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Smart Village Ecosystems: Integrating IoT, Fintech, and Digital Literacy to Boost Inclusive Rural Development

Ani Indah Sari
Universitas Islam Negeri Siber Syekh Nurjati, Indonesia
*Corresponding Author: aniindahsari160625@gmail.com

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Abstract

Background: Rural communities continue to face poverty, limited infrastructure, and economic marginalization, while smart village ecosystems integrating the Internet of Things (IoT), financial technology (fintech), and digital literacy are promoted as pathways to inclusive development.
Objective: This study investigates how such ecosystems advance inclusive rural development by examining technology adoption patterns, digital capability development, financial inclusion mechanisms, and the factors enabling or constraining equitable participation.
Method: A qualitative exploratory comparative case study was conducted in two contrasting villages in Cirebon District, West Java, Indonesia, using 47 semi-structured interviews, participant observation at 12 technology sites, and document analysis, which were analysed thematically.
Results: Setupatok Village demonstrated functional IoT integration, diverse fintech adoption, and digital literacy programming reaching 68% of adults, whereas Karangsuwung Village showed minimal IoT deployment, limited fintech access, and only 23% digital literacy coverage. Even in the advanced village, inclusion was uneven: educated middle-aged men captured most benefits, while women faced gender norms and time constraints, elderly residents faced literacy and usability barriers, and poor households faced affordability and livelihood pressures.
Conclusion: Technology deployment alone does not generate inclusive outcomes; integrated ecosystems require sustained capability building, accessible design, cross-sectoral coordination, and explicit inclusion mandates.

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INTRODUCTION

The global trajectory toward sustainable development confronts a fundamental paradox while technological innovation accelerates exponentially in urban centers and wealthy nations, rural communities particularly in developing countries face persistent development challenges including poverty, limited infrastructure access, inadequate public services, and economic marginalization. Smart village concepts have emerged proposing

that strategic deployment of digital technologies, particularly Internet of Things (IoT) systems, financial technology (fintech) platforms, and digital literacy initiatives, can address rural development constraints by improving agricultural productivity, expanding financial inclusion, enhancing governance transparency, and connecting remote communities to broader economic opportunities (Degada et al., 2021; Malik et al., 2022; Tosida et al., 2022).

However, critical questions persist regarding whether technology-driven development interventions genuinely promote inclusive outcomes benefiting all rural residents across diverse social positions, or primarily advantage already-privileged groups while potentially exacerbating existing inequalities through differential technology access and capability development (Babin et al., 2022; Q. Wang et al., 2022). Indonesia's smart village development trajectory exemplifies both the promise and challenges of technology-driven rural transformation.

Government policies including the Village Law (UU No. 6/2014) and National Medium-Term Development Plan (RPJMN 2020-2024) explicitly prioritize village development and technology deployment, with significant budget allocations supporting infrastructure development and digital literacy programs. By 2024, over 5,000 villages nationwide had initiated smart village programs incorporating various technology components. However, implementation quality varies dramatically, and systematic evidence regarding actual outcomes for diverse community members remains limited.

While showcase villages demonstrate impressive technology arrays and receive substantial media attention, questions persist about whether these technological investments translate to meaningful improvements in villagers' lives, particularly for marginalized populations including women, elderly residents, and economically disadvantaged households (Amit et al., 2024; Mukti et al., 2023; Ruhi et al., 2024). This research investigates smart village ecosystem functioning in practice within Indonesian rural contexts, examining how IoT technologies, fintech platforms, and digital literacy initiatives operate individually and collectively, which community segments successfully access and benefit from these technologies, what barriers prevent universal inclusion, and what implementation factors differentiate more versus less inclusive outcomes.

The study addresses critical knowledge gaps in existing literature, which tends to emphasize technology deployment and functionality rather than examining actual usage patterns, differential access across social groups, and mechanisms generating inclusion versus exclusion. Through comparative case study analysis of two contrasting villages in Cirebon district, West Java one with advanced ecosystem development and one with minimal development the research generates empirical evidence regarding smart village implementation realities and practical implications for achieving genuinely inclusive technology-driven rural development.

The integration of IoT technologies into rural contexts creates unprecedented opportunities for data-driven agricultural management, environmental monitoring, infrastructure optimization, and public service delivery (Widianingsih et al., 2025). Agricultural IoT applications including soil moisture sensors, weather stations, crop monitoring systems, and livestock tracking devices enable precision farming practices improving productivity while reducing resource waste. Village infrastructure IoT including smart water management, electricity monitoring, and waste management systems enhance resource efficiency and service quality (Dziembala et al., 2024; Pimenow et al., 2025).

Governance IoT incorporating digital information systems, participatory budgeting platforms, and service delivery monitoring tools strengthen transparency and accountability. However, realizing these potentials requires not merely technology deployment but comprehensive ecosystem development ensuring rural residents possess necessary capabilities to access, understand, and effectively utilize IoT-generated information for improved decision-making. Financial inclusion through fintech platforms addresses critical constraints on rural economic development where traditional banking

infrastructure remains limited and transaction costs prohibitive for small-value activities typical of rural livelihoods.

Mobile banking, digital payment systems, peer-to-peer lending platforms, and agricultural fintech applications theoretically enable rural households to access formal financial services, reduce transaction costs, build credit histories, and access capital for productive investments (Das, 2025; W. Wang et al., 2025). Indonesian fintech expansion has been remarkable, with mobile banking users increasing from 15 million (2018) to over 150 million (2024), digital payment transaction values growing exponentially, and agricultural fintech platforms emerging specifically targeting smallholder farmers.

Yet questions remain about whether this fintech expansion genuinely reaches rural poor populations or primarily serves already-banked middle-class users, and whether rural residents possess digital literacy and financial capability to safely navigate fintech platforms without exposure to fraud, predatory lending, or inappropriate financial products. Digital literacy constitutes the foundational capability enabling rural populations to access and benefit from both IoT and fintech technologies, yet remains severely underdeveloped in Indonesian rural contexts (Cartile, 2020; Farias-Gaytan et al., 2022).

National statistics indicate that while 73% of urban Indonesians possess basic digital literacy, only 42% of rural residents demonstrate comparable capabilities, with stark disparities across age groups (elderly residents largely digitally illiterate), gender (women significantly less digitally literate than men), and socioeconomic status (poor households lacking both devices and skills). Digital literacy encompasses not merely technical skills operating devices but broader competencies including information evaluation, online safety, digital citizenship, and adaptive learning enabling individuals to navigate rapidly evolving technology landscapes.

Systematic digital literacy programming targeting diverse rural populations represents essential foundation for inclusive smart village development, yet often receives inadequate attention in implementation initiatives emphasizing infrastructure deployment over capability building. Existing literature on smart villages, rural digitalization, and technology-driven development provides important foundations but exhibits critical limitations. IoT research extensively documents technical capabilities, sensor technologies, and data analytics applications but rarely examines whether rural residents actually access and utilize IoT-generated information or whether such information translates to improved decision-making and outcomes (Nagah et al., 2023).

Fintech literature emphasizes platform innovation, business models, and market expansion while paying insufficient attention to digital financial inclusion mechanisms, capability requirements for safe fintech usage, or differential access patterns across rural social groups (Ediagbonya & Tioluwani, 2023). Digital literacy research identifies capability gaps and pedagogical approaches but typically examines urban or general populations rather than rural-specific contexts with distinctive infrastructure, educational, and cultural characteristics (Castilla et al., 2018).

Moreover, (Menza et al., 2024) in their study on mobile money adoption in rural areas highlight how mobile platforms facilitate financial inclusion but focus primarily on the technical aspects, lacking an exploration of how rural residents engage with the technology in their daily lives. The study does not address the influence of digital literacy or socio-cultural factors such as gender and age, nor does it consider varying access levels across different demographic groups, which are crucial for understanding digital inclusion in rural settings. Similarly, (Malik et al., 2022) explore smart village initiatives, focusing on IoT and digital technologies in rural development, but their research overlooks the actual usage of these technologies by rural populations and their impact on daily outcomes, concentrating instead on infrastructure and technical feasibility.

Limited empirical research examining how multiple technology components (IoT, fintech, digital literacy) function as integrated ecosystems rather than isolated interventions; insufficient attention to inclusion and exclusion mechanisms differentiating who benefits

versus who remains marginalized in technology-driven development; inadequate investigation of implementation factors and institutional conditions enabling more versus less inclusive outcomes; and minimal comparative analysis examining variation in smart village development quality and consequences across different contexts.

This research addresses these gaps through systematic comparative case study examining ecosystem integration, differential inclusion patterns, and implementation factors in contrasting Indonesian villages. The concept of inclusive rural development underlying smart village ecosystem approaches emphasizes that development benefits should extend across entire communities rather than concentrating among already-advantaged groups, with particular attention to historically marginalized populations including women, elderly residents, poor households, and those with limited formal education.

Inclusive development frameworks recognize that technology deployment alone proves insufficient achieving inclusion requires intentional design addressing accessibility barriers, capability-building initiatives ensuring diverse populations can effectively utilize technologies, economic enablement demonstrating tangible livelihood benefits motivating adoption, and governance mechanisms ensuring participatory planning and equitable resource allocation. These principles remain inadequately integrated into smart village implementation practice, motivating investigation of how inclusion can be systematically promoted.

This research draws on multiple theoretical frameworks providing analytical lenses for understanding smart village ecosystem dynamics and inclusion patterns. Technology Acceptance Models (TAM and UTAUT) offer insights into factors influencing technology adoption including perceived usefulness, perceived ease of use, social influence, and facilitating conditions. Applied to smart villages, these models help explain why certain community segments embrace technologies while others resist, highlighting roles of usability design, demonstrated benefits, peer effects, and infrastructure availability (Amit et al., 2024; Malik et al., 2022; Q. Wang et al., 2022).

However, acceptance models developed primarily in organizational and urban contexts require adaptation for rural settings where collective decision making, traditional authority structures, and subsistence livelihood pressures create distinctive adoption dynamics. Capability Approach frameworks, particularly as developed by Amartya Sen and Martha Nussbaum, emphasize that development should expand people's capabilities their real freedoms to achieve valuable functionings rather than merely providing resources or infrastructure.

Applied to smart villages, capability perspectives highlight that technology access alone proves insufficient; meaningful inclusion requires developing capabilities to effectively utilize technologies for valued purposes. Digital literacy, financial literacy, critical evaluation skills, and adaptive learning capacities constitute essential capabilities enabling technology to expand rather than constrain freedoms (Degada et al., 2021; Dziembala et al., 2024). The capability approach also emphasizes heterogeneity different individuals and groups require different supports to develop capabilities, suggesting one-size-fits-all technology deployment inevitably produces uneven outcomes requiring differentiated interventions addressing diverse needs.

Digital Divide frameworks analyze how unequal access to information and communication technologies creates or exacerbates social inequalities. First-level digital divides concern physical technology access (devices, connectivity); second-level divides concern digital skills and competencies; third-level divides concern beneficial use translating technology access into tangible outcomes. Research on digital divides demonstrates that providing infrastructure alone (first-level access) proves insufficient without capability building (second-level) and integration into livelihood practices generating benefits (third-level) (Degada et al., 2021; Dziembala et al., 2024). Applied to smart villages, these frameworks direct attention to how villages with similar technology

deployment may exhibit vastly different inclusion outcomes based on capability development and effective usage promotion .

Intersectionality frameworks, originating in feminist scholarship examining how gender, race, class, and other social categories intersect creating distinctive experiences of privilege and oppression, prove essential for understanding smart village inclusion dynamics (Sharma et al., 2023). Technology access and capability patterns reflect intersecting inequalities poor elderly women face compounded disadvantages distinct from challenges experienced by poor elderly men, poor young women, or wealthy elderly women. Intersectionality directs analytical attention to how multiple marginalization axes combine, requiring inclusion strategies addressing specific intersectional positions rather than treating gender, age, and class as separate independent factors amenable to isolated interventions.

Socio-Technical Systems perspectives emphasize that technologies function within and co-evolve with social, institutional, and economic contexts rather than operating as independent deterministic forces. Smart village ecosystems constitute socio-technical systems where IoT sensors, fintech platforms, and digital literacy initiatives interact with existing agricultural practices, financial behaviors, governance institutions, social networks, and cultural norms (Baxter & Sommerville, 2011; Yu et al., 2023). Understanding ecosystem functioning requires analyzing both technical components and social embedding processes, recognizing that technologies designed for urban settings may require substantial adaptation for rural contexts, and acknowledging that implementation approaches substantially shape whether technologies reinforce or transform existing power structures and inequalities.

Taken together, the studies reviewed above reveal a clear research gap. Prior work has largely examined IoT, fintech, and digital literacy as separate interventions and has prioritised technical feasibility, platform innovation, or infrastructure deployment over actual usage, differential access across social groups, and the institutional conditions that determine who benefits. Empirical evidence that treats these three components as an integrated ecosystem, applies an intersectional lens to inclusion and exclusion, and compares villages at contrasting stages of development within the same administrative context remains scarce, particularly in Indonesia.

The novelty of this study lies in three aspects. First, it analyses IoT, fintech, and digital literacy as interdependent components of a single smart village ecosystem rather than as isolated interventions. Second, it combines capability, digital divide, and intersectionality perspectives to explain how gender, age, and socioeconomic status jointly structure inclusion and exclusion. Third, it provides comparative evidence from an advanced and a minimally developed village in the same district, allowing implementation factors to be distinguished from broader contextual differences. Accordingly, this study aims to map the configuration and adoption patterns of smart village technologies, examine digital literacy pathways and capability development, assess fintech-based financial inclusion, identify inclusion and exclusion mechanisms across social groups, and analyse the coordination and sustainability factors that differentiate more inclusive from less inclusive outcomes.

RESEARCH METHOD

This study adopts a qualitative exploratory case study design to examine the functioning of smart village ecosystems in Cirebon, West Java. The research aims to generate a deep contextual understanding of the factors influencing smart village development, focusing on the complexities and diverse stakeholder perspectives that quantitative methods might overlook. Two villages were selected for comparison: Setupatok Village, which has implemented various digital technologies and IoT systems with substantial external support, and Karangsuwung Village, where minimal development has taken place. These villages were chosen to highlight contrasts in smart village progress despite similar economic and demographic profiles.

The research took place between June and August 2024, utilizing multiple data collection methods for comprehensive analysis. Primary data was gathered through 47 semi-structured interviews, with participants from diverse backgrounds such as village leadership, technology providers, farmers, women's groups, elderly residents, and youth. Participant observation was also conducted at 12 technology deployment sites, including agricultural sensor installations, digital literacy training sessions, fintech service points, and government digital platforms, providing insights into technology interactions and service delivery. Document analysis of implementation records, policy documents, and secondary data from village reports and media coverage complemented these findings.

Data analysis followed an iterative thematic approach, starting with familiarization and initial coding of transcripts and field notes. Codes were organized into categories, and relationships between categories were examined to identify patterns across the two villages.

A cross-case comparison was conducted to pinpoint differentiating factors, followed by the development of comprehensive thematic frameworks. Validation strategies, including triangulation of interviews, observations, and documents, member checking, and negative case analysis, were employed to enhance the reliability and quality of the findings. Within-case analysis was first conducted for each village and was then followed by cross-case comparison. This procedure produced five analytical themes that correspond to the research objectives and structure the Results section: ecosystem configuration and technology adoption, digital literacy pathways, financial inclusion through fintech, inclusion and exclusion mechanisms across social groups, and ecosystem coordination and sustainability.

All participants were informed of the purpose and procedures of the study, the voluntary nature of participation, and their right to withdraw at any time, and informed consent was obtained before each interview and observation session. Permission to conduct fieldwork was obtained from the respective village governments. To protect anonymity and confidentiality, participants are identified only by their role or social group, no personal identifiers are reported, and recordings, transcripts, and field notes were stored securely and accessed only by the research team.

RESULT AND DISCUSSION

Smart Village Ecosystem Configuration and Technology Adoption Patterns

This research compares the smart village ecosystems of Astanajapura and Karangsuwung villages in Cirebon, Indonesia, highlighting their different stages of development and resource availability. Astanajapura has advanced considerably in implementing smart village technologies, including IoT agricultural sensors, solar power generation, and mobile money services, with significant community engagement and institutional support.

These technologies, while successful in many areas, show uneven adoption patterns, especially among disadvantaged groups such as small farmers and older populations, due to cost, technical complexity, and lack of continuous support. Conversely, Karangsuwung's ecosystem is fragmented, with limited infrastructure and adoption of smart technologies, largely due to unreliable electricity, slow internet, and insufficient local technical support.

These barriers, compounded by weak institutional capacity and political apathy, have hindered the village's ability to harness smart village benefits. In Astanajapura, the digital infrastructure and mobile money services have been widely adopted, with younger residents showing the most enthusiasm for digital transactions, while older generations and women face barriers related to trust, security concerns, and family dynamics. The solar power system in Astanajapura achieved broad adoption across socioeconomic strata, thanks to a community-managed, affordable model that eliminated individual investment and operational barriers.

On the other hand, Karangsuwung faces persistent challenges with inconsistent electricity and limited internet connectivity, which make it difficult for residents to engage

with IoT or fintech services. These infrastructure issues are compounded by institutional gaps, as the village government lacks the technical expertise to facilitate or support technology adoption, and political elites show little interest in smart village initiatives due to their existing access to urban resources.

The study highlights the critical role of institutional capacity, leadership commitment, and tailored approaches in the successful implementation of smart village initiatives. Astanajapura's success is attributed to strong local governance, external partnerships, and comprehensive digital literacy programs, whereas Karangsuwung's failure to implement similar initiatives is rooted in infrastructure deficits, institutional weakness, and political resistance.

The findings suggest that for smart villages to succeed, there must be a concerted effort to build local technical capacity, ensure equitable access to technologies, and foster inclusive decision-making processes. Additionally, the research demonstrates the importance of addressing both infrastructure and institutional barriers, as well as the need for context-specific strategies that consider local challenges and opportunities for digital transformation.

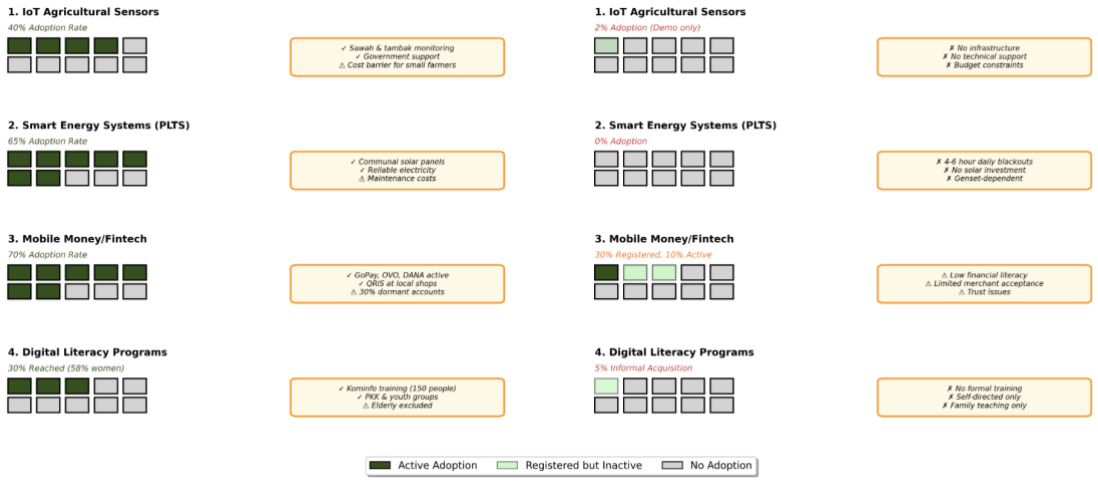

Figure 1. Technology Adoption Patterns Across Village Contexts (Source: Field research data, 2024)

Digital Literacy Pathways and Capability Development

The development of digital literacy in two villages in Cirebon followed distinct paths influenced by available resources, institutional support, and social learning opportunities. In Astanajapura village, formal and informal learning channels, such as digital literacy training from BUMDes, supported residents in acquiring digital skills, with a focus on women through targeted recruitment. Despite these efforts, gaps in digital fluency remained, as the six-session training proved insufficient for building confidence and proficiency. Informal peer networks, especially within women's groups, played a crucial role, providing ongoing learning opportunities through WhatsApp groups and community support, fostering a continuous learning environment despite limited formal training.

In contrast, Karangsuwung village had limited formal training, with sporadic workshops on topics like digital finance and online business, but lacking foundational skills. These workshops often failed due to assumed baseline knowledge, leaving many participants struggling with basic concepts and without adequate hands-on experience. The few residents with functional digital literacy largely acquired skills through self-directed learning, encountering challenges with trial-and-error processes and occasional help from urban-dwelling relatives. The absence of consistent and accessible training opportunities led to gaps in critical digital competencies, particularly in information literacy and online safety.

The study highlighted significant gaps in content creation capabilities, particularly among women and older adults. While young, educated men demonstrated skills in digital marketing and content creation, the majority of residents remained passive consumers. This inequality proved economically significant for digital entrepreneurship, where a strong online presence was critical. Additionally, generational gaps in digital literacy left older residents vulnerable to exclusion from digital services, reinforcing their dependence on younger relatives for access to essential services. To address these challenges, the research recommended sustained, longitudinal training, peer mentoring, and family-based learning approaches to create a more inclusive and supportive digital literacy environment.

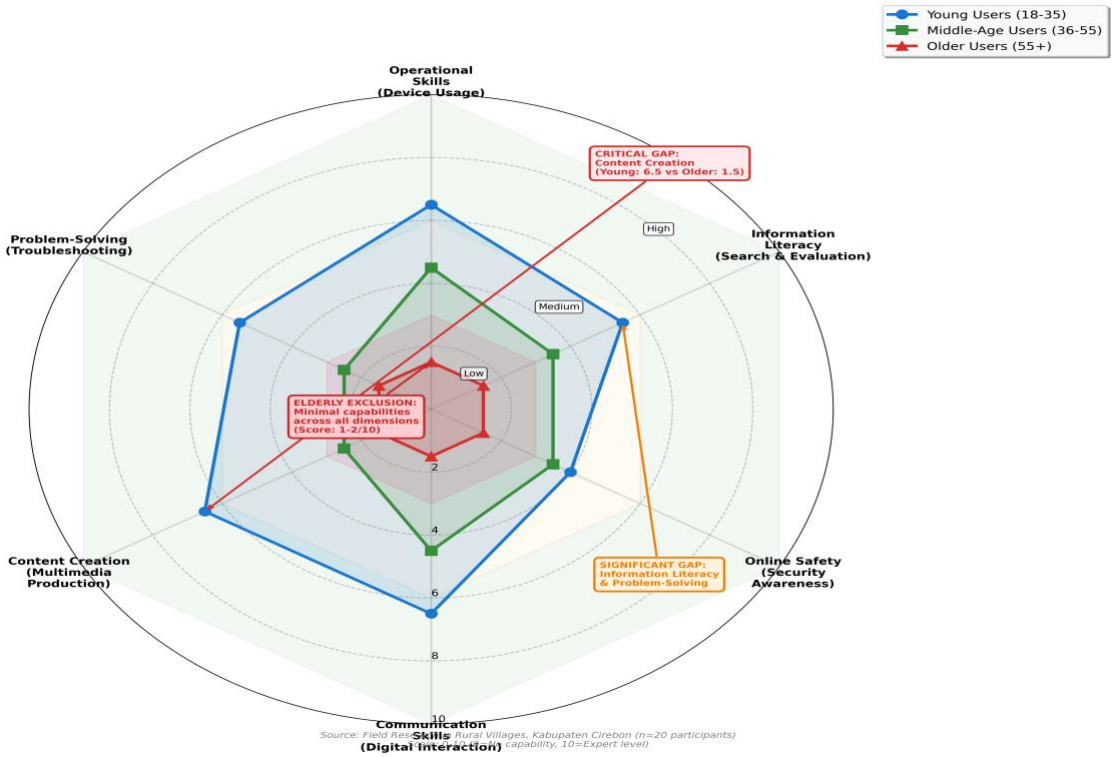

Figure 2. Digital Literacy Capability Dimensions and Gaps (Source: Field research data, 2024)

Financial Inclusion Through Fintech Integration

The integration of financial technology into village ecosystems created new opportunities for financial inclusion while revealing persistent barriers limiting equitable access and meaningful use across the rural population of Cirebon Regency. In Astanajapura village mobile money penetration of 70% represented substantial quantitative inclusion, yet qualitative examination exposed how depth and quality of financial service usage varied dramatically across user segments. Active users, comprising approximately 40% of mobile money registrants, conducted multiple transactions weekly including person-to-person transfers, bill payments, airtime purchases, and increasingly merchant payments as local shops adopted digital payment acceptance.

These users described mobile money as transformatively convenient, eliminating needs to travel to distant bank branches for basic transactions, enabling instant money transfers to family members including urban-based children sending remittances to rural parents with unprecedented speed and lower cost than traditional remittance channels, and providing discrete financial management capabilities particularly valued by women conducting business activities or managing household finances with greater autonomy than joint traditional bank accounts permitted. However, the 30% of Astanajapura village mobile

money registrants whose accounts remained dormant or minimally used revealed important inclusion limitations beyond simple access metrics.

Interviews with inactive users identified multiple constraining factors including low financial literacy creating confusion about account management, fees, and appropriate usage contexts relative to cash transactions; limited merchant acceptance within the village requiring cash for most purchases except utility bills or specific shops that adopted digital payments, reducing practical utility for daily economic activities; persistent trust concerns about digital money's security and reliability, with several participants recounting hearing about others losing money through fraud, platform failures, or confusing transactions they didn't authorize; and social-cultural norms where cash remained preferred for important transactions including ceremonial gift-giving, religious donations, and certain business dealings where physical money exchange held symbolic significance beyond mere financial value.

These inactive users felt pressure to maintain accounts to receive remittances from urban relatives or participate in government programs increasingly disbursing payments digitally, but avoided proactive usage, immediately withdrawing any received funds to cash for comfort and control. Digital credit products offered through mobile lending platforms presented more concerning inclusion patterns, with access concentration among already-economically-secure borrowers while excluding vulnerable populations who might benefit most from expanded credit access. The research identified approximately 15% of Astanajapura village mobile money users who had borrowed through digital platforms including operator-branded services and third-party fintech applications.

These borrowers were disproportionately salaried employees, established business owners, and farmers with substantial landholdings the precise populations who already possessed access to formal bank credit, albeit through more cumbersome application processes. When asked why digital lending, these users emphasized convenience and speed, describing approval within minutes compared to days or weeks for bank loans, minimal documentation requirements, and ability to borrow modest amounts for short-term needs without the social stigma or obligation they associated with borrowing from friends, family, or informal moneylenders.

However, several also described problematic experiences including unexpectedly high interest rates that weren't clearly disclosed upfront, aggressive debt collection practices including automated calls and SMS messages demanding immediate repayment, and damage to their digital credit scores from missing payments during temporary cash flow problems, subsequently limiting their access to better loan terms. The exclusion of poor and economically marginal households from digital credit access despite theoretical promises of alternative data enabling underserving previously unbanked populations represented a significant gap between fintech rhetoric and reality.

Interviews revealed that platform algorithms prioritizing transaction history and patterns systematically disadvantaged poor users whose limited economic activity generated sparse digital footprints inadequate for credit scoring. Day laborers with irregular cash income rarely conducted enough mobile money transactions to establish creditworthiness signals, while smallholders with less than 0.5 hectares of land selling most produce through informal cash markets similarly lacked transaction histories demonstrating regular income flows. Several participants described trying to borrow through digital platforms during genuine financial emergencies only to face rejection or offered loan amounts of USD 5-10 too small to address their needs, forcing them back to informal lenders charging usurious rates.

The cruel irony emerged that fintech's data-driven underwriting, while eliminating traditional documentation barriers, created new exclusion mechanisms privileging digitally active and economically stable populations while marginalizing those most desperately needing affordable credit access. Karangsuwung village more limited fintech landscape provided fewer services but also potentially lower exclusion risks given that limited

adoption meant few residents experienced financial exclusion from fintech per se, though they certainly remained excluded from formal financial services generally.

The digital financial services agent operating from small shops served crucial functions enabling cash-in and cash-out transactions for the 30% of the population with accounts, but service quality varied considerably depending on agent cash and e-float management, with frequent situations where agents lacked sufficient cash to process withdrawal requests or adequate e-float to accept deposits, forcing customers to return later or travel to alternative agents. No digital lending services operated in Karangsuwung village due to population size and transaction volumes falling below minimum thresholds making platform entry commercially viable.

This absence meant residents relied entirely on informal credit sources including family borrowing, rotating savings and credit associations, and traditional moneylenders charging rates of 10-20% monthly, creating severe financial vulnerability yet also avoiding the predatory digital lending practices and credit score damages that concerned some Astanajapura village participants. Agricultural fintech applications theoretically promising transformative impacts for smallholder farmer financial inclusion proved largely absent in both study villages, representing a significant gap between smart village visions and ground-level realities.

Neither village had functional digital agricultural insurance products despite both locations facing weather variability and pest pressures that generated income risk. Participants expressed interest in affordable crop insurance when the concept was explained, but no providers served their locations, with farmers surmising that their individual farms were too small and dispersed to justify insurance company operational costs. Supply chain financing that development literature frequently highlights as fintech application enabling farmers to purchase quality inputs on credit remained unavailable, with the few agricultural input suppliers operating in or near the villages dealing exclusively in cash due to their own capital constraints and risk aversion about credit provision without tangible collateral.

Farmers continued purchasing inputs from whatever sources offered credit, often lower-quality products from informal suppliers charging implicit interest through inflated prices, perpetuating low productivity despite knowing better inputs would improve yields. The integration or lack thereof between fintech and other smart village ecosystem components revealed both missed opportunities and coordination challenges. In Astanajapura village, the absence of connections between agricultural IoT sensors for monitoring rice fields and ponds and digital financial services meant that valuable production data generated by sensors provided no benefit for farmers' creditworthiness assessment, representing a fundamental failure to leverage ecosystem synergies.

Technology providers operated in silos, with IoT installers unaware of fintech platforms, fintech applications lacking interfaces to accept agricultural data inputs, and no intermediary organizations facilitating integration despite obvious mutual benefits. Several farmers noted that if their sensor data demonstrating consistent proper farming practices and stable yield histories could inform credit decisions, they might access better loan terms than current platform algorithms offered based only on mobile money transactions largely disconnected from their primary agricultural livelihoods. The coordination challenges reflected both technical interoperability issues where proprietary systems lacked open data sharing capabilities and institutional fragmentation where government agriculture, ICT, and financial sector agencies each promoted separate initiatives without cross-sectoral coordination mechanisms.

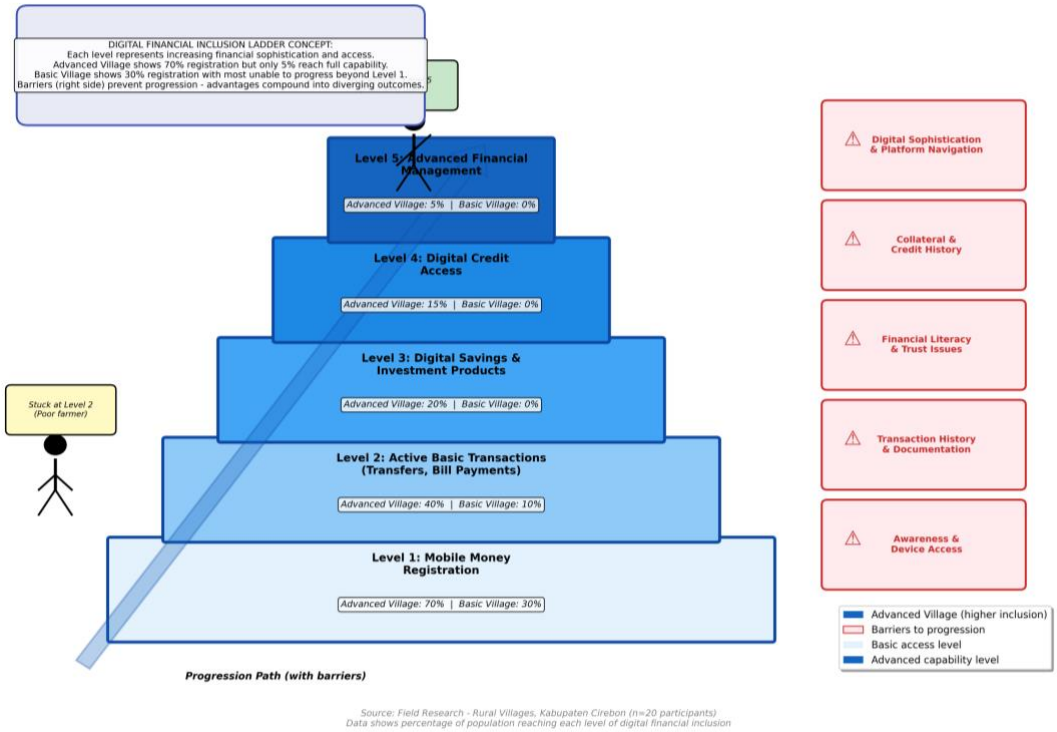

Figure 3. Fintech Usage Patterns and Digital Financial Inclusion Ladder (Source: Field research data, 2024)

Inclusion and Exclusion Mechanisms Across Social Groups

The research uncovered complex, intersecting mechanisms generating differential inclusion and exclusion patterns across multiple social identity dimensions, revealing how smart village ecosystem benefits and burdens distribute unevenly across populations rather than uniformly uplifting all community members. Gender emerged as a pervasive dimension structuring technology access, usage patterns, and outcome distributions in ways that simultaneously created new opportunities for women's economic participation while reproducing and sometimes intensifying existing gender inequalities.

Women participants in Astanajapura village who successfully engaged with smart technologies described how mobile money enabled business activities that traditional banking structures made difficult, citing ability to receive customer payments instantly, maintain private business savings accounts without requiring husband co-signing, and conduct transactions discretely without attracting family attention that might trigger expectations about contributing funds to household expenses or extended family requests. Several women entrepreneurs specifically emphasized how fintech platforms treating them as individual account holders rather than household representatives or male dependents provided dignity and autonomy previously absent in financial interactions.

However, these empowering experiences represented minority patterns among a broader landscape of persistent gender-based barriers that constrained women's technology participation and benefit capture. Household-level technology access dynamics proved crucial, with women in both villages describing how shared family smartphones belonged nominally to husbands or sons who determined usage permissions, created implicit or explicit constraints on women's device time, and sometimes monitored or questioned women's activities generating inhibitions about extensive technology exploration.

Digital literacy disparities reflected and reinforced these access patterns, with women typically possessing fewer opportunities for sustained technology learning given household labor burdens including childcare, cooking, cleaning, and agricultural work limiting time available for training program participation or leisurely experimentation building digital

fluency. Several women described attempting to attend digital literacy workshops but facing family resistance framed through ostensibly reasonable concerns about neglecting household responsibilities, though similar concerns rarely constrained men's participation in development programs.

Cultural norms around appropriate feminine behavior created additional subtle constraints that interview participants struggled to articulate clearly but repeatedly gestured toward in discussions of technology discomfort. Women described feeling that extensive technology engagement particularly for entertainment or social purposes rather than immediately productive applications carried connotations of frivolity or time-wasting that didn't apply equally to men, generating internalized guilt when spending time learning digital skills without clear immediate returns.

The mobile money platform interfaces and marketing materials predominantly featuring male imagery and business contexts conveyed implicit messages about intended users that several women noted made them feel like outsiders appropriating tools designed for men rather than legitimate platform users in their own right. Online spaces including social media and e-commerce platforms could feel unwelcoming or even hostile, with several women recounting experiences of harassment including unwanted advances, inappropriate comments on business pages, and generally dismissive or condescending treatment that created discomfort deterring extensive engagement even when technically capable.

Age-based exclusion patterns proved even more severe than gender, with older residents facing compounding disadvantages around digital technology access, literacy, and meaningful usage that created risks of systematic marginalization from increasingly digital service delivery and social interaction modalities. The research documented a stark generational divide where residents over 55 exhibited minimal technology adoption rates in both villages, with perhaps 20% possessing basic mobile phones used exclusively for voice calls and SMS, and fewer than 5% owning smartphones or engaging with internet-based services.

Older participants consistently described feeling overwhelmed by digital technologies, using terms like "too complicated," "not for people like me," "meant for young people" that revealed not just capability deficits but identity-based perceptions that technology fundamentally belonged to different generations and ages seeking to engage represented futile struggles against natural order. The mechanisms generating age-based exclusion extended beyond digital illiteracy to encompass physical, cognitive, and social dimensions that intersected to create particularly severe barriers for elderly populations.

Visual impairments common in older age created difficulties reading small smartphone screens and navigating interfaces with tiny buttons and subtle color distinctions, while declining fine motor control made precise touch interactions challenging and frustrating. Cognitive processing speed decrements meant that rapidly changing interfaces, multi-step processes requiring remembering sequences, and time-limited operations like one-time passwords expiring before users completed transactions proved especially difficult. Social isolation common among elderly residents limited access to family members or friends who might provide technology assistance, while living alone or with similarly aged spouses meant lacking household members who could explain features, troubleshoot problems, or mediate digital service access when self-operation proved impossible.

The inadequacy of smart village ecosystem designs for elderly user needs represented a systematic failure to consider universal design principles ensuring technology accessibility across diverse capabilities. Default assumptions embedded in platform development processes clearly anticipated young, healthy, educated users with strong vision, fine motor control, digital familiarity, and social support networks providing assistance when needed, rather than designing for populations with sensory impairments, limited prior technology exposure, cognitive processing differences, and potential social isolation.

The absence of accessible alternative interfaces offering larger text and buttons, simplified navigation paths, audio guidance, and extended time limits for completing operations created unnecessary exclusion of populations who could benefit substantially from financial inclusion, information access, and social connectivity digital technologies theoretically enabled. Several younger participants noted their parents or grandparents expressing desires to use mobile money for convenience but finding interfaces too confusing, suggesting that inclusive design rather than inherent elderly technology resistance explained substantial adoption gaps.

Socioeconomic status operated as fundamental dimension structuring inclusion, with poverty creating compounding disadvantages spanning technology access, capability development, and ability to capture benefits from ecosystem participation. Poor households faced immediate affordability barriers around purchasing smartphones, paying for mobile data plans, investing in IoT technologies, or even covering nominal fees for digital literacy training through the Kominfo Digital Literacy Movement programs theoretically available at subsidized rates.

Beyond initial access costs, ongoing sustainability of technology usage required maintaining devices, replacing broken components, purchasing data regularly, and paying transaction fees that accumulated to meaningful burdens for households operating on extremely tight budgets where daily trade-offs between competing urgent needs meant technology expenses often lost to food, medicine, school fees, or other immediate necessities. The opportunity costs of time spent learning digital skills or attending training programs represented additional poverty-specific constraints, as poor households depending on daily wage labor couldn't afford income loss from missing work days attending workshops that wealthier households managed without immediate economic hardship.

The capability disadvantages associated with poverty extended beyond direct financial constraints to encompass educational and social capital deficits that shaped technology engagement possibilities. Limited formal schooling common among poor populations created literacy and numeracy barriers constraining digital literacy development, with text-heavy interfaces, numerical transaction confirmations, and written instructions assuming baseline educational competencies many poor users lacked.

Weak social networks among marginalized populations meant limited access to peer learning opportunities or informal technical support that better-connected residents utilized extensively for troubleshooting and skill development. The exclusion from formal digital literacy training through the Kominfo Digital Literacy Movement program programs ostensibly open to all but implicitly designed for educated populations proved particularly troubling, with poor, low-literacy residents attempting participation but finding themselves unable to follow instructions, embarrassed by their struggles relative to other participants, and ultimately dropping out without acquiring intended skills while perceiving their failures as personal inadequacies rather than program design failures.

The research revealed troubling patterns where smart village ecosystem development risked exacerbating rather than reducing existing inequalities, with benefits concentrating among already-advantaged populations possessing education, resources, social connections, and prior technology exposure enabling effective ecosystem participation, while marginalized groups faced new exclusion dimensions beyond persistent traditional disadvantages.

Several participants explicitly articulated concerns that smart village development served elite interests, noting how village leadership and wealthier residents enthusiastically embraced technologies offering personal benefits while expressing less interest in ensuring technologies served broader populations equitably. The absence of explicit inclusion mandates, accountability mechanisms, or targeted interventions addressing specific marginalization drivers meant that ecosystem development followed paths of least resistance, serving easiest-to-reach populations while leaving hardest-to-serve groups behind, thereby widening rather than narrowing social divides.

Table 1. Inclusion and Exclusion Mechanisms Across Social Groups

Social group	Main barriers	Observed consequences
Women	Shared devices controlled by husbands or sons; household labour burdens; family resistance to training; gendered cultural norms; male-oriented platform imagery; online harassment	Limited device time and digital fluency; only a minority of women entrepreneurs benefit from private mobile money accounts
Elderly residents (over 55)	Digital illiteracy; visual, motor, and cognitive limitations; time-limited one-time passwords; social isolation; designs ignoring accessibility	About 20% use basic phones only and fewer than 5% use smartphones; dependence on younger relatives
Poor households	Costs of devices, data, and fees; opportunity costs of training; limited schooling; weak social networks; sparse digital footprints	Rejected or offered USD 5–10 digital loans; drop-out from digital literacy training; reliance on informal lenders
Educated, better-off men	Few barriers; prior technology exposure and resources	Comprehensive access and benefit capture, including digital credit and IoT adoption

Source: Field research data (interviews, observations, and documents), 2024.



Figure 4. Intersectional Inclusion-Exclusion Matrix (Source: Field research data, 2024)

Ecosystem Coordination, Sustainability, and Implementation Challenges

The coordination of multiple smart village ecosystem components across technology types, implementing organizations, and governance levels emerged as a critical challenge significantly undermining potential benefits and sustainability across both research sites. In Astanajapura village, despite relatively advanced technology deployment, the research documented systematic coordination failures where different initiatives operated in parallel rather than synergistically, missing opportunities for integration that could multiply individual component benefits. IoT agricultural sensor deployment occurred through a government agriculture ministry pilot program.

The consequences of fragmented implementation manifested in multiple problematic ways participants described experiencing despite not always conceptualizing problems as coordination failures. Farmers using IoT sensors manually transcribed and analyzed data in notebooks because sensor systems couldn't interface with mobile apps or cloud platforms accessible via smartphones they already owned, representing fundamental interoperability failure where closed proprietary systems designed without coordination prevented obviously beneficial data mobility. Digital literacy training covered mobile money basics but not IoT agricultural applications because trainers lacked agricultural technology knowledge, while agricultural extension workers promoting sensor adoption possessed minimal digital literacy themselves and couldn't effectively teach farmers to interpret sensor data displayed through smartphone interfaces.

Institutional fragmentation at government levels created downstream coordination challenges as different sector ministries pursued separate smart village initiatives based on sectoral priorities and existing program structures rather than integrated rural development strategies. Agriculture ministry programs focused exclusively on production technology including IoT sensors, fertilizer recommendations, and market price information systems without considering digital literacy prerequisites or financial access constraints that determined whether farmers could actually utilize promoted technologies.

ICT ministry initiatives emphasized connectivity infrastructure and digital skills training but disconnected from actual livelihood applications that might motivate learning and sustained technology usage beyond novelty experimentation. Financial sector regulators promoted fintech expansion but with limited attention to rural-specific challenges or coordination with other rural development programs that could create enabling conditions for meaningful financial service uptake. These vertical sector silos prevented holistic approaches addressing interconnected challenges requiring cross-sectoral coordination beyond any single ministry's mandate.

The sustainability challenges facing smart village initiatives in both research sites raised serious questions about long-term viability of externally-initiated technology deployments lacking adequate attention to local capacity building, maintenance systems, and economic models ensuring continued operation after initial project funding concluded. The IoT sensor pilot in Astanajapura village faced uncertain futures as the five-year project neared conclusion, with no clear plans for ongoing technical support, sensor replacement when devices inevitably failed, or continued subsidies enabling farmers to afford maintenance costs and service fees beyond the pilot's free access period.

Several farmers expressed concerns that while the pilot generated useful learning, they might abandon sensor usage if post-project costs proved prohibitive or technical problems went unresolved without project staff providing troubleshooting. The village-scale solar power plant (PLTS) long-term viability depended on the village cooperative and BUMDes (Village-Owned Enterprises)'s capacity to manage increasingly complex technical and financial operations as the international donor phased out after three years, yet cooperative staff recognized their limited expertise and expressed anxiety about equipment failures they couldn't diagnose or repair without external technician assistance requiring expensive travel costs.

Karangsuwung village, minimal smart village development, paradoxically, meant fewer sustainability concerns, but also no pathway toward actual ecosystem emergence without external catalysts that existing village capacity couldn't generate independently. The village government with the Village Head and Village Apparatus's stated smart village aspirations remained abstract because officials couldn't identify actionable entry points, translate general concepts into specific implementation steps, access technical expertise needed for system design and procurement, or mobilize financial resources beyond minimal regular budgets allocated for maintaining existing basic infrastructure.

The demonstration IoT sensors installed through the government pilot program faced maintenance challenges when minor technical issues emerged after installation team

departed, with neither the host farmers nor agricultural extension workers possessing knowledge to diagnose problems or confidence to attempt repairs fearing they might damage expensive equipment. The installations gradually fell into disuse as mounting issues without resolution made sensor outputs unreliable, and farmers returned to conventional farming practices despite recognizing theoretical sensor benefits they'd witnessed when systems functioned properly.

The research revealed how critical local technical capacity development remained for smart village sustainability, yet found systematic underinvestment in capacity building relative to technology hardware deployment across observed initiatives. The predominant implementation approach involved external technical teams, installing systems and providing brief user training, focusing on operational procedures, rather than deeper technical understanding, enabling troubleshooting and adaptive management. Astanajapura village's village-scale solar power plant (PLTS) installation included only two days of training for cooperative staff on basic system monitoring and meter reading but no explanation of underlying technical principles, electrical system design, or systematic problem diagnosis that would enable staff to independently address emerging issues.

When system faults occurred, staff could only describe symptoms to external technicians arriving days later, meanwhile suffering extended outages that eroded user satisfaction and cooperative credibility. Several staff members explicitly requested more technical training to build genuine system expertise but found providers unwilling to invest time in comprehensive capacity building beyond minimal operational instruction, perhaps because deeper knowledge transfer threatened provider indispensability and ongoing maintenance service revenue.

The role of community ownership and governance in ecosystem sustainability emerged as critical yet underdeveloped dimension across smart village implementations. Astanajapura village's village-scale solar power plant (PLTS) demonstrated that collective ownership through the cooperative created stronger sustainability foundations than individually-owned technologies like IoT sensors, as the cooperative possessed organizational continuity, collective resources for maintenance, and accountability to members generating pressure for sustained service delivery. However, cooperative governance of the microgrid remained relatively passive, with members paying fees but having minimal active engagement in system management decisions, oversight of financial sustainability, or strategic planning for system expansion or upgrading.

The cooperative leadership expressed desires for more active member participation but struggled to engage busy residents who viewed the microgrid as utility service they consumed rather than collectively-owned asset they should actively govern. The tension between service delivery efficiency requiring professional management and democratic governance requiring broad member engagement remained unresolved, with cooperative leadership gravitating toward technocratic decision-making while occasionally feeling vulnerable to member criticism about decisions made without adequate consultation.

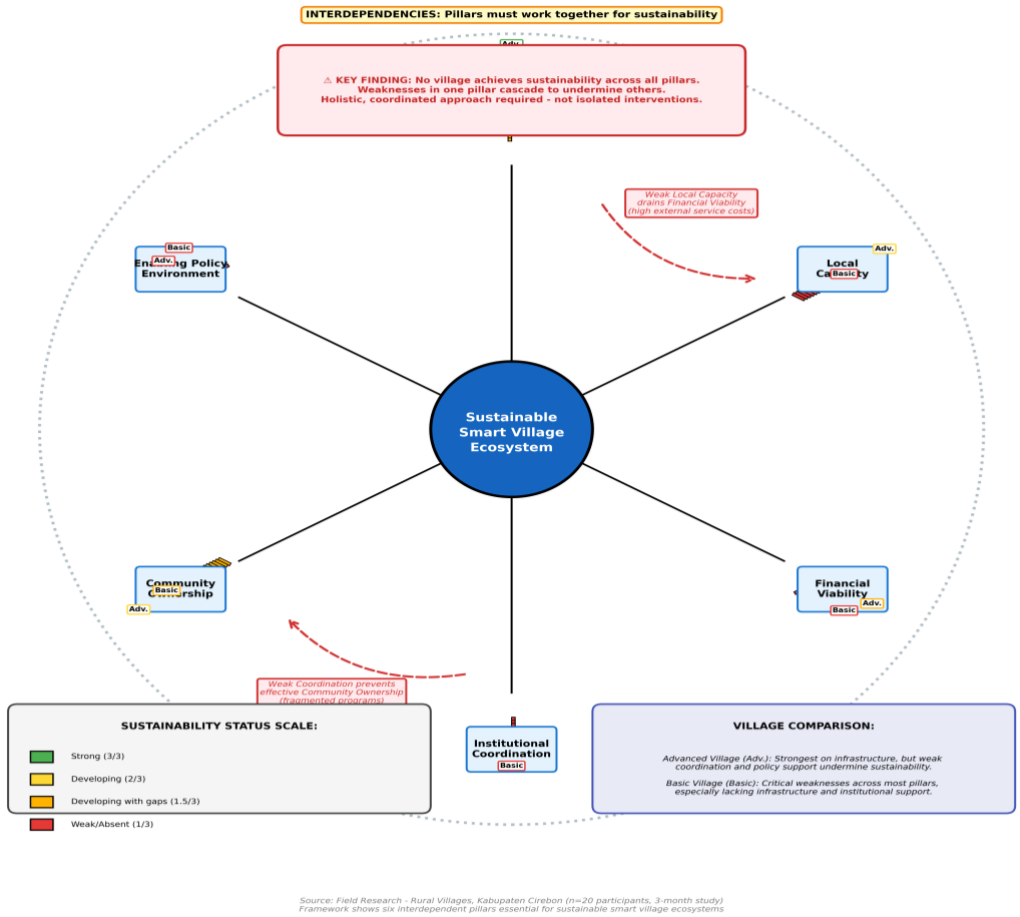

Figure 6. Smart Village Ecosystem Sustainability Framework (Source: Field research data, 2024)

Discussion

The findings of this research align with and extend existing scholarship on smart villages, rural digitalization, and inclusive development while revealing important contextual specificities and challenging some prevailing assumptions in the literature. The documented technology adoption patterns showing selective uptake concentrated among already-advantaged populations resonate with digital divide research demonstrating that technology access alone proves insufficient for equitable participation when underlying capability, resource, and social capital inequalities remain unaddressed (Degada et al., 2021; Lidén, 2016; Q. Wang et al., 2022).

The finding that agricultural IoT sensors for rice field and pond monitoring attracted primarily progressive farmers with land ownership of more than 2 hectares and higher education rather than benefiting smallholders who might gain most from precision agriculture's efficiency improvements mirrors observations from precision agriculture studies in multiple contexts where cutting-edge technologies tend to concentrate among agricultural elites, widening rather than narrowing productivity gaps between large and small farmers.

This pattern contradicts technology optimist narratives suggesting that smart agricultural technologies democratize access to productivity-enhancing tools, instead revealing how implementation approaches failing to address affordability, capability, and support barriers enable elite capture of publicly-funded innovations intended to benefit broad rural populations of Cirebon Regency. The research findings on digital literacy emphasizing the multidimensional nature of digital competencies and persistent gaps even among active technology users contribute to growing scholarly recognition that digital skills

encompass far more than operational device usage, extending to critical evaluation, online safety, content creation, and problem-solving capabilities distributed very unevenly across populations (Mmari et al., 2024; Pant & Agarwal, 2023).

The documented generational digital literacy divide where older residents faced systematic exclusion from digital technologies designed for younger users validates age-stratified digital inequality research while providing granular insight into specific mechanisms generating elderly exclusion. The finding that formal digital literacy training through the Kominfo Digital Literacy Movement program achieved limited effectiveness due to insufficient duration, lack of follow-up support, and inadequate differentiation for diverse learner needs echoes critiques of one-size-fits-all technology training approaches that fail to recognize heterogeneous baseline capabilities, learning styles, and practical constraints facing different population segments.

The research extends existing literature by documenting the crucial role of informal peer learning and family-based knowledge transfer in digital literacy development, suggesting that effective capacity building strategies should leverage and strengthen these organic learning networks rather than relying exclusively on formal training delivery by external experts. The fintech findings revealing how mobile money created meaningful financial inclusion for some users while leaving others excluded despite registration and how digital credit platforms systematically privileged already-creditworthy borrowers while excluding the poor who most need affordable credit access contribute to emerging critical fintech scholarship questioning celebratory narratives about digital financial inclusion.

The research validates concerns that alternative data credit scoring, while eliminating traditional documentation barriers, creates new exclusion mechanisms favoring digitally active populations who generate transaction histories demonstrating regular income flows, while marginalizing day laborers, smallholders with less than 0.5 hectares of land, and others whose livelihood patterns generate sparse digital footprints inadequate for algorithmic underwriting. The findings support arguments that fintech's promises of serving previously unbanked populations often fail to materialize at scale, as profit-seeking platforms target lower-risk borrowers accessible through conventional means while avoiding genuinely marginalized populations whose credit risk cannot be adequately assessed and mitigated through available data.

However, the research findings challenge some prevailing assumptions in smart village literature while revealing important context-dependent variations. The relative success of Astanajapura village solar power plants (PLTS) on a village scale achieving broad adoption across socioeconomic strata contrasts with literature emphasizing persistent energy access inequalities, suggesting that collective ownership and management through cooperatives can overcome individual affordability barriers and achieve more equitable outcomes than household-level technology adoption models. The finding that Karangsuwung village minimal technology adoption reflected not only infrastructure deficits but also institutional capacity gaps, political economy dynamics favoring elite interests, and absence of coordinating mechanisms challenges technology-deterministic narratives suggesting that infrastructure deployment automatically catalyzes ecosystem development.

The research reveals that appropriate institutions, governance arrangements, and implementation strategies prove equally if not more important than technology availability in determining whether smart village initiatives generate inclusive outcomes or reproduce existing inequalities. The documented coordination failures and sustainability challenges extend literature recognizing fragmentation as persistent problem in rural development programming while providing specific evidence about how sectoral silos, institutional fragmentation, and project-based implementation undermine smart village ecosystem integration.

The finding that different ecosystem components operated in parallel without interoperability, data sharing, or complementary capacity building reveals the gap between

theoretical smart village frameworks emphasizing systemic integration and ground-level realities where pragmatic implementation follows existing institutional structures and funding streams that reinforce rather than overcome fragmentation. The research findings on sustainability challenges validate concerns that externally-initiated technology deployments lacking adequate attention to local capacity building, maintenance systems, and financial models ensuring continued operation face high failure rates once external support phases conclude.

The research contributes empirical grounding for arguments that sustainable smart village development requires fundamental shifts from project-based technology delivery toward long-term investments in local human capacity, institutional strengthening, and governance systems enabling communities to manage technology evolution independently. When compared with previous studies, the present findings both corroborate and refine earlier evidence. The fintech results are consistent with (Menza et al., 2024), who reported that mobile platforms facilitate financial inclusion in rural areas; however, this study shows that registration does not equate to meaningful use, as dormancy, low financial literacy, and trust concerns limited active participation.

In line with (Ediagbonya & Tioluwani, 2023), fintech widened access in principle, yet algorithmic underwriting reproduced the exclusion of poor households. In contrast to (Malik et al., 2022), whose smart village model emphasises infrastructure and technical feasibility, this study demonstrates that the value of IoT depended on capability building, interoperability, and maintenance arrangements. The elderly exclusion documented here is consistent with Castilla et al., (2018), who showed that simplified, linear navigation can help older rural users acquire digital skills, suggesting that accessible design is a practical response to the barriers identified. Furthermore, the intersecting disadvantages of gender, age, and socioeconomic status confirm the relevance of the intersectional approach to smart technologies proposed by (Sharma et al., 2023) and extend it from urban to rural settings, while the coordination failures observed support the socio-technical view that technologies succeed only when aligned with institutional arrangements (Baxter & Sommerville, 2011; Yu et al., 2023).

Policy Recommendations

The findings offer several actionable insights for stakeholders aiming to design and sustain inclusive smart village ecosystems. For local government leaders, the research underscores the need for coordinated efforts to integrate technology initiatives, ensuring that digital capacity building is part of a broader, integrated strategy rather than isolated projects. Village leaders should advocate for holistic planning, addressing technology, institutional arrangements, and sustainability from the outset.

Technology providers and implementing organizations are urged to prioritize user-centered design, focusing on rural needs and ensuring accessibility for diverse users, especially the elderly and low-literacy populations. Moreover, local capacity building is essential, with a focus on training local technicians and ensuring the long-term sustainability of smart village systems. For development agencies, investments in infrastructure are crucial, but they must be paired with comprehensive, sustained digital literacy programs that create ongoing learning ecosystems. Lastly, inclusive mandates should be incorporated into policies, ensuring that marginalized groups are not left behind, and that interventions are tailored to specific barriers faced by different population segments.

At the national and regional levels, the government is recommended to establish a cross-ministerial coordination mechanism for smart villages that links the ministries responsible for villages, agriculture, and communication and digital affairs with the financial services authority (OJK); to adopt interoperability and open-data standards so that IoT-generated agricultural data can support credit assessment; to strengthen consumer protection in digital lending through transparent disclosure of interest rates and fees and the regulation of debt collection practices; to allow village funds to finance sustained digital

literacy and local technician training rather than hardware alone; and to require inclusion indicators disaggregated by gender, age, and income in the monitoring and evaluation of smart village programmes.

Limitations and Future Research Directions

Despite providing valuable insights, the research has several limitations that restrict its generalizability and scope. The small sample size and purposive sampling strategy limit the ability to draw broader conclusions about smart village ecosystems, particularly regarding populations that are excluded from participation. The research was constrained by its three-month timeframe, which hindered the ability to assess long-term sustainability and development impacts.

Additionally, the reliance on self-reported data from interviews introduces potential biases and limits objective verification of technology usage patterns. Future studies should consider larger, more diverse samples and employ longitudinal designs to track the evolution of smart village ecosystems. Furthermore, the study's focus on village-level dynamics neglected broader macro-level forces, such as policy and investment decisions, which influence smart village development.

Cross-national and multi-scalar comparative studies are needed to better understand how different contexts shape the success of these initiatives. Future research should also employ mixed-methods approaches that combine qualitative depth with quantitative measurement of adoption patterns and development impacts, and should pursue deeper political economy analysis of the power relations, governance arrangements, and economic interests that determine whose vision of smart villages ultimately prevails and whose interests technology integration serves.

CONCLUSION

This study concludes that smart village ecosystems integrating IoT, fintech, and digital literacy can advance rural development, but their benefits are distributed unevenly. In the advanced village, benefits concentrated among educated, resource-rich, and digitally literate residents, while women, elderly residents, and poor households faced intersecting barriers of affordability, capability, and social-cultural norms. In the minimally developed village, infrastructure deficits and weak institutional capacity prevented an ecosystem from emerging. Fragmented implementation, limited digital literacy, selective fintech inclusion, and fragile sustainability arrangements constrained outcomes in both settings.

These findings imply that infrastructure provision alone cannot ensure inclusion; policymakers and implementers should integrate connectivity, sustained capability building, accessible design, cross-sectoral coordination, community ownership, and explicit inclusion mandates with accountability for equitable outcomes. Inclusive smart villages therefore depend as much on institutions and governance as on technology.

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CONFLICT OF INTEREST

The author declares that this research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The author has no affiliation with, and received no benefit from, the technology providers, fintech platforms, or government programmes examined in this study.

AUTHOR CONTRIBUTION

Ani Indah Sari: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Project administration, Writing – original draft, and Writing – review & editing. The author has read and approved the final version of the manuscript and is accountable for all aspects of the work.

GENERATIVE ARTIFICIAL INTELLIGENCE USAGE STATEMENT

During the preparation of this manuscript, the author used AI solely to improve language clarity and grammatical structure. The tool was not used to design the study, generate or analyse data, interpret findings, or produce citations and references. All AI-assisted text was reviewed and edited by the author, in line with applicable ethical guidelines on the use and disclosure of generative AI in scientific research. The author takes full responsibility for the content, accuracy, and integrity of the published article.

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