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# PAYSADA: An Architectural Design for An Automated Fare Collection and Tracking System for Jeepneys

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**Abstract –** Jeepneys have long served as a vital mode of public transportation in the Philippines. However, the traditional manual fare collection methods commonly used present challenges such as payment delays, human errors, and inefficiencies in route management. This study introduces an architectural design for an enhanced fare collection and tracking system that integrates automated fare processing with Global Positioning System technology. The system leverages Radio Frequency Identification to facilitate contactless fare collection, allowing passengers to pay electronically while enabling real-time tracking of jeepney locations. Targeting both jeepney operators and passengers, the system aims to optimize operations and improve the overall commuting experience. A purposive sampling technique was employed to select relevant participants, including jeepney operators, drivers, IT professionals, and passengers. Data were gathered through surveys, interviews, direct observations, and structured questionnaires. System development tools included Visual Studio Code for website implementation, Figma for user interface design, and Arduino IDE for hardware integration. Results indicate that the combination of RFID and GPS technologies significantly reduces fare-related errors, minimizes disputes, and eliminates the need for manual fare handling. Moreover, the automated system accelerates boarding processes and allows operators to manage routes and fare collection more efficiently. Overall, the study demonstrates that integrating modern technologies into jeepney operations can substantially enhance both operational efficiency and the commuting experience.

**Keywords:** Jeepney, Automated, Fare collection, GPS, RFID technology

## I. Introduction

In the Philippines, the jeepney serves as a crucial mode of public transportation, accommodating passengers across various routes in cities and rural areas, where Filipino passengers use the jeepney as their primary mode of transportation in their everyday lives to get to their desired destination. Public modes of transportation are made because they are more economical and energy-efficient. However, jeepneys encounter operational challenges in the current method of fare collection and route management system. Traditional approaches to fare collection and route management, primarily reliant on manual processes, often lead to various inefficiencies like revenue leakages, operational delays, and overall dissatisfaction among passengers [1].

Integrating Radio Frequency Identification (RFID) technology provides an opportunity to modernize jeepney transportation systems, significantly improving efficiency, convenience, and safety for both passengers and drivers. RFID plays a pivotal role in automated fare collection and tracking systems. As passengers enter or exit public transportation, RFID readers automatically deduct the fare from their accounts [2]. In addition, the adoption of RFID systems allows for real-time tracking of jeepneys, enabling transportation authorities to monitor vehicle locations and movements. This data can be utilized to optimize routes, improve scheduling, and provide accurate arrival time information to passengers. Real-time tracking enhances operational transparency and efficiency, ultimately leading to a more reliable public transportation system [3].

Under the PUJ modernization program of the transportation department in the Philippines, an automated fare collection system should be implemented in every public utility jeepney. Passengers will tap in upon entering the PUJ and tap out before alighting. Fare is calculated depending on the distance traveled [4]. Passengers can conveniently board and disembark using their RFID cards or devices without the hassle of cash payments due to the automated fare collection and tracking system. Besides, websites substantially improve the process of collecting fares for different routes [5]. GPS-enabled websites assist the drivers by broadcasting pertinent updates on traffic, road closures, and other vital information, allowing them to adjust their routes immediately. This optimization minimizes fuel and time expenditure by considering the fastest routes available. Passengers, for their part, use these websites to monitor the current status and reallocation of their jeepneys for better trip planning [6].

This study specifically focuses on the Alaminos City – Dasol Infanta route in Alaminos City, aiming to design and develop an integrated system for modernizing jeepney fare collection and tracking systems. The system recognizably seeks to improve the effectiveness of existing manual systems by integrating RFID technology and supporting a web system [7]. The goal is to analyze the existing methods of collecting fares and managing routes within the whole operational jurisdiction of this department so as to establish the problems that exist and come up with technology-based gadgets to solve them. This is to produce a prototype system followed by rigorous testing and validation.

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In light of these challenges, the authors seek to develop an automatic fare collection and tracking system that makes the collection of fares easier and allows for route tracking in real time. It is their expectation that public transport services will be more effective and reliable as a result of this new strategy. These innovations are a step in the right direction for the automated transport industry and for all users of public transport services and citizens in general [8]. This combined approach has the capacity to revolutionize the functioning of transport systems and gives the prospect of an urban mobility regime that is rationalized for the benefit of all stakeholders.

## II. Methodology

The research design used in this study combined both descriptive and developmental approaches. Descriptive research techniques, including surveys and interviews, were employed to gather insights into the existing fare collection processes. Aligned with Software Development Life Cycle (SDLC) principles, the development process was guided by an adapted agile model [9], which emphasized flexibility and iterative development to ensure continuous improvement and alignment with user requirements. This approach includes several phases: the requirement phase, system design phase, development phase, testing phase, deployment phase, and review phase as illustrated in Fig. 1 below.

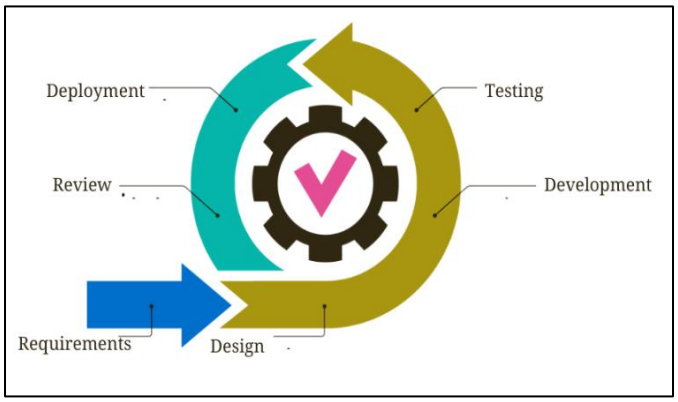



Fig. 1 Agile Model [9]

Requirements Phase. The process began with the first phase, where the team visited the project site to gather information and understand the needs of the stakeholders. The chairman of the Jeepney Operators and Drivers Transport Cooperative in Alaminos City was interviewed to provide insights regarding the operational challenges, processes, and requirements of the transport system.

System Design Phase. This phase involves gaining a thorough understanding of the users' needs and requirements. It focuses on designing the system framework for fare collection and tracking, integrating both hardware and software components to ensure seamless functionality and usability.

Development Phase. The development stage was when actual coding began. Visual Studio was utilized for system development and programming, while Figma was employed for designing the interface and user experience components. Arduino and GPS modules were integrated during this phase to enable hardware interaction and real-time tracking.

Testing Phase. Once the system was developed and designed, an evaluation of its functional and technical parts was carried out. Firstly, IT professionals tried the system out so that necessary errors could be fixed. After this, jeepney drivers and commuters along the Alaminos City-Dasol-Infanta route tried out the system during actual jeepney operations to test its effectiveness and accessibility. This phase was also an opportunity to showcase the system in use.

Deployment Phase. The system was demonstrated to the chairman of the Jeepney Operators and Drivers Transport Cooperative and the clients within the Alaminos City-Dasol-Infanta route. The team gave precise directions as to how the system can be used and prepared all logistical aspects to ensure that it could be deployed when required for fare collection and route monitoring.

Review Phase. The system went through a rigorous evaluation to check whether it met the set user standards and expectations. Feedback was received from the IT practitioners, jeepney operator’s drivers and passengers that were able to use the system during the testing phase. This feedback helped pinpoint areas of weaknesses and validate its effectiveness, dependability, and user friendliness.

This study gathered primary data through interviews with key stakeholders, such as the Chairman of the Jeepney Operators and Drivers Transport Cooperative, as well as selected jeepney operators and passengers along the Alaminos City – Dasol, Infanta route. A survey questionnaire was most feasible way to collect data or information from a large group in certain area. This study employed a four-point Likert-type scale of measurement. The questionnaire’s purpose is to measure the acceptance level of the proposed system.

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The research study was conducted on the Alaminos City Dasol- Infanta route in Alaminos City. In this paper, identified key people were those who would provide important participation in the study. Purposive sampling was utilized in identifying the respondents. These respondents include the jeepney operators, commuters, and IT experts as illustrated in Table I below.

Table I Respondents of The Study

| Respondents | Number of Respondents |
|---|---|
| Jeepney operators along the ACDAI route | 4 |
| Commuters | 44 |
| IT Experts | 2 |
| Total | 50 |

A statistical approach was used to evaluate the respondents' validation of the system during the usability test. The study applied a 4-point Likert Scale, with "Excellent" representing the highest rating and "Poor" indicating the lowest, as shown in Table II. The responses were then summarized and analyzed using a weighted mean. This approach provided a comprehensive evaluation of the system's usability and acceptance.

**Table II the Scale of Measurement for The Acceptability Test**

| Scale | Statistical Limits | Rating | Descriptive Interpretation |
|---|---|---|---|
| 4 | 3.26 - 4.00 | Excellent | Accepted |
| 3 | 2.51 - 3.25 | Very Good | Accepted |
| 2 | 1.76 - 2.50 | Good | Not Accepted |
| 1 | 1.00 - 1.75 | Poor | Not Accepted |

**Limitation of the Study**

While the proposed fare collection and tracking system introduces promising solutions to improve jeepney operations, several limitations must be acknowledged. In terms of scalability, the system is currently designed and tested exclusively for jeepneys operating within the Alaminos City–Dasol–Infanta route. As such, the findings and implementation may not be immediately generalizable to other routes or regions without further adjustments. Variations in route conditions, operator practices, and commuter behavior in other areas may pose unique challenges that were not considered in this study. For Data Privacy, the system does not cover the input or storage of personally identifiable information (PII) of commuters using the RFID card. This design choice was made to simplify implementation and minimize privacy risks. While this enhances user privacy, it also limits the potential for user-specific services such as personalized tracking or usage history. Although RFID technology streamlines fare collection, it is vulnerable to certain security threats such as RFID spoofing or cloning. This study does not explore advanced security protocols or encryption techniques to mitigate these risks. Future enhancements should consider implementing authentication measures to protect against unauthorized access or fraudulent transactions. The system's cloud-based data synchronization relies on stable internet connectivity, which may not always be available in certain areas along the route. To address this, the device is equipped with an SD card for offline data storage. However, this setup may result in delayed access to real-time data until the device reconnects to the internet and successfully syncs.

These limitations highlight important considerations for future development and wider deployment of the system. Addressing them could further enhance the reliability, security, and scalability of the fare collection and tracking solution.

**III. Results and Discussion**

The Automated Fare Collection and Tracking System is designed to improve the fare collection process and to increase the monitoring of passengers and jeepney operators. The existing manual fare collection system involves several steps, such as cash handling, fare calculations, and applying passenger discounts, which often lead to inefficiencies like slow boarding times, fare disputes, and inaccurate tracking of transactions, especially during peak hours. These problems were brought to light by discussion among jeepney drivers and passengers involved in cooperation. To address these challenges, an automated fare collection and tracking system has been designed incorporating RFID as an element for cashless fare payment and a GPS system for real-time routing information. Using this system, the boarding of passengers is made much simpler as they can pay their fare by a very simple tap on their RFID card, allowing for faster and smoother boarding. The fare is automatically calculated based on the distance traveled, with discounts applied for eligible passengers such as students, senior citizens, and PWDs. The proposed system includes a detailed system framework architecture designed to meet the specific requirements and objectives of the study, as illustrated in Fig. 2.

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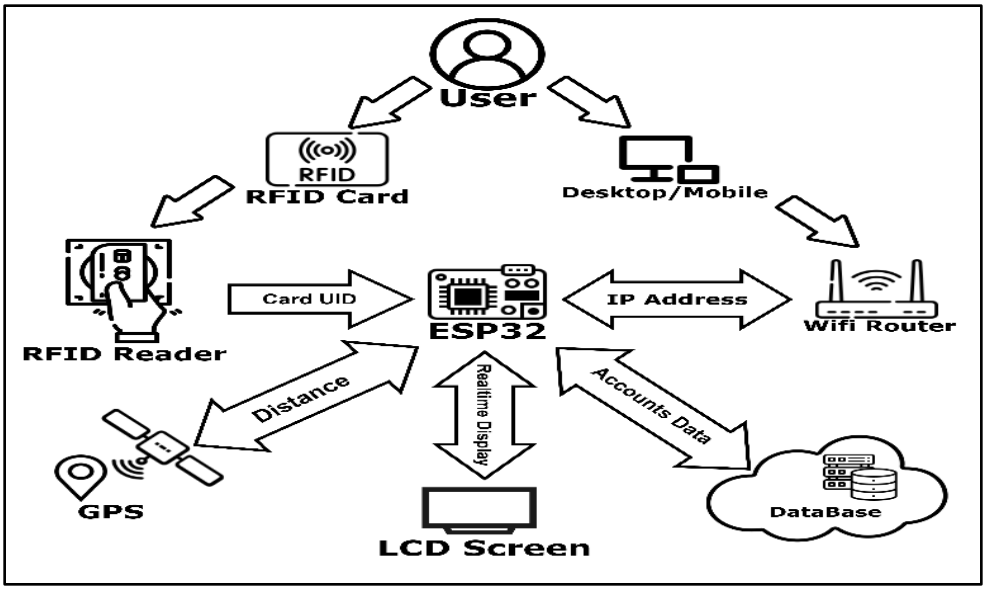



Fig. 2 System Architecture Framework Model

As shown in Fig. 2, the system architecture framework utilizes the ESP32 as the central processing unit; it connects with the RFID reader to obtain card details, and employs GPS to determine the distance and charge fare. This system begins with the user first, who intends to pay by tapping their RFID card on an RFID reader. That card's data gets forwarded to the ESP32, which then estimates the fare based on the GPS system's distance readout and the provided discount. Through a Wi-Fi router, the server and the database are directly communicated to by the ESP32 for the purposes of updating the balance of the user and saving the transaction. The set fare along with the user's remaining balance is displayed on the LCD in real-time. The user, on the other hand, can view their account details and check their balance along with their transactions through a mobile phone or laptop. The development of this system enables the process of fare collection to be efficient, reliable, and convenient. This system significantly reduces human error by automating fare calculations and ensures a faster, smoother boarding experience for passengers. Additionally, it enhances data security by storing user transactions and balance updates in a centralized, cloud-based database for easy access and management.

In addition to the system architecture, the flowchart shown below shows the process of fare collection and tracking as a sequential operation. It also describes important steps, such as RFID card checking, balance checking, and fare and discounting processes. This graph makes it possible to keep track of the overall system performance and operational efficiency, as shown in the figure below.

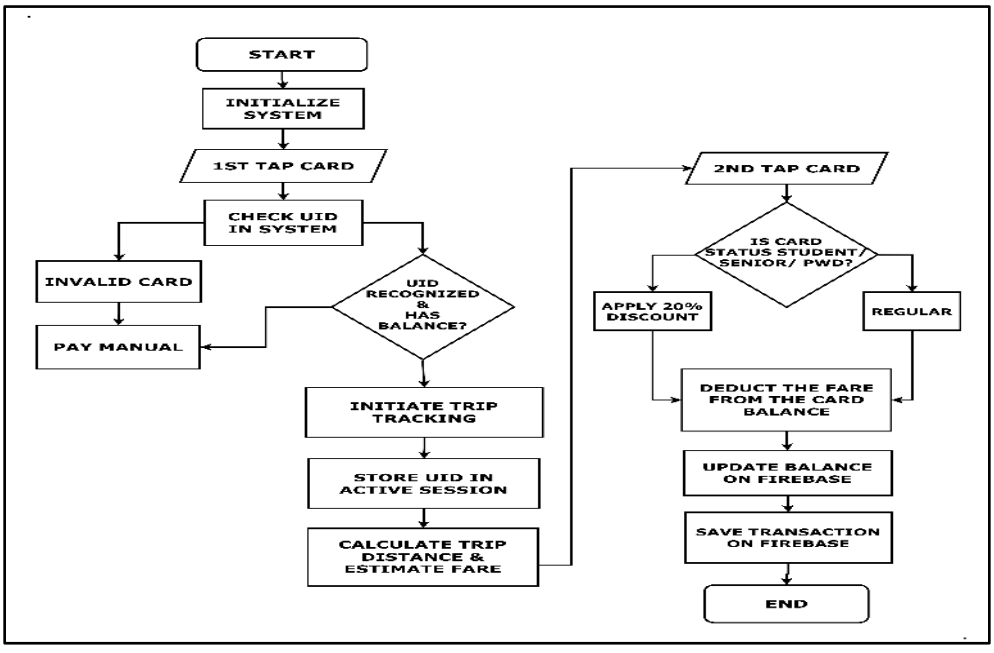



Fig. 3 Fare Collection and Tracking System Process Flow

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As shown in Fig. 3, this process flow illustrates the design of a computerized RFID fare collection and monitoring system for the operation of jeepneys. Initially, the passengers swipe their RFID cards at the system, which checks the registration to the card and the balance. If the card cannot be validated or has an insufficient balance, then cash payment is the only option. The cards that are validated initiate the trip monitoring system and log the UID of the card. At any time during the trip, passengers can swipe their cards a second time, which will compute the fare at the end of the trip based on distance traveled. Students, seniors, and PWD are eligible for discounts if applicable. The system will adjust the fare, charge the card, and update the balance on the card to reflect the new balance. Without the second tap, manual payment may be requested for adequate fare and distance monitoring to take place. The sequence ends after either cash or card has been presented for payment.

**Prototype Development**

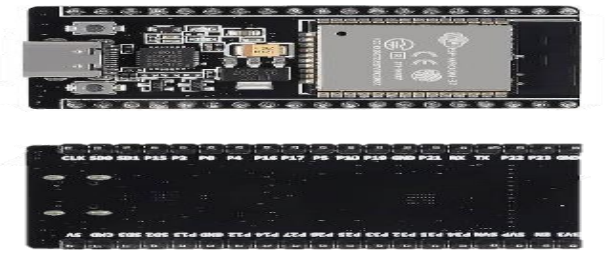


Fig. 4 ESP 32 Microcontroller

As shown in Fig. 4, the ESP32 microcontroller is the main component of the system, serving as the brain of the project. It processes GPS data to track location, calculates fares, reads RFID cards, deducts payments, and applies discounts. It enables Wi-Fi and cloud connectivity for real-time data syncing and works with sensors to detect passengers and integration with additional sensors [10].




Fig. 5 RC522 RFID [11]

As shown in Fig. 5, the RC522 RFID reader plays a key role in the RFID-based fare collection and tracking system. When passengers tap their RFID cards on the reader, the reader sends the card information to a central system that calculates the fare and updates the passenger's balance [11].



Fig. 6 GPS NEO-m8n Module [12]

As shown in Fig. 6, GPS NEO-MN8 module will be used in the Fare Collection and Tracking System to get the distance traveled [12]. This GPS receiver accurately tracks the vehicle's location, enabling the system to calculate the fare based on the distance covered during the trip.

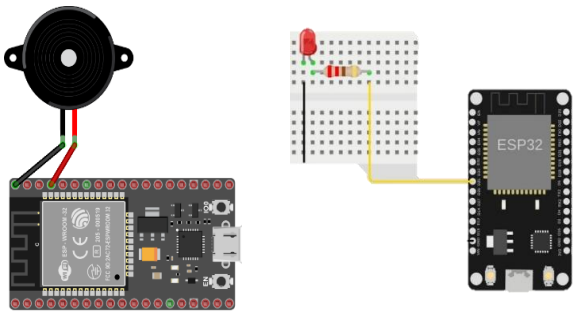



Fig. 7 LED and Buzzer Control

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As shown in Fig. 7, the LED provides visual signals, while the buzzer emits sound alerts, both used to give feedback to users during the payment process [13], [14]




Fig. 8 I2C Screen to 24x12 [15]

As shown in Fig. 8, the 24x12 I2C screen is a compact display that uses the I2C communication protocol to show information such as status, data, or messages in a clear, easy-to-read format. It is used in the system for displaying real-time updates, providing accurate tracking of jeepneys, or notifying users of relevant information [15].

Table III System Evaluation According to Overall Weighted Mean

| Criteria | Mean | Description |
|---|---|---|
| Functionality | 3.31 | Excellent |
| Reliability | 3.16 | Very Good |
| Usability | 3.31 | Excellent |
| Efficiency | 3.17 | Very Good |
| Maintainability | 3.01 | Very Good |
| Portability | 3.26 | Excellent |
| Overall Weighted Mean | 3.20 | Very Good |

Table III shows that the system's overall performance, with a mean weighted score of 3.20 suggests that all of the systems indicate good performance and results, suggesting that user expectations are met and that the system performs surprisingly well. In system functionality, it scored 3.31, which indicates this system can only be expected to be trusted due to its reliable performance, its high error tolerance level, and its efficient fault recovery. This score demonstrates that users can count on the system to work as intended with minimal issues. The reliability of the system was rated 3.16, suggesting that the system performs reliably over time with reasonably good results. Usability was evaluated to be excellent with a score of 3.31, indicating that the system is user friendly and simple to comprehend, especially the RFID and GPS tracking, which users find very easy to use. The system's efficiency was rated at 3.17, meaning it performs faster than the average response time, ensuring smooth and quick processes like fare collection and tracking. The system is quite simple to maintain with a score of 3.01, as it can be analyzed, troubleshot, and tested, which makes modification or repair quite easy. Lastly, the system received a score of 3.26 with respect to portability and can therefore be easily deployed to different environments or platforms and so can work on a variety of devices or systems.

While several commercial fare collection systems such as Beep Card, Tap-to-Pay, and GPS-based transport monitoring platforms exist in highly urbanized areas in the Philippines like Metro Manila and Cebu, such systems are not yet adopted in rural or semi-urban routes, particularly the Alaminos–Dasol–Infanta corridor. These commercial solutions typically require significant infrastructure, high capital investment, and stable internet connectivity—factors that present practical limitations for operators in local routes with fewer resources and less consistent digital infrastructure.

The system developed in this study is uniquely tailored for the Alaminos–Dasol–Infanta jeepney route. Unlike commercial systems that rely heavily on real-time cloud access and centralized platforms, this implementation uses offline data storage (via an SD card) to accommodate areas with intermittent internet connectivity. Data synchronization occurs only when a stable connection becomes available, making it more feasible for rural deployment.

Furthermore, the system introduces affordable, low-power hardware components (e.g., Arduino microcontrollers, basic RFID readers) and avoids complex commuter registration processes to respect local norms and privacy concerns. While commercial platforms often require full user profiling, this system deliberately omits personal data collection to simplify use and address privacy-related apprehensions among commuters. Most importantly, the solution fills a technological gap in an underserved transportation sector. The current fare collection method in the Alaminos–Dasol–Infanta route is purely manual, relying on cash payments and verbal communication between driver and commuter. By introducing automated fare collection and jeepney tracking,

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the proposed system not only streamlines operations but also lays the groundwork for future digital transformation in regional transport systems.In essence, this system does not attempt to replace large-scale commercial solutions but instead offers a locally adapted, cost-effective alternative that addresses the unique operational needs, limitations, and context of the targeted jeepney route.

## IV. Conclusion

The system has been proven to work well beyond expectations because of its speed and ease of operation. With regard to fare collection and monitoring in jeepneys, the use of this system represents a positive change for both the operators regard to fare collection and monitoring in jeepneys, the use of this system represents a positive change for both the operators and the end users. In addition, the automated fare calculations, including discounts for eligible passengers, ensure that fares are applied correctly, which reduces disputes. More importantly, the GPS tracking device allows the monitoring of jeepney operations from anywhere over the internet. The friendly and responsive interface of the system can be noted as well as the fact that it can be set up very fast and, thus, be put into service on a number of jeepney routes, which increases the reliability of service delivery. To strengthen the adoption and long-term impact of the proposed fare collection and tracking system, several key recommendations are made. A full cost analysis is recommended to assess the financial feasibility of deploying the system on a wider scale. Initial development costs were kept low by using open-source tools (e.g., Visual Studio Code, Arduino IDE) and affordable hardware components such as Arduino boards, RFID readers, and basic GPS modules. Compared to commercial fare systems, which require high capital and licensing fees, the proposed system offers a low-cost alternative suitable for rural operators. A cost breakdown can guide jeepney associations or local governments in planning phased rollouts, budgeting replacements or maintenance, and seeking potential funding or subsidies. Local government units (LGUs) and transport cooperatives could collaborate with technology providers or NGOs to subsidize the production and installation of the devices. Public-private partnerships can enhance system sustainability while ensuring that implementation remains inclusive and equitable across multiple routes and municipalities.

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