

Advanced Journal of Engineering and Scientific Applications (AJESA)

Research Paper

Open Access

Available online at www.ajes.com.ng

Vol.4, No.1, 2026. pp.86-93



An IA-Oriented Poultry Farm Monitoring System for Real-Time Environmental Risk Assessment and Alert Management

Njoku Glory Onyinye¹ and Ugwoke F.N²

^{1,2}Department of Computer Science, College of Physical and Applied Sciences, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

Emails: ¹njokuglory227@gmail.com, ²ndidi.ugwoke@gmail.com

Abstract

Poultry farming is an important component of agricultural production and food security; however, effective management of poultry houses requires continuous monitoring of environmental and production conditions. Conventional monitoring practices often depend on manual observation and record keeping, which can result in delayed identification of abnormal conditions, inconsistent records, and slow responses to potentially harmful environmental changes. This study presents the design and development of an IoT-oriented framework for environmental monitoring and risk assessment in poultry farm management. The study adopted a hybrid Object-Oriented Analysis and Design (OOAD) and iterative prototyping methodology to develop a functional web-based poultry farm monitoring system. The proposed system was structured into four layers: data acquisition, communication and data storage, processing, and application/presentation. The system provides facilities for poultry-house registration, batch management, sensor-reading entry, configurable threshold management, environmental risk assessment, dashboard visualization, historical record management, role-based access control, and automated alert generation. Eight poultry-related indicators are considered, including temperature, humidity, ammonia level, light intensity, feed level, water level, mortality count, and bird-weight sample. A centralized MySQL relational database was implemented to store monitoring records, while a rule-based risk assessment engine evaluates environmental readings against administrator-configured threshold values and classifies conditions as Normal, Warning, or Critical. Where abnormal conditions are detected, corresponding alert records are generated and email notification is attempted. System testing covered critical environmental readings, invalid batch selection, dynamic batch retrieval, threshold reconfiguration, duplicate user registration, and role-restricted access. The test results showed that the major functional components operated as expected after identified implementation defects were corrected. In particular, a test temperature reading of 40°C and humidity reading of 75% successfully triggered Critical and Warning classifications respectively, demonstrating the effectiveness of the implemented threshold-based assessment mechanism. The study demonstrates that the proposed framework can provide a structured digital approach to poultry farm monitoring, improve data organization, support consistent environmental risk classification, and facilitate timely notification of abnormal conditions. However, the current implementation uses simulated sensor inputs and a rule-based assessment mechanism rather than physically deployed IoT sensors and a trained machine-learning model. The developed framework therefore provides a practical foundation for future integration of physical sensing devices, machine-learning algorithms, predictive analytics, automated actuators, and mobile-based remote monitoring for intelligent poultry farm management.

Keywords: Poultry Farm Monitoring, Environmental Monitoring, Risk Assessment, Rule-Based System and Smart Agriculture.

I. INTRODUCTION

Background

Poultry farming is an important part of the agricultural sector, providing affordable animal protein through meat and egg production while contributing to food security, employment, and economic development, particularly in developing countries such as Nigeria. However, traditional poultry farming relies heavily on manual monitoring and farmers' experience to manage temperature, humidity, ventilation, feed consumption, and bird health. This approach is time-consuming, labor-intensive, and susceptible to human error, making it difficult to detect sudden



environmental changes and early signs of disease. Poor environmental control can cause stress, reduced productivity, increased disease susceptibility, and higher mortality rates, resulting in significant economic losses (Adebayo et al., 2023; FAO, 2022). These challenges have created the need for more efficient, reliable, and technology-driven approaches to poultry management.

The Internet of Things (IoT) provides an effective approach to improving poultry farm monitoring by using interconnected sensors to collect and transmit environmental data in real time. Sensors can continuously monitor important parameters such as temperature, humidity, ammonia concentration, air quality, and light intensity, providing farmers with accurate and up-to-date information about farm conditions (Ogunleye et al., 2024). IoT systems can also be connected to actuators such as fans, heaters, humidifiers, and ventilation systems, allowing environmental conditions to be automatically regulated when predefined limits are exceeded. This automation reduces the need for constant human supervision, improves response time, and helps maintain suitable conditions for poultry health and productivity. Studies have shown that IoT-based monitoring and environmental control can improve farm management efficiency, feed conversion, mortality rates, and overall production performance (Ogunleye et al., 2024; Kumar et al., 2023; Zhang et al., 2023; Singh & Gupta, 2024).

Artificial Intelligence (AI) further enhances IoT-based poultry farming by providing intelligent analysis, prediction, and decision-making capabilities. Machine learning algorithms can analyze real-time and historical data from sensors to identify patterns, detect abnormalities, and predict potential problems such as disease outbreaks, heat stress, abnormal growth, and changes in feed consumption. Computer vision can also be used to analyze images and videos of birds to identify unusual behaviors such as reduced movement, overcrowding, limping, or irregular feeding patterns, which may indicate illness or environmental stress (Kumar et al., 2023; Zhang et al., 2024). Predictive techniques, including Random Forest and Support Vector Machines, can assist farmers in optimizing environmental conditions, feed management, and production outcomes (Singh & Gupta, 2024; Adeyemi et al., 2023). The integration of AI and IoT therefore enables a transition from reactive farming to proactive and predictive farm management.

Despite the benefits of AI and IoT technologies, traditional poultry farming still faces major problems, including poor environmental monitoring, high mortality rates, delayed disease detection, high labor requirements, and inadequate access to real-time farm data. These problems are further complicated in developing regions by high technology costs, unreliable electricity, limited internet connectivity, lack of technical expertise, and low awareness among small- and medium-scale farmers (Adebayo et al., 2023; FAO, 2023). Therefore, there is a need for an affordable and user-friendly smart poultry monitoring system that can provide continuous environmental monitoring, automated alerts, and intelligent predictions. The aim of this study is to design and implement an AI-driven smart poultry monitoring system using IoT, with objectives that include developing a monitoring prototype, integrating IoT sensors for environmental data collection, applying AI for disease and growth prediction, and developing a user-friendly web-based interface for farmers. Such a system can support timely decision-making and improve poultry farm management (Adeyemi et al., 2024; Kumar & Singh, 2023).

The proposed system is significant because it can improve poultry health, productivity, and welfare while reducing operational costs and human effort. Continuous monitoring of temperature, humidity, and ammonia levels can help maintain suitable environmental conditions, while AI-based analysis can provide early warnings and predictive insights that support timely intervention. The system can also promote efficient use of feed, water, energy, and other farm resources, thereby contributing to sustainable agriculture (Zhang et al., 2024; Singh et al., 2024; FAO, 2023). The scope of the study focuses on sensor-based monitoring of temperature, humidity, and ammonia levels; AI-based alerts and predictions; and the design, implementation, and testing of the complete smart poultry monitoring system. Overall, the integration of IoT, AI, automation, and predictive analytics offers a practical approach to addressing the limitations of conventional poultry farming and promoting more efficient, sustainable, and intelligent poultry production.

II. LITERATURE REVIEW

Conceptual Framework

Development of smart poultry farming systems is based on the integration of Internet of Things (IoT), Artificial Intelligence (AI), data processing, and automated control. The conceptual framework follows a data-to-decision process in which IoT sensors collect environmental and biological information such as temperature, humidity, ammonia concentration, light intensity, ventilation status, and bird activity. The collected data are transmitted through communication technologies such as Wi-Fi, GSM, or LoRa to local or cloud-based platforms for storage and processing. Data preprocessing removes noise, inconsistencies, and missing values before the information is passed to AI models for analysis and prediction. This integration creates a continuous feedback loop capable of supporting real-time monitoring, intelligent decision-making, and automated farm control (Kumar & Singh, 2024; Zhang et al., 2025; Adeyemi et al., 2024).

The AI component serves as the analytical and decision-making core of the proposed smart poultry system. Machine learning algorithms can analyze environmental, production, and behavioral data to identify abnormal conditions, detect possible disease symptoms, and predict growth and productivity trends. AI can also generate alerts and recommendations when risks such as high temperature, excessive humidity, or elevated ammonia levels are detected. In more advanced systems, AI-generated decisions can activate IoT-connected actuators such as fans, heaters, and



ventilation systems. This combination allows poultry management to move from a reactive approach, where farmers respond after problems occur, to a proactive approach that anticipates and prevents potential problems (Zhang et al., 2025; Kumar & Singh, 2024; Adeyemi et al., 2024).

Theoretical review

The theoretical review is based on Automation Theory, Decision Support Systems (DSS) Theory, and Machine Learning Theory. Automation Theory supports the use of sensors and actuators to perform routine farm management activities with minimal human intervention, thereby improving efficiency, accuracy, and productivity (Kumar & Singh, 2024; Zhang et al., 2025). DSS Theory explains how collected farm data and analytical models can be transformed into useful information and recommendations that assist farmers in making timely decisions (Zhang et al., 2025; Adeyemi et al., 2024). Machine Learning Theory provides the foundation for developing systems that learn from historical and real-time data to identify patterns, predict disease outbreaks, forecast growth and egg production, and detect abnormal poultry behavior. These theories collectively provide a strong foundation for developing an intelligent poultry monitoring system.

Empirical studies

Empirical studies generally demonstrate the benefits of applying IoT and AI in poultry farming. IoT-based systems have been shown to improve continuous monitoring of temperature, humidity, ammonia, and other environmental conditions, thereby helping to reduce environmental stress and mortality (Kumar & Singh, 2024; Zhang et al., 2025). AI-based systems improve disease detection, behavioral analysis, feed management, growth estimation, and production forecasting through machine learning and deep learning techniques (Adeyemi et al., 2024; Singh et al., 2025). Furthermore, integrating AI and IoT can reduce the consumption of feed, water, energy, and labor by enabling automated and intelligent resource management (FAO, 2023; Zhang et al., 2025). Research therefore indicates that smart poultry systems can provide greater efficiency, accuracy, sustainability, and animal welfare than conventional farming methods.

Review of related works

The review of related works identifies three major categories of existing systems: IoT-based systems, AI-based systems, and integrated AI-IoT systems. IoT-based systems provide continuous environmental monitoring, cloud storage, remote access, and threshold-based alerts, but they are generally reactive and have limited predictive capabilities (IEEE Internet of Things Journal, 2023; FAO, 2023). AI-based systems provide stronger capabilities for disease detection, behavioral analysis, and production prediction using techniques such as Random Forest, Support Vector Machines, and neural networks; however, they often require large, high-quality datasets and may have limited access to real-time IoT data (IEEE Access, 2024; Springer AI in Agriculture Review, 2023). Integrated AI-IoT systems provide the most comprehensive solution by combining real-time sensing, cloud computing, predictive analytics, automated control, and remote monitoring. Nevertheless, their high cost, technical complexity, dependence on reliable electricity and internet connectivity, and maintenance requirements can limit their adoption, particularly among small-scale farmers (IEEE Access, 2025; Springer Precision Agriculture, 2024).

Knowledge gaps

The literature further reveals important knowledge gaps that remain unresolved. Some AI-based systems depend on offline data processing, resulting in delays when responding to sudden changes such as heat stress, high ammonia levels, or abnormal bird behavior. Other systems focus mainly on descriptive monitoring rather than predictive and prescriptive analytics, meaning that they report current conditions without adequately forecasting future disease outbreaks, growth performance, or environmental risks. Existing studies also show weaknesses in real-time IoT integration, poultry-specific implementation, scalability, and affordability (Adeyemi et al., 2023; Zhang et al., 2025; Singh & Gupta, 2024). These limitations are particularly important in developing regions where unstable electricity, poor internet connectivity, high technology costs, and limited technical expertise may prevent effective deployment.

Overall, the literature demonstrates that AI-IoT integration offers a promising solution to the limitations of conventional poultry farming, but there is still a need for systems that are affordable, scalable, user-friendly, and capable of real-time prediction and automated response. The reviewed studies provide evidence that continuous sensing, AI-based analysis, predictive modeling, and automated control can improve poultry health, productivity, resource utilization, and farm management. However, the identified gaps justify the development of the proposed AI-driven smart poultry farm monitoring system using IoT, which aims to combine real-time environmental monitoring, intelligent predictive analysis, automated alerts, and decision support within a single system. This approach is expected to address the limitations identified in previous studies and contribute to more efficient and sustainable poultry farming.

III. RESEARCH METHODOLOGY, SYSTEM INVESTIGATION AND ANALYSIS

Research Methodology

The research methodology, system investigation, analysis, design, and development process for the proposed AI-Driven Smart Poultry Farm Monitoring System Using IoT. The study adopted a hybrid system development methodology that combines Object-Oriented Analysis and Design (OOAD) with an iterative prototyping approach. OOAD was used to identify and model important system entities such as users, poultry houses, batches, sensor readings, thresholds, and alerts, while iterative development allowed the system to be built and tested in stages. The



development progressed from sensor-data simulation and database integration to risk evaluation, dashboard development, and automated alerting. Prototyping was also used to validate requirements, identify design problems early, and improve system usability. This approach supported incremental verification, reduced development risks, and allowed defects to be identified and corrected during development.

The study employed primary observation, secondary data review, and interviews as its major data collection methods. Primary observation involved examining routine poultry management activities, including temperature and humidity monitoring, ammonia assessment, feed and water availability, and mortality recording. Secondary sources consisted of academic literature, technical documentation, and previous studies on poultry production, IoT monitoring, databases, web development, and automated alerts. Interviews with individuals familiar with poultry operations provided additional information about monitoring challenges, early-warning requirements, and user expectations. The findings from these methods informed the selection of monitored parameters, threshold values, database structure, alert mechanisms, and user-interface requirements. The combined approach ensured that both practical farming requirements and technical system requirements were considered in the development of the proposed system.

Existing manual poultry monitoring system

The analysis of the existing manual poultry monitoring system revealed that monitoring largely depends on periodic physical inspections by farm attendants. Temperature and humidity are measured using basic instruments, ammonia is often assessed through smell and bird behaviour, while feed, water, and mortality are primarily determined through visual inspection and manual records. Although the manual system has advantages such as low cost, simple operation, human judgement, and flexibility, it has significant limitations. Monitoring is periodic rather than continuous, making rapid environmental changes difficult to detect. Manual recording is also vulnerable to human error and inconsistency, while paper-based records make historical analysis difficult. Furthermore, the existing approach lacks automated early-warning mechanisms, meaning that response to abnormal conditions depends heavily on the presence, attentiveness, and judgement of farm personnel.

The New system

The system was therefore designed as a web-based poultry monitoring and alert platform that provides centralized recording, processing, storage, and analysis of poultry farm data. Because physical IoT hardware was outside the scope of the study, the prototype uses structured forms to simulate sensor-generated readings. The system captures temperature, humidity, ammonia, light intensity, feed level, water level, mortality count, and average bird weight. Submitted data are validated and compared with administrator-configured thresholds. Based on the results, the system classifies conditions as Normal, Warning, or Critical. Although the broader research is AI-driven, the implemented prototype uses a transparent rule-based decision mechanism rather than machine-learning algorithms. This distinction ensures that the current system's capabilities are accurately represented while providing a foundation for future integration of actual AI and physical IoT components.

Architecture of the system

The architecture of the system consists of four major layers: simulated sensor/data acquisition, communication/data storage, processing, and application/presentation. The first layer represents sensor data acquisition through the sensor-entry interface, while the second stores readings in a normalized MySQL database. The processing layer retrieves configured thresholds and evaluates submitted readings to determine the appropriate risk level. The application layer presents monitoring results through a Bootstrap-based dashboard and Chart.js graphical visualizations, while PHPMailer is used to send email notifications. The system also incorporates multi-role user accounts, batch registration and mortality tracking, configurable thresholds, automated risk classification, alert history, and graphical monitoring. These features provide centralized and timestamped records, improve early-warning capabilities, and restrict sensitive system functions through role-based access control.

The framework and implemented directly in the working prototype: a Simulated Sensor/Data Acquisition Layer, a Communication/Data Storage Layer, a Processing Layer, and an Application/Presentation Layer.



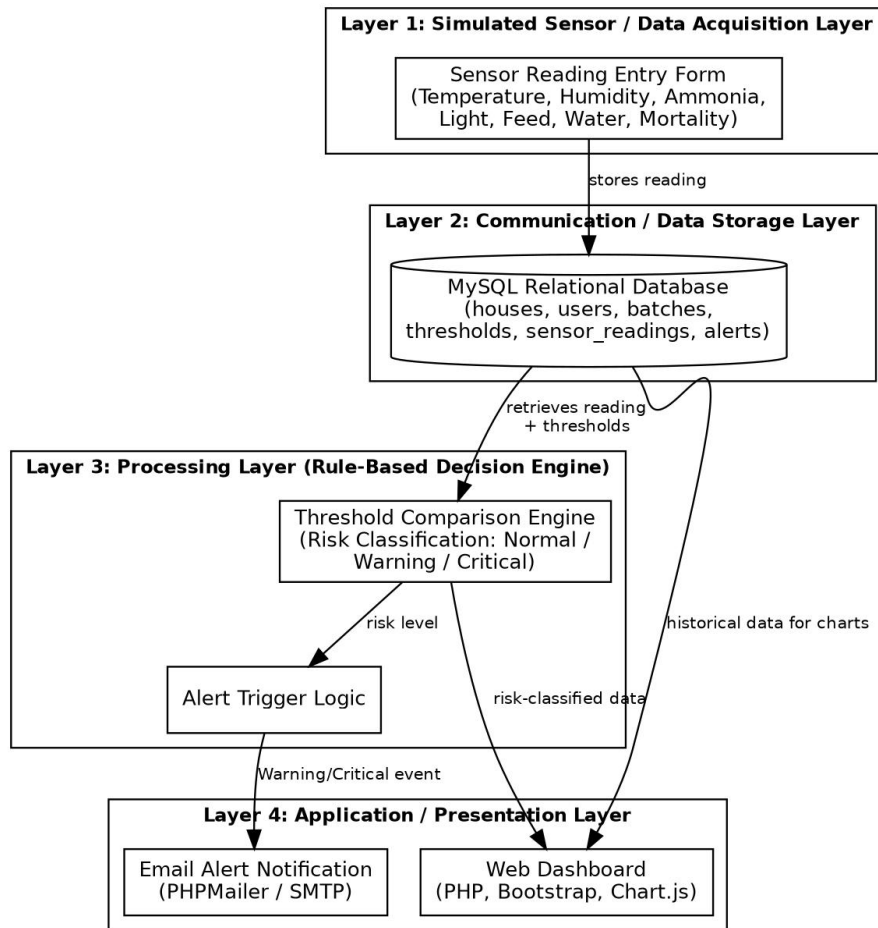


Fig. 1: Four-layer architecture of the system

Unified Modeling Language (UML) and Data Flow

System modelling was conducted using Unified Modeling Language (UML) and Data Flow Diagrams to describe the structure, behaviour, and movement of information within the system. The use case model represents the interaction of farmers and administrators with major functions such as sensor reading submission, risk evaluation, and alert notification. The class diagram models the core entities—House, User, Batch, SensorReading, Threshold, and Alert—and their relationships within the database. The Level 1 Data Flow Diagram describes processes for recording sensor readings, evaluating risk, generating alerts, managing batches and thresholds, and displaying dashboards and reports. Program design was implemented through modular PHP files, including authentication, dashboard, sensor entry, batch management, threshold configuration, user and house management, and alert history modules. The modular design supports maintainability and allows individual components to be tested and modified independently.

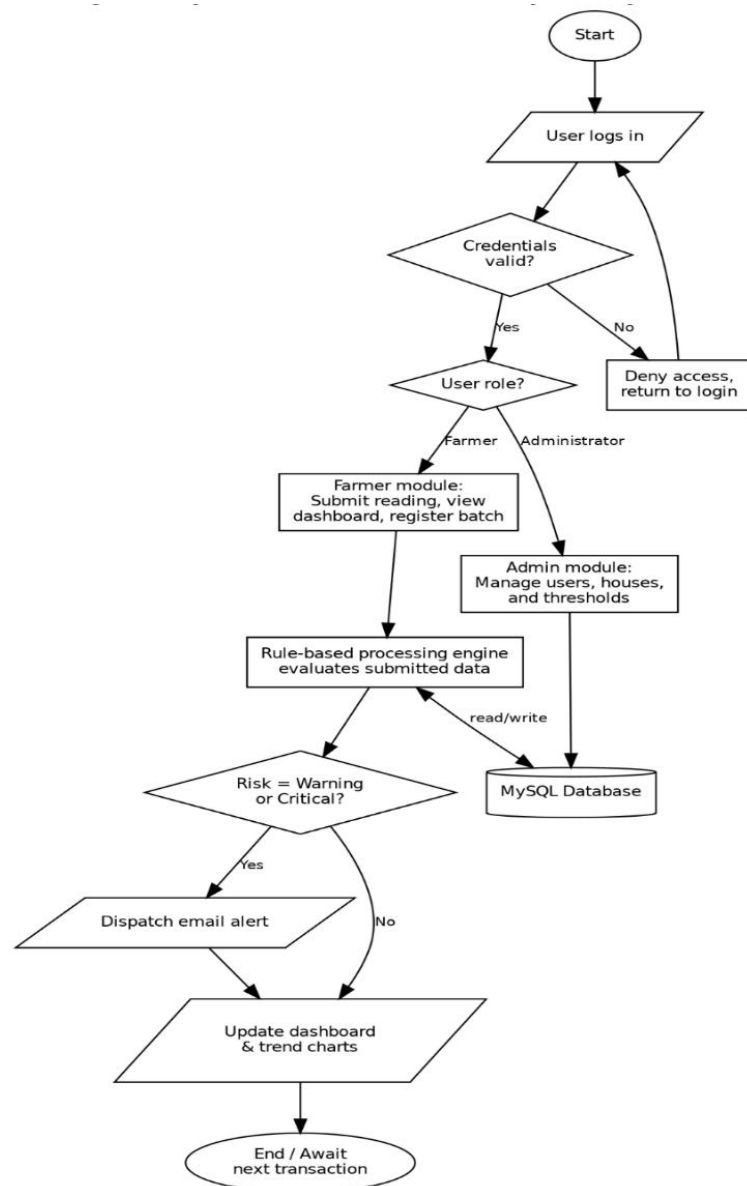


Fig. 2: System flowchart of the developed system

Overall, the system addresses the major weaknesses of the existing manual monitoring approach by providing structured digital records, automated risk classification, configurable thresholds, and immediate email alerts. Unlike manual monitoring, where abnormal conditions may remain undetected until the next physical inspection, the proposed system evaluates every submitted reading immediately and generates an alert when a Warning or Critical condition is identified. It also provides historical records that can be queried across poultry houses and batches, improving consistency and decision-making. However, the study maintains an important limitation: the prototype does not physically deploy IoT sensors or machine-learning models; instead, it simulates sensor input and uses rule-based analysis. Consequently, the system should be understood as a software prototype demonstrating the intended AI-IoT monitoring workflow, with future development capable of incorporating physical sensors, real-time IoT communication, and advanced machine-learning prediction models.

IV. SYSTEM IMPLEMENTATION

The implementation of the AI-Driven Smart Poultry Farm Monitoring System Using IoT, translating the system architecture, UML models, and program design into a functional software prototype. The system was developed using an iterative prototyping approach, with each interface implemented and tested before proceeding to the next. The major input forms include administrator login, farmer registration, poultry house registration, batch registration, threshold configuration, and sensor reading entry. The forms incorporate both client-side and server-side validation to improve data integrity and security. Since physical IoT hardware was outside the project scope, sensor readings were simulated through the sensor-entry interface.

The implemented system provides several output interfaces, including the public home page, administrator user-management page, monitoring dashboard, alert history, registration confirmations, poultry house and batch records, threshold settings, and sensor-reading results. The dashboard presents recent readings, risk classifications, and graphical trends, while the rule-based risk engine classifies conditions as Normal, Warning, or Critical based on



configured thresholds. A test reading containing a temperature of 40°C and humidity of 75% successfully produced a Critical classification and generated separate Temperature and Humidity alerts. Although email notification was implemented using PHPMailer, actual delivery could not be demonstrated because valid SMTP credentials were unavailable in the demonstration environment; importantly, the system visibly recorded the failed notification attempt.

The system uses a normalized MySQL database consisting of six physical tables supporting users, poultry houses, batches, thresholds, sensor readings, and alerts. PHP 8 was used for server-side processing and authentication, while SQL handled database operations. HTML5, CSS3, JavaScript/jQuery, Bootstrap 5, and Chart.js were used to create the interfaces, dynamic forms, responsive layouts, and monitoring charts. The system requires a standard computer with at least 4 GB RAM, a modern web browser, and an XAMPP or equivalent server environment. Installation involves configuring the local server, importing the database, configuring application settings, and optionally providing SMTP credentials for email alerts.

Testing was conducted iteratively through unit, integration, and system testing. The major functions, including sensor validation, risk classification, threshold modification, dynamic batch selection, duplicate registration prevention, and role-based access control, were successfully tested. Defects discovered during development, such as invalid batch references and incorrect script loading order, were corrected through additional validation and implementation adjustments. The system is designed for lightweight staff training, parallel changeover from manual records, and ongoing corrective, adaptive, perfective, and preventive maintenance. The estimated total project cost is ₦300,000, comprising development, hosting, hardware, installation, testing, and documentation costs, while the major software libraries and server tools were obtained at no licensing cost.

V. CONCLUSION

This study focused on the design and implementation of an AI-Driven Smart Poultry Farm Monitoring System Using IoT to address challenges associated with manual poultry farm monitoring, such as delayed detection of abnormal conditions, inconsistent record keeping, and reliance on human observation. The study adopted a hybrid Object-Oriented Analysis and Design (OOAD) and Iterative Prototyping methodology. The developed system was organized into four layers covering data acquisition, communication and storage, processing, and application/presentation. It supports poultry-house and batch management, sensor-reading entry, configurable thresholds, risk classification, dashboard visualization, record keeping, role-based access control, and automated email alerts.

The system monitors important poultry-farm parameters including temperature, humidity, ammonia level, light intensity, feed level, water level, mortality, and bird weight. Submitted readings are stored in a centralized MySQL database and evaluated against configurable thresholds, resulting in Normal, Warning, or Critical classifications. Warning and Critical conditions generate alerts for responsible personnel. Testing demonstrated that the major system functions operated successfully, including critical-condition detection, validation of incomplete submissions, dynamic batch selection, threshold modification, prevention of duplicate registration, and restriction of unauthorized access. However, the prototype currently relies on simulated sensor inputs and a rule-based risk engine rather than physical IoT sensors and a trained machine-learning model.

The study concludes that the developed system provides a functional and practical foundation for improving poultry farm monitoring and management. It offers centralized data collection, digital record keeping, configurable risk assessment, dashboard visualization, access control, and automated notification, thereby addressing several weaknesses of traditional manual monitoring. Nevertheless, the system should be regarded as a prototype rather than a complete IoT and artificial-intelligence deployment. Future improvements should include physical IoT sensor integration, collection of larger poultry datasets, development of validated machine-learning models, real-world farm deployment, improved power and communication infrastructure, additional notification channels such as SMS and push notifications, and integration of automated actuators for environmental control.

The study contributes to knowledge by providing an integrated four-layer framework for smart poultry monitoring, a configurable threshold-based risk-classification mechanism, centralized timestamped monitoring records, and automated alert generation. It also provides a foundation for future machine-learning-based poultry health prediction.

VI. RECOMENDATION

Further research should investigate machine-learning disease prediction, physical IoT deployment, computer vision, edge AI, predictive growth and mortality models, automated farm actuators, large-scale field testing, localized Nigerian poultry datasets, solar-powered and offline-capable systems, mobile applications, cybersecurity, and comparative evaluation of machine-learning algorithms. These developments can transform the current prototype into a more comprehensive, intelligent, and real-time poultry farm management system.

REFERENCES

- [1] Adeyemi, R. A., Bello, M. T., & Akinola, S. O. (2023). Machine learning applications for poultry production forecasting and disease detection. *International Journal of Agricultural Informatics*, 12(4), 210–225.
- [2] Adeyemi, R. A., Bello, M. T., & Akinola, S. O. (2024). AI-based decision support systems for smart livestock farming. *Journal of Smart Agriculture and AI*, 5(1), 33–50.
- [3] Ahmed, K., & Malik, H. (2023). Smart farming systems using IoT and cloud computing. *Journal of Cloud Computing in Agriculture*, 7(1), 15–30.



- [4] Alam, T., & Raza, S. (2024). Deep learning models for livestock health prediction. *IEEE Internet of Things Journal*, 11(4), 2234–2246.
- [5] Ali, F., Khan, M., & Rehman, S. (2023). Sensor-based livestock monitoring systems: A review. *Agricultural Informatics Review*, 5(2), 50–68.
- [6] Bello, A., & Ibrahim, Y. (2024). Real-time poultry monitoring using wireless sensor networks. *International Journal of Smart Systems*, 9(3), 120–135.
- [7] Chen, L., & Zhao, Y. (2023). Artificial intelligence in precision livestock farming. *Computers in Agriculture*, 15(2), 99–115.
- [8] Das, R., & Saha, P. (2022). IoT architecture for smart agriculture systems. *Journal of Embedded Systems*, 8(1), 10–25.
- [9] Debayo, T. O., Oladipo, O. O., & Yusuf, K. A. (2023). Impact of environmental conditions on poultry production efficiency in developing countries. *Journal of Agricultural Systems and Technology*, 18(2), 45–60.
- [10] Fatima, Z., & Noor, M. (2023). Smart poultry farm management using sensor networks. *Agricultural Technology Today*, 6(3), 77–90.
- [11] Food and Agriculture Organization. (2022). Digital technologies and smart livestock systems for sustainable agriculture. FAO.
- [12] Food and Agriculture Organization. (2023). Digital technologies and precision livestock farming for sustainable animal production. <https://www.fao.org>
- [13] García, J., & López, M. (2024). AI-driven agricultural monitoring systems. *IEEE Access*, 12, 99888–99902.
- [14] Hassan, R., & Ahmed, S. (2023). Disease prediction in poultry using machine learning. *Journal of Veterinary Informatics*, 4(2), 45–60.
- [15] Ibrahim, M., & Yusuf, A. (2024). IoT-based livestock monitoring and automation systems. *African Journal of Agricultural Engineering*, 10(1), 33–50.
- [16] Islam, M., Rahman, M., & Hossain, S. (2022). Environmental monitoring in poultry farms using IoT sensors. *Sensors*, 22(7), 3011–3025.
- [17] Johnson, P., & Lee, K. (2023). Smart sensors in agriculture: A review. *Sensors and Systems Journal*, 14(2), 200–215.
- [18] Khan, A., & Ali, R. (2023). Cloud-based agricultural monitoring frameworks. *International Journal of Cloud Computing*, 9(1), 11–28.
- [19] Kim, J., & Park, S. (2024). AI-enabled livestock health tracking systems. *Journal of Agricultural AI Systems*, 8(2), 88–104.
- [20] Kumar, N., & Singh, P. (2023). IoT-enabled smart poultry farming systems: Design and implementation. *Journal of Agricultural Engineering and Technology*, 9(3), 112–128.
- [21] Kumar, N., & Singh, P. (2024). Cloud-based IoT frameworks for real-time agricultural monitoring. *IEEE Access*, 12, 45678–45690.
- [22] Li, X., Zhang, Y., & Wang, H. (2024). Computer vision for poultry behavior analysis. *Artificial Intelligence in Agriculture*, 8(1), 22–40.
- [23] Liang, H., & Wu, J. (2023). IoT and edge computing in smart farming. *IEEE Communications Surveys & Tutorials*, 25(3), 1456–1472.
- [24] Musa, H., & Bello, M. (2023). Smart poultry farming in developing countries. *Nigerian Journal of Agricultural Research*, 18(2), 60–75.
- [25] Nair, S., & Thomas, R. (2024). Machine learning applications in agriculture. *International Journal of Data Science in Agriculture*, 6(1), 12–30.
- [26] Ogunleye, O. A., & Afolabi, J. O. (2024). IoT-based environmental monitoring systems in poultry production. *Nigerian Journal of Agricultural Technology*, 15(1), 88–102.
- [27] Ojo, A., & Adewale, T. (2023). IoT-enabled livestock health monitoring system. *West African Journal of Engineering*, 7(2), 45–62.
- [28] Patel, S., & Shah, M. (2021). AI in smart farming: A review. *IEEE Access*, 9, 112345–112360.

