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GIS-Based Software Engineering to Support Public Participation in Spatial Utilization in Lampung

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Abstract
Managing land use effectively requires citizens to have a say in how their environment is shaped, especially in rapidly urbanizing regions. Recognizing the need for inclusive spatial governance, this study engineers a Geographic Information System (GIS) application to foster grassroots participation, designed for Dinas Perumahan, Kawasan Permukiman dan Cipta Karya Provinsi Lampung, the provincial agency responsible for housing, settlements, and public works. The need is pressing: an agency survey in 2023 found that only 25 percent of residents knew the provincial spatial plan existed, and only 15 percent had ever taken part in preparing it. Development followed a User-Centered Design (UCD) approach and was aligned with the official blueprint in the province's 2025 Draft Gubernatorial Regulation on community empowerment in spatial utilization. The result is an integrated web and mobile GIS platform built around a five-stage participatory reporting mechanism and an architecture of Node.js, PostgreSQL/PostGIS, React Native, and GeoServer. Citizens submit geotagged reports of suspected zoning violations, which the system automatically cross-checks against the digital spatial plan (RTRW) before officers are assigned and follow-up action is tracked. Functional testing confirmed that all core features operated as designed, while qualitative feedback from community representatives and agency officials highlighted the platform's intuitive navigation and practical relevance. The study shows how UCD-driven software engineering can turn a regulatory mandate for participation into a working, two-way channel between citizens and spatial governance.
Keywords: Geographic Information Systems; Public Participation; Software Engineering; Spatial Utilization; User-Centered Design

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1.INTRODUCTION

Whenever we discuss sustainable regional development, the conversation almost always circles back to how land is managed and who gets a voice in those decisions [1]. Moving government operations into the digital realm, particularly through Geographic Information Systems (GIS), is no longer just about looking modern; it is a practical requirement to make public administration more transparent and collaborative [2]. The urgency in Lampung Province is underscored by a population growth rate of 1.2% per year and an urbanization rate of 3.5% per year (BPS Provinsi Lampung, 2023). This rapid demographic shift triggers the conversion of approximately 1,500 hectares of productive agricultural land annually into settlements and industrial zones. Consequently, the province's environmental quality index stands at 65.2, below the national average of 68.5 (Kementerian Lingkungan Hidup dan Kehutanan, 2023). According to the strategic environmental assessment (KLHS) of the Lampung Provincial Spatial Plan (RTRW) 2023–2043, the environmental carrying capacity in Lampung Selatan, Lampung Tengah, and Bandar Lampung has already been exceeded, exacerbating physical

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vulnerabilities in a province where 65% of the territory is at risk of floods and landslides (BNPB, 2023). Giving citizens a legitimate role in spatial utilization is vital to mitigating these escalating environmental pressures and preventing prolonged territorial disputes.

Legislation clearly mandates public involvement, as stipulated in Law Number 26 of 2007 on Spatial Planning (specifically Article 69 regarding community participation), Government Regulation Number 21 of 2021, and Lampung Provincial Regulation Number 14 of 2023 concerning the 2023–2043 Provincial Spatial Plan (RTRW). However, civic involvement in actual spatial monitoring remains alarmingly sparse on the ground. A 2023 survey conducted by Dinas Perumahan, Kawasan Permukiman dan Cipta Karya Provinsi Lampung reveals a stark reality: only 25% of the public is aware of the provincial RTRW's existence, and a mere 15% have ever been involved in its drafting process. The official academic manuscript (Naskah Akademik) of the Draft Gubernatorial Regulation of Lampung Province on the Implementation of Community Empowerment in Spatial Utilization (2025) identifies four fundamental problems driving this gap: (1) the community's low capacity to comprehend complex spatial plans; (2) severely limited access to spatial information and technology; (3) weak participatory mechanisms in spatial decision-making; and (4) the sub-optimal utilization of digital technology in participatory planning. Because residents cannot easily see or report what is happening around them, zoning violations frequently slip by unnoticed, and a noticeable disconnect grows between government blueprints and community realities. E-government research elsewhere confirms that digital channels only improve participation when citizens feel genuinely empowered and can see accountability for their input [3], a lesson echoed by Indonesian evidence that digital transformation raises citizen trust and participation only when services are usable and responsive [4].

Researchers have naturally tried to fix these participation bottlenecks using various digital tools over the years. A comprehensive review of Public Participation GIS (PPGIS) practice shows that barriers have shifted over time from simple technology access toward questions of inclusiveness, data integration, and institutional follow-through [5]. Place-based studies demonstrate the value of what residents actually know: experiential knowledge contributed through PPGIS improves the quality of spatial decisions because it captures conditions that official datasets miss [6]. In Finland, PPGIS data have been used to build place-based priority categories that help planners decide where participatory interventions matter most [7], and multi-sensory extensions of PPGIS show that citizens can contribute richer landscape values when the tools let them express more than a point on a map [8]. Scoping reviews of PPGIS applications confirm a maturing field that is moving from one-off consultations toward continuous, platform-based engagement [9]. Participation, however, does not only flow through official channels; planning activism that uses PPGIS outside formal procedures can amplify voices that institutional processes tend to overlook [10]. At the municipal level, structured e-participation platforms have been shown to raise citizen engagement when they are embedded in real administrative workflows rather than bolted on as showcases [11].

Even with these advancements, there is a glaring hole in the current landscape: very few platforms successfully marry citizen-driven reporting with interactive maps designed for people who are not tech experts. PPGIS initiatives operate at very different scales, from a single neighborhood to an entire region, and tools designed for one scale often fail when transplanted to another [12]. Reviews of digital planning tools repeatedly find that empowerment stalls when applications demand professional GIS skills from ordinary residents [13]. What usually happens is that spatial systems are either locked away for internal bureaucratic use only, or they are so overloaded with complex features that they scare off the average citizen. This leaves a significant research gap: we still need highly accessible, user-centric GIS platforms that treat the local community's experience as the primary driver of the design rather than an afterthought, and that close the loop by telling citizens what happened to their reports.

To address this gap, this study's contribution lies not in a new GIS algorithm, but in a sociotechnical integration across three levels: architecture, engineering process, and policy application. Architecturally, the platform consolidates four functions that previous PPGIS initiatives usually treat separately — geolocation-based public reporting, automatic verification against the digital RTRW zoning, field officer assignment, and feedback to the reporter — into a single closed loop, so that a citizen report travels from submission to outcome without leaving the platform. In terms of process, the

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system was engineered through a User-Centered Design approach in which residents and agency staff shaped every iteration, which is what makes the integration usable by citizens with limited digital literacy rather than only by GIS specialists. In terms of policy application, the platform directly implements, at provincial scale, the community reporting system blueprint set out in the academic manuscript of Lampung's 2025 Draft Gubernatorial Regulation, so the design is embedded in a formal institutional framework instead of standing as an isolated pilot application. It is this combination — an integrated architecture, a user-centered engineering process, and provincial policy embedding — that distinguishes the present work from earlier PPGIS studies.

To fill this void, our research focuses on building an integrated GIS application using a User-Centered Design (UCD) approach, putting residents and agency staff at the center of every design iteration. The approach has a proven precedent in Indonesian government systems, where combining an agile process with UCD produced a geographic information system that agency users could actually operate [14]. Crucially, the 2025 Draft Gubernatorial Regulation explicitly recommends the development of web and mobile-based digital participation platforms to facilitate public consultation and spatial reporting, and its appendix provides an official blueprint for a community reporting system. Aligning with this policy directive, our proposed system bridges the technical divide through a responsive map interface combined with a direct, participatory reporting feature. Citizens can point to and interact with zoning polygons on their screens, an approach purposefully tailored to accommodate the varying levels of technological fluency we encountered in the field. This matters because community involvement in digital governance is strongly mediated by digital literacy; a platform that assumes high literacy silently excludes the residents it is meant to empower [15].

Ultimately, this study aims to engineer and evaluate a GIS software platform designed specifically to catalyze public participation in spatial utilization across Lampung, following the official blueprint of the draft regulation from needs analysis through implementation and testing. We hope to make two distinct contributions. On a practical level, the study provides local authorities with a working digital tool that directly implements the mandate of the upcoming gubernatorial regulation, in line with the broader role of maps in pursuing sustainable, inclusive cities [16]. Methodologically, we want to enrich the academic conversation around how UCD principles can be realistically applied to build geographic information technologies that the public will actually use and embrace, particularly in a provincial setting where participation rates start from a very low base.

2.RESEARCH METHODOLOGY

2.1. Research Design

We anchored our entire development process in the User-Centered Design (UCD) framework because we needed to be absolutely sure the software would survive the practical constraints of its actual users. UCD-based development has repeatedly proven suitable for building location-based public applications whose users are non-specialists [17], and usability thinking is now well established in the GIS domain, where systematic reviews show that evaluation with real users determines whether a geographic application is adopted or abandoned [18]. Our core research activities were deeply embedded within the operational setting of Dinas Perumahan, Kawasan Permukiman dan Cipta Karya Provinsi Lampung. The sequence of our field activities began with an initial mapping of spatial information needs, followed closely by comprehensive interviews and needs-assessment surveys with the end-users. Once the requirements were finalized, we transitioned into the design and prototyping phase, relying on continuous feedback loops. Finally, we conducted iterative trial sessions before finalizing the system.

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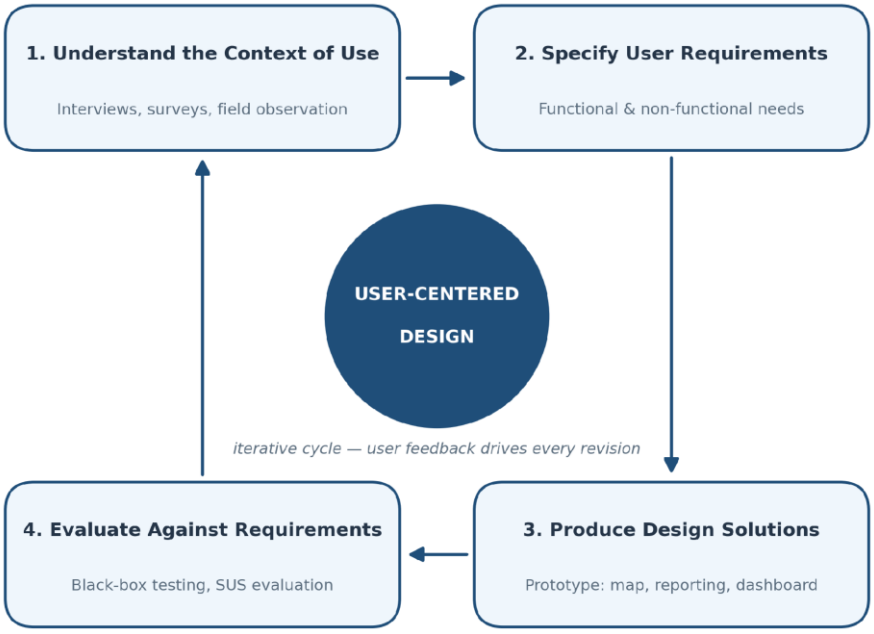


Figure 1. The iterative stages of the User-Centered Design (UCD) approach applied in this study.

As illustrated in Figure 1, the UCD framework consists of four cyclical phases that drove our software engineering process. The first phase focused on understanding the authentic context of use by observing how citizens and agency staff currently struggle with spatial data communication. The second phase systematically translated these observations into concrete user requirements. The third phase involved drafting and developing the GIS prototype, prioritizing layout clarity, platform responsiveness, and participatory mapping features. Finally, the fourth phase centered on evaluating this prototype through continuous user feedback. This iterative loop ensured we caught and corrected design flaws early, aligning the final software with the operational realities of the local government and the civic needs of the Lampung community.

2.2. Data Collection

To gather the necessary insights, we relied on a mixed-methods strategy combining in-depth qualitative interviews with structured surveys. We spent considerable time talking directly with the spatial planners and administrative staff from the relevant divisions at Dinas Perumahan, Kawasan Permukiman dan Cipta Karya Provinsi Lampung, exploring the bureaucratic hurdles that plague their current monitoring workflows. Simultaneously, we engaged with civic representatives from various backgrounds across the province to map out their perspectives. These community surveys gave us the data we needed regarding their actual digital literacy and genuine expectations for a public-facing mapping portal. To support the accuracy of this data collection, tools like QGIS were utilized for initial participatory mapping sessions with the community, while ODK Collect and Kobo Toolbox were deployed to efficiently gather structured field observations from the residents. This way of working treats citizens as data producers, in line with the broader crowdsourcing movement in geospatial science, where volunteered observations complement official datasets at a fraction of the cost [19]. Experience from smart-city monitoring shows that volunteered geographic information can reliably surface problems such as urban decay when the reporting channel is simple and location-aware [20], and within a spatial data infrastructure, such community contributions become far more valuable when they follow shared standards from the start [21].

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The participants were selected purposively, according to the role each group plays in spatial planning and in the intended use of the platform. Three groups were engaged. First, spatial planners from the Dinas contributed the official verification workflow: how zoning designations are interpreted, how incoming reports would be checked, and what evidence a case file must contain. Second, administrative staff of the Dinas described the practical constraints of case handling, including how field officers are assigned and how report data are recorded and monitored. Third, community representatives participated as the intended end-users of the public reporting map; they were drawn from residents with varying levels of digital literacy, so that the design would be tested against the least experienced users it is meant to serve. Data collection took place at the Dinas and in community sessions in Lampung, using semi-structured interview guides for the agency staff, structured surveys on residents' access to and readiness for digital services, participatory mapping sessions in QGIS, and structured field observation supported by ODK Collect and Kobo Toolbox. Because the emphasis of this formative phase was on role representativeness and qualitative depth rather than statistical enumeration, exact participant headcounts for each session were not systematically recorded.

The interview and survey material was converted into the requirements of Table 1 through a traceable sequence. Statements from interviews, surveys, and mapping sessions were first grouped thematically according to the need they expressed; community needs were then cross-checked against the workflow constraints described by agency staff, so that a requirement was only adopted when it was both wanted by users and workable inside the agency's procedures; the surviving needs were prioritised together with the agency, and each was finally rewritten as a functional or non-functional requirement statement. One trace illustrates the path: during the participatory mapping sessions, community representatives repeatedly had difficulty interpreting the technical zoning maps, with their regulatory codes and legend conventions; that finding became the functional requirement that the interactive zoning map present each polygon's designation and permitted uses in plain language (Table 1), and it also motivated the non-functional requirement that the interface remain operable by users with limited digital literacy.

2.3. User Requirements

The fieldwork condensed into a compact set of requirements. Agency staff needed the official RTRW zoning layers served digitally, an automatic way to check incoming reports against those layers, and a dashboard to assign and monitor follow-up. Community representatives asked for the opposite of a professional GIS: a map they could read at a glance, a reporting flow that works with a phone camera and GPS instead of forms full of codes, and visible confirmation that a report had been received and acted upon. Table 1 summarizes the resulting functional and non-functional requirements that governed the design.

Table 1. Functional and non-functional requirements of the participatory GIS platform.

Category	Requirement	Description
Functional	Interactive zoning map visualization	The system must render the official RTRW zoning polygons in layered, color-coded form and allow citizens to identify the designation of any location.
Functional	Geolocation-based reporting	Citizens must be able to submit a report with automatic GPS coordinates, a photo, a category, and a short description.
Functional	Automatic verification and officer assignment	Each report must be cross-checked automatically against the digital RTRW data, then

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		routed to the responsible field officer.
Functional	Administrative dashboard and notifications	Agency staff must be able to monitor report status and participation statistics, while reporters receive status notifications.
Non-functional	Accessibility without installation	Core consultation features must run in a standard web browser so participation does not depend on installing software.
Non-functional	Responsive, low-complexity interface	The interface must adapt to common smartphones and remain operable by users with limited digital literacy.

Table 1 separates what the system must do from the conditions under which it must do it. The functional requirements trace directly to the five-stage reporting mechanism mandated by the draft regulation's blueprint, while the non-functional requirements come from the field reality of Lampung: modest devices, uneven connectivity, and users who may be opening a digital map for the first time. Every design decision in the next stage was checked against this table, and every test case in the evaluation stage was derived from it.

2.4. System Design and Tools

To ensure the software directly addresses the region's regulatory goals, we adopted the official system blueprint from the appendix of the 2025 Draft Gubernatorial Regulation. The architecture is built around a streamlined, five-stage participatory reporting mechanism: (1) citizens input violation reports directly through the application; (2) the system conducts automatic verification by cross-referencing the report's location against digital RTRW data; (3) the platform generates an automated task assignment for field verification officers; (4) follow-up actions, ranging from spatial enforcement to mediation, are executed based on verified findings; and (5) continuous feedback and status notifications are pushed back to the reporter. The platform is implemented as a three-layer architecture, following the open-source geospatial stack pattern that has proven effective for public WebGIS deployments [22], [23] and for land-planning data management in university and government settings [24].

One stage of this mechanism deserves clarification, because it combines automation with human oversight. At the assignment stage, the platform does not dispatch a case on its own: after automatic verification, the system routes the case to the field officer responsible for the report's administrative area and category, and places it in the administrator's dashboard. The administrator confirms the assignment, or reassigns the case when the suggested officer is unavailable or the case falls outside that officer's remit, before the officer is notified. References to automatic assignment elsewhere in this paper should be read in this hybrid sense: automatic routing by the system, followed by administrator confirmation.

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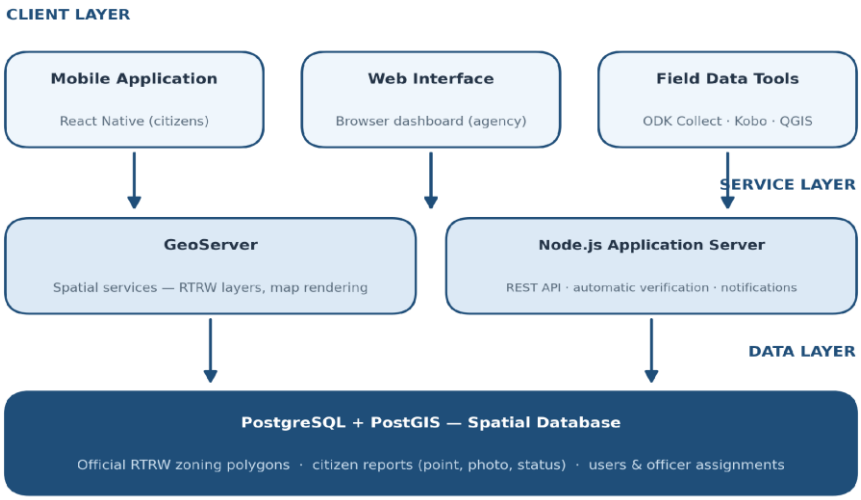


Figure 2. The three-layer system architecture of the participatory GIS platform.

Figure 2 shows how the components divide the work. The client layer meets each user group where it already is: citizens on a React Native mobile application, agency staff on a browser-based web dashboard, and field teams on ODK Collect, Kobo Toolbox, and QGIS for structured data capture. The service layer separates concerns between GeoServer, which publishes the official RTRW layers as spatial services and renders map tiles, and a Node.js application server that exposes the REST API, executes the automatic point-in-polygon verification against the zoning data, routes assignments, and sends notifications. All spatial and transactional data converge in the data layer, a PostgreSQL database with the PostGIS extension that stores the zoning polygons, geotagged citizen reports, and user and assignment records in a single spatially indexed store.

Table 2. System architecture and feature requirements based on the official blueprint.

Component	Technical Implementation / Feature Description
Core Features	Automatic GPS location tagging, photo uploads, and violation descriptions.
User Interface	Integration with digital RTRW maps and a community participation monitoring dashboard.
Mobile Front-End	React Native framework for cross-platform mobile accessibility.
Web and GIS Server	GeoServer for dynamic spatial rendering, ensuring responsive map tiles.
Backend and Database	Node.js coupled with PostgreSQL/PostGIS for robust spatial data management.

Table 2 outlines the core features and technological stack of the proposed GIS system, adapted directly from the government's official academic manuscript. On the user-facing side, we prioritized crucial participatory features such as automatic GPS tagging and direct photo uploads to lower the barrier for public reporting. Architecturally, the mobile application leverages React Native to guarantee smooth operation across various citizen devices, while GeoServer handles the heavy lifting of rendering spatial layers. Behind the scenes, the backend relies on Node.js and a PostgreSQL/PostGIS database to securely process the complex geometry of official zoning polygons and real-time crowdsourced coordinates. This specific combination of technologies ensures the system remains scalable, responsive, and fully capable of supporting the five-stage automated verification flow mandated by the provincial blueprint.

2.5. Testing Design

Once the prototype was built, we split our evaluation into two distinct tracks to measure technical stability and human reception. First, we ran black-box testing to make sure the core functions, such as

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plotting coordinates, matching GPS data to RTRW polygons, and routing automated assignments, actually produced the right outputs without crashing the system. After establishing that the codebase was solid, we moved on to usability assessment using the System Usability Scale (SUS), following the practice in comparable spatial decision support research of evaluating not only whether users can operate the tool, but also whether they judge it useful for their real tasks [25]. This allowed us to capture qualitative feedback on how satisfied, efficient, and comfortable both the community members and the agency officials felt when they tested the software in simulated real-world scenarios. For clarity on the second track, the SUS is a standardised ten-item questionnaire whose items are rated on a five-point scale and which is conventionally summarised as a composite score between 0 and 100 [18], [25]. In the evaluation reported in this study, the sessions were analysed qualitatively: participants' responses and comments were organised along the usability dimensions of ease of navigation, learnability, and satisfaction, and no composite SUS score is reported; we return to this limitation in the Usability Evaluation subsection.

3.RESULT AND DISCUSSIONS

3.1. System Implementation and Main Features

Translating the official policy blueprint into a functioning digital infrastructure was the core challenge of this research phase. The resulting implementation is a fully operational web and mobile GIS platform structured around five interdependent modules designed to democratize spatial data: an interactive zoning map, a location-based reporting module, an open feedback channel, an administrative dashboard, and a spatial data verification module. Each module is described below as it was implemented and exercised during the trials.

The interactive zoning map is the primary visual interface and the front door of the whole system. It renders the official RTRW zoning polygons as color-coded layers over a base map, so a resident can open the application, find their neighborhood, and immediately see which designation applies to a parcel: residential, agricultural, protected, public facility, or another official category. Layer toggles let users isolate one designation at a time, and tapping a polygon reveals its permitted uses in plain language rather than regulatory codes. For many trial participants, this was the first time they had ever seen the plan that governs their own land rendered in a form they could read.

The location-based reporting module turns that map into an instrument of oversight. A resident who suspects a violation, such as construction rising on land designated as protected or agricultural, drops a report directly at the location: the application captures the GPS coordinates automatically, attaches a photo, and asks only for a category and a short description. Removing manual coordinate entry was a deliberate UCD decision; field trials confirmed that typing coordinates or addresses was the single largest source of abandoned reports in earlier, form-based channels. The open feedback channel complements incident reporting with a slower form of participation: residents can comment on planned spatial changes and upcoming consultations, giving the agency a standing channel for aspirations rather than only complaints.

On the government side, the administrative dashboard aggregates everything the public sends in. Agency staff see incoming reports on a map and in queues ordered by status, the spatial distribution of reports by district and category, and participation statistics that show which areas are active and which remain silent. The fifth module, spatial data verification, is the analytical engine behind the dashboard: it performs the point-in-polygon check of every report against the official zoning polygons, flags agreements and conflicts, and prepares the case for officer assignment. Together, the dashboard and verification module shift the agency's workload from manually locating and classifying complaints to acting on cases that arrive pre-located and pre-classified.

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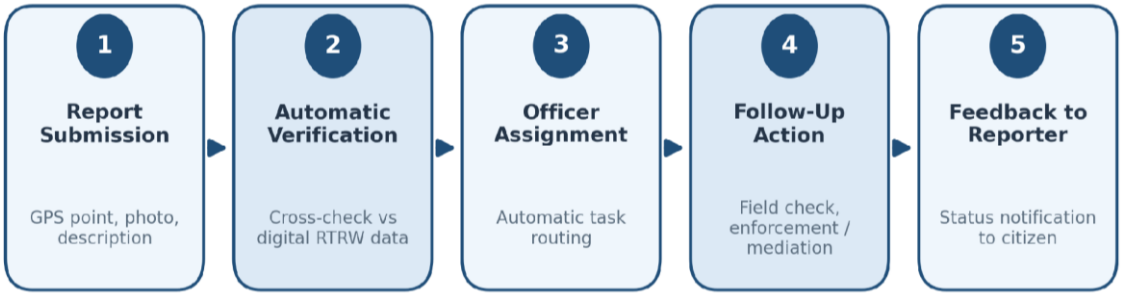


Figure 3. The five-stage automated spatial reporting mechanism adopted from the 2025 Draft Gubernatorial Regulation blueprint.

As detailed in Figure 3, the system operationalizes a strict five-stage mechanism to ensure accountability and responsiveness. The cycle initiates when a citizen inputs a report through the application, complete with a geotagged photo and a brief description. Immediately following this, the platform executes an automatic verification process, matching the submitted coordinates directly against the digital RTRW layers to identify potential spatial discrepancies. If a conflict is detected, the system generates an automated task assignment, instantly routing the case to the designated field verification officer. This leads to the fourth stage, where concrete follow-up actions, ranging from formal mediation to spatial enforcement, are determined based on ground realities. The loop closes with the system pushing automated status notifications back to the original reporter, thereby maintaining a transparent feedback loop that builds public trust.

This hybrid protocol also governs the third stage shown in Figure 3. The assignment the system generates is a routing decision, not a final dispatch: the case is matched to the officer mapped to the report's jurisdiction and category, the routed case appears in the administrative dashboard, and an administrator confirms it — or reassigns it in light of staff availability and workload — before the field officer receives the task. The complete workflow is drawn in Figure 5.

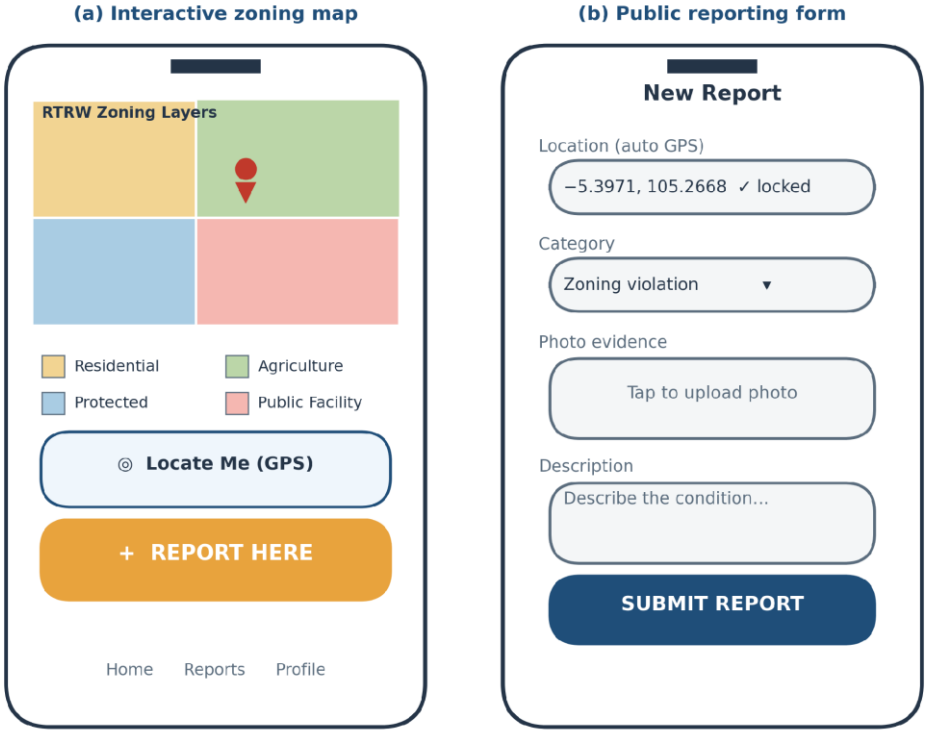


Figure 4. The mobile interface displays (a) the interactive zoning map and (b) the geolocation-based reporting form.

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Figure 4 illustrates the user-facing implementation of our User-Centered Design philosophy. Knowing that our target demographic possesses vastly different levels of digital literacy, we deliberately stripped away the complex, cluttered toolbars typically associated with professional GIS software. Instead, the interface relies on bold, intuitive visual cues: a prominent "Report Here" button, automated GPS fetching to minimize manual data entry, and a straightforward photo upload field. By hiding the complex spatial querying processes in the backend and presenting a clean, accessible frontend, the application significantly lowers the barrier to entry, ensuring that ordinary citizens can participate without needing prior technical training.

3.2. Functional Testing Results

Before exposing the platform to end-users, we subjected the architecture to black-box testing to guarantee that the system behaved exactly as intended under various interaction scenarios. Test cases were derived one-to-one from the functional requirements in Table 1 and executed against the running prototype.

Table 3. Black-box functional testing results of the core system modules.

No	Feature Tested	Test Scenario	Expected Result	Result
1	Login and Registration	User attempts to create an account and access the platform.	System authenticates credentials and grants role-based access.	Passed
2	Interactive Map	User toggles different spatial zoning layers.	Map renders the correct geospatial polygons without latency.	Passed
3	Report Submission	User submits a violation report with a photo and GPS location.	Data is successfully recorded and stored in the spatial database.	Passed
4	Automatic RTRW Verification	System processes a newly submitted geolocation.	The backend accurately cross-references the point against official zoning data.	Passed
5	Officer Assignment	System auto-routes a verified case to the officer responsible for its area and category; the administrator confirms or reassigns the case in the dashboard.	The confirmed field officer receives a real-time notification of the assignment.	Passed
6	Status Notification	An officer updates the resolution status of a report.	The original reporter receives an automated update regarding the outcome.	Passed
7	Admin Dashboard	Agency staff accesses the participation overview.	The dashboard correctly aggregates and visualizes all public engagement data.	Passed

The outcome of the functional evaluation, summarized in Table 3, confirmed the robustness of our software engineering approach. Every core feature, from the initial user authentication to the complex spatial intersections required for the automatic RTRW verification, functioned as designed without triggering system crashes or data loss. The successful execution of these test scenarios gave us the confidence to proceed with the user trials, knowing the underlying technical foundation could handle the unpredictable nature of real-world user inputs and fluctuating network conditions.

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3.3. Automated Spatial Verification: Mechanism, Accuracy Handling, and Limits

The spatial verification module executes a point-in-polygon match in PostgreSQL/PostGIS between the report's GPS point and the RTRW zoning polygons. Incoming GPS coordinates are stored in EPSG:4326, and before any match is computed, the RTRW layers and the report point are harmonised to a common coordinate reference system, so that a mismatch of reference systems cannot silently shift a point into a neighbouring designation.

Because field data are imperfect, the matching applies four explicit handling rules. First, the device-reported GPS accuracy radius is taken into account: if a point lies near a zoning boundary and its accuracy radius crosses that boundary, the match is flagged as uncertain. Second, a point that falls exactly on, or very close to, a polygon boundary is categorised as borderline and bypasses automatic classification; it is routed directly to manual field verification. Third, where RTRW designations overlap, all matching polygons are returned and the case is escalated for human review, so that the system never issues contradictory classifications. Fourth, where the RTRW data for an area are incomplete and no polygon matches, the report is logged as unverified rather than being labelled compliant or violating.

Illustrative example (hypothetical). A citizen reports a suspected industrial building in a residential area. The device records the location in EPSG:4326 with a reported accuracy radius of 15 metres. When the point-in-polygon check is run, that accuracy radius crosses the boundary between the residential polygon and an adjacent commercial polygon, so the system cannot determine the designation reliably; it flags the report as "uncertain – boundary overlap" and routes it to manual field verification instead of recording a potential violation.

It must be emphasised that the result of this automatic matching is a preliminary indication only. It is not, and must not be read as, a final determination that a spatial-planning violation has occurred; that determination can only be made through field verification and the authorised decision process of the responsible agency.

3.4. Officer Assignment Workflow

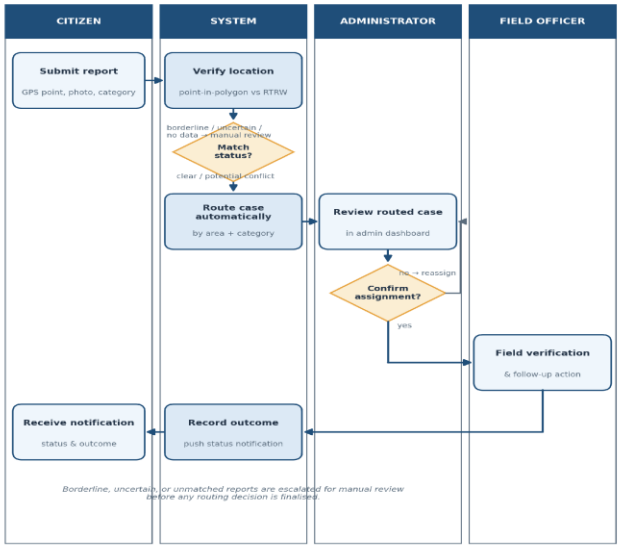


Figure 5. Activity diagram of the hybrid officer assignment workflow: automatic routing by the system, administrator confirmation or reassignment, field verification, and notification of the outcome to the reporter.

Figure 5 makes the division of labour in the assignment stage explicit. The system performs the spatial verification and proposes the assignment by matching the case to the officer responsible for the report's administrative area and category; borderline, uncertain, or unmatched reports are held for manual review before any routing is finalised. The administrator reviews the routed case in the

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dashboard and either confirms the proposed assignment or reassigns the case, for example when the officer is unavailable. Only after confirmation is the field officer notified and field verification carried out, and the outcome recorded by the system is pushed back to the reporter as a status notification, closing the five-stage loop of Figure 3.

3.5. Performance and Scalability Considerations

Anticipating the demands of a provincial-scale deployment, the architecture incorporates several performance and scalability provisions. PostGIS spatial indexes are maintained on the zoning polygons and on the report points, so that point-in-polygon queries do not scan the full datasets. GeoServer tile caching serves pre-rendered zoning layers, keeping the interactive map responsive without re-rendering tiles for every request. Uploaded photos are compressed on the device before transmission, reducing the bandwidth each report consumes. Status notifications are dispatched through an asynchronous queue, so that traffic spikes do not block the submission and verification flow, and the administrative dashboard loads its case lists in paginated form. Finally, the mobile application supports offline drafting: a report composed without connectivity is stored on the device and submitted automatically when a connection returns, which is essential for rural areas with intermittent coverage. Table 4 defines the evaluation protocol by which these provisions are to be measured at deployment scale.

Table 4. Performance and scalability evaluation protocol for provincial-scale deployment.

Metric	What is measured, and how	Test condition
Map response	Time between a pan or zoom action and the complete rendering of the zoning tiles on the client.	Mobile network connection, with the GeoServer tile cache enabled.
Spatial verification processing	Server-side execution time of the coordinate harmonisation and point-in-polygon match for one report.	The full multi-layer provincial RTRW polygon dataset.
Photo upload	Transmission time and payload size of a report photo after on-device compression.	Variable network conditions, including weak-signal rural connections.
Concurrent reports	Server response behaviour and error rate while multiple users submit and track reports simultaneously.	Simulated simultaneous submissions against the application API.
Storage growth	Increase in database size per 1,000 stored reports, including geometries and compressed photos.	Accumulated report records in PostgreSQL/PostGIS.

The evaluation reported in this study is limited to black-box functional testing and qualitative usability feedback; the provisions above describe how the architecture is designed to scale, not measured performance under load. A provincial-scale performance evaluation following the protocol in Table 4 — including testing under the limited-connectivity conditions of rural Lampung — is therefore required before full public deployment, and is planned as the immediate next step of this work.

3.6. Usability Evaluation

Moving beyond technical stability, our field evaluation examined the human–computer interaction aspect of the platform qualitatively, organising participants' feedback along the dimensions that the System Usability Scale (SUS) is designed to capture: ease of navigation, learnability, and user satisfaction. The feedback from the community representatives was strongly positive; many noted that the platform felt far more intuitive than they had initially anticipated. The learnability of the system was a frequently praised attribute, with older residents successfully submitting test reports after only a brief introduction. From the perspective of the agency staff, the qualitative reception was equally encouraging. Spatial planners expressed relief at the automation features, noting that the system

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drastically reduced the time they typically spent manually verifying the locations of public complaints. Overall, the satisfaction levels across both user groups validated our decision to adhere strictly to the UCD methodology, while also pointing to where support is still needed, a theme the Discussion takes up in detail.

Methodologically, the ten standard SUS items served as the thematic coding framework for this qualitative analysis. Each item corresponds to a usability dimension — perceived complexity, ease of use, functional integration, internal consistency, learnability, user confidence, and the perceived need for technical support — and participants' comments were categorised under these dimensions during the analysis, so that every design iteration could be traced to a specific aspect of usability. Under this framework, the responses reported above fall principally under learnability, in the ease with which first-time and older users completed their test reports, and functional integration, in the planners' reception of the automated verification within their existing workflow.

One limitation of this evaluation must be stated plainly. Because the sessions were analysed qualitatively, this study does not report a composite SUS score, participant-level questionnaire results, or statistical summaries; the positive reception described above should therefore be read as formative evidence from the iterative UCD trials, not as a summative usability measurement. A fully quantified SUS evaluation, administered to a larger and formally sampled group of community and agency users, is required to establish the platform's usability level and is planned for the expanded deployment stage of this work.

3.7. Discussion

When contextualizing our deployment against the broader landscape of e-government literature, the advantages of a spatially aware platform become obvious. Previous studies evaluating conventional text-based grievance portals often highlighted a chronic lack of geographical context, which inevitably stalled bureaucratic responses. By embedding reporting directly into an interactive map, our system solves this issue at the source, ensuring every public interaction is grounded in precise spatial reality. The design also speaks to a lesson from recent PPGIS research: participation data becomes most valuable when it flows into actual planning priorities rather than accumulating in inboxes, and integrating participatory inputs with structured decision-making is what converts reports into policy signals [26]. Our automatic verification stage performs the first step of that conversion inside the platform itself, classifying each report against the official plan before a human ever touches it.

Our approach aligns closely with the Technology-Enabled Participatory Planning (TEPP) framework of UN-Habitat (2022), which the provincial academic manuscript adopts as its guiding model and which rests on four pillars. The first pillar, digital infrastructure, is addressed by the platform itself: a web and mobile GIS, an open-source spatial stack, and a single spatial database replace the fragmented files and paper maps that previously carried spatial information. The second pillar, capacity building, is where the study deliberately reaches beyond software. The draft regulation's own training module for community cadres, three days and twenty-four hours covering GIS basics, participatory mapping, QGIS, GPS data input, field survey with ODK Collect, and introductory spatial analysis, describes exactly the mediation layer our trials found necessary; the platform was designed so that trained cadres can accompany residents who cannot yet report independently. The third pillar, data governance, is served by the verification workflow: citizen reports are not treated as authoritative on arrival, but are cross-checked against the official RTRW data, timestamped, and tracked through a visible status history, which keeps community data usable for enforcement and planning while protecting reporters from arbitrary dismissal of their input. The fourth pillar, a clear legal framework, is supplied by the draft regulation itself, and the software was engineered to implement it rather than improvise around it.

That legal alignment deserves emphasis, because it distinguishes this platform from a generic reporting application. Draft Article 6 of the regulation mandates the use of spatial and digital technologies, naming GIS, remote sensing, artificial intelligence, and related tools as instruments of spatial governance; our stack is a direct, proportionate implementation of that mandate at provincial scale. Draft Article 7, paragraph 4, requires digital platforms that facilitate public participation, transparency, and accountability at every stage of spatial utilization, which is precisely the function of

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the five-stage mechanism with its closed feedback loop. Draft Article 8 enumerates the participation channels the platform must serve (public consultation in the preparation of the RTRW and detailed spatial plans, submission of aspirations, focus group discussions, and development planning deliberations, alongside community monitoring and reporting of violations), and the module structure mirrors that enumeration: the feedback channel serves consultation and aspirations, while the reporting module serves monitoring. The academic manuscript's recommendations point in the same direction, including the establishment of a dedicated participatory spatial technology unit within the agency and pilot deployment areas; the dashboard was designed with such a unit in mind as its operating home.

However, executing this vision on the ground in Lampung surfaced several real-world challenges that technology alone cannot instantly fix. One major hurdle was the sheer complexity of integrating the government's legacy spatial data, which often existed in fragmented or overlapping formats, into a unified digital environment. Additionally, while the interface was designed to be user-friendly, a persistent digital literacy gap among certain segments of the population still requires ongoing mediation by cadres and agency staff. We also observed that in several rural districts, intermittent internet connectivity hampered the ability to upload high-resolution photos or render dynamic map tiles in real time. Addressing these physical and educational infrastructure deficits remains a critical prerequisite for achieving truly universal public participation, and it is why this study presents the platform as one component of the regulation's broader empowerment program rather than as a standalone fix.

Returning to the contribution claimed in the Introduction, Table 5 summarises how the platform differs from the PPGIS implementations reviewed earlier. Earlier studies repeatedly identify the weak link in participatory spatial systems as the disconnect between community input and bureaucratic follow-through [5], [9]. By placing automatic RTRW verification and the routing of cases to officers — under administrator confirmation — inside the same platform that receives the report, this study removes that disconnect at the point where it usually occurs. Tying this UCD-engineered process directly to the official 2025 Draft Gubernatorial Regulation framework gives the technological contribution a legal and administrative home, offering a replicable template for other provincial governments seeking to operationalise spatial participation [11], [12].

Table 5. Comparison of typical previous PPGIS implementations and the platform developed in this study.

Feature	Typical previous PPGIS implementations	This study
Reporting channel	Standalone tools or text-based e-government portals, separated from the official spatial data.	Geolocation-based reporting inside the interactive zoning map, tied directly to the RTRW polygons.
Verification against the spatial plan	Manual checking by agency staff after a report is received.	Automatic point-in-polygon cross-check against the digital RTRW at submission, as a preliminary indication.
Officer assignment	Handled outside the platform, through separate administrative workflows.	Automatic routing by area and category within the platform, confirmed or reassigned by an administrator.
Feedback to the reporter	Often one-way; citizens rarely learn the outcome of a report.	Closed loop: status and outcome notifications are pushed back to the original reporter.
Policy embedding	Usually isolated academic pilots or proofs of concept.	Designed from the official blueprint in the academic manuscript of the 2025 Draft Gubernatorial Regulation, at provincial scale.

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Table 5 also marks the boundary of the claim: none of the individual features is new on its own. The contribution is their integration into one closed loop, engineered with the intended users and anchored in a provincial policy instrument, so that participation data enters the agency's workflow at the moment it is submitted rather than accumulating outside it.

4.CONCLUSION

This research successfully engineered and implemented a GIS-based software platform designed to bridge the widening gap between government spatial planning and grassroots civic involvement in Lampung Province. By anchoring our development in a User-Centered Design approach and aligning directly with the official blueprint of the 2025 Draft Gubernatorial Regulation, the resulting five-stage participatory reporting system provides an accessible, transparent mechanism for spatial monitoring: citizens report with GPS and photo evidence, reports are automatically verified against the digital RTRW, officers are assigned without manual triage, and reporters can follow their case to its outcome. Black-box testing confirmed that all core features function as designed, and qualitative usability feedback from community representatives and agency officials indicated that the platform is learnable and practically relevant for both groups. For Dinas Perumahan, Kawasan Permukiman dan Cipta Karya Provinsi Lampung, the system offers a strategic asset to surface land-use conflicts earlier and to practice collaborative governance on a continuing basis rather than only at formal consultation events.

Nevertheless, the study's limitations are evident in its dependency on stable internet connectivity and baseline digital literacy, which pose ongoing challenges in rural deployment, and in the qualitative nature of the present evaluation, which should be extended with larger-scale deployment data. For future development, we recommend executing the GIS training program for agency staff and community cadres stipulated in the official policy documents, expanding deployment beyond the initial pilot zones, and progressively integrating the additional technologies the draft regulation names, such as remote sensing change detection and environmental sensor feeds, so that citizen reports can be corroborated by independent spatial evidence. Realizing these steps would move Lampung closer to the goal the regulation sets: inclusive, transparent, and sustainable spatial governance in which the community is a standing partner, not an occasional consultee. Two extensions follow directly from this limitation: a quantified SUS evaluation with a larger participant group, and a provincial-scale performance evaluation under varied network conditions, both of which are planned before full public deployment.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Taufik: Conceptualization, Methodology, Software, Writing – original draft. **M. Okta Pura Nugraha:** Data curation, Validation, Writing – review & editing.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors used Generative AI to improve the writing clarity of this paper. They reviewed and edited the AI-assisted content and take full responsibility for the final publication.

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