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WasteGPS: A GPS-Based Mobile Application Connecting Households and Informal Collectors for Plastic Waste Collection in Airmadidi, Indonesia

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Abstract. Informal waste collectors recover a considerable share of the plastic produced by Indonesian households. Interviews in Airmadidi District, North Sulawesi, however, revealed that collectors spend much of their working day searching for households with plastic to sell, while residents have no way to tell collectors that their sorted plastic is ready. To address this problem, we designed and implemented WasteGPS, a two-role Android application that connects residents and collectors through GPS-tagged reports. A resident submits a report containing the location coordinates, a description of the plastic, and a photograph. A collector sees each open report as a map marker, navigates to it with Google Maps, communicates with the resident through in-app chat, and closes the report after pickup. Collectors also post the types of plastic they buy and their price per kilogram. The application was developed with the prototyping model: requirements were elicited through interviews with two collectors, and the system was modeled in UML. All 20 black-box test scenarios (ten per role) passed on one Android 10 phone, covering the main path with valid input. The study contributes a functionally validated prototype of a role-based, location-aware workflow for independent collectors, a group that waste applications built for municipalities, pickup officers, and waste banks leave out. It also specifies the safeguards and the field pilot that deployment requires.

Keywords: GPS, Mobile Application, Plastic Waste, Informal Waste Collectors, Prototyping

1 Introduction

Indonesia generated about 67.8 million tonnes of municipal waste according to the Ministry of Environment and Forestry, and the volume grows with the population [1]. Plastic forms a stubborn share of that stream. Jambeck et al. [2] ranked Indonesia second among coastal countries by the mass of mismanaged plastic waste that can reach the ocean, and Geyer et al. [3] estimated that only about 9% of all plastic waste generated worldwide up to 2015 had been recycled. Plastic bags, bottles, and packaging made from polystyrene or polyvinyl chloride persist for centuries once discarded, and accumulated plastic waste damages marine life, clogs drainage, and threatens public health.

Indonesian Law No. 18 of 2008 on Waste Management treats waste as a resource to be recovered, with reduction and handling as the two pillars of management [4]. Much of the recovery of plastic takes place outside formal municipal services. Informal collectors, known locally as *pengepul*, buy sorted plastic from households and resell it to recycling depots. Digital tools that turn waste into income, such as the Traxchange application [5], show that residents respond when the exchange is easy.

In Airmadidi District, North Minahasa, we interviewed two collectors who buy plastic in Sidon and Bukit Zaitun. Both described the same bottleneck: they do not know which households have plastic ready, so they start each day without a destination. They also lose time separating plastic from mixed household rubbish. One collector identified the student boarding houses near Universitas Klabat as the richest source of plastic bottles. Both already owned Android phones, and both said that an application listing ready plastic would make their search easier.

Indonesian researchers have applied GPS and mobile technology to waste handling before. Earlier work covers waste reporting and pickup by sanitation officers [6], waste banks [7], monitoring of municipal collection fleets [8], [9], and pickup requests from boarding houses [10]. These systems serve government agencies, fleets, or formal waste banks. None of them links a household directly to an independent collector who buys plastic at a posted price, and none combines photographic evidence of the plastic, a price list, and two-way chat in a single workflow.

We address this gap with WasteGPS, a mobile application for monitoring and collecting household plastic waste with GPS. The study asks how to design and build a mobile application that lets residents of Airmadidi report plastic waste together with its location and lets collectors find, contact, and collect from those residents. We make three contributions: a set of requirements elicited from working collectors; a UML design for a two-

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role, location-aware collection workflow; and a working Android implementation validated through functional testing of the main path, together with a specification of the safeguards and evaluation that deployment requires.

2 Related Work

Table 1 compares WasteGPS with five Indonesian studies that apply mobile or GPS technology to waste handling. Bahri et al. [6] built an Android application in which residents report waste and sanitation officers navigate to the pickup point with GPS. Andriyanto and Wansen [7] built an Android waste bank application in which collectors view collection places on a map and record transactions with weight and total price. Sudirman and Dewantoro [8] used the Google Maps API and GPS to track municipal collection vehicles and their routes in Stabat, and Yasmi and Chandra [9] built a web system for monitoring the operational vehicles of the Sukabumi sanitation agency in real time. Rabbani and Pratama [10] connected students and boarding-house residents with pickup officers through the Mapbox Maps and Navigation SDKs.

Two observations follow from the comparison. First, GPS in these systems serves an official actor: an officer, a driver, or a waste bank. Second, the household rarely has a way to show what it offers or to negotiate directly. WasteGPS keeps the GPS map at the center but gives the household a photo-backed report and gives both sides a shared channel for messages and prices.

Table 1. Comparison of WasteGPS with related studies (– = not reported in the cited study).

Study	Platform	Primary users	Role of GPS	Photo	Chat	Prices
Bahri et al. [6]	Android	Residents, sanitation officers	Navigation to pickup point	–	–	–
Andriyanto and Wansen [7]	Android	Waste bank, collectors	Map of collection places	–	–	Yes
Sudirman and Dewantoro [8]	Android	Municipal fleet, agency	Fleet location and route	–	–	–
Yasmi and Chandra [9]	Web	Sanitation agency	Vehicle monitoring	–	–	–
Rabbani and Pratama [10]	Android	Residents, students, officers	Pickup point and navigation	–	–	–
WasteGPS (this study)	Android	Residents, informal collectors	Report location, map, routing	Yes	Yes	Yes

GPS receivers compute position from the signals of a constellation of 24 operational satellites orbiting at about 20,200 km, which lets a smartphone tag a report with coordinates without manual address entry [11]. WasteGPS relies on the phone's built-in receiver for this step.

3 Methodology

3.1 Development Model

We followed the prototyping model of software development [12], shown in Figure 1. The model suits projects in which users cannot state every requirement up front: the developers build an early version, the users react to it, and the developers revise it. We worked through seven stages. We gathered requirements from collectors and the literature, built a prototype of the main screens in Figma, and evaluated the prototype against the interview findings. A failed evaluation sent us back to requirements gathering. After the prototype stabilized, we coded the system, tested it, and evaluated it against the requirements, returning to coding when a function fell short. The final stage covers deployment to users and maintenance.

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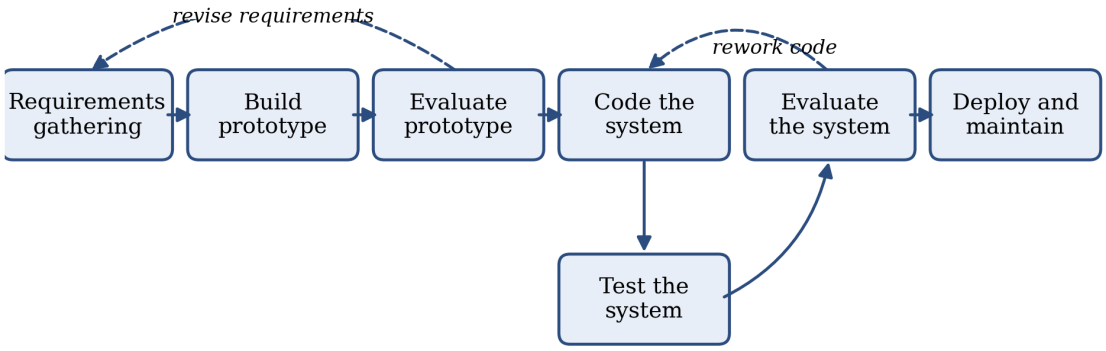


Figure 1. Prototyping model followed in the development of WasteGPS.

3.2 Data Collection

We collected primary data through semi-structured interviews and direct observation, and secondary data through a literature study. We interviewed two plastic waste collectors at their homes, using six prepared questions on daily volume, prices, plastic types, buyers, phone ownership, and problems with the current manual process. We then observed both collectors at the sites where they sort and store plastic. For the literature study, we searched Google Scholar for journal articles on GPS-based and mobile waste management systems. Table 2 summarizes the interview findings that shaped the requirements.

Table 2. Summary of interview findings from two plastic waste collectors.

Topic	Collector 1 (Sidon)	Collector 2 (Bukit Zaitun)
Volume collected	About 5–7 kg of sorted plastic per day	Up to about 100 kg per week, collected two or three times a week
Plastic types	Bottles and broken buckets	Clear and colored bottles, caps separated, oil containers
Price paid to residents	About Rp 1,500/kg	About Rp 4,000/kg for plastic bottles
Downstream buyer	Collected by a buyer at the disposal site	Sold onward for recycling
Smartphone ownership	Owns a phone; considers it essential	Owns an Android phone; believes most collectors do
Main problems	Manual search for households with plastic	Sorting plastic mixed with water and other rubbish; few residents know they can sell

The findings point to two needs. Collectors need to know where plastic is waiting, and residents need to know that collectors buy plastic and at what price. The price gap between the two collectors also shows why the application should let each collector publish his or her own rates instead of fixing a single tariff.

3.3 Development Environment and Testing

We wrote the application in JavaScript with the React Native framework, which renders native Android interfaces and exposes device features such as the camera and location services [13]. We edited code in Visual Studio Code and used Android Studio for emulation and builds. A MySQL 8 database with the InnoDB engine stores users, reports, collector notices, and messages [14]. We designed the interface in Figma [15] and drew the UML diagrams in draw.io. The software was developed on a computer running Windows 10 (64-bit) with a 1920 × 1080 display and an SSD, and it was tested on a Samsung Galaxy S9+ running Android 10 with an Exynos 9810 processor and 6 GB of RAM. Google Maps supplies the base map and turn-by-turn routing.

We modeled the system with the Unified Modeling Language [16]: use case diagrams and scenarios for each role, activity diagrams, sequence diagrams, and a class diagram. We verified the implementation with black-box testing [17], in which we executed each feature through the user interface, compared the observed output with the expected output, and recorded the result.

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4 Results and Discussion

4.1 Requirements and Scope

The interviews and observations yielded requirements for two user roles. The resident role covers registration and login; reporting plastic waste with GPS coordinates, a description, and a photograph; viewing the locations of collectors and the buying notices they post; chatting with collectors; and managing the profile and password. The collector role covers the same account functions; creating buying notices that state which types of plastic the collector buys and at what price per kilogram; viewing open resident reports on a map and as a list; generating a route to a selected resident; and chatting with residents.

These requirements come from two collectors and from observation of their work. No residents took part in elicitation, so the resident-facing features (reporting, price information, chat, location sharing, and pickup arrangement) reflect the collectors' view of residents' needs. This study does not examine how residents perceive the risks of sharing their location and phone number, how comfortable they are with the application, or whether they would use it. Siwawa [18] found that waste pickers in Cape Town who took part in designing a mobile platform became active contributors to its development. We therefore treat the resident-facing features as hypotheses, and Section 4.8 describes how they will be tested.

We set three limits on scope. Payment takes place in cash at pickup, so the application has no payment function. The application shows positions at the time of reporting and does not track collectors live. The prototype also sends no push notifications, so users see new reports and messages only when they open the relevant screen.

4.2 System Design

Figure 2 shows the conceptual design. Residents feed reports into the application, and collectors feed buying notices into it. Each side reads what the other has posted, and the MySQL database holds the shared state.

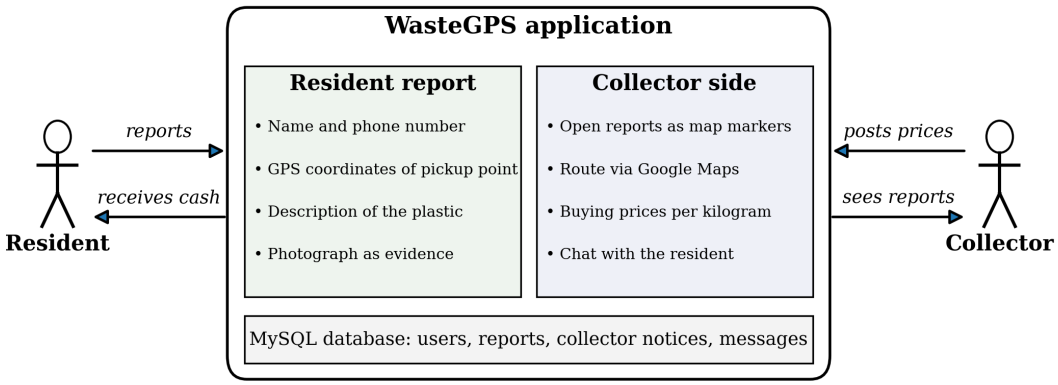
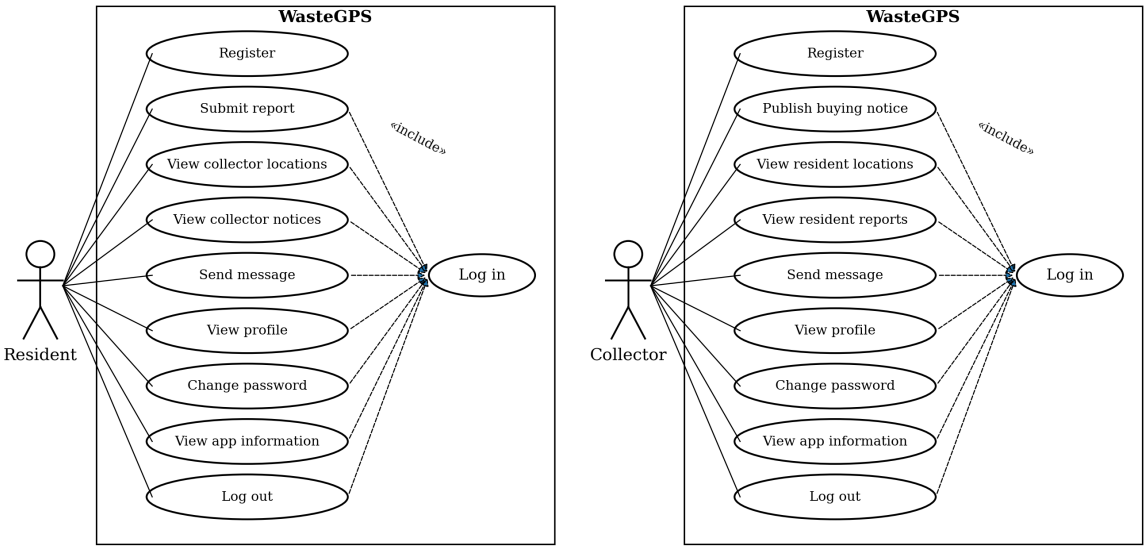


Figure 2. Conceptual design of WasteGPS.

Figure 3 presents the use case diagrams. Each role has nine use cases. Registration stands alone, and every other use case includes *Log in*. During registration, the user enters a first name, telephone number, address, e-mail address, and password and selects a role; the selected role determines the main menu shown after login. The two diagrams are largely the same and differ only in the use cases that produce content. In the prototype, anyone can choose the collector role at registration; Section 4.5 treats this as a security gap.

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(a) Resident (b) Collector

Figure 3. Use case diagrams for (a) the resident role and (b) the collector role.

We wrote a use case scenario for each of the 18 use cases and derived 12 activity diagrams and 20 sequence diagrams from those scenarios. The report flow illustrates the design. After login, the resident opens *Submit report*. The application pre-fills the name and phone number; the resident taps *Get location* to read the device's coordinates, types a description such as "1 kg of plastic bottles ready," and takes or attaches a photograph. On *Submit report*, the application writes a record to the database, and the record appears on the collector's map and report list. The class diagram groups behavior into registration, login, report or notice creation, location, information, messaging, profile, password change, application information, and logout.

Table 3 lists the six database tables. Separate tables for residents and collectors let the application load role-specific lists quickly, while *tb_user* handles authentication for both roles. Section 4.5 discusses how the prototype handles the credentials and personal data in *tb_user*.

Table 3. Database tables in WasteGPS.

Table	Contents and use
tb_user	Accounts for both roles: ID, name, phone number, address, e-mail, password, role, and registration date; used for registration and login
tbl_masyarakat	Records of users registered with the resident role
tbl_pengepul	Records of users registered with the collector role
data_log	Resident plastic waste reports, including the photo file name
data_log2	Collector buying notices, including the photo file name
chat_messages	Messages exchanged between residents and collectors

4.3 Implementation

Both roles share a splash screen, a sign-in screen, and a sign-up screen with a role selector. After login, each role sees a main menu of seven tiles and a logout button. Figure 4 shows the resident side. The main menu displays the user's name and address and offers *Submit report*, *Location*, *Information*, *Messages*, *Profile*, *Password*, and *About*. The report form captures coordinates with one tap, so the resident never types an address. The map screen marks nearby collectors around the Universitas Klabat area, and the information screen lists collector notices with a photograph, the plastic type, and the price, such as clear bottles at Rp 1,200/kg.

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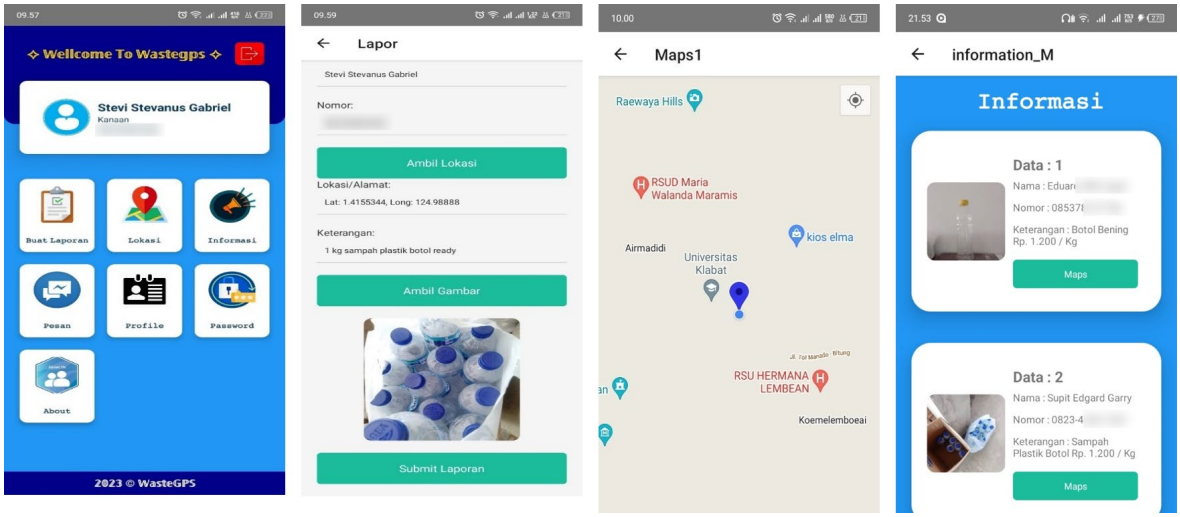


Figure 4. Resident screens: (a) main menu, (b) report form with GPS coordinates and photograph, (c) collector map, and (d) collector buying notices. Phone numbers and a third-party name are blurred.

Figure 5 shows the collector side. The collector's menu replaces *Submit report* with *Create notice*. On the map, the collector taps a resident marker and then the route icon, and Google Maps opens with directions to that point. The report list shows the resident's name, phone number, description, and photograph, with a *Maps* button and a *Finished* button. Tapping *Finished* after pickup removes the report from the list, which keeps the list limited to plastic that is still available. The chat screen lets the collector agree on a pickup time with the resident. Every collector sees every open report, and the prototype has no claim step, so two collectors can travel to the same household.

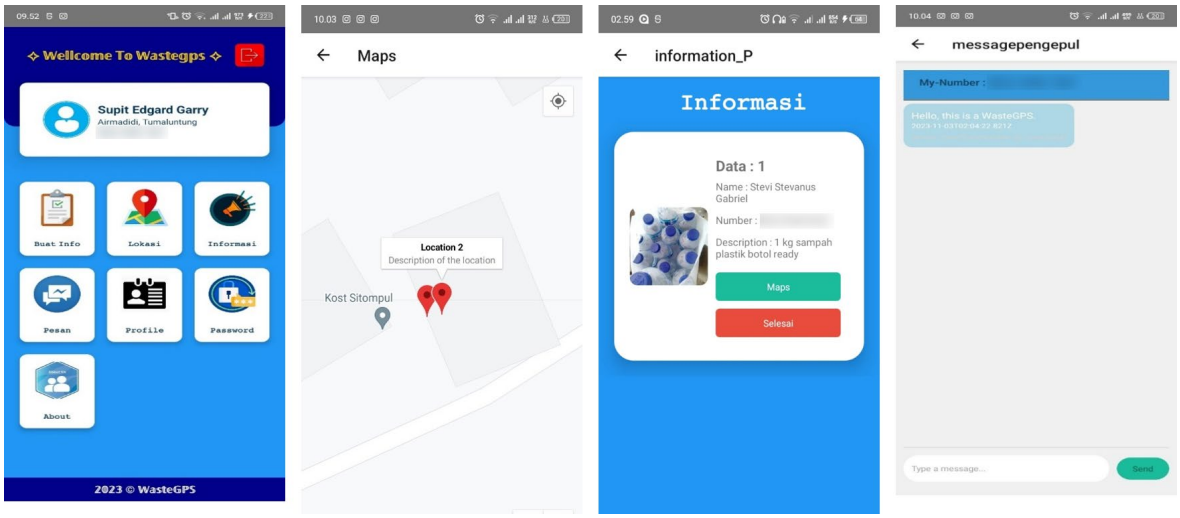


Figure 5. Collector screens: (a) main menu, (b) map of resident reports, (c) report list with *Maps* and *Finished* actions, and (d) chat. Phone numbers are blurred.

4.4 Functional Testing

Table 4 reports the black-box test results. We ran ten scenarios for each role, 20 in total, on the Samsung Galaxy S9+. Every scenario produced the expected output. All 20 scenarios followed the main path with valid input on one device and one Android version. We did not test negative or boundary cases; Section 4.8 lists them.

Table 4. Black-box test results for both roles.

Feature	Expected output (resident)	Expected output (collector)	Result
Sign up	New resident account created	New collector account created	Pass
Sign in	Resident main menu opens	Collector main menu opens	Pass
Report / notice	Plastic report saved with location and photograph	Buying notice saved with type and price	Pass
Location	Collector positions shown on map	Resident reports shown on map; route opens	Pass

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Feature	Expected output (resident)	Expected output (collector)	Result
Information	Collector notices listed	Resident reports listed; report can be closed	Pass
Messages	Message sent to a collector	Message sent to a resident	Pass
Profile	Account details displayed	Account details displayed	Pass
Password	Password changed	Password changed	Pass
About	Application information displayed	Application information displayed	Pass
Log out	User leaves the application	User leaves the application	Pass

4.5 Account Verification, Access Control, and Privacy

The prototype trusts the role that users select for themselves. Anyone can register as a collector and then see every open report, including the resident's name, phone number, location coordinates, and a photograph often taken in front of the house. A malicious user could collect these data to profile households. Passwords are stored in the *tb_user* table together with other profile attributes, and the project documentation does not describe password hashing or protection of the traffic between the application and the database. Apart from role-based menus, the prototype has no access policy, and the chat function lets any user message any other user, with no blocking or archiving.

Indonesia's Personal Data Protection Law requires a lawful basis, consent, purpose limitation, and safeguards for such data [19]. Table 5 lists the controls we specify for deployment. Password handling follows the NIST guidance on salted, slow hashing of memorized secrets [20], and the security tests in Section 4.8 follow the OWASP Mobile Application Security Verification Standard [21].

Table 5. Security and privacy gaps in the prototype and controls required before deployment.

Gap	Risk	Required control
Self-selected collector role	Impostors obtain household locations, phone numbers, and photographs	A local partner, such as the village office or a waste bank, verifies each collector's identity and activity before an administrator activates the account.
Password in *tb_user*	Credential theft if the table leaks	Store only a salted hash produced by a slow algorithm such as bcrypt or Argon2; serve the API over HTTPS only; lock the account after repeated failed logins.
Full resident data shown to all collectors	Unnecessary exposure of personal data	Show an approximate location and the plastic description before a claim; reveal the exact pin and phone number only to the collector who claims the report, and hide them again after completion.
No server-side access policy	Residents read other residents' data; collectors edit others' notices	Check the user and role on the server for every request; residents access only their own reports and chats; collectors edit only their own notices and claimed reports.
Unmoderated chat	Harassment, scams, or unwanted contact between strangers	Open a private chat only between the resident and the collector who claimed the report; add blocking and reporting; retain messages for a set period after the transaction; an administrator reviews reported chats.
No consent or retention policy	Non-compliance with Law No. 27 of 2022	Present a consent notice at registration that explains the use of each data item; delete accounts and reports on request; notify users and the competent authority within 72 hours (3 × 24 hours) of a breach.

4.6 Location Accuracy

WasteGPS depends on the coordinates that a phone records when the resident taps *Get location*, yet we did not measure their accuracy. Smartphone GNSS error depends mainly on the environment: positions indoors and next to buildings degrade even near low structures [22], and in dense urban streets the error can exceed the distance needed to tell one side of a street from the other [23]. A resident who taps the button indoors may therefore place the pin on a neighbor's property.

For deployment, we specify three measures. First, the application should store the horizontal accuracy estimate that Android reports with each fix and reject a fix whose estimate exceeds a threshold, prompting the resident to step outside; we propose an initial threshold of 20 m, to be validated against the typical plot width in the study area. Second, the resident should confirm or drag the pin on a map. Third, the resident should add a short landmark description. Section 4.8 includes a field test that compares recorded coordinates with surveyed reference points indoors, outdoors, between buildings, and under weak signal.

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4.7 Coordination among Collectors and Transaction Records

The prototype serves a single collector well but leaves several collectors uncoordinated. Every collector sees every open report, and nothing stops two of them from traveling to the same house. The prototype also stores price notices without a date, so a collector can leave a stale or inflated price online, and it records no weight, agreed price, or payment, so a resident cannot check what was paid. Studies of recycling platforms in Thailand link fair prices for waste pickers to transparent records of each sale [24].

Table 6 specifies the states and records that a multi-collector deployment needs. A collector claims a report before traveling, which locks it for other collectors. A claim expires at the end of a period agreed between the collectors and the program, and a canceled or expired claim returns the report to the open pool. Each price notice carries a date and a validity period, and expired notices are hidden from the application. At pickup, the collector enters the weight and the price per kilogram, and the resident can flag a record in which the price paid falls below the price the collector posted.

Table 6. Report states and records proposed for a multi-collector deployment.

State or record	Trigger	System behavior
Open	Resident submits a report	All verified collectors see an approximate location and the plastic description
Claimed	A collector claims the report	The report is locked for other collectors; the exact location and phone number become visible to the claimant; chat opens
Expired claim	No pickup within the claim period	The report returns to *Open*, and the resident is notified
Canceled	Collector or resident cancels	The report returns to *Open* or closes, with a reason recorded
Failed pickup	Resident absent or plastic not as described	The collector records the reason; repeated failures are flagged for review
Completed	Collector records weight and price per kilogram	The application computes the total; the resident confirms or disputes the record
Price notice	Collector publishes or updates prices	Each notice carries a date and expiry; expired notices are hidden; disputed transactions are linked to the notice

4.8 Evaluation Plan

Table 7 sets out the evaluation that must precede deployment. Because the black-box tests in Table 4 checked only the main path, the first stage adds negative and boundary cases and extends testing to other devices. Security, location, and usability evaluations follow, leading to a field pilot with residents and several collectors. Surveys of residents on privacy, digital literacy, and willingness to use the application will run alongside the pilot.

Table 7. Evaluation plan for the next stage.

Stage	Method	Measures
Negative and boundary tests	Denied GPS permission, invalid login, duplicate e-mail, missing photograph, lost network, invalid coordinates, database failure, two collectors opening one report, oversized images, failed Google Maps routing	Pass rate; correct error messages; no data loss
Compatibility	Low- and mid-range devices running at least three Android versions, including the current one	Crashes, layout defects, location and camera failures
Security	Impostor registration, cross-user data access, and chat abuse scenarios tested against the controls in Table 5, following MASVS [21]	Share of attempts blocked
Location accuracy	Repeated fixes at surveyed points indoors, outdoors, between buildings, and under weak signal	Horizontal error; share of fixes within the threshold
Usability	Task-based sessions with residents and collectors, rated against the ISO/IEC 25010 quality characteristics [25] and the System Usability Scale [26]	Task success, errors, SUS score
Field pilot	Several collectors and resident households in selected villages over several weeks, compared with a baseline period of manual search	Successful pickup rate, search time, travel distance, kilograms per trip, report-to-pickup time, failed pickups, user retention, perceived trust

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4.9 Discussion

WasteGPS is designed to meet the two needs identified in the interviews, and the functional tests show that its main path works. A collector who opens the map sees which households have plastic waiting and what each has, backed by a photograph. A resident who opens the information screen sees which collectors buy plastic and at what price. Compared with the systems in Table 1, WasteGPS shifts the use of GPS from fleet management to matching households with buyers, and it adds the photograph, price, and chat functions that such matching requires. Whether these functions reduce search time or increase the quantity of plastic collected is still unknown. The contribution should therefore be read as a functionally validated prototype, not as evidence that the application improves plastic waste collection.

The design also addresses the collectors' sorting problem indirectly. A resident who must describe and photograph the plastic before reporting it has a reason to separate bottles from other rubbish, and the collector can judge the quality of the plastic before traveling. We have not measured this effect, and it should be tested in the field.

The study has six limitations. First, the requirements came from two collectors, and no residents took part in elicitation. Second, the prototype lets anyone register as a collector, does not document password protection, and exposes resident contact details to every collector. Third, we did not measure GPS accuracy. Fourth, the prototype has no claim step or transaction record, so it works for one collector per report but cannot coordinate several. Fifth, testing covered only the main path on one device and one Android version. Finally, the application sends no push notifications, so a user must open the chat to learn that a collector is on the way.

Sections 4.5 to 4.7 describe the measures that address these weaknesses, and Table 7 sets out the tests and the field pilot required before deployment and expansion to other districts.

5 Conclusion

WasteGPS is an Android application that connects households and independent plastic collectors in Airmadidi District through GPS-tagged reports, buying notices, routing, and chat. Interviews with two collectors showed that the main obstacle to collection was the lack of information about which households had plastic ready for sale. The application was developed with the prototyping model, modeled in UML, and implemented in React Native with a MySQL database. All 20 black-box scenarios on the main path passed, which shows that the prototype functions as designed. The study's contribution is a two-role workflow built around the independent collector. Issues that must be resolved before deployment include collector verification, data privacy, location validation, claim locking, and transaction records. Claims about the effectiveness of WasteGPS for plastic waste collection should wait until a field pilot with households and collectors has been carried out.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the research, authorship, and publication of this article.

Author Contributions

S.S.G.: Conceptualization, Investigation, Software, Writing – Original Draft. S.E.G.: Investigation, Software, Visualization, Writing – Original Draft. J.H.M.: Methodology, Supervision, Writing – Review & Editing. S.W.T.: Validation, Supervision, Writing – Review & Editing. All authors have read and approved the final version of the manuscript.

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Artificial Intelligence (AI) Use Statement

During the preparation of this manuscript, the authors used Claude (Anthropic) to translate the text from Indonesian into English, to condense it into journal format, and for language editing, formatting to the journal template, and conversion of references to IEEE style. All AI-assisted output was reviewed, verified, and revised by the authors. The authors take full responsibility for the accuracy, integrity, originality, and final content of the manuscript.

Data Availability Statement

The interview records, design documents, and source code supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics Statement

Ethical approval was not required for this study because it involved only non-sensitive interviews with adult informants about their work and collected no health or personally identifying data for analysis. Verbal informed consent was obtained from both interview participants.

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