
- F_{expected}: the number of functionalities expected by users based on surveys.

If Fmatch approaches 100%, it means the application meets user expectations. If the value is low (e.g., below 50%), the application has significant gaps that should be addressed by implementing new features.

3.3 Step 3. Definition of new functionalities

After identifying the currently available functionalities and analysing passenger needs, it is possible to propose additional enhancements that could be implemented into mobile applications to improve the comfort and efficiency of travel within public passenger transport. These new functionalities should address the existing shortcomings and introduce innovative solutions that simplify travel planning, improve access to relevant information, and enhance overall user satisfaction.

As an example of innovative functionalities, intelligent delay prediction based on historical data, traffic conditions, and analysis of vehicle movement patterns could be implemented. This feature would allow passengers to prepare for possible delays and choose alternative routes in case of transport disruptions.

Another significant innovation is enhanced multimodal navigation, which would combine various modes of transport into a single journey and offer comprehensive solutions for passengers. In addition to traditional connections, the application could consider options such as shared mobility, bike-sharing, or walking routes and recommend the optimal route according to user preferences.

Travelling personalization is also a highly desired feature, which would allow passengers to set preferred routes, favourite stops, or preferred modes of transport. Notifications could be adapted to the individual needs of the user, thereby reducing information overload and increasing the efficiency of the application.

Implementation of these new functionalities would contribute to a more efficient and convenient use of public transport, thereby increasing its share in overall population mobility and supporting the shift from individual car use to more sustainable modes of transportation.

The new functionality introduces estimated delays (T_{before}), while the accuracy of the prediction (P_{before}) is evaluated using Eq. (5):

$$P_{before} = \frac{|T_{real} - T_{before}|}{T_{real}} \times 100\% \quad (5)$$

where:

- T_{real}: the actual delay (e.g., of a train);
- T_{before}: the predicted delay.

3.4 Step 4. Ensuring the development of new functionalities

This part of the methodology involves the actual development and testing of new functionalities. The mathematical models of return on investment (ROI) and Efficiency of Time Savings (E_{new}) are useful here to predict the effectiveness of implemented solutions. ROI indicates whether a given investment into a new functionality is justified, while the time savings model helps confirm whether the introduced functionalities accelerate and improve the processes for users.

After identifying new functionalities that can enhance the user experience and efficiency of public passenger transport, the next step is their development and testing. This process is essential to ensure the proper implementation of the proposed solutions and their smooth operation in real-world conditions.

The development of new functionalities for mobile applications takes place in several phases. First, a technical design is created, which defines how the new features will be integrated into existing systems and what technological solutions will be used. Then, the programming and implementation phase begins, during which developers work to ensure seamless integration with current transport databases, GPS tracking, or payment gateways for ticket purchases. Once the development is complete, an internal testing phase follows, where the new functionalities are tested in a controlled environment. Testers verify whether the application works correctly, whether connection data is accurate, and whether the new functions are compatible with various types of mobile devices and operating systems. In this step, initial errors are resolved, and the application's performance is optimized. For effective planning of development and deployment of new functionalities, it is necessary to consider costs, benefits, and the return on investment (ROI). The implementation of new digital solutions requires investment, and their effectiveness should be measured based on ROI, calculated using Eq. (6):

$$\text{ROI} = \frac{\text{Increase in satisfaction} \times \text{Number of users}}{\text{Development costs}} \times 100\% \quad (6)$$

where:

- Increase in user satisfaction: the difference between the values of S_{after} (average satisfaction after) and S_{before} (average satisfaction before), expressed as a percentage.
- Number of users refers to the number of active users of the application. Development costs include all expenses related to the development, testing, and implementation of the new functionalities.

If the ROI is high, it indicates that the investment in the new functionality was effective.

If the ROI is low or negative, it means that the investment did not bring the expected improvement, and it is necessary to reconsider the approach or the implemented solution.

In addition to user satisfaction, the effectiveness of new functionalities can also be evaluated based on time savings during the execution of individual tasks, using Eq. (7):

$$E_{new} = \frac{T_{new} - T_{old}}{T_{old}} \times 100\% \quad (7)$$

where:

- T_{old}: the average time required to complete a specific task (e.g., ticket purchase) before the implementation of the new functionality.
- T_{new}: the average time required to complete the same task after the implementation.

If E_{new} yields a negative value, it indicates that the new functionalities are ineffective and lead to longer process times. On the other hand, if the value is positive, it means that the implementation of new solutions has shortened the time required to perform the task and improved user comfort.

3.5 Step 5. Implementation of new functionalities

Another important step is pilot testing in real-world conditions, involving selected passengers or user groups. These testers provide feedback on how the new functionalities work in practice and whether they effectively address the identified issues. Based on their comments, additional adjustments can be made before the new features are officially released to the public.

After successful testing, the new functionalities are deployed into full operation, with ongoing monitoring of their performance and reliability. If necessary, the application is continuously updated and improved based on user feedback. This process ensures that the new solutions not only reflect the needs of passengers but also contribute to improving the overall quality of services in public transport.

3.6 Step 6. Implementation of recommended functionalities

The following functionalities should be part of modern mobile applications, as they are among the most important for end users (passengers). These include:

- Personalized planning: users can create profiles and set preferences – e.g., avoid transfers, prefer environmentally friendly options, or prioritize speed over cost.
- Dynamic planning and navigation: real-time consideration of traffic conditions (delays, closures, accidents).
- Problem prediction: algorithms for anticipating potential delays or service disruptions along the route.
- Interactive map: displays real-time vehicle locations, availability of bicycles or scooters, and directions to the nearest stop.
- Unified ticketing: a single ticket valid for all types of transport, which can be purchased directly within the app.
- Flexible payment options: credit/debit cards, mobile wallets, subscription packages, QR codes.
- Eco-friendly transport solutions: discounts for users combining sustainable transport modes (e.g., bike + train).
- Offline mode support: option to download routes, tickets, and maps for use without internet access.
- Accessibility for all: interface customization for people with special needs (e.g., voice navigation, large text).
- Analytical tools: data collection on route usage, popular paths, and transfer points to improve services.
- Information management: rapid updates on service changes, disruptions, and new service additions.
- Support for regional integration: easy integration of smaller transport providers into the system.

3.7 Step 7. Ensuring sustainability of the design

This step includes the design of a mechanism for the regular collection of feedback from users and transport operators, and the creation of a system for evaluating the effectiveness and environmental contribution of the proposed solution.

4 Discussion

The presented methodology systematically addresses the development and implementation of advanced digital functionalities in public transport applications. Each of the seven steps contributes to a comprehensive transformation of the user experience and transport system efficiency.

An integral part of this final stage is also the inclusion of a roadmap for further development, which allows for expanding the system with advanced technologies such as artificial intelligence, machine learning–based delay prediction, or automated route planning. These innovations not only improve the functional range of applications but also ensure adaptability to the evolving needs of modern mobility ecosystems.

The benefits of implementing digital solutions in public transport, as summarized in Table 4, highlight the multidimensional impact of the methodology. For passengers, the integration of dynamic and personalized features results in simplified trip planning and enhanced comfort. For operators, improved route management, data analytics, and unified ticketing systems lead to more efficient operations and increased customer retention. From a societal perspective, digitalization contributes to sustainable mobility by encouraging modal shift, reducing emissions, and modernizing infrastructure.

While the methodology is designed to be generalizable, its application may vary based on regional conditions, technological infrastructure, and operator readiness. Therefore, its effectiveness is conditional on proper implementation, including thorough stakeholder engagement

Table 4 Benefits of implementing digital solutions in transport

Advantages	Passengers	Increased simplicity and comfort in trip planning
		Better access to eco-friendly transport options
	Operator	More efficient operation and route management
		Increased customer satisfaction and revenue
	Society	Reduced emissions and promotion of sustainable mobility
		Modernization of transport infrastructure

and iterative evaluation based on indicators such as functionality matching, user satisfaction, return on investment, and task efficiency.

Moreover, the pilot testing and feedback loop outlined in steps 5 and 7 play a pivotal role in ensuring not only the technical viability but also the long-term sustainability of the implemented features. Through continuous monitoring, the system can remain responsive to user preferences and technological trends.

In conclusion, the proposed methodology is not a static framework, but rather a dynamic model for innovation in public transport, scalable and adaptable to different urban contexts and mobility strategies. Its implementation can substantially increase the competitiveness of public transport, facilitate compliance with future EU digital and environmental directives, and promote inclusive and intelligent urban mobility.

5 Conclusion

The development and digitalization of public passenger transport represent a significant step towards a more efficient and environmentally sustainable mode of transportation. Digitalization enables better organization of transport services, route optimization, and improved accessibility of public transport for a wide range of users.

The proposed methodology offers a systematic and flexible approach to improving mobile applications in public transport while reflecting current user needs and technological trends. The analysis of passenger behavior and the evaluation of available functionalities made it possible to identify key areas where user satisfaction can be improved and the efficiency of transport solutions increased. The strength of this methodology lies in its ability to connect technological innovation with real user demands. The development process also includes testing and feedback phases, which are essential to ensure high quality and functionality of the proposed solutions.

The main advantages of the methodology include its systematic structure, the ability to quantify results (e.g., through user satisfaction, return on investment, or time efficiency indicators), and adaptability to different regional and operational conditions. A major contribution is also its alignment of technology with principles of sustainable mobility, enabling support for environmental goals and compliance with the requirements of current European transport policy.

However, the methodology also has certain limitations. Its successful implementation depends on the availability of high-quality input data, which is essential for accurate analysis and predictions. The development and integration of new functionalities may require significant financial and technical resources, particularly for smaller transport providers. Interdisciplinary collaboration, the need for digital literacy among users, and the requirement for regular system updates are additional factors that may influence the overall effectiveness of the implementation.

In the long term, it will be essential to continue optimizing the proposed solutions, testing them under real-world conditions, and adapting them to the dynamic changes in the transport sector. The proposed functionalities – such as personalized route planning, intelligent delay prediction, multimodal integration, and unified travel ticketing – can significantly transform the way passengers interact with public transport. Their implementation will increase comfort, attractiveness, and sustainability of public transport, thereby supporting quality of life and the modernization of transport systems.

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