Design and Development of a Smart Automated System for Poultry Farm Management Using Internet of Things (IOT)

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Abstract: Worldwide, poultry farming is one of the fastest-growing sectors and is a key source of livelihood for thousands of small and medium-sized farmers in India, but maintaining optimal environmental conditions - temperature, humidity, and air quality - is critical and also difficult for the health and mortality of chicks. This research work leads to the design and development of a smart, automated poultry farm management system using the Internet of Things (IoT). The system consists of two major components: a hardware module built around a Raspberry Pi and a user-friendly mobile application. The hardware module includes environmental sensors: DHT22 for temperature and humidity, MQ137 for ammonia, and MQ135 for CO_2. The solution tracks environmental conditions and transmits all information in real time to the mobile app via Firebase Cloud. The mobile app allows farmers to remotely control all environmental parameters. It includes features that recommend rationing feed for future chicks based on age, record mortality rates, batch dates, breed, feed log, and sales records, and that provide access to all information via graphical apps for better visualization. It was observed to reduce chick mortality from 5% to 1.66%, which was a savings of approximately USD 34 (for every batch of 5000 chicks) and or a projected annual benefit of around USD 210. This solution has allowed farmers to be more productive and profitable while also reducing labour and stress during adverse weather conditions. It is worth noting that this success demonstrates the potential to transform traditional poultry farming into a smarter, more sustainable approach through the use of IoT.

Keywords: IoT; poultry farm; smart farming; automation; livestock monitoring

1. Introduction

Poultry farming is an important aspect of global agriculture. The wide variety of chicken products (eggs and meat) provides a good source of protein for the population. According to the Food and Agriculture Organization (FAO), the world produced 137 million tonnes of poultry meat in 2021, and it continues to increase due to population growth and changing diets [1]. India's meat production in FY 2023-24 was 10.25 million tonnes, which was up 4.95 percent from the previous year. Egg production was 142.77 billion, up 3.18 percent from the previous year. The meat-producing states were West Bengal (12.62%), Uttar Pradesh (12.29%), and Maharashtra (11.28%), and the egg-producing states were Andhra Pradesh (17.85%), Tamil

Nadu (15.64%), and Telangana (12.88%) [2]. In India, poultry farming contributes about 3% of the total agricultural GDP and supports millions of small- and medium-scale farmers [3].

Traditional poultry farming relies heavily on manual monitoring of farm conditions. Much monitoring is very rudimentary, produces insufficient data, and is inefficient and error-prone. Farmers find it hard to cope with changes in potential temperature and humidity caused by weather fluctuations. The farmers find it difficult to control harmful gases, ammonia (NH_3) and carbon dioxide (CO_2), when they accumulate in farms where airflow is restricted, leading to respiratory problems for the birds [4]. Another issue for farmers is feed management, which generally involves an inappropriate or unviable feed schedule or insufficient feed provision, which may affect poultry weight gains and feed conversion ratios, negatively impacting optimal growth rates and, ultimately, feed conversion ratios [5], resulting in economic losses. Countries with advanced poultry industries have been able to mechanize systems to manage these problems much more easily. However, the price implications and the scope of operations have prevented smaller and medium-scale farmers in India from benefiting from the technology. To address these hurdles, IoT-based smart farming offers a practical, economical, and easy-to-use alternative. These automated systems use sensor and actuator technology to monitor and control key environmental parameters continuously. Using smart control and Machine Learning, the systems can manually or automatically ventilate, cool, and heat to maintain optimal conditions for poultry health, growth, etc. Additionally, the automated system can use analytical processes to manage feeds, producing highly specific recommendations based on chick age and number.

Three theme groupings can be used to broadly categorize current research on smart poultry farming, viz., environmental monitoring systems, feeding and farm operations management, and AI-based analytics systems. To enhance chicken welfare, environmental monitoring and control systems focus on detecting temperature, humidity, and hazardous gases, as well as automating ventilation and climate management. Research by Kristensen and Wathes [1], Lashari et al. [5], Phiri et al. [4], Liu et al. [7], Esnaola-Gonzalez et al. [13], Kale et al. [19], and Sasirekha et al. [21] shows how IoT-enabled sensing and cloud-based platforms can effectively maintain ideal environmental conditions inside poultry houses. Feed optimization, bird tracking, mortality monitoring, and behavioral evaluation are the main focuses of research on feed, behavior monitoring, and farm operations management. Research by Broderick et al. [2], Dorninger et al. [3], Cruz et al. [8], Sharma and Aggarwal [23], Neethirajan [24], and Li [22] emphasizes how computer vision, tracking systems, and automated feeding procedures may increase productivity and decrease manual intervention. Predictive modeling, anomaly detection, and intelligent decision support for poultry management are the main focuses of AI and machine learning-based analytics. The use of deep learning, AIoT, and ML approaches for disease detection, behavior analysis, and predictive health diagnostics is demonstrated in studies such as Ahmed and Salih [9], Ehsan and Mohtavipour [10], Singh [11], Gandhi [16], and Rajendran et al. [24].

Despite these developments, most current systems focus only on feeding management, environmental control, or intelligent analytics. For small- and medium-sized poultry farms in developing nations like India, there remains a glaring research gap for an integrated, affordable, and field-validated smart poultry management system that combines real-time environmental monitoring, feed recommendations, mortality tracking, and farm record management. To overcome these restrictions, the current study aims to use IoT and cloud-connected mobile applications to design and build a smart, automated poultry farm management system that offers Indian poultry farmers a comprehensive, practical, and reasonably priced solution. The proposed Intelligent Automated Poultry Management System (IAPMS) stands out for accessibility, integration, cost-effectiveness, and field validation, especially for small and medium-sized farms in developing nations, despite several recent studies investigating IoT-based poultry monitoring. Through a mobile application, sensor data, ML-based recommendations, and actuator reactions work together in a closed-loop control architecture. It also goes beyond disease detection by providing a comprehensive farm management platform that combines cloud-based data persistence, productivity analytics, and environmental control. Together, these characteristics improve the system's usability, efficacy, and suitability for practical implementation in chicken farming settings with limited resources.

2. Materials and Methods
2.1 Overall System Architecture
2.1.1. Block diagram of the system

The proposed remote poultry management system is a low-cost, intelligent solution that automates and simplifies key farm operations. It uses a modular architecture, is based on input sensors, Raspberry Pi, relay boards, actuators, cloud connection, and a mobile application to provide easy control of poultry operations. The scalable Automation approach uses input sensors to monitor environmental conditions, including temperature, humidity, and ammonia/gases. The software enables real-time, automated responses using a built-in machine learning model to determine when action is needed and what action to take- if any. The system features dual-mode operation, allowing actuator control (fans, lights, heaters, etc) to be either manually or automatically controlled. The mobile app is intuitive and allows farmers to access real-time control of their operations even when they are away from the farm. Mobile app features also provide real-time camera access to the farm, enabling farmers to visually check on the flock without physically being there. Figure 1 shows the system block diagram. The app includes a sophisticated feed advisory feature that calculates the optimal feed requirements based on the number and age of chicks, helping promote healthy chick movement. The Mobile app enables disease prevention by including vaccination reminders tailored to target species/breeds and proper poultry management to ensure they remain productive. All data from the farm, including environmental statistics, sales, mortality, etc., is stored in the cloud and can be easily organized into graphical data in the mobile app for user functionality.
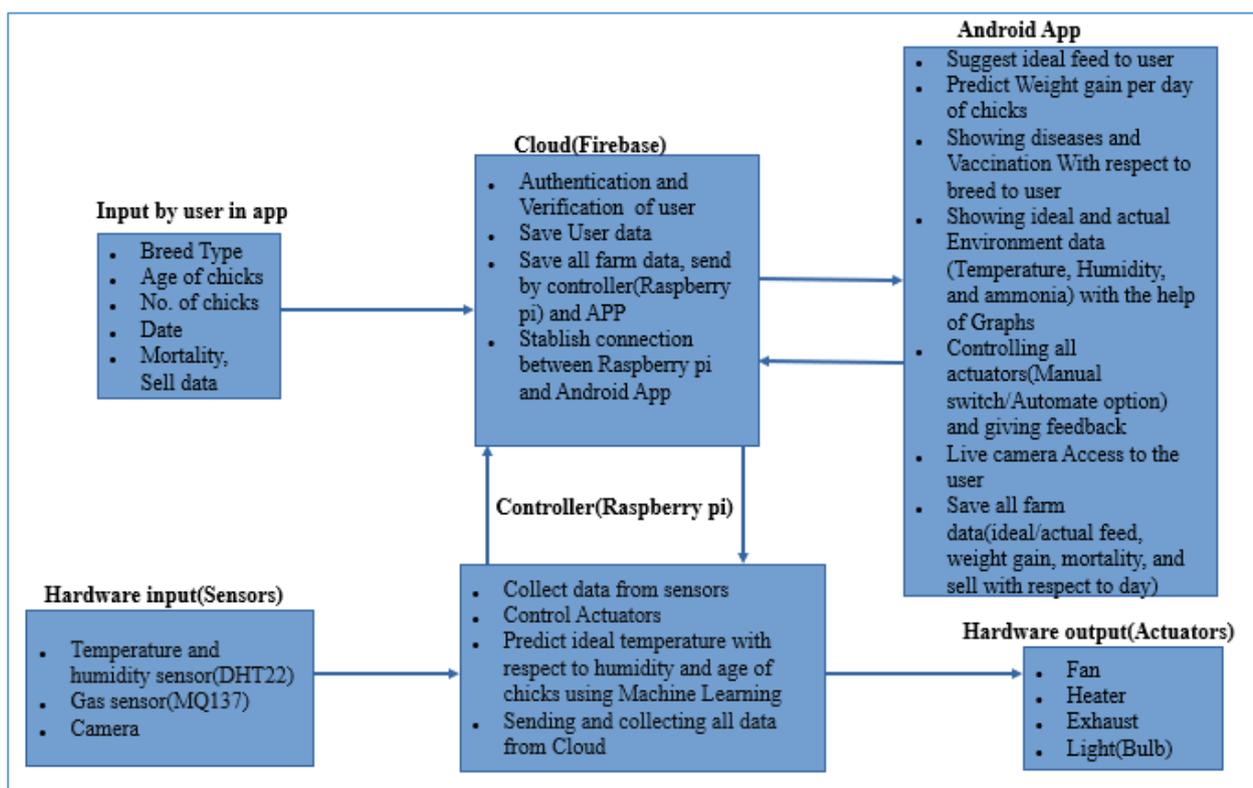

Figure 1. Block Diagram of the System

2.1.2 Brief explanation of the working mechanism

An experimental setup was created at a Jassal poultry farm to test and evaluate the performance and reliability of the IoT-based poultry management system. The system hardware consisted of a Raspberry Pi 4 Model B as the primary processing unit, with integrated DHT22 and MQ137 sensors to measure environmental temperature, humidity, and ammonia gas levels, respectively. An ADS1115 analog-to-digital converter was

used to read and convert the MQ137 sensor's analog output to a digital value. To control the farm's actuators (fans, heaters, exhaust systems, and lights), a 4-channel relay module was used to actuate the farm in accordance with sensor data or user input. A 5MP Raspberry Pi camera module was mounted inside the farm to provide video streaming for surveillance and remote monitoring. Every data and control function was also connected to a custom mobile app developed in Android Studio to run on an Android mobile device. The mobile app communicates with the Raspberry Pi through Firebase Cloud. The Firebase platform was used to provide authentication, sync the real-time database, and provide long-term data storage. Figure 2 represents the circuit diagram for the hardware used in the present research work.

2.2 Hardware Components

The optimal temperature for a chicken house is predicted using a supervised regression-based machine learning algorithm. Poultry management recommendations and past farm data are used to train the model offline. Relative humidity, current temperature, and chick age (days) are examples of input features. The appropriate temperature for optimal chick growth and comfort is the aim variable. The trained model provides real-time inference and decision support. Figure 2 and Figure 3 represent the circuit diagram for the poultry farm control and the various hardware components used, respectively.
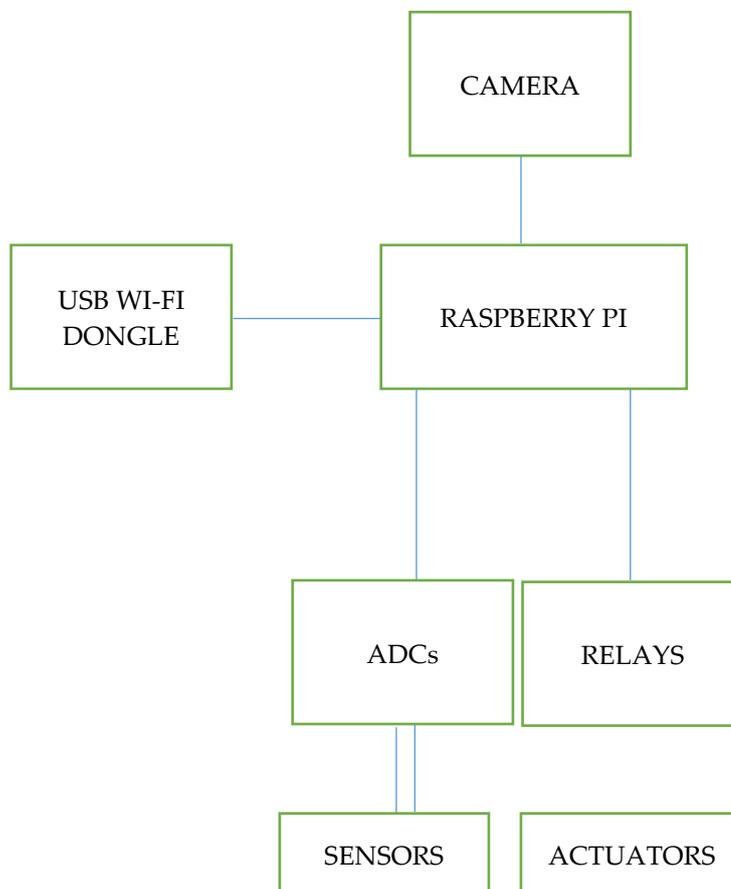

Figure 2. Circuit Diagram for poultry farm control

The list below contains the hardware components and modules used in the proposed solution.

a) *Raspberry Pi:*

At the heart of the system is a Raspberry Pi 4 Model B (2GB), selected for its high performance, 1.5 GHz quad-core ARM Cortex-A72 processor, and 2 GB LPDDR4 RAM. The single-board computer is affordable while capable of processing and streaming real-time data and video, and managing data. The Pi features dual-band Wi-Fi, Bluetooth 5.0, and Gigabit Ethernet connections for reliability. USB 3.0 ports, a 40-pin GPIO

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header, a dedicated camera port 27, and a dedicated display port place the model in a range, making it a strong candidate for smart/bind farming solutions. Cloud platforms such as Firebase and Google Cloud extend the ability to achieve higher-level, scalable automation via an infinitely connected computer system, creating an effective, practical solution for small- to medium-sized poultry farms.

b) *DHT22 Sensor:*

The DHT22 sensor was chosen for temperature and humidity monitoring due to its accuracy and reliability. It has a temperature accuracy of ±0.5°C and humidity accuracy of ±2–5% RH. It operates at temperatures between -40°C and +80°C and humidity levels of 0 to 100% RH. Its sampling rate is 0.5 Hz (1 every 2 seconds) and is low power (< 2.5 mA), making it very useful for continuous monitoring of poultry environment factors. Figure 2a and 2 b show the complete hardware system.

c) *MQ-137 Sensor and ADS1115 ADC:*

The MQ-137 sensor was used for ammonia (NH_3) gas detection, a crucial factor in poultry health. This sensor operates at temperatures from -10°C to 50°C and a humidity range of 20% to 90% RH. It outputs an analog (sensor) signal. Because the Raspberry Pi does not have an analog input, an ADS1115 16-bit ADC was used to convert the sensor's output to a digital signal with minimal error.

d) *Relay Module:*

The relay module allows the control of electrical items, such as fans, lights, heaters, and exhaust systems, among others. All of these items can be automatically controlled to switch on or off based on sensors, or manually via the mobile application, to support improved climate control.

e) *Camera Module:*

The Raspberry Pi Camera Module V1 has a 5MP sensor for real-time video monitoring. This camera connects directly to the Raspberry Pi and provides remote visual monitoring of the user's poultry and farming practices.

f) *Wi-Fi Dongle:*

A USB SIM-based 4G LTE dongle was used to provide data connectivity for real-time data transmission, remote monitoring, and cloud capture and transmission.
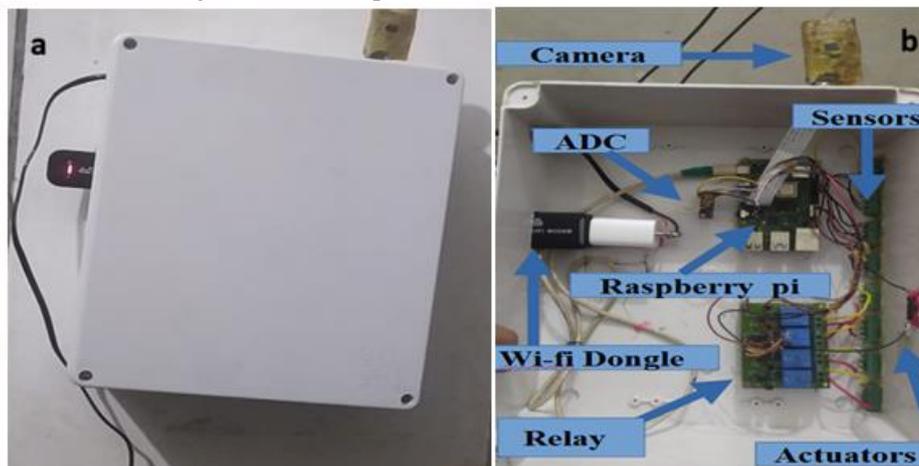

Figure 3. a) Hardware device (outer box) used in the present research, b) Various hardware components used

2.3 Software Design

2.3.1 Android Application and Cloud-Based Integration:

A customized Android application was developed using Android Studio, allowing users to register, link their farms via a unique hardware identifier, enter batch details (Breed, Number of chicks, Start date, and feed type), use the application to display and monitor data, control actual equipment, including regulated alerts; and then maintain all crucial farm records in the cloud. The poultry farm is monitored and controlled using a custom Android mobile application developed in Android Studio.

2.3.2 App User Interface (UI):

The application interface is divided into five sections:

a) The application will indicate ideal feed intake, expected daily gain, and total weight, and allow the user to report actual feed intake, mortality, and sales (number, weight, and date).

b) Alerts the user to disease risk and vaccinations based on breed and age.

c) Will report environmental conditions (temperature, humidity, ammonia, etc.) in actual and ideal values with machine learning predictions.

d) Will allow the user to control actuators (manual or automatic), i.e., fans, lights, exhausts, and heaters

e) Will allow the user to view live farm video through the camera module, and all farm data is stored in the cloud.

2.3.3 Cloud Integration:

The system uses Firebase Cloud Messaging as a middleman between the mobile application and hardware. The Firebase service used is:

- Authentication for secure user login and account management.
- Firestore Database to store all farm data, including poultry farm data.
- Firebase Realtime Database- to manage live update data from the mobile application and device.

Figure 4 shows the flow of data through the hardware interface and the output on the Android mobile app. Figure 5a, b shows the user interface of the Android application, along with the camera-enabled system, which has a provision to enter data and obtain outputs in the form of temperature, humidity, and ammonia level.
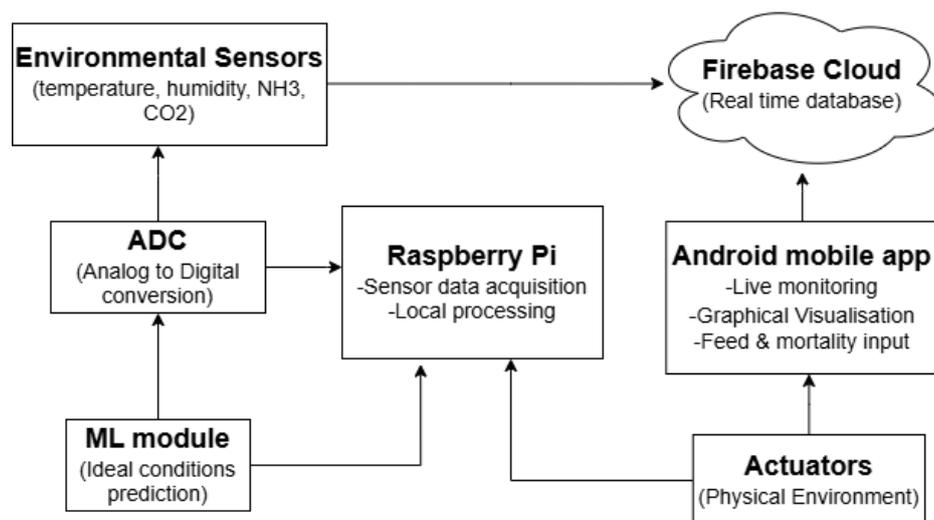

Figure 4. Flowchart representing the data flow decision process of the installed hardware and software

The application's primary operational dashboard, shown in Figure 5(a), allows users to view and enter crucial farm parameters for batch management and production performance. Batch details, including batch number, bird age (in days), total number of chicks, cumulative feed consumption, daily and total weight gain, mortality count, and sales data, are displayed on the interface. Daily feed intake, mortality records, and sales data can be manually entered and stored in a cloud database for time-stamped recordkeeping and performance assessment. Along with ideal reference values generated by the Machine Learning (ML) model, the dashboard also displays current environmental characteristics, including temperature, humidity, and ammonia concentration. The camera-enabled monitoring mode of the application, which displays live video streaming from the Raspberry Pi camera module, is shown in Figure 5(b). Without being physically present at the farm, this function enables remote visual observation of bird behavior, stocking density, feeding activity,

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and overall farm hygiene. To ensure contextual awareness of agricultural circumstances, environmental elements are updated in tandem with the live video feed.

Figure 5. a) User interface of the Android App   b) User interface when the camera is enabled

2.3.4 Data Collection and Processing Method:

The environmental data, temperature, humidity, ammonia levels, and ideal temperature (according to humidity and age of chicks) are collected by the Raspberry Pi and sent to Firebase Firestore. The data is stored in an array, with each data record time-stamped for accurate data tracking and time-lapse analysis.

When collecting environmental data, the IoT system also collects user-input data on actual feed intake, mortality counts, mortality dates, number of birds sold, selling weights, and selling dates. This user-input data is also stored in Firebase for future analysis and evaluation of farm performance.

2.3.5 Processing Method:

When the user opens the mobile application, it retrieves all relevant environmental and user-input data from Firebase and displays it in a user-friendly format. It will also retrieve configuration and control data from Firebase and operate appropriately when the hardware is powered up.

2.4 Power Management

Power management must be considered for any automated IoT system, especially on poor and semi-urban poultry farms, where achieving stable power is potentially difficult. Accordingly, the proposed smart poultry management system was devised with energy-efficient and power-management designs to facilitate continuous monitoring and control.

The system power supply was powered from 7-24V using a regulated AC-to-DC adapter that provided 5V to the Raspberry Pi, which was also the power control controller for the overall system. The main controller (Raspberry Pi) controls all sensors and actuators via GPIO pins. However, to protect against failure points and prevent potential overload of the GPIO pins and component failure during use, there are also voltage-regulated designs (which automatically drop as the supply voltage increases) as well as protection designs (diodes) on various sensor/actuator circuits. For the actuators/devices that require higher-voltage (high-side) operation (heating elements and ventilation fans, etc.), the operations are relatively controlled with

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the established relay schematic on a power supply of their own, with regulated power that continuously provides medium power. Table 1 summarizes the equipment used and the respective component costs.

Table 1. Equipment used for the poultry monitoring system with cost

Category	Component/Module	Purpose	Approx Unit cost (USD)
Hardware	Raspberry Pi 4 Model B (2GB RAM)	CPU for the sensor data acquisition, cloud communication, and actuator control	42
	DHT22 Sensor	Temperature and humidity monitoring	4
	MQ-137 Gas sensor	Ammonia gas detection	14
	ADS1115 (16-bit ADC)	Analog-to-digital conversion for gas sensor output	7
	Relay Module (4–8 Channel)	Switching control	5
	Raspberry Pi Camera Module V1 (5 MP)	Live video monitoring	14
	4G LTE USB Wi-Fi Dongle	Internet connection	12
	Enclosure, wiring, connectors	Connecting wires	7
Power supply	AC–DC Regulated Adapter	Power supply for system operations	6

With a total deployment cost of about USD 110–120, the suggested system is intended to be an affordable yet scalable smart chicken farm management solution. The suggested approach offers a far more economical option without sacrificing crucial monitoring and control features compared to commercial smart poultry automation systems in industrialized nations, which frequently cost between $500 and $1000.

3. Results and Discussion

The intelligent automated poultry management system underwent extensive field tests to assess its performance, accuracy, reliability, and overall impact on poultry production management. The evaluation was comprehensive and included sections on sensor accuracy, system response, program usability, financial benefits, and limitations encountered during the deployment of the intelligent automated poultry management system (IAPMS).

3.1 Sensor accuracy and system response

The hardware system, constructed by interfacing a Raspberry Pi with a DHT22 (temperature and humidity), MQ137 (ammonia), MQ135 (CO_2), and 1 feed level sensor, operated mostly as expected in our test scenarios. The DHT22 displayed consistent temperatures within ±0.5°C and humidity within ±2% RH, as measured by reference digital instruments. The MQ137 and MQ135 were capable of detecting the changes in ammonia and carbon dioxide, but had to be calibrated fairly often, especially in high-dust environments encountered in poultry houses.

The data intercepted from the sensor was sent to the Raspberry Pi and uploaded to Firebase Cloud. The system had low latency, with approximately 1.7 seconds elapsed from the time the data was captured to the time it was relayed. The actuators responded quickly when environmental conditions changed, in most

cases initiating responses (fan, heater, feeder) with a nominal time of 2-3 seconds from the input command from the mobile application or from environmental thresholds.

3.2 Real-time monitoring and user interface

The mobile application was developed, integrating Firebase backend capabilities, and was important for the implementation of real-time monitoring and management of poultry production. The app dashboard, accessed by an Administrator or Manager, displayed real-time environmental conditions, fed recommendations based on chick age, and presented historical data in a time-series charting and tabular format. Screenshots taken during deployment showed a clean, user-friendly interface with color-coded alerts, mortality records by batch, and graphs of ammonia and CO_2 levels over time. The user could turn controls on and off manually or let the system run solely on sensor inputs.
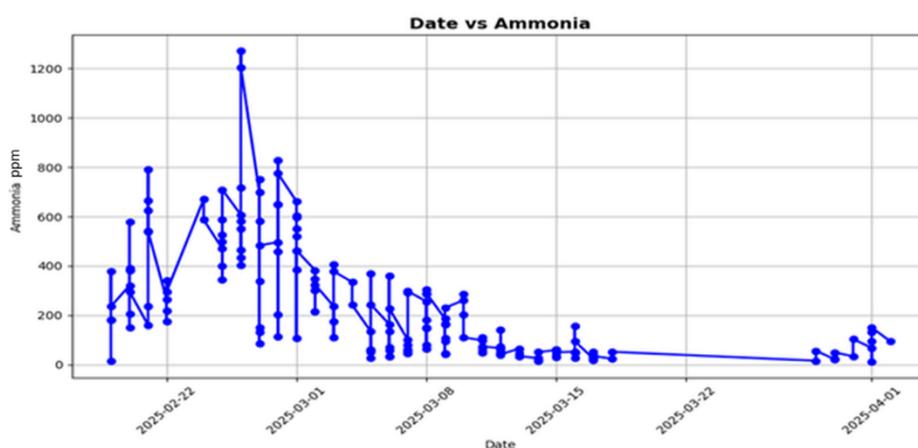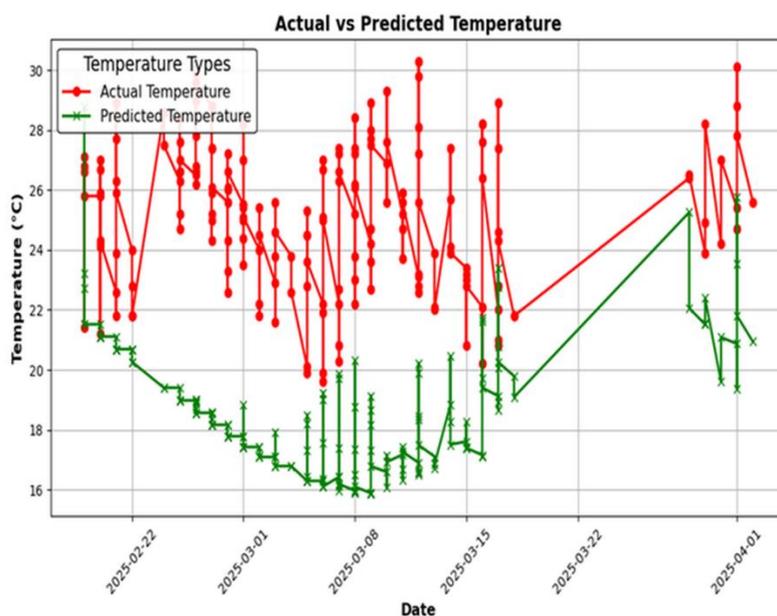

Figure 6. Graphical Analysis of Ammonia Vs Time

Figure 7. Graphical Analysis of Actual and Predicted Temperature

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The graph in Figure 6 above depicts fluctuations in ammonia concentration over time while the system was installed at Jassal Poultry Farm. At first, ammonia concentrations were highly variable, peaking at 1200 ppm, which is detrimental to poultry health and often results in higher mortality and slower growth. Implementing the smart automated monitoring system, however, clearly demonstrates a reduction in ammonia levels throughout the period of activity, particularly after the early part of March. By the end of the period of reference (April 1st, 2025), ammonia levels would remain stable at less than 50 ppm, which is an ideal concentration for a poultry environment. This strongly illustrates how our systems and processes would optimize the birds' health in the study, as the farmers were able to take action quickly based on real-time alerts and remote controls via the mobile application. Not only were mortality rates significantly reduced, but flock performance also improved. A combination of poor ventilation techniques, poultry litter buildup, and a lack of ongoing environmental feedback before system installation can be blamed for the initially high and erratic ammonia concentrations seen during the early stages of deployment (Figure 6). After installing the intelligent automated poultry management system (IAPMS), prompt activation of ventilation systems and exhaust fans was enabled by continuous monitoring and real-time notifications. Ammonia levels consequently steadily dropped and stabilized.

Figure 7 further demonstrates that the actual temperature readings showed variability. At the same time, the system's machine learning algorithm provided accurate ideal temperatures from chick age and humidity levels, and while we could notice that the values were not at ideal levels initially, through time, the predicted values aligned more steadily with the real conditions provided to establish the conditions for the farmers to maintain the environment. This intelligent process predicted conditions to make adjustments, allowing birds to adapt and reducing discomfort to optimize overall performance. As members of the poultry technologies roast of an ML system, farmers could get real-time, permanent data to make informed decisions while using the mobile application, in support of environmental issues and farm efficiency. A supervised regression-based machine learning model trained offline using standard poultry management guidelines and historical farm data produced the projected temperature values shown in Figure 7. The model's target output is the optimal temperature, and its input features include chick age and relative humidity. The Raspberry Pi was used to implement the model for real-time inference and decision assistance. Due to pre-existing environmental conditions and delayed correction activities, such as inadequate insulation, delayed ventilation response, and legacy agricultural practices, the measured (actual) temperatures during the initial deployment period differed from the projected optimum temperatures. The actual temperature values steadily aligned with the anticipated optimal range as the system gradually adjusted actuator responses based on ML guidance and real-time input.

3.3 Effectiveness and Economic Value

On the performance side, the system maintained over 97% uptime during a 30-day continuous test period at Jassal Poultry Farm in Punjab. The system had negligible latency, and the end-user was always aware of and in control of it in real time. As illustrated by the data in Figure 8, the application of the smart poultry farm device led to a substantial decrease in chick mortality. In fact, during the first use of the device, 250 chicks were lost (5.0%). Following the use of the smart poultry farm device, mortality would not exceed 83 chicks (1.66%). This reduction in mortality demonstrates the application of the device in supporting better living conditions for the chick growth stage of the overall poultry system, particularly through better management of ammonia and temperature. Because poultry is a more delicate animal, it has better living conditions, so it will survive and thrive. Figure 9 shows the actual daily feed given to the chicks compared to the ideal quantities suggested by the system. The actual feed closely mirrored or surpassed the ideal feed early on; now, starting on day 20, the actual quantity of feed is less than the ideal level. The system uses machine learning to suggest how much feed to provide per day for the chicks, based on their age and environmental conditions. This helps ensure that chicks do not get under- or overfed, so they do not achieve optimal growth or flock health.

3.4 Aspects of Improving Poultry Farm Efficiency

The implementation of the smart poultry farm management device improved efficiency and reduced lost opportunities for poultry farmers. Farmers using conventional methods were often limited by a chick

mortality rate of about 4-6%, primarily due to inadequate control of temperature and humidity and environmental factors. The introduction of the smart system reduced the mortality rate to 1.66%. Out of 5000 chicks, there were 83 deaths, compared with 250 in the prior fallow period.
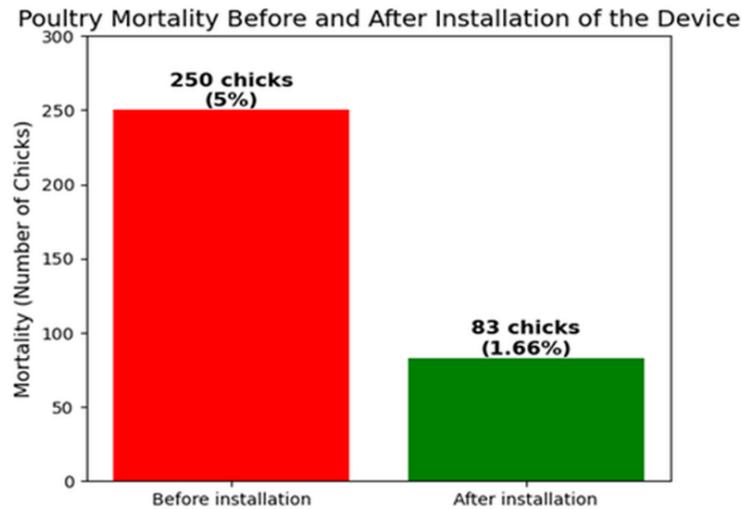

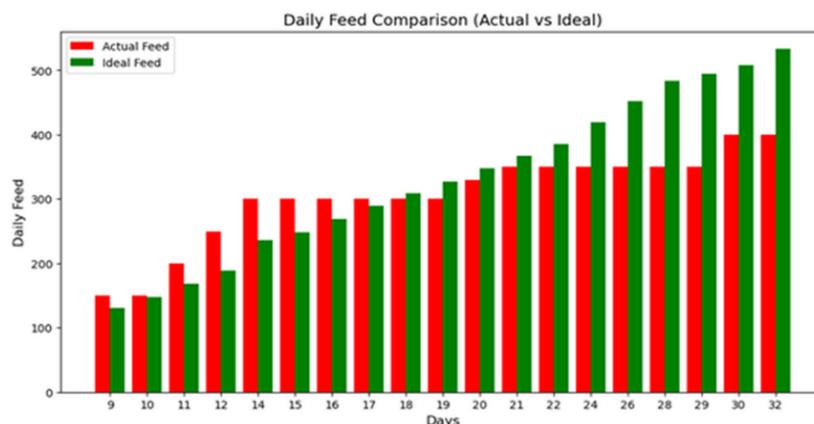**Figure 8.** Mortality before and after the installation of the device on the farm

Figure 9. Ideal and Actual feed

The technique greatly enhanced growth performance and feed consumption efficiency, while reducing mortality. Growth performance was uneven before installation due to erratic feeding schedules and shifting environmental conditions. Following implementation, Figure 6 shows that both underfeeding and feed waste were reduced, with actual feed intake nearly matching the ML-recommended ideal feed curve.

Farmers who use conventional agricultural methods must pay USD 55.8 per week for the lodging of 250 chicks. He is saving USD 37.2 per batch after purchasing the equipment, but he is losing USD 18.5 per batch (83 chicks at USD 0.22 each). Farming six batches for USD 600 a year results in a yearly savings of USD 223.7. Additionally, the device eliminates labor by automating manual monitoring, reducing costs without compromising efficiency. The system's economic advantages, which immediately produced an outstanding return on investment (ROI) in year one, far exceed those of the system.

4. Conclusions

According to the graphical analysis and observed findings, temperature stability, in conjunction with ammonia control, had a major impact on lowering the mortality rate. As seen in Figure 6, ammonia

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concentrations initially reached dangerously high levels (>1000 ppm), known to cause immunosuppression, respiratory stress, and increased chick mortality. After the intelligent automated poultry management system was installed, ammonia levels were lowered to less than 50 parts per million, thanks to real-time detection and closed-loop control that enabled prompt ventilation and exhaust activation. The following are the conclusions drawn from the research work:

- An automated IoT-based poultry farm management system has been successfully developed using low-cost components, including a Raspberry Pi and multiple environmental sensors (DHT22, MQ137, and MQ135).
- The system provided real-time monitoring of fundamental environmental parameters: temperature, humidity, ammonia, and CO_2 concentration, providing better overall environmental control within the poultry houses.
- The mobile application supported farmers with an easy-to-access live data stream, graphical displays, and reporting of environmental parameters, feed recommendations, mortality listings/historical mortality, and batch data.
- Implementing the system in the field greatly improved operational efficiency and reduced base mortality from 5% to 1.66%, leading to an annual total cost benefit of over USD 210 for small-scale poultry farms.
- It also provided very reliable data, with greater than 97% uptime, and reduced latency between the sensors and applications (including 2 seconds).
- The smart system reduced labour requirements compared to manual methods, which typically required the farmer to visit the poultry multiple times a day to monitor the birds, and enabled the farmer to start deriving conclusions from the data and data-derived insights.
- The hardware and software were designed to be useful, scalable, and flexible to a range of farm sizes and local conditions.
- The design of this system will support redevelopment with enhancements (e.g., solar power integration, offline caching, and the introduction of AI tools for predictive analytics) and address poultry health before issues arise.

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a. Conceptualization: Jaiinder Preet Singh, Piyush Gulati
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c. Hardware: Hemant Kumar, Prakash Mahto, Ashish Choudhary
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e. Investigation: Jaiinder Preet Singh, Hemant Kumar, Prakash Mahto, Ashish Choudhary
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h. Writing-review and editing: Jaiinder Preet Singh, Piyush Gulati, Vikas Sharma
i. Supervision: Jaiinder Preet Singh, Piyush Gulati

Future Work:
While the progress made so far with the current system for automating poultry farm management using IoT has been good, there are many opportunities for future enhancement. One of the main areas will be to incorporate solar power so the system can run in circumstances where the power supply is unreliable, promoting sustainability and reducing long-term energy costs. Another opportunity for enhancement will involve the application of artificial intelligence (AI) algorithms, which will enable predictive analytics for disease detection, feed optimization, and early warning alerts based on historical and real-time data. The mobile app will be improved by adding offline functionality with local data caching and processing, so that

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farmers can continue operating even in poor internet conditions and not lose surveillance or control of their poultry. To increase accessibility, particularly for farmers without a technological background, adding voice commands in regional languages will help. The current sensor array could be extended to include hydrogen sulfide (H_2S) sensors and cameras for behaviour monitoring, which would provide a better overview of overall poultry health and the environment. There will be improvements to the alerts and notifications system, via SMS and app notifications, to inform and guide users in serious situations. Another area of development will be a centralised cloud-based dashboard that supports multiple farms. With a general overview of many farms, the development of a module for inventory tracking, and possibly a market-monitoring module as well, a smart poultry business can be managed end-to-end.

Conflict of interest: The authors declare no conflict of interest.

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