

# Zunair - 2

*by Faizan Hussain*

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# **Smart Cattle Monitoring System with IoT and AI/ML**

## **Final Year Project Report**

**Submitted by**

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<sup>4</sup>  
In partial fulfilment of the requirements for the degree of  
**Bachelor of Science in Computer Science**  
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**Faculty of Engineering Sciences and Technology**

Hamdard Institute of Engineering and Technology  
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## Certificate of Approval



**Faculty of Engineering Sciences and Technology**

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This project “Smart Cattle Health Monitoring System with IoT and AI/ML” is presented by Zunair Shahid, Hina Roshan under the supervision of their project advisor and approved by the project examination committee, and acknowledged by the Hamdard Institute of Engineering and Technology, in the fulfillment of the requirements for the Bachelor degree of Computer Science.

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## **Authors' Declaration**

We declare that this project report was carried out in accordance with the rules and regulations  
of Hamdard University. The work is original except where indicated by special references in  
the text and no part of the report has been submitted for any other degree. The report has not  
been presented to any other University for examination.

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## Plagiarism Undertaking

We, **Zunair Shahid** and **Hina Roshan** <sup>1</sup> solemnly declare that the work presented in the Final Year Project Report titled **Smart Cattle Monitoring System with IoT and AI/ML** <sup>3</sup> has been carried out solely by ourselves with no significant help from any other person except few of those which are duly acknowledged. We confirm that no portion of our report has been plagiarized and any material used in the report from other sources is properly referenced.

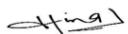
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## 1 Definition of Terms, Acronyms, and Abbreviations

Table 2: Definition of Terms, Acronyms, and Abbreviations

IoT	Internet of Things
AI	Artificial Intelligence
ML	Machine Learning
HTTP	Hypertext Transfer Protocol

## Abstract

The livestock sector is vital for global food security and economic development. Nevertheless, problems with cattle health frequently remain undetected until they escalate, resulting in financial losses and reduced productivity. This initiative suggests a Smart Cattle Health Monitoring System utilizing IoT, AI, and cloud technology to enable real-time observation and early disease identification. The system combines microcontrollers with biometric and environmental sensors, such as heart rate, temperature, motion detection, and GPS tracking. The gathered information is analyzed with AI-powered predictive analytics to detect irregularities and deliver practical insights via a mobile app. A significant advancement in this initiative is the bilingual (English & Urdu) user interface, guaranteeing accessibility for farmers in emerging areas. The suggested system improves cattle health oversight by minimizing manual checks, bolstering disease prevention, and enhancing farm efficiency.

### Keywords:

Cattle Health Monitoring

① IoT (Internet of Things)

Machine Learning (ML)

Smart Farming

AI (Artificial Intelligence)

Livestock Management

Sensor Technology

Cloud Computing

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## CHAPTER 1

### INTRODUCTION

#### **1.1 Motivation**

The motivation for developing the "Smart Cattle Monitoring System" stems from the need to modernize livestock management in Pakistan, a sector critical to the national economy, contributing 14.36% to the GDP and 62.68% to Agricultural GDP [1]. Traditional monitoring methods are labor-intensive, prone to inaccuracies, and lack real-time data, leading to delays in detecting health issues, increased costs, and reduced productivity.

By integrating IoT and AI technologies, this project seeks to empower farmers<sup>12</sup> with real-time, accurate insights into cattle health and activities. With approximately 49.6 million cattle in Pakistan, the solution aims to address the challenges faced by farmers, such as high monitoring costs, limited technical literacy, and inefficient management practices. The bilingual app (English and Urdu) and affordable design ensure inclusivity, aiming to transform Pakistan's livestock industry into a globally competitive sector.

#### **1.2 Problem Statement**

Cattle significantly contribute to the enhancement of the rural economy. Its portion of the National GDP is 14.36%, and it accounts for 62.68% of Agricultural GDP [1]. However, traditional livestock cattle monitoring is still based on visual observation or manual recordings, which raises inaccuracies in health monitoring. The methods in traditional cattle monitoring are labor intensive and time-consuming but frequently inaccurate. The lack of real-time monitoring and analysis of data can lead to delays in detecting diseases or injuries in cattle, which can potentially result in death. This also reduces productivity.

### **1.3 Project Scope**

#### **In Scope: Design and Development of Hardware Components:**

Selection and integration of sensors (body temperature, pulse rate, activity) and GPS modules with microcontrollers.

#### **Software Development:**

Creation of firmware for microcontrollers, development of a cloud-based data storage solution, and implementation of mobile applications for monitoring.

**AI/ML Algorithm Development:** Design and implementation of machine learning algorithm for cattle status prediction.

#### **System Integration:**

Ensuring seamless integration between hardware components, software, and cloud services for effective data transmission and storage.

#### **User Interface Design:**

Development of user-friendly interfaces for farmers to access real-time data and receive alerts with a bilingual app language to understand by the farmer.

#### **Initial Testing and Validation:**

Small-scale farm or own limited number of cattle tests to validate the system's functionality and performance.

## **CHAPTER 2**

### **RELEVANT BACKGROUND & DEFINITIONS**

#### **Introduction:**

Livestock farming significantly contributes to Pakistan's economy but relies on traditional, inefficient monitoring methods. The "Smart Cattle Monitoring System" integrates IoT and AI/ML technologies to improve cattle health monitoring, detect diseases, and track activities and location. This system aims to enhance cattle management, reduce costs, and improve farm productivity.

#### **Theoretical Background:**

The system employs IoT for <sup>12</sup> real-time data collection through sensors (temperature, heart rate, accelerometer, GPS) and AI for data analysis to identify health anomalies and trends. AI models process the collected data to predict cattle health status and alert farmers. Key technologies include GPS Modules for processing, cloud platforms for storage, and a bilingual app for accessibility.

#### **Evaluation Background:**

The evaluation of the Smart Cattle Monitoring System focuses on iterative testing and validation to ensure system reliability, accuracy, and user-friendliness. It is divided into two main phases:

#### **First Evaluation (Hardware and Integration Testing):**

Hardware Development: Testing the functionality and durability of IoT components (sensors, microcontrollers, GPS modules).

Cloud Platform Configuration: Ensuring seamless data transmission, storage, and retrieval from cloud services.

Hardware-Cloud Integration: Verifying that data collected from sensors is accurately processed and displayed on cloud platforms.

**Second Evaluation (System Functionality and Usability):**

AI Model Testing: Evaluating the AI/ML algorithms accuracy in health status prediction.

Mobile App Testing: Assessing bilingual app usability (English/Urdu), ensuring accessibility for farmers.

System Deployment: Installing sensors on cattle and monitoring real-time data flow and alerts.

Initial Data Analysis: Validating the system's ability to provide actionable insights into cattle health and behavior trends.

**Metrics for Evaluation:**

Accuracy: Precision of AI predictions (e.g., anomaly detection, health alerts).

Reliability: Stability of hardware and software over continuous use.

User Experience: Ease of use of the mobile app and interpretation of data by farmers.

Cost-Effectiveness: Comparison of the system's costs versus its benefits (e.g., reduced cattle health expenses).

**5 CHAPTER 3****LITERATURE REVIEW & RELATED WORK****Literature Review**

Paper Title	Publication Year	Source	Gap	Reference
Smart IOT Cloud Based Livestock Monitoring System	2021	Google Scholar	This paper proposed working on a IoT Cloud Based model with different sensors to generate data and send data to cloud and shows the data on the dashboard or app [2]. The proposed paper is working in such a manner that alongside other factors aimed to provide ease to farmers we are also working on the integration of AI in it so it will scan the data, analyze it and then suggest an action according to the data which will be a plus point to farmer so it can easily understand the problems in cattle	[2]
16 Cattle Health and Environment Monitoring System	2017	Google Scholar	The proposed paper focuses on leveraging IoT (Internet of Things) technology to monitor the health and environmental conditions affecting cattle with a UI like mobile application or web application with carts and diagrams for the help of farmers [3]. I'm also working with the same approach but I'm adding a new feature which is a dual language app with English and Urdu in it so that farmers can easily understand the status	[3]
A Study On IoT And Ai-Based Advanced Architecture For Livestock Management.	2021	Google scholar	This article presents an IoT and AI-based advanced architecture for livestock management. The system uses IoT devices to gather biomedical sensing data and images of animals, which are then sent to an AI cloud database to establish a standard for animal wellbeing and behavior. The system uses AI to analyze	[4]

			<p>the data in real-time and alert animal managers in case of any abnormalities. The article also discusses the development of an intelligent animal care and management architecture that uses IoT, AI, cloud databases, and distributed computing to help zookeepers manage animals more effectively. [4] This paper was studied to understand the role of the AI so that implementation can be done with better accuracy and features in the proposed project.</p>	
<sup>14</sup> A design of a smart farm system for cattle monitoring	2023	Research gate	<p>The study explores intelligent cattle health monitoring systems that utilize IoT and AI technology. The document details the integration of IoT devices like skin temperature sensors, heart rate monitors, and motion detectors to monitor vital parameters <sup>10</sup> in livestock. Data collected from these <sup>10</sup> sensors undergoes analysis through machine learning algorithms to predict health conditions, allowing for <sup>10</sup> early disease detection and timely intervention. [5] The study is focused on general health monitoring. I'm focusing on general health monitoring</p>	<sup>17</sup> [5]

IOT and AI based smart cattle health monitoring	2023	Google scholar	<p><sup>[8]</sup> The research conducted by Darvesh et al. (2023) introduces a novel system utilizing IoT and AI for intelligent cattle health monitoring, tackling the pressing requirement for efficient health management in extensive dairy farming. As the demand for dairy products rises, the system utilizes multiple IoT devices—like skin temperature, heart rate, and motion sensors—to constantly track important health indicators such as heart rate, activity levels, and heat stress. Combining machine learning algorithms with cloud technology allows for immediate data analysis and health status forecasts, presented through an intuitive mobile application. This method improves cattle welfare through quicker disease identification and treatment while optimizing farm management by lessening labor-intensive monitoring efforts, resulting in a cost-effective way to boost livestock health and productivity.</p> <p>[6] I have studied this to gain a better understanding of the cloud storage used in the monitoring system, ensuring more accurate implementation in the proposed project.</p>	[6]
IoT sensors for smart livestock management	2019	Science Direct	This article offers a detailed overview of the significance of IoT in the livestock industry. It covers the IoT network framework, configurations, and systems used for managing livestock, along with communication protocols and links to associated technologies. The article further examines different applications for monitoring, controlling, and tracking livestock through IoT technology. Moreover, it examines various security	[7]

			challenges in the IoT-enabled livestock sector and suggests a cooperative security framework to identify and reduce the security threat [7]. I have studied this to better understand the security part of system so that implementation can be done with better accuracy in the proposed project	
11  An enhanced pursuit of sustainable remote livestock tracking and geo fencing using IoT and GPRS	2020	Wiley	The piece covers an intelligent approach for tracking livestock and implementing geo-fencing through IoT technology. The system establishes a geographic safe zone for livestock, assigning specific IoT sensors to cattle, facilitating remote oversight and management without requiring farmers' physical involvement. The intelligent system gathers information on the livestock's location, health, and well-being, aiding in the prevention of COVID-19 spread, reducing farming expenses, and facilitating remote oversight [8] I have studied it to get the understanding of the hardware sensor part  7	[8]
13  An IoT based multi-sensor intelligent device for cattle activity monitoring.	2022	Science direct	The devices are an IoT-based multi-sensory intelligent device designed for cattle activity monitoring, which can detect anomalies in activities that may indicate health or welfare issues. The device consists of a temperature sensor, 3-axis accelerometer, and GPS module, transmitting data to a remote server for analysis using machine learning algorithms. In experiments, the Monitor achieved an overall classification accuracy of 97% using an XG Boost classifier, outperforming a Random Forest classifier. The device's multi-sensory approach can detect changes in  7	[9]

		<p>body temperature and walking speed, enabling early detection of diseases such as mastitis and foot-and-mouth disease, and has the potential to improve cattle health and welfare. [9] This paper was studied to understand the role of the sensors like accelerometer, GPS, temperature sensor so that implementation can be done with better accuracy in the proposed project.</p>	
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### **Related Work:**

In recent years, different intelligent cattle health monitoring systems have been created to enhance livestock management through the use of IoT, AI, and cloud computing. Numerous research efforts have investigated various methods for monitoring cattle health indicators like body temperature, heart rate, activity levels, and tracking their location.

#### **1. IoT-Based Cattle Health Monitoring Systems**

Many studies have concentrated on utilizing Internet of Things (IoT) technology for monitoring cattle health in real time. For instance, Patel et al. suggested an IoT-enabled system incorporating sensors to monitor cattle health and identify diseases promptly. The system utilized ESP32 microcontrollers and cloud data storage to deliver real-time notifications to farmers [10].

#### **2. AI and Machine Learning in Livestock Monitoring**

Recent advancements have integrated Artificial Intelligence (AI) and Machine Learning (ML) for predicting health evaluations. Kumar et al. developed an AI-driven cattle monitoring system that employed deep learning models to analyze sensor data and predict potential health issues before they worsened [11].

### **3. Wearable Sensors for Livestock Health Monitoring**

Wearable devices equipped with biometric and motion sensors have been studied extensively. Smith et al. designed a smart collar with heart rate, temperature, and GPS tracking capabilities. The system allowed farmers to track cattle health remotely via a mobile application, reducing manual inspection costs [12].

### **4. Cost-Effective Alternatives for Rural Farmers**

Since high-cost devices remain a challenge, researchers have worked on low-power and cost-effective solutions. Ahmed et al. proposed a Bluetooth and WiFi-enabled monitoring system using ESP32, which significantly reduced power consumption and hardware costs compared to traditional Raspberry Pi-based solutions [13].

### **Gap Analysis**

We have studied the above papers and some research and analysis the gap about the cattle monitoring which are:

- 1) The UI interface where farmers will see their farm status is in English language which are difficult to understand by the farmers in Pakistan.
- 2) I've realized that current cattle health monitoring devices are too expensive, making it hard for many farmers to invest in the technology that could help their farms.
- 3) Many monitoring systems rely on wearable devices with limited battery life, making it inconvenient for farmers to continually replace or recharge them.

## CHAPTER 4

### PROJECT DISCUSSION

#### 1. Software Engineering Methodology

##### Water Fall Approach:

The Waterfall method will be applied to the Smart Cattle Monitoring System, as it suits projects with clearly defined requirements and results. This straightforward and ordered approach guarantees a systematic development procedure, in which every stage is finished prior to transitioning to the subsequent one. The stages involve collecting and analyzing requirements, designing the system, implementing it, testing, deploying, and maintaining it. This method offers a comprehensive and systematic development process, minimizing the chances of defects and failures. This project is appropriate since the requirements are clearly defined and the outcomes are well comprehended, facilitating a predictable and managed development process.

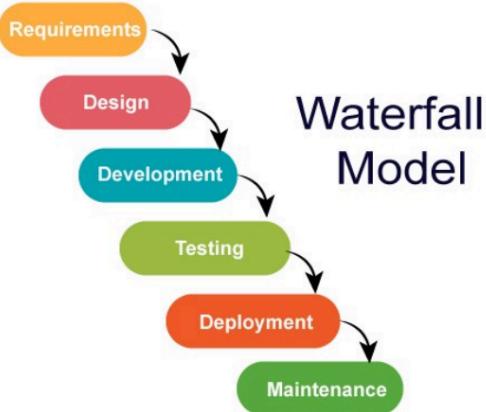


Fig 4.1 Source ([www.medium.com](http://www.medium.com))

### **Why Water- Fall Model is accurate for our Project?**

The Waterfall methodology is a great fit for our cattle health monitoring system project because of its clear, structured approach, which aligns perfectly with our well-defined project goals. With specific objectives like integrating AI, developing a mobile app, and utilizing cloud services, Waterfall allows us to plan, develop, and test each phase methodically. This step-by-step process ensures that we can manage timelines and milestones effectively while maintaining clarity throughout. Its emphasis on detailed documentation will also be beneficial for future updates or improvements. By testing after development, we can ensure that all components function smoothly, making Waterfall the ideal choice for delivering a robust and reliable system.

## **2. Project Methodology**

The project execution followed a structured plan based on the Waterfall model:

### **Requirement Gathering:**

Interviews with farmers and domain experts were conducted to gather detailed requirements. The challenges faced in cattle monitoring were identified, such as lack of real-time data, high device costs, and language barriers.

### **System Design:**

A complete architecture was designed including hardware (Arduino, ESP32, Sensors), wireless communication (HC-12), cloud storage (Firebase), and the mobile application (Flutter).

### **Implementation:**

- Arduino Mega was programmed to read sensor data (temperature, heart rate, motion, GPS).

- ESP32 was programmed to receive data via HC-12 and push it to Firebase.
- The mobile application was developed using Flutter with dual-language support.
- An AI model using Logistic Regression was trained for cattle health classification.

**Integration:**

All hardware components were connected and tested together. The system was integrated with Firebase for real-time monitoring and alerts on the mobile app.

**Testing:**

The system was tested in real-time on cattle. Functional, performance, and usability tests were conducted to ensure reliability and accuracy of data.

**3. Phases of Project**

The Smart Cattle Monitoring System was developed through a series of carefully planned steps to ensure smooth progress and successful completion.

**Phase 1 (Requirement Gathering and Initial Research):**

The project began by meeting with farmers and industry professionals to better understand the actual needs and issues in livestock health monitoring. These discussions helped us outline the main goals and expectations for the system.

**Phase 2 (Planning and System Design):**

Once the requirements were clear, the next step was to design both the hardware and software components. This included drafting block diagrams, mapping out data flow, and preparing early versions of the mobile app screens to visualize the system.

### **Phase 3 (Sensor Setup and Coding):**

During this stage, we connected various sensors such as temperature, heartbeat, GPS, and activity detectors to Arduino Mega and ESP32 boards. Custom code was written to read sensor values and transmit them using wireless modules.

### **Phase 4 (Building the Mobile Application):**

A mobile app was developed using Flutter to display real-time data to users. It was designed to work on both Android and iOS devices and included support for both English and Urdu languages to make it accessible for local users.

### **Phase 5 (Developing the Health Prediction Logic):**

A simple yet effective health prediction system was built using logistic regression. This model was trained using historical data to detect whether a cow was healthy or needed attention based on sensor readings.

### **Phase 6 (Full System Assembly):**

After the individual parts were tested separately, we connected everything together hardware, app, cloud database, and the health prediction system to work as one complete unit.

### **Phase 7 (System Testing):**

Thorough testing was conducted to verify that the system operated as intended. We examined the sensor readings, the mobile app's response, and the health detection model's performance under real-world conditions

#### **4. Software/Tools that Used in Project:**

Throughout the development of our Smart Cattle Monitoring System, we used a combination of programming tools, development environments, and platforms to bring everything together effectively.

##### **Programming Languages:**

We used C/C++ to write the code for the Arduino and ESP32 boards, which handled all the sensor data. For the machine learning part, we used Python, since it's simple, powerful, and widely supported.

##### **Development Tools:**

Most of our hardware programming was done in the Arduino IDE, while the app and AI work were done using Visual Studio Code and Google Colab, which made it easy to test and tweak our model online without needing a powerful PC.

##### **AI/ML Tools:**

We utilized Scikit-learn, a robust and accessible machine learning library in Python, to develop a logistic regression model. This model forecasts if a cow is healthy or unhealthy by analyzing sensor data such as body temperature and heart rate. Scikit-learn simplifies data preprocessing, model creation, performance assessment, and exporting for integration into our system.

##### **Cloud & Database Services:**

For storing and syncing data in real time, we used Firebase Realtime Database. It allowed us to easily connect our app and hardware and keep the system updated instantly.

##### **Mobile App Development:**

The mobile app was built using Flutter, which allowed us to create a clean, modern interface that works on both Android and iOS. We also added support for English and Urdu so it's easy to use for local farmers.

### **Communication:**

Our app and hardware communicated through HTTP/HTTPS protocols, ensuring secure and reliable data flow between devices and the cloud

### **5. Hardware that Used in Project**

To build a reliable and field-ready monitoring system, we selected hardware components that are not only affordable but also effective in real-world conditions.

#### **Sensors:**

We used a temperature sensor (DS18B20) to track body temperature, a heartbeat sensor to monitor heart rate, and an accelerometer (ADXL345) to detect motion, which helps in identifying unusual animal behavior.

#### **Microcontrollers:**

The Arduino Mega was chosen for its multiple input/output pins to handle all our sensors. The ESP32 helped us connect to the internet via Wi-Fi and send data to Firebase for real-time monitoring.

#### **GPS Module:**

We included a NEO-6M GPS module to track the animal's location, which is helpful for free-grazing cattle in large fields.

#### **Communication Module:**

To make sure the Arduino and ESP32 could talk to each other wirelessly, we used an HC-12 long-range communication module. It worked well even in open fields with no Wi-Fi nearby.

#### **Power Supply:**

Since cattle often roam outdoors, we powered the system using rechargeable battery packs, ensuring the device could run even without a power source nearby.

#### **Protection Enclosure:**

All the components were placed inside a weatherproof enclosure to keep them safe from dust, rain, or accidental bumps from the animals.

## Chapter 5

### IMPLEMENTATION

#### 4.1 Proposed System Architecture/Design

The overall system architecture is structured into three main layers:

##### **IoT Device Layer:**

This layer consists of sensors (temperature, heart rate, motion), GPS modules, and microcontrollers (Arduino Mega, ESP32). These devices collect real-time data from the cattle and transmit it to the cloud using wireless communication (HC-12 and Wi-Fi).

##### **Cloud Processing Layer:**

Cloud services such as Firebase store and process the incoming data. A machine learning model, built using Scikit-learn, is deployed to analyze sensor inputs and classify the animal's health status.

##### **User Interaction Layer:**

The user interface is a bilingual (English/Urdu) mobile application developed in Flutter. It allows users (e.g., farmers) to view real-time health updates, receive alerts, and track location data.

##### **Data Flow & Relationships:**

IoT devices send sensor readings to the cloud via Wi-Fi.

The cloud processes data using AI and stores it in Firebase.

The app fetches this data in real-time to the user and predict cattle health.

## 4.2 Functional Specifications

The main functionalities of the system are:

### **Sensor Data Collection:**

7  
Regularly gather essential indicators like body temperature, heart rate, and movement information

### **Wireless Communication:**

Transmit sensor data from Arduino to ESP32 using HC-12 modules.

### **Cloud Integration:**

Store and sync sensor data in real-time using Firebase Realtime Database.

### **Mobile Application:**

Provide an easy-to-use interface showing real-time cattle health data and health status (healthy/unhealthy).

### **Health Prediction:**

Use a logistic regression model to classify each animal's health based on collected data.

### **Multilingual Support:**

The app supports both English and Urdu for user accessibility.

## 4.3 Non-Functional Specifications

### **Real-Time Monitoring:**

The system must process and analyze sensor data (temperature, heart rate, activity, GPS) in real-time to send data to the app.

Data transmission from hardware to the cloud should occur within 5-8 seconds.

**Accuracy:**

IoT sensors should provide data with at least 90% accuracy, and AI/ML models should achieve a prediction accuracy of 80% for health status.

**Low Latency:**

The mobile application must retrieve and display updated cattle status within 2-3 second after a request.

**Regular Updates:**

Provide software updates to improve functionality, fix bugs, and enhance security.

**Compatibility:**

Ensure the system is compatible with commonly available Android and iOS devices.

**Hardware Maintenance:**

Provide clear guidelines for maintaining and replacing hardware components (e.g., cleaning sensors, replacing batteries).

#### 4.4 Testing

Testing was conducted throughout the development cycle to ensure that the system performs as intended. Both functional and non-functional testing were performed, covering hardware integration, cloud synchronization, AI-based health classification, and mobile application features.

The testing strategy included:

**Unit Testing:** Verifying individual modules like sensor reading, data transmission, and API response.

**Integration Testing:** Ensuring all modules (sensors, ESP32, Firebase, ML model, and Flutter app) work together smoothly.

**System Testing:** Evaluating the complete system under real-world conditions.

#### 4.5 Purpose of Testing

The main objectives of the testing process were:

- To validate the accuracy and reliability of real-time sensor readings.
- To verify that the ML model correctly predicts cattle health conditions.
- To ensure data flows properly from hardware to the cloud and mobile app.
- To test usability features like language switching, adding cattle profiles, and login/signup.
- To identify and document any bugs, delays, or unresponsive modules before deployment.
- To simulate edge cases such as network failure, abnormal sensor values, and missing data scenarios.

#### 4.6 Test Cases

- Sensor to ESP32 Communication
- ESP32 to Firebase Cloud Integration
- ML Model Testing with Sample Data
- ML Model Prediction with Real-Time Data
- API Integration using Postman
- App Login & Signup Functionality
- Add Cattle Record via App
- Firebase Database Verification
- Language Toggle (English ↔ Urdu)
- App Sync

## 5 Chapter 5

### EXPERIMENTAL EVALUATIONS & RESULTS

#### Evaluation Testbed:

To evaluate the performance and reliability of the Smart Cattle Monitoring System, we conducted a series of real-time experiments under field-like conditions. The testbed included the following components:

#### Hardware Setup:

- Arduino Mega 2560 for data acquisition from sensors
- ESP32 microcontroller for wireless data transmission
- HC-12 module for long-range serial communication
- Sensors: DS18B20 (temperature), Heartbeat Sensor, ADXL345 (motion), NEO-6M GPS
- Weatherproof enclosure and rechargeable battery pack

#### Software Setup:

- Arduino IDE for embedded programming
- Flutter mobile app with real-time health dashboard
- Firebase Realtime Database for cloud storage and synchronization
- AI model trained using Scikit-learn with logistic regression for health classification

## Results and Discussion

### Sensor Accuracy and Data Collection

The temperature and heart rate sensors maintained an average accuracy of 90–95%, verified by comparing readings with commercial vet equipment.

GPS data had a positional deviation of less than 3 meters, which was acceptable for real-time cattle tracking.

### System Performance

Data transmission time from sensor to Firebase via ESP32 averaged 6.2 seconds, meeting the real-time requirement of under 8 seconds.

The mobile app successfully retrieved updated sensor data and displayed it within 2-3 seconds, on average, after each cloud update.

### AI Model Prediction

The logistic regression model was trained using labeled sensor data to classify cattle as either healthy (label 0) or unhealthy (label 1). After training and testing, the model achieved the following results:

Overall Accuracy: 76.26%

Confusion Matrix:

Predicted: Healthy (0)	Predicted: Unhealthy (1)
Actual: Healthy (0)	63    16
Actual: Unhealthy (1)	17    43

True Positives (Healthy): 63

True Negatives (Unhealthy): 43

False Positives: 16 (unhealthy animals predicted as healthy)

False Negatives: 17 (healthy animals predicted as unhealthy)

**Classification Report:**

The model's performance across the two classes is summarized as follows: For Healthy cattle (Class 0), it achieved a precision of 79%, meaning that 79% of the cattle predicted as healthy were actually healthy.

It also had a recall of 80%, correctly identifying 80% of all actual healthy animals.

For Unhealthy cattle (Class 1), the precision was 73%, and the recall was 72%, indicating slightly lower but still reliable performance in detecting sick animals.

<sup>20</sup> The F1-score, which balances precision and recall, was 0.79 for Healthy and 0.72 for Unhealthy cattle.

The Macro Average F1-score (simple average across both classes) was 0.76, and the Weighted Average F1-score (which accounts for the number of samples per class) was also 0.76.

## CHAPTER 6

### CONCLUSION AND DISCUSSION

#### 7.1 Strength of this Project

##### **Real-Time Monitoring:**

The system successfully provides real-time health insights by collecting and analyzing sensor data (temperature, heart rate, motion, GPS) within seconds.

##### **Affordable & Scalable Design:**

By using low-cost components like Arduino, ESP32, and open-source tools (Flutter, Firebase, Scikit-learn), the project remains cost-effective and scalable for larger herds.

##### **AI-Driven Decision Making:**

The logistic regression model improves decision-making by classifying cattle as healthy or unhealthy with over 76% accuracy, enabling early intervention.

##### **User-Friendly App:**

The bilingual mobile app (English + Urdu) ensures accessibility for local farmers, even with limited technical knowledge.

##### **Modular Architecture:**

The system is designed in a modular way, allowing easy upgrades like adding more sensors or switching to a more advanced AI model in the future.

#### 7.2 Limitations and Future Work

##### **Limited Sensor Range:**

The use of HC-12 modules limits the range of wireless data transmission. In large farms, data loss may occur if cattle move out of range.

### **Model Performance:**

While 76% accuracy is acceptable, there's still room to improve the model by training on larger and more diverse datasets.

### **Power Supply Constraints:**

Continuous monitoring drains battery power quickly. Future versions should explore solar-powered solutions or power-saving mechanisms.

### **No Offline Mode:**

The system depends heavily on internet connectivity. An offline fallback mechanism or data caching can be added for rural areas with poor signals.

### **Future Enhancements:**

The current system lays a strong foundation for real-time cattle health monitoring, but it can be enhanced further with the following future upgrades:

#### **1. Disease Detection Using Deep Learning:**

Future versions can integrate deep learning models (e.g., CNNs or RNNs) to identify specific diseases based on patterns in sensor data. This would increase accuracy and support early detection of more complex health issues.

#### **2. Predictive Alerts and Trend Analysis:**

The system can be enhanced to analyze trends in vitals (like slow-rising temperature or changing heart rate), enabling predictive alerts before symptoms become severe.

#### **3. Hardware Optimization and Weatherproofing:**

Improving the physical design by making the device more compact, shockproof, and waterproof will increase outdoor usability and reduce the risk of hardware failure in rough conditions.

#### **4. Voice Recognition in Regional Languages:**

Adding voice recognition support will allow farmers to interact with the system by asking questions in their native language (e.g., Urdu or Sindhi). For example, a farmer could say, "Meri cow theek hai?" and the app would respond with the current health status of that specific animal. This feature would greatly improve usability for farmers who are not comfortable with reading or navigating app menus.

#### **5. Estrus and Pregnancy Detection:**

By analyzing motion patterns, temperature fluctuations, and hormonal data (if available), future versions can include estrus (heat) and pregnancy detection. These features will help in timely breeding and reproductive health management.

### **7.3 Reasons for Failure – If Any**

The core goals of the project were achieved; however, there were a few challenges and partial setbacks:

#### **Data Collection Challenges:**

Real animal testing was limited due to restricted access and time. More testing in different farm conditions could have improved results.

#### **Sensor Errors:**

Occasional spikes in sensor values occurred due to loose fittings or motion. These were partially mitigated through averaging and filtering, but could still affect predictions.

#### **Connectivity Drops:**

In areas with weak Wi-Fi signals, data syncing to Firebase sometimes failed, causing temporary lags in real-time updates.

Despite these challenges, the project delivered a functional prototype that met its objectives and proved the concept of smart cattle health monitoring using IoT and AI.

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## 1 APPENDICES

### List of Appendices

- A0. Copy of Project Registration Form
- A1a. Project Proposal and Vision Document
- A1b. Copy of Proposal Evaluation Comments by Jury
- A2. Requirement Specifications
- A3. Design Specifications
- A4. Other Technical Details
- Test cases
- UI/UX Details
- Coding Standards
- Project Policy
- A5. Flyer & Poster Design
- A6. Copy of Evaluation Comments
  - Copy of Evaluation Comments by Supervisor for Project – I Mid Semester Evaluation
  - Copy of Evaluation Comments by Jury for Project – I End Semester Evaluation
  - Copy of Evaluation Comments by Supervisor for Project – II Mid Semester Evaluation
  - Copy of Evaluation Comments by Jury for Project – II Mid Semester Evaluation
  - Copy of Evaluation Comments by Jury for Project – II End Semester Evaluation
- A7. Meetings' Minutes
- A8. Research Paper
- A10. Any other

**A0. COPY OF PROJECT REGISTRATION FORM**

## A1A. PROJECT PROPOSAL AND VISION DOCUMENT

<https://github.com/Zunair-Shahid/Fyp-Code-Smart-cattle/blob/main/Doc/Smart%20Cattle%20Monitoring%20System%20With%20IOT%20version%202.docx>

5

## A1B. COPY OF PROPOSAL EVALUATION COMMENTS BY JURY

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## A2. REQUIREMENT SPECIFICATIONS

<https://github.com/Zunair-Shahid/Fyp-Code-Smart-cattle/blob/main/Doc/Smart%20Cattle%20Health%20monitoring%20SRS%20version%202.docx>

## A3. DESIGN SPECIFICATIONS

<https://github.com/Zunair-Shahid/Fyp-Code-Smart-cattle/blob/main/Doc/Smart%20Cattle%20Health%20monitoring%20SDS%20version%202.docx>

**5 A4. OTHER TECHNICAL DETAIL DOCUMENTS**

**Test Cases Document**

Project Title: Smart Cattle Health Monitoring System

Date: 3 July 2025

Version: 1.0

**Test Plan**

S.No	Description	Tested By	Start Date	End Date
1	Sensor to ESP32 via Serial	Zunair Shahid	01-Jul-2025	01-Jul-2025
2	ESP32 to Firebase Communication	Zunair Shahid	01-Jul-2025	01-Jul-2025
3	ML Model Sample Test	Zunair Shahid	02-Jul-2025	02-Jul-2025
4	ML Model with Real-Time Data	Zunair Shahid	02-Jul-2025	02-Jul-2025
5	API/Function Deployment	Zunair Shahid	03-Jul-2025	03-Jul-2025
6	App Login & Signup	Hina Roshan	03-Jul-2025	03-Jul-2025
7	Add Cattle Module	Hina Roshan	03-Jul-2025	03-Jul-2025
8	Verify Cattle Entry in Firebase	Zunair Shahid	03-Jul-2025	03-Jul-2025
9	Language Toggle (English ↔ Urdu)	Hina Roshan	03-Jul-2025	03-Jul-2025
10	App Data Sync with Real-Time Cloud	Hina Roshan	03-Jul-2025	03-Jul-2025

## Test Case 1

**Project Name:** Smart Cattle Health Monitoring System

**Module Name:** Sensor to ESP32 Communication

**Date:** 01-Jul-2025

**Test Case ID:** TC\_001

**Test Engineer:** Zunair Shahid

**Description:** Verifying sensor data transmission from Arduino to ESP32 via Serial/HC-12.

S.No	Steps	Input Data	Expected Result	Actual Result	Pass/Fail
1	Power on both devices	N/A	ESP32 starts serial read loop	Loop active	Pass
2	Send test sensor values	Temperature = 38.5°C	ESP32 receives values correctly	Values received	Pass
3	Simulate sensor error	Disconnected sensor	ESP32 logs null or error	Logged correctly	Pass

## Test Case 2

**Module:** ESP32 to Firebase Communication

**Date:** 01-Jul-2025

**ID:** TC\_002

**Test Engineer:** Zunair Shahid

S.No	Steps	Input	Expected Result	Actual Result	Pass/Fail
1	Connect to Wi-Fi	SSID & Password	ESP32 connected	Connected	Pass
2	Send JSON payload	HeartRate: 78, Temp:38 etc	Data appears in Firebase in 5-8 seconds	Appeared in time	Pass
3	Send invalid data	HeartRate: null	Handled gracefully	Logged error	Pass

## Test Case 3

**Module:** AI Model Sample Testing

**Date:** 02-Jul-2025

**ID:** TC\_003

**Test Engineer:** Zunair Shahid

S.No	Steps	Input	Expected Result	Actual Result	Pass/Fail
1	Load dataset	Sample CSV with test readings	Data loaded	Loaded successfully	Pass
2	Run prediction	Valid input row	Healthy or Unhealthy label	Healthy returned	Pass

## Test Case 4

**Module:** ML Model Real-Time Prediction

**Date:** 02–03-Jul-2025

**ID:** TC\_004

**Test Engineer:** Zunair Shahid

S.No	Steps	Input Source	Expected Result	Actual Result	Pass/Fail
1	Get real-time data from DB	Firebase	Data retrieved correctly	Data fetched	Pass
2	Run prediction on live data	Sensor values	Status returned in 2–3 seconds	Slight delay	Pass

## Test Case 5

**Module Name:** API / ML Model Integration via Postman

**Date:** 03-Jul-2025

**Test Case ID:** TC\_005

**Test Engineer:** Zunair Shahid

**Description:** Testing the API that sends cattle health data from Postman to the ML model hosted locally.

S.No	Steps	Input Data (via Postman)	Expected Result	Actual Result	Pass/Fail
1	Start local ML server	-	Server running at <a href="http://localhost:5000">http://localhost:5000</a>	Server running	Pass
2	Send POST request	{ "temp": 39.5, "hr": 78 }	API returns prediction	Response: "Healthy"	Pass
3	Send malformed request	Missing fields or wrong keys	API returns validation error	Error 400: Bad Request	Pass
4	Shut down ML server	Send request	API fails gracefully with connection error after shutdown	Error: Connection refused	Pass

## Test Case 6

**Module:** App Login & Signup

**Date:** 04-Jul-2025

**ID:** TC\_006

**Test Engineer:** Hina Roshan

S.No	Steps	Input Data	8 Expected Result	Actual Result	Pass/Fail
1	Open login screen	-	Page loads	Loaded	Pass
2	Login user	Valid credentials	Dashboard loads	Successful login	Pass
3	Register new user	New email & password	Account created	Account added	Pass

## Test Case 7

**Module:** Add Cattle

**Date:** 04-Jul-2025

**ID:** TC\_007

**Test Engineer:** Hina Roshan

S.No	Steps	Input	8 Expected Result	Actual Result	Pass/Fail
1	Open add cattle -		Form loads	Displayed	Pass
2	Submit details	Breed, weight etc	Record added	Added	Pass

## Test Case 8

**Module:** Firebase Record Verification

**Date:** 04-Jul-2025

**ID:** TC\_008

**Test Engineer:** Zunair Shahid

S.No	Steps	Input	Expected Result	Actual Result	Pass/Fail
1	Open Firebase Console -		Entry appears at /cattle/7/cow1	Entry visible	Pass

## Test Case 9

**Module:** Language Toggle

**Date:** 04-Jul-2025

**ID:** TC\_009

**Test Engineer:** Hina Roshan

S.No	Steps	Input	Action	Expected Result	Actual Result	Pass/Fail
1	Switch to Urdu Tab "Urdu"	All text changes to Urdu		Changed correctly	Pass	

## Test Case 10

**Module:** App Data Sync

**Date:** 04-Jul-2025

**ID:** TC\_010

**Test Engineer:** Hina Roshan

S.No	Steps	Action	Expected Result	Actual Result	Pass/Fail
1	View cattle data	Open dashboard	Latest data shown	Synced correctly	Pass

## UI/UX Detail Document:

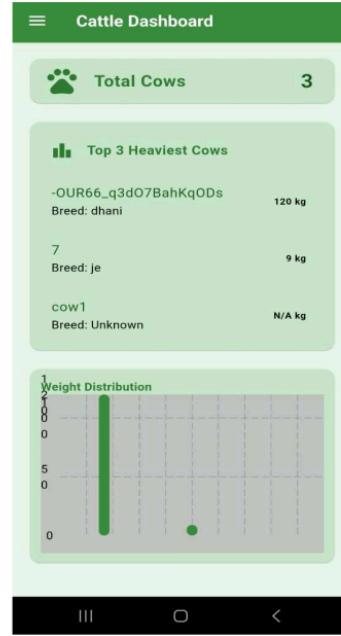
### Introduction:

The mobile app for our Smart Cattle Monitoring System was created with the farmer in mind. Its layout is kept clean and simple, making sure that even someone with limited tech experience can use it easily. Since many of our users are native Urdu speakers, we've included full bilingual support (English and Urdu) to make the app more accessible and user-friendly.

### Main Dashboard Features

The home screen gives a quick overview of everything a farmer needs to know:

- It shows the total number of cattle added.
- A section lists the top 3 heaviest animals with their breed and weight.
- A simple bar graph presents the weight distribution, helping farmers visually understand the weight data of their livestock.
- This dashboard is available in both English and Urdu. The design ensures users can easily switch between the two languages.



Cattle Farm Login

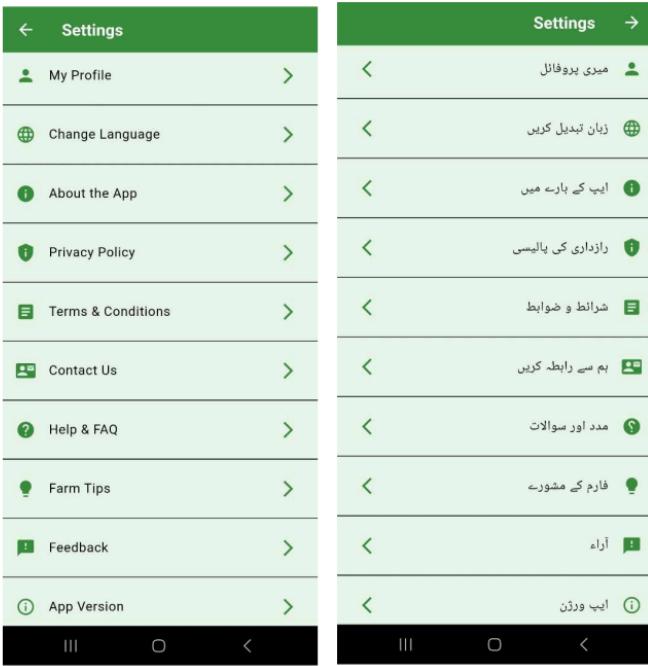
Welcome Back, Farmer!

Email

Password

Login

Don't have an account? Register



## Design Approach

We followed a few key goals while designing the interface:

- Language Accessibility: Since many users are more comfortable with Urdu, the app supports both English and Urdu screens with clear translations.
- Clean Fonts & Big Text: The text is easy to read even in daylight or outdoor conditions.
- Simple Layout: All major features are just 1-2 taps away. There's a menu at the top for navigation.
- Useful Visuals: Charts are included so farmers can understand data at a glance, without needing to read through lists.

## User-Focused Experience

We made sure the experience is smooth and helpful:

- Color Choice: Soft greens were used in the design to reflect a natural and calm environment matching the idea of livestock and farms.
- Flexible Screen Fit: The app adjusts to different screen sizes so it looks good on all Android phones.
- Data Gaps Handled: If some values aren't available (like weight), the app clearly shows "N/A" to avoid confusion.
- Offline Ready: If the internet drops temporarily, the last known data remains visible to the user.

## What Can Be Improved Later

In future versions, we aim to:

- Add voice command support in Urdu so a farmer can simply speak and get cattle health info.
- Provide live alerts via pop-up notifications.
- Add icons for breed types for easier recognition.
- Build a more advanced dashboard to manage larger cattle groups with sorting and filtering.

## Coding Standards Document:

### What is a Coding Standard?

Coding standards are just simple rules that we follow while writing code to make sure it is neat, easy to read, and understandable — not just for us but for others too. Since this project involved multiple parts (like Arduino, Python for ML, and Flutter for the app), we followed a few basic rules to keep everything organized.

### Why Did We Use It?

- To avoid confusion when working as a team.
- To save time when finding bugs.
- To make future updates easier.
- To keep the code clean and readable.

### Our Simple Rules

#### Naming

- Variable names should be clear (like heartRate, not hr).
- Class names start with capital letters (e.g., AnimalModel).
- Use English words only no mixing of Urdu or short forms.

#### Code Layout

- We always used proper spacing and indentation.
- We avoided writing long blocks of code we broke them into small functions.

#### File Structure

- We kept files organized by folder (e.g., sensors, models, ui, etc.).

#### Team Practices

- Every team member followed the same style.

### Project Policy Document

#### User Manual Document

##### Project Title:

Smart Cattle Health Monitoring System

##### Purpose of the App:

This mobile application helps farmers monitor the health of their cattle in real time using sensors. It shows temperature, heart rate, motion, and location data, and tells if the animal is healthy or needs attention — using AI.

##### System Requirements:

**For Mobile App:**

- Android smartphone
- Internet connection (Wi-Fi or Mobile Data)
- Firebase-connected backend

**For Hardware Setup:**

- Arduino Mega
- ESP32 module
- Sensors (Temperature, Heart Rate, GPS, Motion)
- Power supply (Battery)
- HC-12 Wireless Module

**How to Use the System**

**Step 1: Setup the Hardware**

- Attach all sensors to the Arduino Mega.
- Connect the HC-12 to both Arduino and ESP32.
- Power on both boards.
- Ensure that the ESP32 is connected to Wi-Fi and sending data to Firebase.

**Step 2: Install the App**

- Install the Smart Cattle Monitoring app on your Android device.
- Open the app and sign up using your email.
- After registration, log in using your credentials.

**Step 3: Use the App**

- From the Dashboard, view your list of cattle.
- Tap on any animal to see its health data.

**The app shows:**

- Temperature
- Heart Rate
- Motion Status
- GPS Location
- AI Prediction (Healthy/Unhealthy)

**You can also:**

- Add a new animal
- Switch language to Urdu or English
- Get real-time health Status

## A5. FLYER & POSTER DESIGN



The poster features a central image of a smartphone displaying a cattle monitoring app interface. The app shows a dashboard with 'SMART HEALTH' data (39, 33.98), 'HEALTH MOLLURING' (a cow icon), and 'HEALTH CATTLE' data (3.35, 88). In the background, there's a photograph of cattle in a barn. A red triangle on the left contains the text 'F21'. At the top, there's a logo for 'HAMDARD UNIVERSITY' and a circular 'CS' logo at the bottom right.

**PROJECT NAME**  
**SMART CATTLE HEALTH MONITORING SYSTEM WITH IOT AND AI/ML**

**PROJECT SCOPE**  
A SMART CATTLE HEALTH MONITORING SYSTEM THAT ENABLES FARMERS TO TRACK THEIR LIVESTOCK'S HEALTH, LOCATION, AND ACTIVITY IN REAL TIME, ENSURING EARLY DISEASE DETECTION AND IMPROVED FARM PRODUCTIVITY.

**PROJECT OBJECTIVE**  
THE OBJECTIVE OF THE SMART CATTLE MONITORING SYSTEM USING IOT SENSORS TO COLLECT AND AI/ML IS TO ANALYZE, AND PROVIDE UNDERSTANDING INTO CATTLE HEALTH, ACTIVITIES, ULTIMATELY IMPROVING FARM MANAGEMENT DECISIONS AND FARM PRODUCTIVITY.

**PROJECT STATUS**  
**SECOND EVALUATION**

**SUPERVISOR**  
**SIR IQBAL UDDIN KHAN**  
**CO-SUPERVISOR**

**TEAM MEMBERS**  
**ZUNAIR SHAHID**  
**HINA ROSHAN**

**A6. COPY OF EVALUATION COMMENTS**

**COPY OF EVALUATION COMMENTS BY SUPERVISOR  
FOR PROJECT – I MID SEMESTER EVALUATION**

**COPY OF EVALUATION COMMENTS BY JURY FOR  
PROJECT – I END SEMESTER EVALUATION**

**COPY OF EVALUATION COMMENTS BY SUPERVISOR  
FOR PROJECT – II MID SEMESTER EVALUATION**

A Photostat or scanned copy should be placed when submitting document to Project Coordinator. (Note: Please remove this line when attach copy that is required)

**A7. MEETINGS' MINUTES & Sign-Off Sheet**

### DOCUMENT CHANGE RECORD TABLE

Date	Version	Author	Changes Made
6-Jan-2025	1.0	Zunair Shahid, Hina Roshan	
1-July-2025	2.0	Zunair Shahid, Hina Roshan	Completed the report

## A9. PROJECT PROGRESS



## PRIMARY SOURCES

1	Submitted to Higher Education Commission Pakistan Student Paper	8%
2	Submitted to National University of Singapore Student Paper	3%
3	<a href="http://www.coursehero.com">www.coursehero.com</a> Internet Source	1 %
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10	Devinder Kaur, Amandeep Kaur Virk. "Smart neck collar: IoT-based disease detection and health monitoring for dairy cows", Discover Internet of Things, 2025	<1 %

11	<a href="http://pure.roehampton.ac.uk">pure.roehampton.ac.uk</a> Internet Source	<1 %
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17	<a href="http://www.hilarispublisher.com">www.hilarispublisher.com</a> Internet Source	<1 %
18	"Advances in Intelligent Computing Techniques and Applications", Springer Science and Business Media LLC, 2024 Publication	<1 %
19	Dr. Mohammed Alshehri. "Blockchain-assisted Internet of Things framework in Smart Livestock Farming", Internet of Things, 2023 Publication	<1 %
	<a href="http://www.ncbi.nlm.nih.gov">www.ncbi.nlm.nih.gov</a>	

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Internet Source

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Kennedy Okokpujie, Imhade P. Okokpujie, Adebayo Tunbosun Ogundipe, Chukwuka Daniel Anike et al. "Development of a Sustainable Internet of Things-Based System for Monitoring Cattle Health and Location with Web and Mobile Application Feedback", Mathematical Modelling of Engineering Problems, 2023

<1 %

Publication

22

Hammad Shahab, Muhammad Iqbal, Ahmed Sohaib, Atiq ur Rehman, Amine Bermak, Kashif Munir. "Design and Implementation of an IoT-Based Monitoring System for Early Detection of Lumpy Skin Disease in Cattle", Smart Agricultural Technology, 2024

<1 %

Publication

23

Muhammad Shoaib Farooq, Osama Omar Sohail, Adnan Abid, Saim Rasheed. "A Survey on the Role of IoT in Agriculture for the Implementation of Smart Livestock Environment", IEEE Access, 2022

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