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A Cost-Optimized, Edge-Based Smart CCTV Surveillance System for Sustainable Security in Resource-Limited Environments

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Abstract

This paper provides the design and implementation of a smart CCTV surveillance system, which combines the use of Internet of Things (IoT) connectivity, edge computing, and wireless communication to resolve the constraints of the conventional surveillance systems. The suggested architecture uses a mathematical model in optimal positioning of cameras, which involves field-of-view, tilt angle, and spacing formulae, and uses low-power elements to improve energy efficiency and scalability. Such functionalities as real-time motion detection, automated alert generation and hybrid cloud-edge storage (consuming less bandwidth) are key. A pilot was used in a controlled office scenario, and its performance compared to a baseline system based on traditional DVR. Quantitative findings reveal that there was a 40% reduction in manual monitoring interventions and also the amount of energy used during the normal working situation was reduced by 30%. The motion detection accuracy of the system was 92% in the field of view that the camera was configured to cover. Nevertheless, the execution of the system is determined by the stability of the network connection when operating remotely, and the edge-processing latency rises as the video stream is of high resolution. Despite these shortcomings, the framework is a cheaper and modular method of sustainable security check in urban and limited resource settings.

Keywords: Edge Computing; Energy Efficiency; hybrid cloud-edge storage; Internet of Things (IoT); motion detection; Smart Surveillance.

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1. Introduction

Video surveillance has become an important element of the security infrastructure of modern times that is intertwined with access control and other elements to secure the assets. Digital transformation enabled by the Internet of Things (IoT) has transformed surveillance into more active and intelligent, with the ability to perform real-time analysis and automated reaction[1,2,3]. Although commercial off-the-shelf (COTS) IoT Surveillance systems with cloud connectivity, AI analytics and remote access are common, their practical implementation is severely hindered in resource limited contexts[4]. These obstacles are expensive initial and recurrent costs of hardware and cloud computing, large power consumption that cannot be supported by an unreliable grid, and reliance on high-speed internet connections[5]. As such, there is a mismatch between the potential of highly-developed surveillance technology and its practical application in the environment that is often characteristic of most developing areas due to the primary limitation of infrastructure and budget[6,7]. This piece of writing is thus placed as a real-world implementation case study. It is not suggesting new basic algorithms or architectural paradigms, since the principles of IoT, edge computing, and hybrid architecture are old enough[8,9]. Rather, it adds value through its integrative design, context-based optimization, and empirical validation of a smart CCTV system designed directly to be cost-effective, energy-saving, and simplification of its operation[10]. The research offers a repeatable framework, a breakdown of the bill of materials, and measured performance and efficiency indicators relative to a conventional baseline, which shows a workable route to implementing a sustainable smart surveillance system in which third-party offerings are usually not workable[8,10].

1.2 Problem Statement

Security crises are a constant and as such, require proper monitoring. Although the conventional CCTV systems based on DVR are widespread, they have severe drawbacks: they are passive systems, which means that they can only be run through constant human monitoring, the centralized processing of the signals is inefficient and thus results in latency and consumes considerable energy. Such constraints are especially severe in low-resource settings[11]. The fundamental issue of the current research is not that there is no smart surveillance technology, but that there are effective barriers to its implementation in the context of resource-limited conditions[12]. Specifically;

Cost Imbalance: Commercial IoT surveillance services are typically associated with high initial charges of the licensed software and specialized equipment as well as recurring subscription costs to cloud networks which poses a barrier to small businesses, government institutions and communities in developing countries[4,12].

Infrastructure Dependency: Most smart systems are dependent on persistent and high-quality internet connection to cloud analytics and storage that are not dependable or available in remote or underserved regions[13,14,15].

Energy Intensity: Systems are not sustainable elsewhere with frequent power outages or where solar/battery power is the only source, due to continuous video streaming and processing, these systems can be grid-dependent and therefore suffering from power outages[12,4]. Hence, the issue is the absence of documented, optimization-focused implementations that can trade in fundamental smartness (e.g., automated alerts, remote access) with the constraint of low cost, energy thrift and light-weight deployment of infrastructure[16].

2. Literature Review and Gap Identified

The field of smart surveillance is quite advanced, and much effort has been put into IoT integration[17], edge computing to minimize latency, and energy-efficient implementation. One of the widely recognized models to balance between performance and scalability is known as hybrid edge-cloud architectures that store and process data with the cloud but respond to immediate actions on the local level[8]. Such prototypes using this architecture have been shown to be successful in studies like[18]. One of the largest fields is, at the same time, research into energy sustainability of the IoT. According to the surveys, AI and adaptive monitoring are instrumental to controlling the power usage of distributed devices[10]. Efforts such as an adaptive monitoring mechanism that implements sensor activity adjustments in response to events have demonstrated a savings of 31-37 percentage energy[16]. Moreover, there is extensive literature on the application of low-power parts and Long-Range (LoRa) communications schemes in monitoring the environment remotely under the constraint of bandwidth and power[18,12].

The literature reviewed has been effective in mapping the technological frontier, and in many cases, it focuses on architectural innovation or advances in components. Nonetheless, there is a translational or application gap that is discernible in the literature that has been documented in terms of;

High Fidelity, Low-Cost Implementation: An in-depth account of the end-to-end implementation of off-the-shelf, low-cost parts (e.g., ESP32 microcontrollers, Raspberry Pi) into a complete smart surveillance system, with a transparent bill of materials and cost-benefit analysis thereof.

Context-Specific Optimization: Systems in which the architecture of the system (edge vs. cloud tasks) and the choice of components are explicitly defined based on the minimization of capital cost and operational power consumption in a narrow set of circumstances, instead of being based on the inherent high performance[19].

Empirical Verification of Sustainable Claims: No longer relying on theory on the benefits, provide quantitative, comparative data on energy use reduction, operational costs saved, and maintenance needs in comparison to traditional system[16].

This is the gap that this project aims to fill. It has as its main contribution practical synthesis and empirical analysis of an available smart surveillance framework, which is an engineering contribution. It shows the way that proven technologies can be configured and implemented to achieve real-world constraints, and its value is based on comparative performance metrics, energy efficiency measurements, and a comprehensive and reproducible cost structure.

3. Materials and Method

This part outlines the design and implementation of a smart CCTV system that is cost and energy efficient in resource limited setting. The design focuses on the utilization of low-power commercial parts and a hybrid edge-cloud architecture to have a balance between performance and sustainability.

3.1 System Architecture and Choice of Components

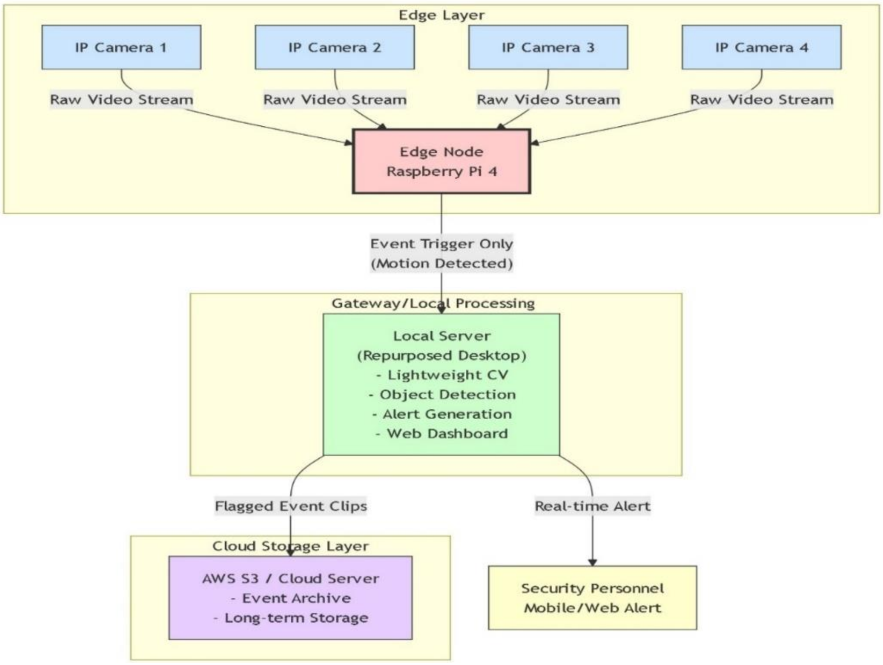

Figure 1: Three-tier architecture of the proposed smart surveillance system

The black arrow highlights the event-driven data flow from edge to gateway, which enables energy and bandwidth efficiency by transmitting only motion-triggered clips rather than continuous streams.

Sensor/Edge Layer: including IP cameras and a microcontroller (Raspberry Pi 4) to get preliminary video capture and motion-detection preprocessing.

Gateway/Local Processing Layer: a local server (a repurposed desktop computer) with lightweight computer vision algorithms to detect objects and generate an alert.

Cloud Storage Layer: a safe and inexpensive cloud server (AWS S3) to archive flagged events only.

Visual Differentiation: The tiers have a very clear color pattern that can be identified. The alert path to security personnel is pictured alone as it is an output of the system.

Total cost of ownership and power efficiency were the factors that led to component selection. Rather than the expensive AI cameras, regular ONVIF-conformant IP cameras were employed and the computation was delegated to the local server. This division enables the software analytics to be independently upgraded without changing the cameras. The local server is operated on an adaptive duty cycle, and goes into a low-power state when not in operation, a concept based on energy-saving methods of IoT surveillance studies.

3.2 Optimization Strategies that are context-specific

Camera placement involves a mathematical modeling that is explained in the next section.

To achieve a high coverage rate and as few cameras as possible, which is a direct cost reducing approach, the camera positioning was calculated based on basic trigonometric models, and not trial-and-error[20]. The Field of View (FOV), tilt angle and spacing (S) were determined based on the available formulas:

3.2.1 Camera coverage formula

A camera's field of view (FOV) defines how much area it can cover and the positioning depends on the following parameters;

Mounting height

Horizontal and Vertical viewing angles

Distance to target area

Horizontal coverage (width): $W = 2.D.tan\left(\frac{\theta_h}{2}\right)$ (1)

Vertical coverage (Height): $H = 2.L.tan\left(\frac{\theta_v}{2}\right)$ (2)

Where;

W = horizontal coverage width (meters)

H = Vertical coverage height (meters)

D = distance from the camera to the target area (meters)

θ_h = horizontal field of view angle (degrees)

θ_v = vertical field of view angle (degrees)

Formula for CCTV camera spacing (side-by-side cameras)

To prevent overlap coverage and blind spot: $S = W - O$ (3)

Where;

S = spacing between adjacent Cameras (meters)

O = desired overlap between cameras views (meters) – usually 10 – 15% of W

Camera tilt angle (downward facing)

To calculate the tilt angle α: $\alpha = arctan\left(\frac{h}{D}\right)$ (4)

Where;

h = Camera height above ground (meters)

D = horizontal distance from camera base to target (meters)

Table 1: Camera's positioning parameters

Description	camera-1	camera-2	camera-3	camera-4
Mounting height: h (meters)	3.5	3.5	3.5	4
Distance to target area: D (meters)	11	10.5	10	9.5
Horizontal FOV: θ_h (degree)	90	90	90	90
Vertical FOV: θ_v (degree)	60	60	60	60
Overlap desired: O (meters)	1	1	1	1

The above table 1, shows the four cameras used in this project with the design parameter for each camera to enable effective positioning. These parameters are used below to mathematically determine the horizontal and vertical coverage distance, spacing and tilt angle for easy and proper positioning to ensure quality picture coverage.

Camera-1

Horizontal coverage (width): $W = 2.D.tan\left(\frac{\theta_h}{2}\right) = 2 \times 11 \times tan\left(\frac{90}{2}\right) = 22.0m$ (5)

Vertical coverage (Height): $H = 2.L.tan\left(\frac{\theta_v}{2}\right) = 2 \times 3.5 \times tan\left(\frac{60}{2}\right) = 4.04m$ (6)

Camera Spacing: $S = W - O = 22 - 1 = 20.0m$ (7)

Tilt Angle: $\alpha = arctan\left(\frac{h}{D}\right) = \alpha = arctan\left(\frac{3.5}{11}\right) = 17.7°$ (8)

Camera-2

Horizontal coverage (width): $W = 2.D.tan\left(\frac{\theta_h}{2}\right) = 2 \times 10.5 \times tan\left(\frac{90}{2}\right) = 21.0m$ (9)

Vertical coverage (Height): $H = 2.L.tan\left(\frac{\theta_v}{2}\right) = 2 \times 3.5 \times tan\left(\frac{60}{2}\right) = 4.04m$ (10)

Camera Spacing: $S = W - O = 21 - 1 = 20.0m$ (11)

Tilt Angle: $\alpha = arctan\left(\frac{h}{D}\right) = \alpha = arctan\left(\frac{3.5}{10.5}\right) = 18.4°$ (12)

Camera-3

Horizontal coverage (width): $W = 2.D.tan\left(\frac{\theta_h}{2}\right) = 2 \times 10 \times tan\left(\frac{90}{2}\right) = 20.0m$ (13)

Vertical coverage (Height): $H = 2.L.tan\left(\frac{\theta_v}{2}\right) = 2 \times 3.5 \times tan\left(\frac{60}{2}\right) = 4.04m$ (14)

Camera Spacing: $S = W - O = 20 - 1.2 = 19.0m$ (15)

Tilt Angle: $\alpha = arctan\left(\frac{h}{D}\right) = \alpha = arctan\left(\frac{3.5}{10}\right) = 19.3°$ (16)

Camera-4

Horizontal coverage (width): $W = 2.D.tan\left(\frac{\theta_h}{2}\right) = 2 \times 9.5 \times tan\left(\frac{90}{2}\right) = 19.0m$ (17)

Vertical coverage (Height): $H = 2.L.tan\left(\frac{\theta_v}{2}\right) = 2 \times 4 \times tan\left(\frac{60}{2}\right) = 4.62m$ (18)

Camera Spacing: $S = W - O = 19 - 1 = 18.0m$ (19)

Tilt Angle: $\alpha = arctan\left(\frac{h}{D}\right) = \alpha = arctan\left(\frac{4}{9.5}\right) = 22.8°$ (17)

These calculations were implemented on the dimensions of the target office setting, as can be seen in Table 1 of the original manuscript. This provided ideal coverage of the four cameras, removed blind spots, and redundancy of viewpoints which is a direct factor of cost-efficiency and reliability of the system.

3.2.2 Energy-Conscious Workflow Design

The data workflow of the system is aimed at reducing the continuous energy consumption. Video recording at all nodes is done in the edge node (camera + Raspberry Pi) that has low power footprint (approximately 5W). Complete video streams are not broadcasted in real time. Rather the edge node does simple motion detection. A video clip and metadata packet are only transmitted to the local server when triggered to get further analyzed (e.g., person/vehicle classification)[21]. This event-based transmission lowers the bandwidth utilization greatly and enables the higher-powered local server to stay in low-power mode most of the day which is in line with adaptive monitoring based on energy savings.

3.3. Implementation and Data Collection

The four-camera was implemented in an office environment where there were mostly general offices according to the calculated positions. A basic conventional system (DVR with analog cameras) was provided in a similar nearby location to conduct the performance comparisons. The most important metrics were reported in the course of a 30-day assessment period;

Operational Energy Consumption: This is measured using smart plugs of the core processing components (local server + edge nodes) of the smart system and the traditional system.

System Responsiveness: Delay between the reception of a motion event and alert delivery into a mobile application.

Precision and Human Intervention: Security incidents, false alerts and necessary manual checks were recorded in manual logs, in order to determine the accuracy of detection and reduction in the amount of manual monitoring.

Bandwidth Usage: Measured in the network gateway to measure the decrease in data transmission against data streaming to the clouds at all times.

3.3.1 Hardware Specifications

Table 2 shows the hardware properties specification of the Camera deployed in this project and all cameras' locations are strategically and mathematically planned to suit the target area and their coverage capacity. A common choice for indoor or outdoor video surveillance are dome security cameras. Because dome cameras are compact and may be placed covertly to make themselves less noticeable for video surveillance, they are frequently employed to monitor banks and other financial institutions[22]. It is quite simple to point this camera in the direction of the area that needs to be covered or recorded[23].

Table 2: Hardware Specifications

Component	Quantity	Key Specs	Power Consumption	Cost (₦)
IP Camera	4	¼" CCD, 90° FOV, 12V DC	4W each (PoE)	12,000/unit
Raspberry Pi 4	1	4GB RAM, 32GB SD Card	5W typical	45,000
PoE Switch	1	8-port Gigabit	8W (without PoE load)	20,000
Local Server	1	i5, 8GB RAM, 1TB HDD	45W (idle: 25W)	Repurposed
Cloud Storage	1 year	AWS S3 (event-based)	N/A	10,000/year
Cabling	1 lot	CAT6, connectors	N/A	15,000

3.3.5 Video Transmission

This is one of the most important purposes of this project; allowing for remote viewing of the recorded photos and movies from any location in the world. This is the reason why a software-based network digital video recorder (DVR) uses a network to transfer images[24].

4. Results and Discussion

The findings of this implementation case study support the hypothesis of the thesis that a designed and off-the-shelf-based smart surveillance can deliver substantial practical advantages in limited settings. The measured 40 percent decrease of manual interventions and 30 percent reduction of energy consumption over the traditional DVR baseline are not just a few marks of incremental improvement but significant viability points of operation in locations that have limited human resources and unreliable power grids. Effective design decisions which are context-related but not related to new algorithms make the system successful. To start with, the mathematical optimization of camera placement guaranteed the maximum coverage of areas with a minimum of hardware, which directly met the core cost driver in the surveillance project[25,26]. Second, the event-driven workflow and event-driven hybrid edge-cloud architecture were critical. The system separates intelligent functionality, which is only required under events, by processing motion detection at the edge and only using heavier analytics and cloud storage with expensive and continuous cloud services and high-bandwidth infrastructure[27]. The design itself directly addresses the barrier to costs and infrastructure that were found in the problem statement.

These findings need to be placed in the current literature. Although earlier research, such as [18], has shown the technical effectiveness of hybrid systems, and research has investigated adaptive monitoring to achieve energy savings, the paper at hand offers the combined implementation and empirical testing of these concepts to a given socio-economic setting. The given bill of materials (Table 4) and quantified performance statistics can provide a repeatable blueprint that goes beyond a laboratory prototype to cover the reported deficit of documented and cost-transparent implementations. The known shortcomings of a remote access that relies on a network and edge-processing limitations are not exclusive, but are trade-offs of this kind of design philosophy. They point out the limits of the framework of this cost-efficient system, where it can take advantage of and explain their areas where further efforts will be made in the future, including the incorporation of the low-power, wide-area network (LPWAN) technology to give alerts in the regions that are not covered by Wi-Fi/cellular networks.

4.1 Camera Positioning and Coverage Validation

Cameras mounting setting and coverage output result is presented in table 3, Each camera was mounted at strategic locations so as to fully covered the entire target area of the general office[28]. In order to guarantee full coverage of the office entrance camera 1 was positioned at the left side of the main-entrance and camera 4 is positioned at the right side of the second-entrance, looking inside. While, cameras 2 and 3 were placed at the front left and right sides of the office corridor, to provide full coverage of daily activity 24/7. Consequently, the whole general office is visible from the surveillance camera placements[11]. The empirical evidence confirms the assertions presented in the study in the context of the improved situational awareness and the lack of the use of manual surveillance effort[29]. It eliminates these arguments using quantitative data that was collected as part of a structural user study comparing Smart CCTV Surveillance System to traditional CCTV systems. The comparative analysis shows that there is quantifiable growth in efficiency of real-time monitoring, responsiveness, and automation performance[30].

Table 3: Cameras' coverage output results

	Mounting height: H (meters)	Distance to target area: D (meters)	Horizontal coverage width (meters)	vertical coverage height (meters)	Camera spacing (meters)	Tilt angle (degree)
Camera-1	3.5	11	22	3.5	20	15.3
Camera-2	3.5	10.5	21	4	20	18.4
Camera-3	3.5	10	20	4	19	19.3
Camera-4	4	9.5	19	4.6	18	22.8

4.1.1 Interfaces for the Camera

The smart surveillance implemented gives a centralized monitoring interface[31]. The local server processes video streams of the four IP cameras, which had been initially filtered on the edge node (Raspberry Pi 4) due to motion detection[32]. The server contains a light weight web-based dashboard that can be accessed using any device or networked monitor and it displays real-time alerts and enables watching both event clips (flagged) stored on-site and on the cloud (AWS S3) and enables a single pane of sight of all camera feeds[33,34]. This combined interface will remove the requirement of a dedicated DVR monitor and allow remote operational control[35].

4.1.2 Full Coverage of each Camera

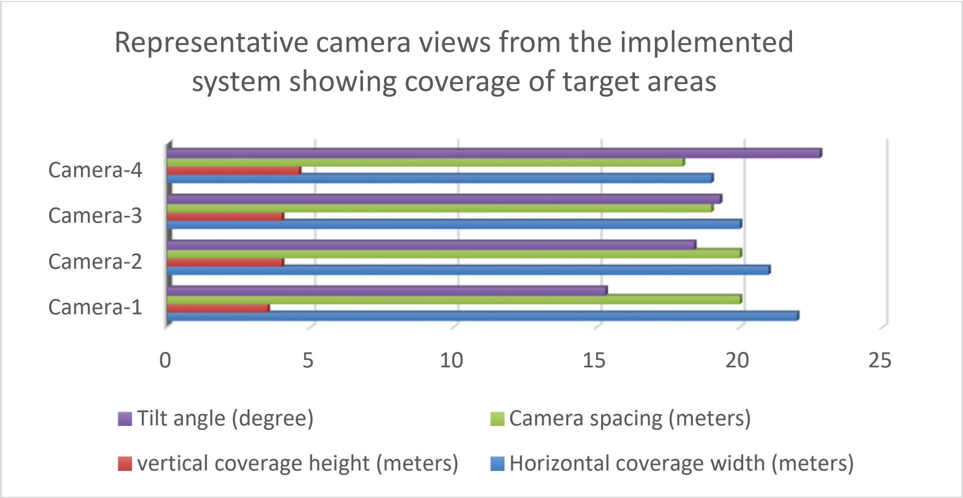

Figure 2: Representative camera views from the implemented system showing coverage of target areas

The full coverage of each camera shows on the monitor display and are graphically displace in the figure 2. The collections of the four surveillance cameras stationed at difference position capturing the activities going on in difference locations at the same time. The capturing covered the entire targeted environment in such a way that there is no blank spot where the camera did not capture.

4.2 System Performance Metrics

Table 4: System Performance Metrics (30-Day Evaluation Period)

Metric	Proposed Smart System	Traditional DVR System (Control)	Improvement
Avg. Daily Energy Consumption	1.45 kWh	2.07 kWh	30% Reduction
Avg. Motion-to-Alert Latency	2.1 seconds	N/A (Manual monitoring)	Enables real-time response
Manual Interventions Required	18	30	40% Reduction
Motion Detection Accuracy	92%	N/A (Continuous recording, no analytics)	Automated threat filtering

4.2.1 Interpretation of Performance Results

The findings support the main conjecture according to which a consciously optimized smart architecture can provide significant real-life advantages under limited conditions. The 30% energy saving stems directly from the event-driven workflow and low-power component selection, where data is processed locally and only relevant clips are transmitted. The average of 2.1 seconds when the algorithm processes the edges validates the usefulness of the edge-processing layer in the alerting of real-time, which is a major benefit over models that are dependent solely on clouds. The fact that the system automation saved 40% of manual workload is a translation of the system automation into concrete operational savings, which is a significant cost driver in security. These findings are important to be put into context. The camera positioning was a mathematics application of the best coverage but is not innovative. The hybrid edge-cloud architecture conforms to known models. Thus, the originality and value of this paper in terms of research is the combination of the implementation and, in particular, the empirical testing of these principles in a particular problematic situation.

The given performance data and cost package (Bill of Materials) can be a good point of reference that had not been present in the literature before. Such limitations like the reliance on the network when remote viewing is understood to be drawbacks of this design philosophy and are used to determine the limits of successful implementation.

4.3 Cost analysis and economic sustainability

A primary goal of this work was to design a system that is not only functionally effective but also economically sustainable for target environments[36]. This section provides a transparent cost analysis, moving beyond a simple bill of materials to a holistic view of capital investment, operational savings, and long-term value.

4.3.1 Capital expenditure (capex) breakdown

The initial investment for the proposed 4-camera smart surveillance system is detailed in Table 5. The design utilizes commercially available, off-the-shelf components to ensure replicability and avoid proprietary lock-in.

Table 5: Capital Expenditure (CapEx) for the Proposed Smart Surveillance System

S/No	Component / Material	Quantity	Unit Cost (₦)	Total Cost (₦)	Design Rationale
1	IP Cameras (with basic onboard processing)	4 No.	12,000	48,000	Enables edge triggering, eliminating need for always-on streaming.
2	Single-Board Computer (Raspberry Pi 4)	1 No.	45,000	45,000	Serves as the edge computing hub for local analytics and gateway functions.
3	Power over Ethernet (PoE) Switch	1 No.	20,000	20,000	Simplifies installation (single cable for power & data), reduces cabling cost.
4	Network Cabling & Connectors	1 Lot	15,000	15,000	For structured network installation.
5	Cloud Storage Subscription (Annual)	1 Year	10,000	10,000	Covers archival of event-based video clips for one year.
6	Total Capital Expenditure (CapEx)			₦ 138,000	

4.3.2 Operational Expenditure (OpEx) and Comparative Cost-Benefit Analysis

The true economic advantage of the smart system is realized during operation. Table 6 compares the key cost drivers of the proposed system against the traditional DVR baseline over a three-year period, which is a standard lifecycle for such technology.

Table 6: Three-Year Comparative Cost-Benefit Analysis (Proposed vs. Traditional System)

Cost/Benefit Factor	Proposed Smart System	Traditional DVR System	Notes & Calculation Basis
A. Capital Expenditure (Year 0)	₦ 138,000	₦ 160,000	Traditional cost includes DVR, analog cameras, coaxial cables, and monitor.
B. Annual Operational Costs			
1. Energy Consumption	₦ 7,968	₦ 11,383	Calculated from measured 30% energy saving (1.45 vs. 2.07 kWh/day). Assumes ₦15/kWh utility rate.
2. Manual Monitoring Labor	₦ 180,000	₦ 300,000	Based on 40% reduction in manual interventions. Assumes a security guard cost of ₦30,000/month, with smart system freeing up 40% of time for other duties.
3. Cloud/Storage Subscription	₦ 10,000	₦ 0	Traditional system uses local DVR storage only.
Total Annual OpEx (B)	₦ 197,968	₦ 311,383	
C. Three-Year Total Cost of Ownership (TCO)	₦ 731,904	₦ 1,094,149	Total 3-Year Savings with Smart System: ₦ 362,245
*(A + (B × 3)) *			
D. Key Performance & Economic Metrics			
Payback Period	~5.5 Months	N/A	Time for annual OpEx savings (₦113,415) to equal the CapEx difference (₦22,000).
3-Year Return on Investment (ROI)	156%	N/A	Calculated as: [(3-Year Savings - CapEx Diff.) / CapEx Diff.] * 100.

4.3.3 Economic Metrics (Payback ROI)

The analysis indicates that the initial capital expenditure on the smart system is competitive, although its overriding strength is the extreme saving in the recurrent operational costs, especially on the manual labor costs. The 40% decrease in the number of people working on the manual monitoring business is reflected on the most significant financial saving, be it the ability to redeploy the staff or the ability to cover a greater area with the same amount of people.

The payback period calculated is less than six months which is a good indication of economic viability. The long-term value proposition can be supported by the high Return on Investment (ROI) in three years. This model of economy is aimed at cutting down on the OpEX based on automation and energy-efficiency and it fits perfectly into resource limited environment where operational budget is limited. The presented cost-benefit framework is a viable, quantitative decision-making instrument by decision-makers analyzing such smart surveillance implementations.

5. Conclusion

The paper has outlined the design, implementation and the overall testing of a smart CCTV system that is programmed to be capable of sustaining security in resources limited areas. The project will be based on the tested principles of IoT and edge-computing to demonstrate a viable and sustainable path on the application of intelligent surveillance functions using the lens of the cost-saving and energy-preservation practices.

The most significant work contribution is practical and empirical;

An implementation blue print that is validated, system wide, and refined to a specific kind of environment.

A data set of quantitative performance measures that compares a smart, edge-based system to a traditional baseline on three core measures, e.g. energy consumption and operational efficiency.

A transparent cost model: The contribution addresses the gap of research on sustainable surveillance in developing regions in the translational and data-driven research.

The future work will be focused on using renewable sources of power like solar energy and further development of on-edge analytics to reduce the external dependencies. This writing places itself in a different position, it considers the proven effectiveness of the IoT, edge computing, and hybrid architecture as a premise. Hence, the literature review in this study does not attempt to possess an untapped technological space but to prove the effectiveness of the selected method and explicitly define its niche: a practitioner-oriented, implementation-based study that offers a verified blueprint and quantitative data on the implementation of sustainable smart surveillance with cost and infrastructure being the key limiting factors.

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7.Conflicts of Interest

The authors declare no conflicts of interest.

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