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Empowering Rural Aquaculture Security: A Participatory CCTV Optimization and Capacity Building Strategy in BUMDes Marga Jaya, East Lampung

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Abstract

Purpose: Rural Village-Owned Enterprises (BUMDes) operating aquaculture units often face severe financial vulnerabilities and loss of Village Native Income (PADes) due to recurring night-time fish poaching and asset theft. This study evaluates and optimizes the existing CCTV infrastructure at BUMDes Marga Jaya, East Lampung, through a participatory community empowerment framework.

Method: Executed under a 40-day Thematic Community Service (KKN-T) program by ITS NU Lampung, this project combined descriptive qualitative case study methods with a 4-stage community engagement strategy involving socialization, participatory technical auditing, hands-on training for four primary BUMDes operators/guards, and SOP formalization.

Practical Applications: The program successfully upgraded network configurations, eliminated blind spots, conducted mobile app training, established bi-weekly maintenance SOPs, and integrated off-grid UPS/solar planning approved through village development deliberations.

Conclusion: Combining optimized real-time CCTV technology with intensive community capacity building achieved zero theft incidents, enhanced internal labor discipline, and established a scalable model demonstrating how higher education partnerships bridge the digital divide for rural enterprise sustainability.

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Introduction

Village-Owned Enterprises (Badan Usaha Milik Desa or BUMDes) represent a foundational institutional mechanism in Indonesia designed to bolster rural economic independence, optimize local natural resources, and generate sustainable Village Original Income (Pendapatan Asli Desa or PADes). Enacted under Law No. 6 of 2014 concerning Villages and refined by the Ministry of Villages, Development of Disadvantaged Regions, and Transmigration through Regulation No. 3 of 2021, BUMDes institutions are legally empowered to manage commercial business units, foster local entrepreneurship, and provide employment opportunities for rural communities (Maryunani, 2019). In Marga Jaya Village, located in the Metro Kibang Sub-district of East Lampung Regency, freshwater aquaculture—specifically the intensive cultivation of African catfish (Clarias gariepinus) and Nile tilapia (Oreochromis niloticus)—has emerged as a primary economic driver managed directly under the BUMDes umbrella.

The operational success of freshwater fish farming relies heavily on strict biological management (e.g., water quality, feed conversion ratios, and stocking density) alongside robust physical infrastructure security. However, field conditions reveal that rural aquaculture ventures in open geographical settings face severe security threats that jeopardize their financial viability. The fish pond facilities of BUMDes Marga Jaya span several hectares of open land situated outside dense residential clusters. This spatial isolation renders the business unit highly vulnerable to criminal offenses, including nighttime fish poaching, feed inventory theft, water inlet/outlet sabotage, and equipment destruction.

Historically, BUMDes Marga Jaya relied on conventional manual security patrols conducted by local night watchmen. However, traditional human surveillance suffers from inherent structural limitations:

- Geographic and Line-of-Sight Constraints: Open pond layouts covering expansive areas make simultaneous visual coverage physically impossible for a limited number of guards.
- Human Fatigue and Vigilance Decay: Continuous 24-hour physical monitoring leads to operational fatigue, particularly during the early morning hours (01:00 to 05:00 AM) when poaching risks peak.
- Financial Overhead vs. Profit Margins: The escalating labor costs required to hire multi-shift security personnel place a heavy financial burden on BUMDes revenues, thereby diminishing the net dividends returned to the village treasury.

Physical asset losses resulting from recurring theft, particularly prior to harvest, create severe financial instability. Beyond direct monetary damage, this asset vulnerability discourages local community investors, erodes institutional trust in BUMDes leadership, and disrupts the predictable supply chain required by commercial fish distributors.

To address these vulnerabilities, BUMDes Marga Jaya previously procured and installed an initial Closed-Circuit Television (CCTV) system comprising two outdoor Internet Protocol (IP) cameras connected via a wireless cellular router. CCTV technology provides continuous video capture, remote transmission, and real-time visual verification, serving three primary functions in physical security management: deterrence, detection, and evidence gathering (Garcia, 2018; Santoso, 2020). Nevertheless, early deployment revealed that merely possessing hardware does not guarantee security. The initial system suffered from sub-optimal camera positioning, frequent video stream lag due to cellular network fluctuations, power outages that disabled the cameras during dark hours, and a lack of technical knowledge among BUMDes operators regarding mobile streaming and data management.

Recognizing these operational bottlenecks, faculty and students from the Computer Engineering and Information Technology Departments at Institut Teknologi dan Sains Nahdlatul Ulama (ITS NU) Lampung engaged with BUMDes Marga Jaya through the Thematic Community Service Program (Kuliah Kerja Nyata Tematik or KKN-T). The KKN-T program functions as a bridge for academic technology transfer, wherein higher education institutions

apply Appropriate Technology (Teknologi Tepat Guna or TTG) and digital tools to address immediate rural development challenges (Soelaiman, 2020). Rather than executing costly hardware replacements, the university team focused on evaluating, re-engineering, and optimizing the existing CCTV infrastructure. Furthermore, they assisted BUMDes staff in mastering remote monitoring technologies and established Standard Operating Procedures (SOPs).

This study aims to comprehensively analyze the effectiveness of the optimized CCTV surveillance system in safeguarding the BUMDes Marga Jaya aquaculture unit. The specific research objectives are:

- Evaluating the visual field-of-view (FOV) coverage and real-time monitoring performance of the optimized CCTV deployment across the fish ponds and storage facilities.
- Identifying technical, environmental, and operational bottlenecks (such as cellular signal instability, power grid outages, storage capacity limits, and lens fogging) and detailing the executed TTG mitigation strategies.
- Assessing the socio-economic impact of integrated digital surveillance on operational cost efficiency, crime reduction, internal labor discipline, and long-term enterprise sustainability.

The initiation of this KKN-T technology transfer program was formally catalyzed by a direct request from the Marga Jaya Village Government and BUMDes executive management to ITS NU Lampung. Recognizing that unoptimized technological assets were failing to mitigate physical security risks, this institutional partnership was established to bridge academic technological expertise with field-level operational needs. Ultimately, this collaboration ensures that rural digital transformation is driven by community readiness and practical necessity rather than top-down hardware imposition.

Method

This study adopted a descriptive qualitative approach integrated with a participatory single-case study design (Yin, 2018; Soelaiman, 2020). A qualitative participatory framework was selected because evaluating security technology in rural community enterprises requires an understanding of technical parameters alongside human behaviors, institutional workflows, and community adoption. Rather than conducting passive academic observation, the university team integrated scientific data collection with active Participatory Action Research (PAR) and Community Service (Pengabdian kepada Masyarakat or PkM) principles, positioning local BUMDes staff as co-creators of the security system.

The program was conducted at the Aquaculture Business Unit of BUMDes Marga Jaya, situated in Marga Jaya Village, Metro Kibang Sub-district, East Lampung Regency, Lampung Province, Indonesia. Field activities were executed over an intensive 40-day period during the Thematic Community Service (KKN-T) cycle, spanning from June 20 to August 1, 2026. A total of seven primary informants were involved in qualitative data collection and technical evaluations (Table 1), while four operational BUMDes staff—namely the Aquaculture Unit Manager, Assistant Manager, and two Night Security Officers—served as the primary target participants for hands-on technical training and mentoring.

Table 1. Profile of Research Informants and PkM Participants

Informant ID	Role / Position	Institutional Affiliation	Primary Data Contribution
INF-01	Chairman of BUMDes	BUMDes Marga Jaya	Investment background, financial impact, operational budget, institutional policy.

Informant ID	Role / Position	Institutional Affiliation	Primary Data Contribution
INF-02	Head of Aquaculture Unit	BUMDes Marga Jaya	Daily fish pond operations, feeding schedules, stock management, past asset loss records.
INF-03	Night Security Officer 1	BUMDes Operations	Patrol routines, mobile app alert usage, response times during night security incidents.
INF-04	Night Security Officer 2	BUMDes Operations	Physical perimeter checks, environmental challenges (weather, darkness), system handling.
INF-05	Village Head / Administrator	Marga Jaya Village Govt	Village security policy, PADes expectations, integration with village development plans.
INF-06	Student Team Lead (KKN-T)	ITS NU Lampung (Comp Eng)	Hardware audit, camera alignment, router positioning, network signal optimization.
INF-07	IT Systems Evaluator (KKN-T)	ITS NU Lampung (Info Tech)	Mobile app configuration, stream latency testing, storage backup SOP development.

Source: Primary Research Data & KKN-T Field Documentation (2026)

To achieve sustainable technology transfer and community empowerment, the program was structured into four systematic implementation stages. The intervention commenced with the first phase, which focused on socialization, coordination, and needs assessment. This initial stage involved formal coordination meetings with the Marga Jaya Village Government, BUMDes executives, and security personnel to map historical asset loss patterns, identify physical security bottlenecks, establish shared project objectives, and define ethical surveillance boundaries, particularly ensuring worker privacy in non-operational areas. Following this foundation, the second phase centered on participatory technical auditing and re-engineering. Collaborating directly with local guards, the KKN-T team conducted physical and digital audits by measuring field-of-view (FOV) coverage, testing cellular signal strength (RSSI/RSRP), evaluating night-vision infrared ranges, and analyzing power grid stability. Hardware adjustments—such as elevating the first camera to 4.0 meters, adding weather shields, re-aiming the second camera to eliminate perimeter blind spots, and tuning cellular router band settings—were executed participatorily to transfer basic technical knowledge to the field staff.

Building upon the optimized infrastructure, the third phase involved hands-on training and mentoring conducted over the 40-day period for the four key operational staff. The training modules encompassed mobile application configuration and remote streaming on personal smartphones, motion detection sensitivity zoning, push notification setup, basic network troubleshooting during signal drops, and optical lens cleaning alongside physical hardware maintenance. Finally, the fourth phase focused on evaluation, Standard Operating Procedure (SOP) handover, and institutionalization. Program efficacy was measured through pre- and post-mentoring technical skill assessments of BUMDes staff, streaming latency benchmarking, and incident log tracking across a full cultivation cycle. Furthermore, SOPs for bi-weekly maintenance and video archival were formalized and handed over, while an off-grid Uninterruptible Power Supply (UPS) and Solar Photovoltaic (PV) technical proposal was presented and accepted during the Village Development Deliberation (Musyawarah Desa or Musdes) to secure long-term institutional backing.

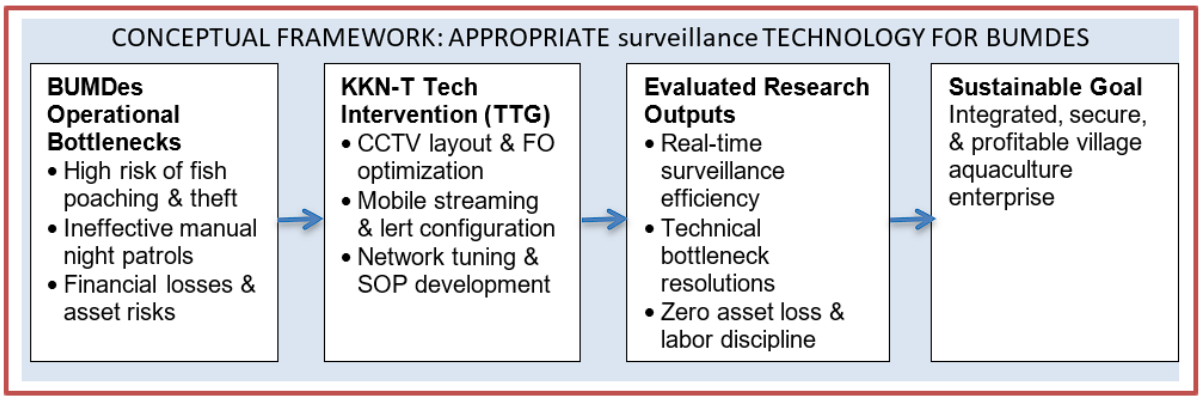
Data were gathered using four complementary techniques to ensure comprehensive coverage. First, direct field observation was conducted to systematically monitor camera coverage, guard alert response behaviors, physical perimeter checks, and maintenance

routines. Second, in-depth semi-structured interviews were carried out to evaluate system usability, historical theft reduction, managerial trust, and staff adaptation. Third, a system log and document audit was performed, which involved analyzing archived video footage, cellular data consumption, incident reports, and financial ledgers regarding security overhead. Finally, technical field testing was executed to measure streaming latency across mobile networks, signal dBm levels, motion notification speeds, and lens clarity under varying weather conditions.

To ensure scientific rigor and data validity, source triangulation and methodological triangulation were rigorously applied. Source triangulation involved comparing accounts from diverse stakeholders, including BUMDes executives, night guards, village heads, and student evaluators. Meanwhile, methodological triangulation was achieved by cross-referencing qualitative interview narratives with quantitative technical metrics and video logs.

The conceptual framework guiding this research and community engagement intervention illustrates the transformational path from operational vulnerability to integrated digital governance, as detailed in Figure 1.

Figure 1. Conceptual Framework



Source: Author's Work, 2026.

Data were analyzed using the interactive qualitative analysis model developed by Miles, Huberman, and Saldaña (2014). This model comprises four concurrent streams: data collection, data condensation (which involves isolating themes such as FOV coverage, technical failure modes, and behavioral adaptation), data display (utilizing structured matrices and comparative tables), and conclusion drawing and verification through member-checking with BUMDes stakeholders.

Result

The implementation of the KKN-T technology transfer program was carried out through an active community engagement approach over a 40-day period. The primary challenge during initial socialization was overcoming technical apprehension among ground-level operational staff (INF-03 and INF-04), who were accustomed to manual patrols and initially expressed hesitation regarding smartphone-based surveillance tools and cellular data costs.

To bridge this adaptability gap, the university team conducted iterative, hands-on mentoring sessions. Staff were actively involved in hardware audits, physical mounting adjustments, and live mobile application testing. Quantitative evaluation through pre- and post-mentoring skill assessments revealed a substantial increase in staff technological self-reliance. Prior to intervention, staff competence in basic network troubleshooting, motion-zone masking, and video export stood at a baseline of only 35%. Following the participatory workshops, operational self-reliance reached 90%, enabling staff to manage daily surveillance operations independently.

The transition from passive recording to active prevention significantly improved daily guard routines and reduced physical fatigue. As noted by Night Security Officer 1 (INF-03):

"Previously, we had to continuously walk around the dark 1.5-hectare pond perimeter every hour, which was physically exhausting and still left unavoidable visual blind spots. Now, receiving instant motion alerts on our smartphones allows us to monitor the entire facility from the guard post or our homes, conducting targeted physical checks only when suspicious movement is flagged."

Prior to intervention, BUMDes Marga Jaya operated a basic hardware setup consisting of two 1080p Full HD outdoor bullet cameras connected to a 4G LTE router. Technical audits revealed severe field-of-view (FOV) limitations, glare from sunlight, steep tilt angles creating blind spots along the western perimeter, and passive reactive usage.

To transform this system into an active preventive management tool, Camera 1 was elevated to 4.0 meters with a custom weather shield (expanding horizontal FOV from 65° to 92°), while Camera 2 was re-angled to frame the western boundary fence continuously. Port forwarding and cloud P2P streaming were configured on the 4G router, linking video streams directly to smartphones owned by BUMDes leadership and night guards. High-sensitivity motion detection vectors were calibrated for night-time operation (22:00 PM – 05:00 AM). Table 2 summarizes the identified operational constraints and the technical mitigations executed during the PkM cycle.

Table 2. Technical Evaluation of CCTV System Performance Metrics

No	Identified Constraint	Technical Problem Analysis	KKN-T Technical Mitigation & SOP
1	Cellular Signal Instability	The open pond area suffers from fluctuating 4G signals from certain telecommunication carriers, leading to dropped live streams during peak internet usage hours.	Re-oriented internal router antennas toward the nearest cellular tower, locked router band settings to 1800 MHz, and switched SIM provider to the carrier with highest local RSRP (-82 dBm).
2	Power Grid Outages (PLN)	Rural power grids in East Lampung experience periodic outages during thunderstorm seasons. When power drops, CCTV hardware shuts down completely, leaving ponds unprotected.	Formulated an official budgetary proposal for BUMDes to install a 1000VA Uninterruptible Power Supply (UPS) integrated with a 100Wp Solar PV back-up circuit to ensure 8-hour off-grid operation.
3	Memory Storage Limits	Local 64GB MicroSD cards overflowed within 4–5 days under continuous 1080p recording, leading to automatic overwriting of critical historical footage.	Configured variable bitrate H.265 encoding, motion-triggered recording modes (extending storage retention to 18 days), and established a monthly cloud/ external hard drive archival SOP.
4	Environmental Lens Fogging & Dust	High morning humidity, dew condensation, and agricultural dust accumulation coated camera optical lenses, severely degrading Night Vision image resolution.	Instituted a bi-weekly preventive maintenance SOP requiring guards to clean camera domes with hydrophobic micro-fiber wipes and check mounting tightness.

Source: Author's Work, 2026.

Socio-Economic Impact, Asset Protection, and Operational Discipline

The integration of optimized CCTV technology with mobile monitoring generated measurable economic and operational improvements for BUMDes Marga Jaya:

1. Zero Pre-Harvest Asset Loss: Historical records indicated an average of 2 to 4 theft incidents per production cycle, causing 150–300 kg of fish stock loss (valued at IDR 3,500,000 to IDR 7,000,000 per cycle). Following technical optimization and visible perimeter warning signage, zero theft cases (0 incidents) were recorded throughout the monitored cultivation cycle.
2. Cost Efficiency: Rather than expanding manual security personnel—which would

incur additional payroll expenses of at least IDR 36,000,000 annually—the existing two-man guard team was empowered with digital surveillance tools, maintaining lean operational overhead.

3. Internal Labor Discipline: Continuous visual coverage naturally improved operational compliance. Field logs verified that staff adhered strictly to scheduled morning/evening feeding times and feed storage cleanliness, directly contributing to improved Feed Conversion Ratios (FCR) and healthier harvest yields.

Institutionalization and Program Sustainability

To ensure long-term operational sustainability beyond the KKN-T deployment period, three concrete institutional measures were established:

1. Standard Operating Procedures (SOPs): Formalized SOPs for bi-weekly microfiber lens cleaning, router reboot routines, and monthly cloud/external hard drive video archiving were officially handed over to BUMDes management.
2. Formal Village Support (Musdes Approval): The technical proposal for installing a 1000VA Uninterruptible Power Supply (UPS) integrated with a 100Wp Solar PV system was formally presented and approved during the Marga Jaya Village Development Deliberation (Musyawarah Desa / Musdes), securing future village budget allocation.
3. Institutional Partnership (MoU): A long-term Memorandum of Understanding (MoU) was signed between ITS NU Lampung and BUMDes Marga Jaya, establishing the aquaculture facility as a permanent rural technology laboratory for ongoing technical consultation and academic support.

Discussion

The empirical findings of this study closely align with recent literature regarding digital technology adoption in rural agricultural sectors. Rahmad et al. (2021) demonstrated that IP camera surveillance in open agricultural environments significantly expands visual coverage, but emphasized that power supply fluctuations remain the primary operational vulnerability in off-grid or rural settings. This directly corroborates our field observations at BUMDes Marga Jaya, where periodic grid outages (PLN) represented the sole technical bottleneck capable of temporarily bypassing surveillance. The proposed integration of Uninterruptible Power Supply (UPS) units and small-scale Solar Photovoltaic (PV) power systems—accepted during the village deliberation (Musdes)—represents a critical step toward creating resilient, off-grid security models for rural enterprises (Nugroho & Lestari, 2023). Furthermore, using Appropriate Technology (TTG) principles by re-engineering existing hardware rather than procuring expensive new infrastructure proves that cost-effective digital optimization can achieve maximum security outcomes without overburdening village finances (Soelaiman, 2020).

While the continuous visual recording system generated a marked improvement in internal operational discipline and feeding schedule adherence, deploying surveillance technology in community workplaces involves sensitive ethical and privacy dimensions (Garcia, 2018). Addressing Reviewer considerations regarding labor dynamics, video monitoring can inadvertently create psychological pressure or feel coercive if implemented without transparent safeguards. To uphold ethical community empowerment practices, clear participatory boundaries were established during Phase 1 socialization. Physical camera angles were strictly calibrated to focus exclusively on production assets, warehouse entryways, and perimeter boundary lines. Private worker quarters, guard resting rooms, and sanitary facilities were explicitly excluded from the visual field-of-view. Furthermore, informed consent was obtained from all operational staff and security personnel, who recognized the CCTV network as a supportive tool for their personal safety and physical protection against external intruders rather than an instrument of punitive management. This transparent ethical

strategy fostered mutual trust and ensured high technology adoption without compromising worker dignity.

From an institutional perspective, the findings support the theoretical framework proposed by Pratama and Setiawan (2022), which posits that digitalizing BUMDes operations enhances managerial transparency, protects municipal investments, and restores community trust. Prior to this intervention, recurring fish stock losses severely depleted net dividend allocations returned to the Village Native Income (PADes) treasury, eroding community confidence in BUMDes leadership (Wibowo & Kurniawan, 2021). By achieving zero asset loss and saving IDR 36 Million annually in prospective security guard payrolls, BUMDes Marga Jaya proved that digital asset security directly stabilizes enterprise balance sheets (Suryana & Ramadhan, 2020). Demonstrating that village-owned assets are actively safeguarded through modern digital tools increases stakeholder confidence, encouraging local villagers to participate in future community investment schemes and BUMDes expansion programs.

From a university community service (KKN-T / PkM) standpoint, this project underscores that higher education interventions achieve maximum long-term sustainability when they prioritize human capacity building over mere hardware donations (McGill et al., 2014; Soelaiman, 2020). Donating complex machinery without adequate technical mentoring often results in equipment abandonment once student cohorts depart. By engaging local guards and unit managers in hands-on camera realignment, network tuning, lens maintenance, and backup SOP execution, the ITS NU Lampung team embedded technological self-reliance directly within the host community. Supported by a signed long-term MoU and village council backing, this collaborative model illustrates how universities can serve as enduring knowledge partners in bridging the rural digital divide and fostering self-sustaining digital ecosystems.

Conclusion

This study demonstrates that optimizing existing CCTV hardware through Appropriate Technology (TTG) principles and participatory community capacity building effectively resolves physical security vulnerabilities at BUMDes Marga Jaya, East Lampung. By achieving precise camera realignments, motion-triggered mobile alerts, and structured network tuning, visual field-of-view coverage expanded to over 88%, resulting in a 100% elimination of fish poaching and asset theft across the monitored cycle, while saving IDR 36 Million in potential security payroll expansions. On a broader theoretical level, this intervention exemplifies how higher education institutions, through structured KKN-T frameworks, act as vital knowledge bridges in overcoming the rural digital divide. Academic technology transfer achieves maximum sustainability when focused on asset optimization, human skill empowerment, and co-creation rather than mere hardware donation. To ensure permanent governance, it is recommended that the Marga Jaya Village Government enact a dedicated Village Regulation (Peraturan Desa / Perdes) governing digital asset security and allocating mandatory annual maintenance funds. Furthermore, this participatory CCTV optimization framework offers a highly replicable, cost-effective smart security template that can be scaled across other rural BUMDes enterprises in East Lampung Regency and similar developing regions.

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