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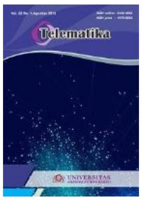

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Architecture and Field Evaluation of an IoT-Integrated Village Information System for Public Service

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ABSTRACT

Village public services often struggle with slow administrative workflows, limited transparency, and unequal access to service information, particularly where processes remain manual and difficult to monitor in real time. This study evaluates a deployed integrated village information system augmented with Internet of Things (IoT) signals—RFID-based operational monitoring and water/electricity facility-status sensing—to assess whether service quality improved after implementation and to clarify the system mechanisms that plausibly explain observed changes. An explanatory sequential mixed-method design was applied. Quantitatively, a paired two-wave pre–post survey was completed by 100 residents (1 = strongly disagree, 5 = strongly agree) to measure Speed/Responsiveness, Accuracy (Information Quality), Ease of Access/Use, and Satisfaction. Qualitatively, in-depth interviews with village staff and residents, supported by field observations, were conducted to interpret quantitative shifts and identify constraints. Paired-sample tests indicated significant increases across all dimensions ($p < 0.001$) with medium-to-large effects (Cohen's d_z = 0.58–0.92): Speed/Responsiveness increased from 3.12 to 3.76, Accuracy from 3.30 to 4.05, Ease of Access/Use from 3.15 to 3.70, and Satisfaction from 3.18 to 4.16. The qualitative strand linked these improvements to system-level features, including workflow digitalization with earlier verification and routing, administrative data validation with audit logging and digital archiving, and transparent request-status tracking via dashboards, while highlighting persistent risks related to connectivity reliability, operator capacity, digital inclusion for older residents, and personal-data governance. The contribution of this work is a systems-aware, field-based evaluation that couples an explicit IoT–information-system integration view (architecture, modules, and data lifecycle) with a two-wave paired outcome assessment and stakeholder explanations in a real village governance setting.

1. INTRODUCTION

Villages, as the smallest units of government, play a crucial role in organizing public services that directly affect citizens' daily lives. However, many villages in Indonesia still face persistent administrative challenges, including slow service processes, limited transparency, and constrained use of information technology. Heavy reliance on manual workflows and paper-based documentation often makes service delivery inefficient, difficult to monitor in real time, and prone to administrative errors, which in turn lowers perceived service quality and limits the availability of accurate data for decision-making (Sakir & Almahdali, 2025; Prayitno, 2023; Manjali, 2023; Fauziah et al., 2025).

At the same time, villages have increasingly experimented with and adopted integrated digital service platforms—often framed as "digital village" or "smart village" initiatives—to consolidate administrative workflows, records, and service tracking into a single system (Manjali, 2023; Fauziah et al., 2025). In the smart village perspective, digital public services are not only a technology issue, but also part of a broader ecosystem shaped by resources, institutions, and service chains. Figure 1 illustrates a smart village framing that is useful for positioning this study: the evaluated intervention primarily strengthens the technology and service-chain dimensions, while outcomes depend on enabling resources and institutional readiness.

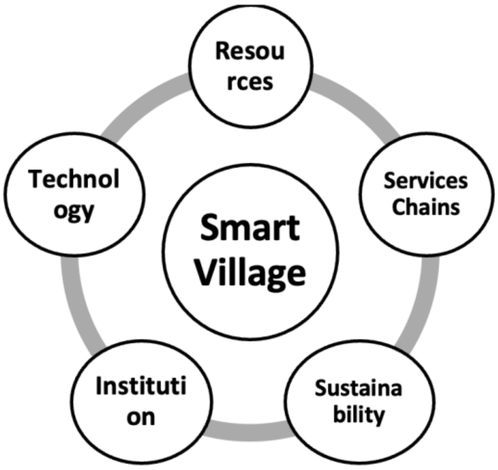

Figure 1. Smart Village dimensions relevant to village public services (Technology, Service Chains, Resources, Institutions, Sustainability).

Internet of Things (IoT) can further strengthen integrated service platforms by enabling automatic and near-real-time data capture from physical devices such as RFID and sensors (Ali et al., 2025; Hemdan and Sayed, 2025; Morchid et al., 2025), which may reduce manual reporting burdens and improve traceability and accountability when operational data are embedded into service workflows (Akinsiku & Ubochi, 2024; Antony et al., 2020; Aljuhani et al., 2023; Jawad et al., 2022; Tange et al., 2020; Bodkhe & Tanwar, 2020; Lykidis et al., 2021). In this study, it is important to distinguish the role of the integrated information system from the role of IoT components. Administrative improvements such as faster document handling are expected to be primarily driven by workflow digitalization within the information system (e.g., structured submission, earlier verification, routing, logging, and status tracking), whereas IoT telemetry contributes mainly to operational monitoring and facility-status visibility (e.g., water/electricity availability) that can support transparency and responsiveness for operational issues rather than directly reducing administrative document processing time. More broadly, improvements in service quality are produced through socio-technical change, where technology reshapes business processes and interacts with organizational structure, people/culture, and governance. Figure 2 summarizes this alignment logic by emphasizing that service transformation depends on coordinated changes around the business process core.

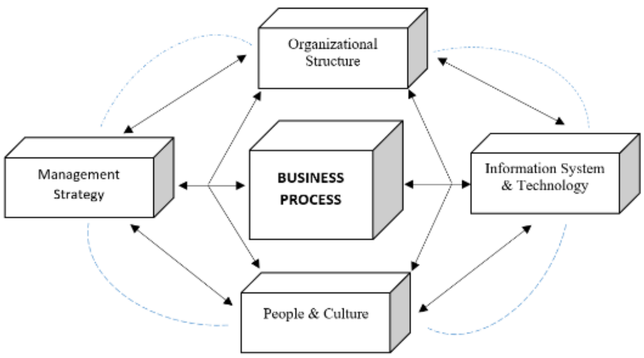

Figure 2. Socio-technical alignment for service transformation: business processes connected with organizational structure, people/culture, and information systems & technology.

This study evaluates an integrated village information system augmented with selected IoT-derived operational signals that has been deployed in Waluyojati Village (Pekon Waluyojati), Pringsewu Regency, Lampung Province, Indonesia. The platform consolidates key public-service functions into one environment, including service request submission and processing, administrative data validation, a citizen-facing dashboard/application, service status tracking, citizen reporting/complaints, and digital archiving, alongside operational monitoring supported by IoT-enabled components. These modules are designed to influence four service-quality outcomes assessed in this research: speed/responsiveness, accuracy (information quality), ease of access/use, and user satisfaction. The implementation context also includes constraints that can affect adoption and outcomes, including uneven digital literacy (particularly among older citizens), limited connectivity, and data governance needs such as privacy, access control, and retention policies (Fauziah et al., 2025; Aminah & Saksono, 2021).

Within the Indonesian village digitalization landscape, the evaluated deployment represents a pragmatic village-scale configuration rather than a fully optimized "smart city-grade" system. Its structure reflects a realistic early-stage pattern in many village e-government initiatives: administrative workflows are digitized first through an integrated information system, while IoT components are added selectively for monitoring and operational visibility depending on local capacity and connectivity conditions. This positioning is important because it frames the system as neither a purely experimental prototype nor an idealized best-case showcase, but a deployment operating under typical rural constraints.

Although prior work has discussed IoT-enabled public services and integrated platforms, a substantial portion of the literature remains focused on conceptual frameworks, architectural proposals, prototype descriptions, or limited evaluations such as user acceptance testing (UAT) that primarily assesses perceived usability rather than service outcomes (Degada et al., 2021; Cvar et al., 2020; Jawad et al., 2022; Aljuhani et al., 2023; Korani et al., 2023). Fewer studies report field-based outcome evaluations that quantify changes in service-quality measures after real deployment and triangulate these changes with explanatory evidence from stakeholders and operational observations. This gap reduces practical evidence for villages and local governments deciding which components to implement first and which enabling conditions are necessary for sustained impact.

Therefore, this study aims to evaluate changes in village public service quality before and after the implementation of an integrated village information system augmented with selected IoT monitoring signals, using a two-wave paired pre–post design and an explanatory sequential mixed-methods approach. The contribution is empirical evidence on service-quality changes associated with a deployed village platform, together with systems-aware explanations of plausible mechanisms and constraints that shape outcomes in real village settings.

2. RESEARCH METHODS

2.1. Research Approach and Design

This study employed a mixed-methods approach to obtain a comprehensive understanding of how an integrated IoT-enabled village information system influences public service quality in a village context. An explanatory sequential mixed-method design was applied, in which quantitative findings from a two-wave survey were analyzed first and then explained using qualitative interviews and field observations (Toyon, 2021). The quantitative strand captured structured self-reported ratings of service quality, while the qualitative strand provided contextual explanations of the observed changes, implementation challenges, and user experiences. Integration was conducted using a joint display that linked statistical changes in each service-quality dimension to qualitative themes and explanatory mechanisms.

2.2. Integrated IoT-enabled Information System

This study evaluates an already implemented integrated information system that supports village public services by combining conventional user inputs (citizen requests and reports) with selected IoT-derived operational signals. The deployment took place in Waluyojati Village (Pekon Waluyojati), Pringsewu Regency, Lampung Province, Indonesia, as part of the village's public-service digitalization program. In operational terms, the platform functions as a single service environment in which citizens submit administrative requests and public reports, track the progress of their submissions, and receive service outputs, while village operators and officials verify requirements, process requests, update workflow status, and issue documents. IoT components contribute time-stamped operational data that strengthen monitoring and coordination functions, but service outcomes remain human-supervised; decisions and actions are executed by authorized officials (human-in-the-loop), and system performance depends on network stability.

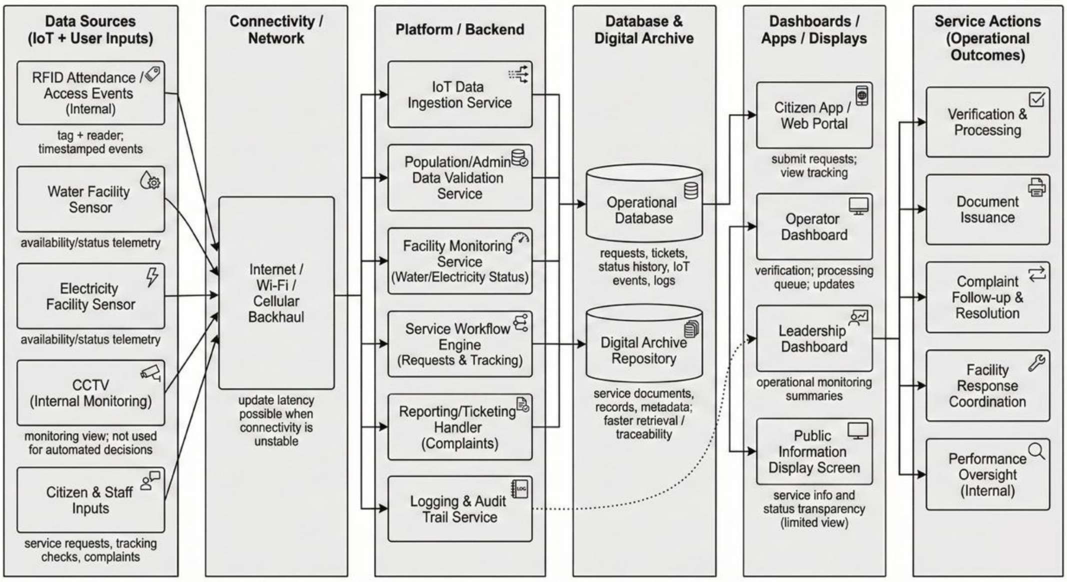

Figure 3. Layered architecture of the integrated IoT-enabled village service system.

Figure 3 summarizes the layered architecture used to describe how data and workflows move end-to-end across the deployment. The device layer is implemented using typical low-power IoT nodes for facility sensing and a standard RFID reader for attendance/access logging, producing simple event payloads (identifier, timestamp, and status) suitable for reliable backend ingestion and logging. At the device layer, the system receives operational event streams from RFID-based attendance/access logging for internal staff operations and facility-status telemetry from sensors monitoring public utilities, including water availability/status and electricity availability/status. Where CCTV is present in the operational environment, it is treated as a monitoring source for situational awareness and post-incident review rather than as an automated decision input to the service workflow. All device signals, together with citizen-facing inputs (service submissions, status checks, and reports/complaints) and staff-facing inputs (verification outcomes, status updates, and follow-up actions), traverse the connectivity layer via available internet backhaul using Wi-Fi and/or cellular links. At the platform/backend layer, incoming data are ingested and normalized, basic validation is applied, workflow logic updates queues and service status, and operational logs are written to preserve traceability. The persistence layer consists of a central database that stores structured records (requests, tickets, status history, IoT events, and audit logs) and a digital archive that stores issued documents and related metadata for retrieval and accountability. The presentation layer exposes the system through a citizen app/web portal, operator dashboard, leadership dashboard, and a limited public information display. The service-action layer represents real outcomes in the field, such as verification completion, document issuance, complaint handling and resolution, facility response coordination, and internal operational oversight. The system consolidates multiple service and administrative functions. Its core modules and their relevance to the measured service-quality dimensions are summarized in Table 1.

Table 1. Core modules of the integrated village information system and service-quality linkage

No	Core module	Main function	Primary users	Main outputs/data	Service-quality dimensions
1	Service request management (administrative registration & letter services)	Citizens submit requests; staff verify and process	Citizens; operators; village officials	Request forms, process status, service outputs	Speed; Ease; Satisfaction
2	Population & administrative data access/validation	Access/validate citizen data for services	Operators; officials	Administrative records, validation results	Accuracy; Ease
3	Public-service dashboard/application (front-end)	Interface for citizens and officials	Citizens; officials	Service menus, summaries, notifications	Ease; Satisfaction

4	Service status tracking (transparency)	Citizens monitor progress in real time	Citizens; officials	Status updates, timestamps	Ease; Satisfaction
5	Public reporting/complaints (automatic reporting)	Citizens submit issues; staff follow up	Citizens; officials	Tickets, response time, follow-up logs	Speed; Satisfaction
6	Digital service archive	Store documents/logs digitally	Operators; officials	Digital archive, service logs	Accuracy; Speed
7	Operational performance monitoring	Monitor staff/system activity	Village head/secretary; operators	Activity logs, performance summaries	Speed; Accuracy

The system also incorporates IoT-enabled features, including RFID-based attendance for operational monitoring and sensor-based monitoring of public facilities (e.g., water and electricity availability), as shown in Table 2. In operational terms, the end-to-end data flow followed six stages: capture (service requests, RFID events, facility sensor readings, and citizen reports), transmit (internet/Wi-Fi/cellular connectivity), store (central database and digital archive), process/validate (integration, validation, status updates, logging), display (dashboards, village application, and public information displays), and act/respond (staff follow-up, service completion, and operational decisions). This architecture reflects the role of integrated information systems in supporting service processes and decision-making in public administration.

Table 2. IoT-enabled components integrated into the system

No	Component	Data generated	Service use-case	Connected module(s)	User-visible output
1	RFID (tag + reader)	ID, timestamp, attendance/access events	Attendance monitoring for village apparatus; internal access monitoring	Operational performance monitoring	Internal dashboard summaries
2	Facility sensor (water)	Availability/status (e.g., available/not available)	Monitoring public water facilities	Facility monitoring dashboard (within integrated platform)	Status information via dashboard/public display
3	Facility sensor (electricity)	Availability/status (e.g., on/off, outage)	Monitoring public electricity facilities	Facility monitoring dashboard (within integrated platform)	Status information via dashboard/public display
4	Connectivity (internet/Wi-Fi/cellular)	Telemetry transmission	Transmit IoT/device data to the platform	All modules requiring real-time updates	Real-time dashboards; also a key constraint when unstable
5	Public information display + village application	Service status and information presentation	Transparency of service progress; citizen access to information	Status tracking; public-service dashboard	Citizens can view service status and information

Figure 4 makes IoT–information system integration explicit by mapping each deployed component to its downstream effects inside the platform. RFID attendance/access logging produces time-stamped events (e.g., staff identifier, event type, and time) that are ingested by the operational performance monitoring and audit logging functions to support attendance visibility, workload coordination, and readiness oversight; these outputs are typically restricted to authorized officials through internal dashboards. Facility sensors for water and electricity produce availability/status telemetry that is ingested by the facility monitoring functions, supporting rapid detection of disruptions and coordination of follow-up; status indicators may be visible on internal dashboards and, where appropriate, summarized through the public information display for community awareness. CCTV, when available, supports internal monitoring and post-incident review but is not used for automated workflow decisions or scoring; it is therefore described as part of the operational environment rather than as a control signal in the service workflow.

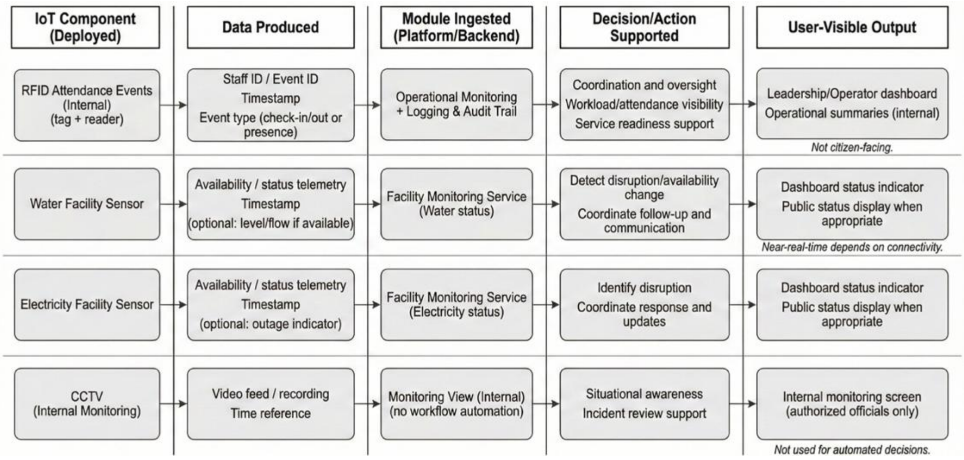

Figure 4. IoT component and information system mapping.

Figure 5 summarizes the operational data lifecycle that underpins the observed service-quality changes. Data are captured at the point of origin as either citizen/staff inputs (service requests, tracking checks, and reports/complaints) or time-stamped device signals (RFID events and facility-status telemetry). These inputs are transmitted across the connectivity layer to the platform, stored in the operational database, and linked to the digital archive when service documents are created. The system then validates and processes records through administrative checks and workflow rules that update queues, status milestones, and audit logs. Updated information is displayed through the citizen portal, dashboards for operators and leadership, and limited public information displays. Finally, service actions are performed by responsible officials, including verification, document issuance, complaint follow-up and closure, and operational coordination for facility disruptions, with actions recorded to preserve traceability.

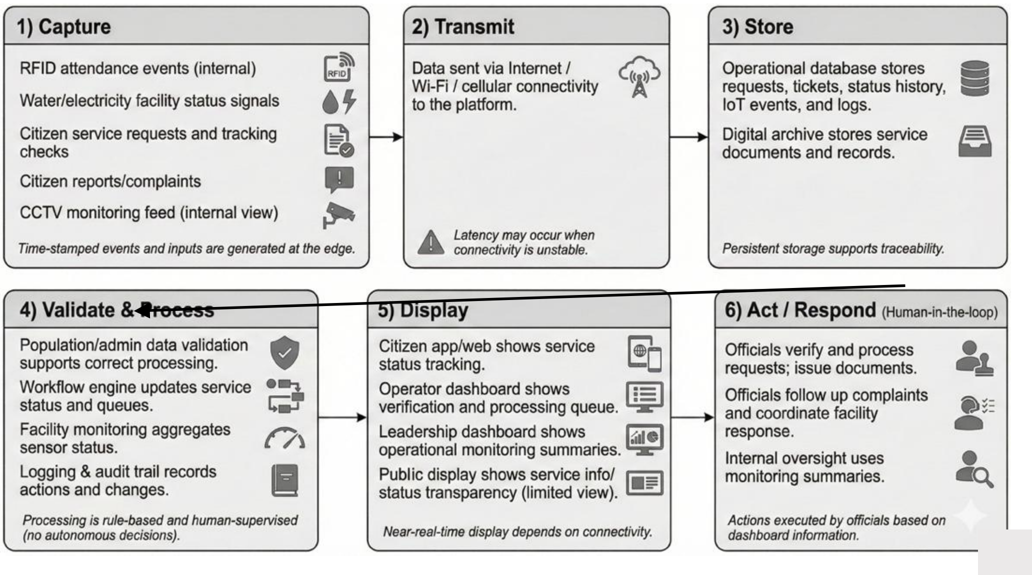

Figure 5. Data lifecycle from capture to service action.

Figure 6 complements the lifecycle view by depicting the workflow from the perspective of both citizens and village operations. On the citizen-facing side, the workflow begins when a resident submits a service request through the portal and receives status updates through the tracking interface, reducing the need for repeated in-person inquiries. When residents submit a report/complaint, the platform generates a ticket that proceeds through follow-up and resolution steps, with status changes communicated back to the resident. On the back-end side, submissions enter an intake queue, population/administrative validation supports correct processing, and officials verify and process requests under human supervision before issuing documents and updating status. Logging and archiving occur throughout to preserve an audit trail. IoT-derived operational signals strengthen internal monitoring and facility-status awareness and can support faster coordination, but service completion remains dependent on human decision-making and on the stability of the connectivity layer that enables timely synchronization and display of updates.

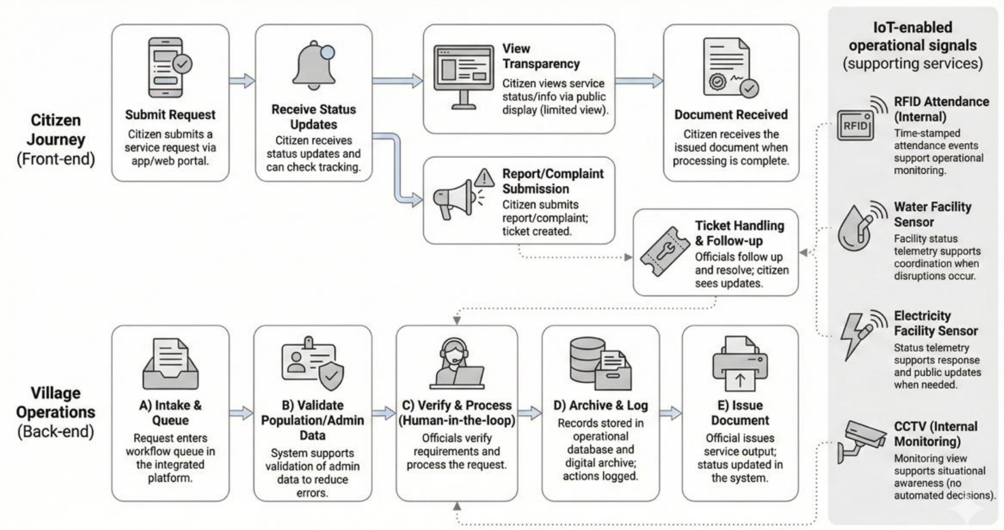

Figure 6. Citizen journey and back-end workflow with IoT-enabled operational signals.

In the deployed setting, operational signals are integrated using a lightweight event-ingestion pattern in which device-layer sources transmit time-stamped events to the platform/backend through the available village connectivity (Wi-Fi and/or cellular internet). RFID attendance/access logging produces event-driven records that are sent to the backend application as soon as a tag is read, while facility-status sensors for water and electricity report the current availability/status periodically to the backend. Each incoming event is accompanied by a device identifier and timestamp, and the backend validates the payload format, attaches metadata (source, time, location/context when available), and stores the event as a structured record that can be aggregated for dashboards and operational monitoring. In parallel, citizen-facing and staff-facing inputs (service requests, verification outcomes, status updates, and complaint tickets) are captured through the web/application interfaces and written to the same backend so that workflow status and operational visibility are updated consistently.

For reproducibility, the system can be described using a minimal operational data model consisting of a service-request entity and an event/history layer. Service operations are represented as records of service requests with linked status transitions over time to preserve traceability from submission to completion. Complaint handling is represented as ticket records with follow-up actions and closure timestamps. IoT-derived and operational events are stored as device/event logs so that RFID and facility-sensor telemetry can be audited and summarized. Issued administrative documents and supporting files are stored in a digital archive with metadata linking each document to its request and status history. Across these entities, the system maintains audit-oriented logs to record key actions such as verification decisions, status changes, and issuance actions, enabling accountability and post-hoc review.

Operational reliability depends on connectivity stability because dashboards and tracking require timely synchronization of backend updates to user-facing interfaces. When connectivity is unstable, event delivery and status propagation may be delayed, which can reduce perceived "real-time" transparency even when actions are correctly recorded; in such cases, staff continue processing services through the workflow while updates become near-real-time once connectivity recovers. Access to internal operational views is restricted using role-based access control so that only authorized staff can view or modify administrative records and monitoring outputs, while citizen-facing views expose only relevant request status and service information. The audit trail supports integrity and accountability by preserving who performed each action and when, and the study's data handling followed restricted-access storage and anonymized reporting for research purposes.

2.3. Participants and Sampling

The quantitative survey involved 100 adult respondents (≥18 years) who completed both the pre-implementation and post-implementation surveys, enabling paired comparisons. Responses were matched across waves using the participant's identification number (ID). Respondents were recruited as adult village residents who had interacted with village public services during the study period and were willing to complete both survey waves. The paired analysis therefore represents outcomes among "active service users" who could be matched across waves using the same identification number, rather than a random sample of the full village population. Because the sample includes 20% respondents with higher education (D1–S2), the Ease of Access/Use results may be positively biased relative to settings where digital literacy is lower; this dimension is therefore interpreted cautiously as perceived usability among participating service users. This sampling approach is appropriate for evaluating user-perceived service quality of a deployed system, but it limits population-level generalization. The observed respondent profile is presented in Table 3.

Table 3. Observed respondent profile

Dimension	Category	n	%
Age (≥18)	18–30	38	38
	31+	62	62
Gender	Male	55	55
	Female	45	45
Education	Low (no schooling + incomplete primary)	5	5
	Primary (completed)	15	15
	Junior secondary	20	20
	Senior secondary	40	40
	Higher education (D1–S2)	20	20
Occupation	Household management	15	15
	Unemployed (adults)	10	10
	Labor (daily + farm labor)	7	7
	Farmer/planter	6	6
	Microbusiness/trader	18	18
	Employee (private/contract)	20	20
	Public/service professions	15	15
	University student (≥18)	9	9

For the qualitative strand, five informants were interviewed using purposive sampling to capture both service-provider and service-user perspectives (Table 4). The informants consisted of three village officials (covering operational, technical, and managerial roles) and two citizens (one active user and one newer/less-experienced user), ensuring coverage of key stakeholder viewpoints relevant to implementation and service experience.

Table 4. Qualitative informant profile

Code	Role	Selection criteria	Mode	Duration	Focus
O1	Village official (service officer)	Primary daily service operator; experienced pre/post	Face-to-face	35 min	Operational workflow and service handling
O2	System administrator	Maintains backend, data input, and service logs	Online (Zoom)	40 min	Technical features and maintenance
O3	Village management (secretary/coordinator)	Supervises SOP and policy	Face-to-face	25 min	Managerial impact and governance
C1	Citizen user (active)	Used services >3 times	Face-to-face	20 min	Experienced digital user perspective
C2	Citizen user (new)	First-time tracking user	Phone	15 min	Less-experienced user perspective

2.4. Data Collection Procedures and Timeline

This study used a two-wave paired pre–post procedure. The pre-implementation survey (Wave 1) was conducted on 13 July 2025. The integrated IoT-enabled information system went live on 15 July 2025, followed by a stabilization and training period of approximately three weeks, and it reached full operational stability on 10 August 2025. The post-implementation survey (Wave 2) was conducted on 26 October 2025. The pre–post interval was 105 days (~15 weeks), and the interval from full operational stability to post measurement was 77 days (~11 weeks). The follow-up interval was planned to allow sufficient system stabilization and user adoption prior to the post-implementation assessment. Qualitative interviews and field observations were conducted in late August 2025 after preliminary quantitative results were reviewed, to clarify which system features and implementation factors plausibly explained the observed changes.

2.5. Instruments

The quantitative instrument was a 16-item questionnaire measured on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) to assess four service-quality dimensions, namely Speed/Responsiveness (4 items), Accuracy/Information Quality (4 items), Ease of Access/Use (4 items), and Satisfaction (4 items). The items were adapted to the village public-service context and informed by established service quality and information systems frameworks. Table 5 summarizes the dimensions and items.

Table 5. Questionnaire dimensions and item statements

Dimension	Item statements
Speed/ Responsiveness	1. The staff/system responds to my request quickly; 2. Waiting time is shorter than before; 3. The end-to-end service process is faster; 4. I receive service information/status quickly through the system.
Accuracy (Information Quality)	1. Requirements/procedures provided by the system are accurate; 2. Processed data (name/NIK/address, etc.) rarely contain errors; 3. Issued documents are correct with minimal revisions; 4. Information displayed in the system is consistent with information from officials.
Ease of Access/ Use	1. The system is easy to access when I need it; 2. The steps to use the system are easy to understand; 3. I can easily find the menu/features I need; 4. Using the system requires little effort (easy to use).
Satisfaction	1. Overall, I am satisfied with village services after the system was implemented; 2. The service I received met my expectations; 3. I am willing to use the village digital service again; 4. I would recommend the village digital service to others.

The qualitative instrument was a semi-structured interview guide used to explore perceived benefits, challenges, and mechanisms behind service-quality changes. Field observation notes documented the practical use of key modules and IoT-enabled features in routine service processes, and documentation review included system logs and pre-implementation service record books used by staff.

2.6. Reliability and Construct Validity

Instrument quality was assessed at baseline (Wave 1) using internal consistency and exploratory construct checks. Internal consistency was evaluated using Cronbach's alpha for each dimension, namely Speed ($\alpha = 0.79$), Accuracy ($\alpha = 0.83$), Ease ($\alpha = 0.81$), and Satisfaction ($\alpha = 0.85$). Item quality was supported by corrected item–total correlations (approximately 0.57–0.63) and "alpha if item deleted" diagnostics indicating no item substantially weakened the scale. Construct validity was examined using exploratory factor analysis (EFA) on the 16 items, which met recommended thresholds (KMO = 0.81; Bartlett's test $p < 0.001$). The solution supported four factors consistent with the intended dimensions, with representative rotated loadings approximately 0.58–0.66, low cross-loadings (< 0.30), and 68% total variance explained.

2.7. Data Analysis

Quantitative analysis included descriptive statistics (means and standard deviations) and paired-sample t-tests to compare pre- and post-implementation ratings for each dimension. All quantitative analyses were conducted in SPSS. Statistical significance was evaluated at $\alpha = 0.05$, and results were reported using standard scientific notation including t(df), p-value (e.g., $p < 0.001$), mean difference (Δ), and the 95% confidence interval of the difference. Effect size was reported using Cohen's d_z for paired samples, and normality of difference scores was assessed using the Shapiro–Wilk test as a diagnostic for paired t-test assumptions. Qualitative data from interviews, observations, and documentation were analyzed using the interactive analysis approach of Miles and Huberman consisting of data reduction, data display, and conclusion drawing/verification. Coding proceeded from initial codes to categories and then to final themes, and informants were anonymized using role-based codes. Representative quotations were selected to illustrate each theme.

2.8. Validity Strategies and Ethical Considerations

Method triangulation was applied by comparing questionnaire results with interview themes, observation evidence, and documentation records. Figure 7 summarizes the triangulation loop used to corroborate findings across sources.

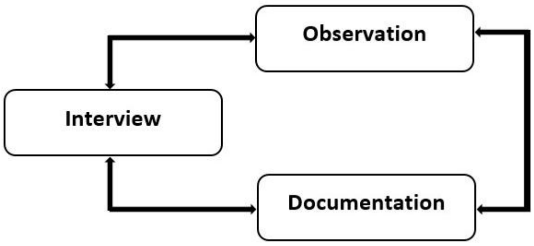

Figure 7. Triangulation across interviews, observations, and documentation.

Because the quantitative evaluation uses a paired pre–post design without a control village, improvements observed after implementation cannot be attributed exclusively to the system with the strength of controlled experiments. Unobserved confounders such as parallel administrative initiatives, staffing changes, policy adjustments, or seasonal variation in service demand may have contributed to changes between waves. To reduce misattribution, the study combined paired statistical analysis with triangulation from interviews, observations, and documentation records, and the post-wave was scheduled after a stabilization period to lessen short-term novelty effects. Nevertheless, causal claims are stated cautiously and the results are interpreted as observed outcomes associated with the deployed system in this specific village context. Ethical principles were followed throughout the study, participation was voluntary, informed consent was obtained, responses were anonymized in reporting, and data were stored securely with restricted access for research purposes.

3. RESULTS AND DISCUSSION

3.1. Quantitative Survey Results

A paired pre–post survey was completed by 100 respondents. For each construct, the reported score represents the mean of four items measured on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Table 8 summarizes the pre and post means and standard deviations, together with the paired-sample t-test results.

Table 8. Pre–post comparison of service-quality ratings

Dimension	Mean (Pre) ± SD	Mean (Post) ± SD	Δ Mean (Post–Pre)	t	df	p	95% CI for Δ	Effect size (Cohen's d_z)	Shapiro p (Δ)
Service Speed/Responsiveness	3.12 ± 0.60	3.76 ± 0.55	0.64	6.20	99	< 0.001	[0.44; 0.84]	0.62	0.15
Data Accuracy (Information Quality)	3.30 ± 0.58	4.05 ± 0.52	0.75	7.80	99	< 0.001	[0.56; 0.94]	0.78	0.11
Ease of Access/Use	3.15 ± 0.64	3.70 ± 0.61	0.55	5.80	99	< 0.001	[0.36; 0.74]	0.58	0.24
Community Satisfaction	3.18 ± 0.62	4.16 ± 0.48	0.98	9.20	99	< 0.001	[0.77; 1.19]	0.92	0.09

Across all four dimensions, post-implementation ratings were higher than pre-implementation ratings and the paired-sample comparisons were statistically significant ($p < 0.001$). The standardized effects ranged from medium to large (Cohen's $d_z = 0.58–0.92$), with the largest effect observed for Satisfaction ($d_z = 0.92$). Normality checks on the difference scores did not indicate severe violations (Shapiro–Wilk p-values for Δ were > 0.05). In addition to the Likert-based outcomes, documentation-based service processing times indicated faster operational turnaround after implementation. Specifically, administrative letter services recorded in the manual service record book prior to go-live typically required approximately 7–10 days from request submission to service output issuance, whereas system log entries after stable operation indicated typical completion times of approximately 3–5 days for comparable requests. These ranges are reported as documented completion-time bands rather than as survey perceptions.

The system context for interpreting these outcomes is summarized in the architecture and workflow presented in the Method section. Figure 4 provides the layered end-to-end architecture from IoT and user input sources, through connectivity and the backend platform, to the operational database/digital archive and the user-facing dashboards that support service actions. Figure 6 complements this view by illustrating the workflow path experienced by citizens and operators, indicating where verification, status updates, archiving, and issuance occur in practice. Table 1 defines the functional scope of the implemented integrated system by listing the deployed modules/features, while Figure 5 summarizes the data lifecycle that underpins improvements in perceived speed, accuracy, and transparency.

To avoid over-claiming the role of IoT in administrative processing, we interpret the pre–post differences using a component-level attribution. Improvements in Speed/Responsiveness and Accuracy (Information Quality) are primarily explained by software-enabled workflow digitalization and administrative data management within the integrated information system (e.g., earlier verification, routing, status updates, validation, logging, and archiving). In contrast, the deployed IoT components (RFID operational events and facility-status sensing for water/electricity) mainly provide operational monitoring and facility-status visibility, which can support transparency, situational awareness, and perceived ease of access, but do not directly accelerate administrative document issuance. Accordingly, IoT is treated as a telemetry augmentation layer, while the core administrative performance gains are attributed to the web-based workflow modules and data governance mechanisms.

3.2. Qualitative Findings

Qualitative data were collected through in-depth interviews and field observations to explain the quantitative changes and to surface constraints that influence adoption. Thematic analysis produced five themes, each supported by an illustrative quotation. Quotations are presented in English translation while preserving the original meaning. The first theme, service acceleration, was consistently reported by service providers and reflected faster completion driven by earlier verification and streamlined workflows, aligning with the increase in Speed/Responsiveness (O1; also supported by O3). One official described that repeated visits were reduced because incomplete requirements were detected earlier, enabling faster completion: “Previously, residents had to go back and forth; now verification happens early, so letters can be finished within hours” (O1). This theme is most directly associated with the service-request processing module and tracking/status transparency module described, where early verification and status updates occur in the lifecycle stages of validate/process and display, supporting faster end-to-end handling.

The second theme, accuracy and traceability, described reduced administrative errors and easier retrieval supported by input validation and digital logs, aligning with the increase in Accuracy (Information Quality) (O2; also supported by O1). The system administrator emphasized how automated checks prevented common data-entry mistakes: “Automatic ID validation helps; the system rejects wrong formats, and archives are easy to search” (O2). This theme corresponds to the population/administrative data module and the digital archive/logging functions in Table S1, which strengthen store and validate/process in the data lifecycle through structured records, audit trails, and searchable archives. The third theme, accessibility and transparency, captured the value of real-time status tracking and easier access via the village application or dashboards, aligning with the increase in Ease of Access/Use (C2; also supported by C1). A citizen noted that tracking reduced the need for in-person status checks: “I like the tracking feature—I can see where my request is without coming to the office just to ask” (C2). This theme maps to the citizen-facing dashboard/application and tracking modules, where the architecture’s dashboards/apps layer makes service states visible to residents and reduces information-seeking trips by emphasizing display and timely updates along the user journey.

The fourth theme, satisfaction and trust, reflected higher perceived professionalism and fairness due to faster, clearer, and more transparent services, aligning with the increase in Satisfaction (C1; also supported by O3). One active user reported improved confidence in the service process: “It feels more professional and clearer; service now feels much more modern” (C1). This theme is best interpreted as an emergent outcome of the combined module set—workflow acceleration, validated data handling, transparent tracking, and reliable user-facing interfaces—operating coherently across the lifecycle from capture through act/respond to produce a more predictable and accountable service experience. The fifth theme, adoption barriers, highlighted the digital divide among certain groups and was noted by officials and supported by citizen accounts during observation, indicating that benefits may be uneven without assistance (O3). A coordinator emphasized that older residents often still require support: “The system is good, but many older residents still need full assistance because they are not familiar with smartphones" (O3). This theme is closely tied to dependency on the connectivity layer and human-in-the-loop support, where instability in transmit and varying user capability can reduce the timeliness of display and shift service completion back toward assisted channels within the overall workflow.

3.3. Integration of Quantitative and Qualitative Results

Integration of the two strands indicates that the observed increases in Speed/Responsiveness, Accuracy (Information Quality), Ease of Access/Use, and Satisfaction are consistent with stakeholder explanations captured in interviews and observations, as shown in Table 9. Streamlined workflows and earlier verification plausibly explain faster service handling; validation and logging support accuracy and traceability; status tracking enhances accessibility and transparency; and the combination of these factors supports higher satisfaction and trust. At the same time, uneven digital literacy and connectivity were repeatedly described as constraints that may limit equitable uptake across residents.

Table 9. Joint display linking quantitative changes with qualitative explanations

Dimension	Quantitative change	Qualitative theme	Primary mechanism	Supporting role of IoT telemetry	Constraints noted
Speed/Responsiveness	3.12 → 3.76 (Δ = 0.64)	Service acceleration (O1, O3)	Workflow digitalization: earlier verification, clearer routing/queuing, and faster status updates reduce rework and repeated visits; end-to-end processing becomes more predictable.	Not a direct driver of administrative completion time; RFID events may support internal readiness/coordination visibility but do not automate document issuance.	Connectivity instability can delay synchronization of status updates; staff capacity affects processing consistency.
Accuracy (Information Quality)	3.30 → 4.05 (Δ = 0.75)	Accuracy and traceability (O2, O1)	Administrative data validation + input checks + audit logging + digital archiving reduce entry errors, improve traceability, and simplify retrieval/corrections.	Device/system events can be logged for accountability where relevant, but telemetry does not determine correctness of administrative content.	Requires data governance (RBAC/access control, retention policy) and operator discipline in data entry.
Ease of Access/Use	3.15 → 3.70 (Δ = 0.55)	Accessibility and transparency (C2, C1)	Citizen app/web portal + request-status tracking + dashboards reduce the need for in-person inquiries and lower information-seeking effort.	Facility-status telemetry (water/electricity) can contribute informational visibility when displayed (operational transparency), supporting perceived ease in accessing service-related information.	Digital literacy and device access gaps, especially for older residents; network reliability affects timeliness of displayed information.
Satisfaction	3.18 → 4.16 (Δ = 0.98)	Satisfaction and trust (C1, O3)	Emergent outcome from faster workflows, fewer errors, and clearer tracking; perceived professionalism improves when milestones are visible and outputs are consistent.	Indirect contributor through operational monitoring/visibility that can strengthen the "modern and transparent" perception, but not the main cause of administrative satisfaction gains.	Uneven adoption can moderate perceived benefits; trust depends on consistent service performance and privacy safeguards.
Cross-cutting (adoption barriers)	n/a	Adoption barriers (O3)	Human-in-the-loop dependence means benefits require staff follow-through, training, and	IoT and real-time dashboards are more sensitive to connectivity; instability affects telemetry	Digital divide, unstable internet, operator capacity, and

Dimension	Quantitative change	Qualitative theme	Primary mechanism	Supporting role of IoT telemetry	Constraints noted
			consistent SOP execution across modules.	transmission and timeliness of monitoring/visibility.	privacy concerns may reduce equitable uptake.

3.4. Interpretation of Improvements in Service-Quality Dimensions

The observed improvement in Speed/Responsiveness is consistent with the qualitative evidence that the service workflow became more streamlined after implementation. In this context, the observed reduction in documented completion-time bands (from approximately 7–10 days to 3–5 days) is most plausibly explained by software workflow changes (submission, verification, routing, and issuance tracking) rather than by facility sensors. Officials described that earlier verification and clearer process tracking reduced rework and repeat visits, which plausibly shortened waiting time and improved responsiveness from the user perspective. This mechanism aligns with service-quality perspectives that emphasize responsiveness as a core indicator of public service performance and user experience. Accuracy (Information Quality) also increased, which is consistent with reported mechanisms related to input validation and the availability of searchable digital records. The system administrator highlighted that automated checks reduced common data-entry errors and that digital logs and archiving improved traceability. From an information-systems perspective, improvements in information quality can increase confidence in administrative outputs and reduce correction cycles, which may indirectly support faster completion and more reliable service delivery.

Ease of Access/Use improved after implementation, and qualitative responses suggest that real-time access to status information and service interfaces reduced the need for in-person inquiries. Citizens emphasized the practical benefit of tracking requests through an application or information display, which can reduce uncertainty and transaction costs for users. At the same time, informants and observations indicated that ease is not uniform across residents and may depend strongly on digital literacy and access to stable connectivity. IoT-derived facility status indicators, where surfaced to dashboards or public displays, are best interpreted as supporting operational transparency and information visibility rather than directly affecting administrative processing speed. Satisfaction showed the largest standardized effect among the four dimensions, and the qualitative findings suggest that satisfaction rose because the experience of service became faster, clearer, and more transparent. Citizens described increased trust and perceived professionalism when service progress was visible and when outcomes were delivered with fewer delays and corrections. In combination, improvements in responsiveness, accuracy, and accessibility can strengthen user satisfaction by reducing uncertainty and increasing perceived fairness and reliability.

3.5. Mechanisms Supported by Qualitative Findings

The integration of quantitative and qualitative evidence suggests that the system's impact is best understood as a combination of workflow digitalization and data-driven transparency. First, digital submission, early verification, and clearer routing of requests reduce idle time and manual bottlenecks, which supports faster service handling. Second, data validation, logging, and digital archiving reduce human error and make records easier to retrieve, which supports accuracy and traceability. Third, interfaces that expose real-time status updates to residents support transparency and reduce the burden of repeated visits. These mechanisms are consistent with broader accounts of how integrated digital-government platforms can improve service responsiveness and decision-making through centralized, timely information flows (Degada et al., 2021) and with IoT literature emphasizing near-real-time data capture and automated reporting as enablers of more efficient service operations (Cvar et al., 2020; Aljuhani et al., 2023; Antony et al., 2020). However, the qualitative results also indicate that benefits may be uneven across residents. Informants emphasized that older residents or those with limited device access may need assistance to use digital features effectively. This pattern aligns with Indonesian digital-divide and village digitalization evidence that highlights uneven digital literacy and infrastructure as barriers to equitable adoption (Aminah & Saksono, 2021). In this deployment, IoT functions primarily as an operational telemetry augmentation (monitoring and facility-status visibility), while the main administrative service gains are explained by digital workflow and data management in the integrated platform.

3.6. Comparison with Prior Studies and Indonesian Village Digitalization Context

The findings contribute to the empirical evidence base on village-level digital transformation in Indonesia, where implementation remains uneven but adoption of integrated digital service initiatives has accelerated in many localities. Policy and empirical studies of Indonesia's e-government trajectory highlight persistent constraints in subnational implementation—especially infrastructure, capacity, and coordination—which can manifest as slower administrative processes and limited transparency in service delivery (Prayitno, 2023; Manjali, 2023). At the same time, village case studies and smart-village discussions document increasing experimentation with integrated platforms intended to improve access and service quality, albeit with heterogeneity in outcomes across settings (Fauziah et al., 2025). In this context, the observed post-implementation increases in responsiveness, accessibility, information quality, and satisfaction are directionally consistent with prior work arguing that transparency and facilitating conditions are central determinants of citizen acceptance and perceived performance of e-government services in Indonesia (Sabani, 2020). The adoption barriers identified in this study, particularly among older residents and those facing connectivity limitations, also mirror recurring constraints reported in village digital-service deployments and rural ICT-use studies (Fatimah et al., 2023; Aminah & Saksono, 2021; Fauziah et al., 2025).

3.7. Implementation Challenges and Practical Implications

Despite the positive changes observed, three implementation challenges emerged consistently from interviews and observations and are well aligned with the constraints highlighted in prior IoT and digital-government research. First, unstable connectivity can delay data synchronization and reduce the perceived timeliness of updates, which may weaken both responsiveness and transparency when users rely on real-time status information. Second, operators reported a need for ongoing training to handle technical issues and to use advanced system features consistently; without this capacity, service quality may vary across staff and over time. Third, data protection and information security were described as critical for sustaining public trust because the system processes personally identifiable administrative data; concerns about misuse or breaches can reduce willingness to adopt digital services. This concern is consistent with IoT security and data-governance literature emphasizing confidentiality (Paki et al., 2025; Nallagattla et al., 2025), access control (Khan et al., 2024; Jalali et al., 2025), and secure dissemination when IoT data are integrated into public platforms (Tange et al., 2020; Bodkhe & Tanwar, 2020; Lykidis et al., 2021; Das and Namasudra, 2022; Jawad et al., 2022). These challenges imply that village digitalization should be treated as a socio-technical change rather than as a purely technical deployment. Connectivity strengthening, routine operator training, and clear governance for access control and data retention are necessary complements to technological implementation. In addition, inclusive adoption strategies—such as assisted service channels, mentoring, or simplified interfaces—may be needed to reduce digital exclusion among residents with limited digital skills.

For scaling to other villages, a phased rollout is recommended. In settings with limited internet reliability or lower operator capacity, prioritizing the core administrative modules (service request management, administrative data validation, digital archiving, and basic status tracking) can deliver the primary gains in speed, accuracy, and transparency with lower dependence on continuous telemetry. After workflows stabilize and user support/training becomes routine, IoT extensions (facility-status sensing and RFID-based operational monitoring) can be integrated to strengthen operational visibility and monitoring, which are more connectivity-sensitive. This staged approach reduces early technical risk and helps align governance practices (RBAC, logging, retention) before expanding telemetry-driven features.

3.8. Limitations and Threats to Validity

Several limitations should be considered when interpreting the findings. The study used a paired pre–post design without a control group; therefore, improvements observed after implementation cannot be attributed exclusively to the system with the same strength as in controlled experiments, and unobserved confounders (e.g., parallel administrative reforms or seasonal variation in service demand) may have contributed to changes. This research was conducted in a single village, which limits generalizability to other settings with different infrastructure, staffing capacity, or community characteristics. The quantitative measures are Likert-based perception ratings that are commonly analyzed with mean comparisons, but they remain subjective and may be influenced by social desirability or novelty effects. Finally, documentation-based service-time ranges (e.g., days-to-completion bands) provide operational context but may vary by service type and recording practice; they should be interpreted as supporting evidence rather than as precise performance metrics. In addition, the post-implementation survey was conducted approximately 11 weeks after the system reached stable operation, so the findings mainly reflect short-term adoption; longer-term follow-up is needed to assess sustainability, maintenance/training effects, and whether perceived improvements persist after novelty effects decline.

4. CONCLUSIONS AND RECOMMENDATIONS

This study provides a field-based evaluation of an integrated IoT-enabled village information system implemented in Waluyojati Village, Pringsewu Regency, Lampung, Indonesia. Using a paired two-wave pre–post survey complemented by qualitative interviews and observations, the study assessed changes in perceived public service quality across four dimensions: Speed/Responsiveness, Accuracy (Information Quality), Ease of Access/Use, and Satisfaction. The results indicate that all four dimensions improved after implementation, with statistically significant pre–post differences ($p < 0.001$) and medium-to-large standardized effects (Cohen's $d_z = 0.58–0.92$), where Satisfaction showed the largest effect. Qualitative findings converged on plausible mechanisms—streamlined workflows and earlier verification, validation and digital logging/archiving, and transparent status tracking—while also highlighting constraints related to connectivity, operator capacity, digital inclusion, and personal-data governance. Because the evidence comes from a single-village paired pre–post design without a control group, causal attribution and generalization should be made cautiously; nonetheless, the findings suggest that sustaining and scaling similar systems requires reliable networks, continuous training, inclusive support for less digitally literate residents, and clear data-protection practices.

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