SMARTROSE: AI-IOT PLATFORM FOR SMART GREENHOUSE ROSE FARMING IN SRI LANKA

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Project Proposal Report

Rodrigo U M T H

B.Sc. (Hons) Degree in Information Technology Specialized in Information Technology

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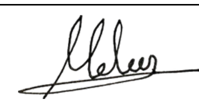
DECLARATION

I declare that this is my own work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning, and to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Name	Student ID	Signature
Rodrigo U M T H	IT22888648	

The supervisor(s) should certify the proposal report with the following declaration:

The above candidate is carrying out research for the undergraduate Dissertation under my supervision.

Signature of the supervisor: Date

ABSTRACT

Greenhouse-based rose cultivation provides enhanced control over environmental factors, resulting in improved flower quality and year-round production. However, middle-scale rose farmers often face challenges in managing multiple greenhouses efficiently. Manual monitoring of environmental conditions and the uncoordinated use of grow lights, misting systems, and fans can lead to excessive energy consumption, plant stress, and inconsistent yields. These problems are further compounded by unreliable internet access in rural agricultural regions, limiting the effectiveness of fully cloud-dependent automation systems.

To address these issues, this research introduces a Centralized Stress Prediction and Energy Optimization System, a key component of the SmartRose AI–IoT platform. The system deploys long-range LoRa-enabled sensor nodes to collect real-time data from individual flower beds across multiple greenhouses. These nodes monitor temperature, humidity, UV intensity, air quality, and soil moisture. Data is transmitted to a centralized ESP32-based gateway capable of operating offline and synchronizing with the cloud when connectivity becomes available.

A lightweight machine learning model analyzes the sensor data to predict stress-prone conditions and generate recommendations for optimizing the use of energy-intensive systems such as lighting, misting, and ventilation. A centralized dashboard presents greenhouse- and bed-level visualizations, alerts, and optimization suggestions. By integrating predictive analytics with real-time data fusion and energy-aware decision-making, this component offers a scalable and cost-effective solution for improving rose health, reducing electricity usage, and streamlining greenhouse management for mid-scale growers.

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LIST OF ABBREVIATIONS

Abbreviation	Description
AI	Artificial Intelligence
ML	Machine Learning
IoT	Internet of Things
LoRa	Long Range Communication
ESP32	Espressif ESP32 Microcontroller
UV	Ultraviolet
RF	Random Forest
MQTT	Message Queuing Telemetry Transport

1. INTRODUCTION

Rose cultivation is one of the most commercially valuable segments of floriculture, with growing demand in both local and export markets. To meet quality and supply expectations, many farmers have adopted greenhouse-based rose farming to control environmental variables such as temperature, humidity, and light exposure. This approach enables year-round production and improved flower quality. However, maintaining a stable microclimate across multiple greenhouse tunnels remains a complex task, especially for middle-scale growers who operate with limited automation or connectivity infrastructure [1], [2].

Manual monitoring of each tunnel or flower bed becomes labor-intensive and inefficient as the number of structures increases. Unregulated environmental control often leads to plant stress, affecting flowering rates, petal coloration, and vase life. Moreover, excessive use of grow lights, misting systems, and fans—without real-time monitoring—results in higher electricity consumption and operational costs [3]. In many rural or semi-urban regions, internet connectivity is unreliable, making cloud-reliant systems impractical for continuous greenhouse management [4].

To address these limitations, the SmartRose platform integrates intelligent Internet of Things (IoT) and Machine Learning (ML) technologies to support precision rose farming. This project proposes one of several components within that platform: a Centralized Stress Prediction and Energy Optimization System. The system deploys Long Range (LoRa)-enabled IoT sensor nodes across multiple greenhouses to monitor Ultraviolet (UV) intensity, temperature, humidity, air quality, and soil moisture in real time. These nodes transmit data to a centralized ESP32 microcontroller (ESP32)-based gateway that can function offline and synchronize with cloud storage once connectivity is restored [4], [5].

A lightweight ML model processes this environmental data to predict early-stage stress conditions and recommend targeted interventions—such as adjusting misting duration, reducing grow light usage, or controlling ventilation. These decisions aim to minimize energy consumption while maintaining optimal conditions for rose growth. A centralized dashboard visualizes real-time greenhouse- and bed-level conditions, highlighting zones under stress and suggesting energy-efficient responses to the farmer.

Unlike prior systems, this component is specifically designed for middle-scale rose greenhouse networks and includes offline functionality, LoRa-based communication, and per-bed stress prediction. By combining long-range wireless communication, real-time sensing, predictive modeling, and edge-capable infrastructure, this system provides a low-cost, scalable solution for mid-scale rose growers. It reduces the need for manual oversight, improves energy efficiency, and ensures a stable microclimate across distributed greenhouse setups [5], [6].

1.1. BACKGROUND & LITERATURE SURVEY

Greenhouse-based rose farming has become increasingly important in meeting the quality demands of local and export floriculture markets. Regions with cooler climates, such as Nuwara Eliya in Sri Lanka, offer favorable conditions for cultivating premium rose varieties. However, most mid-scale growers in these regions lack access to advanced automation systems and rely heavily on manual methods to maintain optimal growing conditions. This results in uneven microclimate management, inefficient use of resources, and higher labor costs.

The use of IoT technologies in agriculture has enabled real-time monitoring of environmental factors such as temperature, humidity, UV intensity, and soil moisture. IoT-based greenhouse monitoring systems using LoRa communication have been shown to provide effective long-distance, low-power data transmission across multiple greenhouse zones. For example, Mezouari et al. [1] proposed a LoRaWAN-based intelligent system for multi-greenhouse environmental data collection and visualization, while Gowri et al. [2] implemented LoRa to monitor and control temperature, light, and irrigation in multi-span greenhouses using threshold logic.

In parallel, machine learning (ML) techniques are increasingly being integrated into smart farming systems. ML models such as Random Forest (RF) and Artificial Neural Networks (ANNs) have been applied to classify environmental stress conditions and improve decision-making accuracy in greenhouse control systems [3], [4]. Specifically in floriculture, Bhat et al. [5] demonstrated how ML can be used to optimize microclimate conditions for rose crops, showing improved results in both stress prevention and energy efficiency.

However, many of these systems either lack offline operational capability or are designed for large-scale commercial operations, making them less accessible for medium-scale rose farmers. For instance, Microsoft's FarmBeats project introduced an edge-computing architecture for intermittent connectivity in agriculture [6], but it was targeted at open-field crop monitoring. Meanwhile, Sacăleanu et al. [7] presented an IoT-enhanced decision support system for greenhouse control using LoRa and cloud-based dashboards, but without integrated ML-based stress prediction or zone-level control.

Commercial solutions such as Sense2Grow, implemented in Dutch rose farms, utilize LoRa for sensor data acquisition and visualization [8]. However, these platforms are costly and typically do not offer open-source flexibility or intelligent automation features like energy optimization and per-bed stress analytics.

The literature demonstrates that while individual technologies—such as LoRa, IoT sensing, and ML—have been successfully applied in agriculture, a unified, scalable, and offline-capable system specifically designed for mid-scale rose greenhouse operations remains largely unexplored. This research aims to fill that gap by integrating LoRa-based multi-zone sensing, stress-level prediction using ML, and real-time energy optimization into a single decision-support platform. The proposed system is designed to operate reliably even in low-connectivity settings and to provide actionable, bed-level insights through a centralized dashboard.

1.2. RESEARCH GAP

Recent advancements in smart agriculture have demonstrated the effectiveness of integrating IoT-based monitoring, LoRa communication, and ML-based control in improving crop productivity and energy efficiency. However, their application in Sri Lanka's floriculture sector—especially for rose greenhouse operations—remains limited and fragmented. Most middle-scale growers still rely on manual supervision and fixed control routines for managing lighting, misting, and ventilation, leading to delayed detection of plant stress and high operational costs.

Although LoRa-based greenhouse monitoring systems have shown promise for wide-area environmental sensing [1], [2], they often lack real-time stress analytics and zone-specific optimization. ML models have been applied for climate control, irrigation forecasting, and pest detection in greenhouse agriculture [3], [4], but such models are typically trained on vegetable or field crops and do not translate well to rose farming, where environmental sensitivity and flower bed variations are more nuanced.

Furthermore, many of these systems assume uninterrupted cloud connectivity and are unsuitable for low-infrastructure rural setups.

Commercial deployments such as Sense2Grow demonstrate the feasibility of LoRa sensor networks in floriculture [5], but these systems are cost-prohibitive, closed-source, and do not provide localized decision support or energy management features. Similarly, research platforms that propose cloud-based dashboards for greenhouse monitoring do not support offline data buffering or edge-level intelligence [6].

This highlights a significant research gap: there is no integrated, zone-aware, and energy-optimized system that leverages long-range sensing and ML-based stress prediction specifically for middle-scale rose greenhouses. Moreover, the absence of offline-capable, per-bed analysis tools limits the scalability of existing solutions for rural agricultural settings. This research addresses that gap by developing a centralized system that supports LoRa-based multi-zone data acquisition, offline synchronization, and real-time stress forecasting with energy-saving recommendations.

1.3. RESEARCH PROBLEM

Despite the growing interest in smart greenhouse systems globally, many mid-scale rose farmers continue to rely on manual inspection and fixed schedules to manage their greenhouse microclimate. This approach is time-consuming, energy-intensive, and reactive—often leading to delayed responses to plant stress, overuse of lighting and misting systems, and inconsistent flower quality across beds.

Existing IoT-based greenhouse systems primarily focus on irrigation or single-zone environmental monitoring [1], [2], and are typically designed for vegetable crops or large-scale commercial farms. These solutions often depend on constant internet connectivity and do not support decentralized, offline-capable operations suitable for rural settings. While LoRa-based communication systems have been used in smart agriculture [3], few studies combine LoRa with bed-level analytics, centralized dashboards, and real-time ML-based decision support tailored for floriculture.

Similarly, recent research on ML in smart farming focuses heavily on pest detection, evapotranspiration, or irrigation prediction [4], [5], with limited application in rose cultivation or per-bed stress forecasting. Commercial platforms such as Sense2Grow provide basic microclimate tracking for rose farms but remain expensive and closed-source, offering limited adaptability or intelligent automation features.

As a result, there is a clear gap in the development of an integrated, low-cost, multi-zone system that combines long-range sensing, offline operation, ML-based stress prediction, and zone-specific energy optimization. This research aims to address this challenge by developing a Centralized Stress Prediction and Energy Optimization System that supports per-bed decision-making across multiple greenhouses—enhancing crop health, reducing electricity consumption, and enabling scalable management for Sri Lanka's middle-scale rose farmers.

2. OBJECTIVES

2.1. MAIN OBJECTIVES

To develop a centralized, intelligent decision-support system that predicts flower bed stress and recommends energy-saving actions in multi-greenhouse rose farming environments, using real-time IoT sensor data, LoRa-based communication, and ML models with offline operational capability.

2.2. SPECIFIC OBJECTIVES

- To design and implement LoRa-enabled sensor nodes that monitor UV intensity, temperature, humidity, air quality, and soil moisture in real time across multiple greenhouse zones
- To build an ESP32-based central gateway capable of offline data storage and cloud synchronization
- To collect and preprocess multi-sensor environmental data for machine learning model training
- To train and evaluate a lightweight ML model that predicts stress levels based on fused environmental inputs
- To develop an energy optimization logic that recommends or automates lighting, misting, and ventilation adjustments based on predicted stress conditions
- To design a centralized dashboard that visualizes zone-wise environmental readings, system recommendations, and stress alerts in a farmer-friendly format
- To validate the system's performance through a testbed experiment simulating mid-scale greenhouse operation in Sri Lanka, measuring accuracy, power efficiency, and usability

3. METHODOLOGY

This research adopts a phased, iterative development approach to design, implement, and evaluate a centralized greenhouse monitoring and energy optimization system tailored for middle-scale rose farming. The system integrates hardware (IoT sensors, microcontrollers), wireless communication (LoRa), machine learning (ML)-based stress prediction, and a visualization interface for decision support. Emphasis is placed on offline operation, modular deployment, and per-bed resolution to suit real-world farming conditions in Sri Lanka.

3.1. PROJECT EXECUTION APPROACH

The project will be carried out in five main phases:

3.1.1. REQUIREMENT ANALYSIS AND PLANNING

- Analyze the environmental challenges and operational practices of middle-scale rose farmers
- Identify functional and non-functional requirements for the sensor network, gateway, and ML model
- Define performance goals for energy savings, stress detection accuracy, and system responsiveness

3.1.2. HARDWARE DESIGN AND SENSOR NODE DEVELOPMENT

- Select and configure sensors to measure temperature, humidity, UV, soil moisture, and air quality
- Interface the sensors with an ESP32 or equivalent microcontroller and integrate a LoRa transceiver
- Program each node to transmit data packets periodically via LoRa to the central gateway

3.1.3. GATEWAY AND COMMUNICATION INFRASTRUCTURE

- Set up an ESP32 or Raspberry Pi-based LoRa receiver as a centralized gateway

- Implement local data storage for offline operation using SD card or embedded flash
- Enable cloud synchronization capability using MQTT or HTTP when internet is available

3.1.4. DATA COLLECTION AND PREPROCESSING

- Log multi-sensor environmental data from multiple simulated greenhouse zones over several days
- Label data with expert feedback (or simulated thresholds) to classify plant stress levels
- Normalize and preprocess data for ML training, handling missing or noisy values

3.1.5. MACHINE LEARNING MODEL DEVELOPMENT

- Train and evaluate lightweight classification models such as Random Forest (RF), Gradient Boosting, or Decision Tree to predict flower bed stress
- Evaluate model accuracy, false positive/negative rates, and inference speed for edge deployment
- Export the trained model to run directly on the gateway or as part of the dashboard logic

3.1.6. DASHBOARD DESIGN AND SYSTEM EVALUATION

- Design a centralized web-based dashboard using Node-RED, Flask, or Firebase
- Display per-bed sensor readings, predicted stress status, and energy-saving recommendations
- Validate system performance in a prototype greenhouse testbed using simulated or real plants
- Evaluate usability from a farmer's perspective, including alert clarity, accessibility, and reliability

3.2. WORK BREAKDOWN STRUCTURE

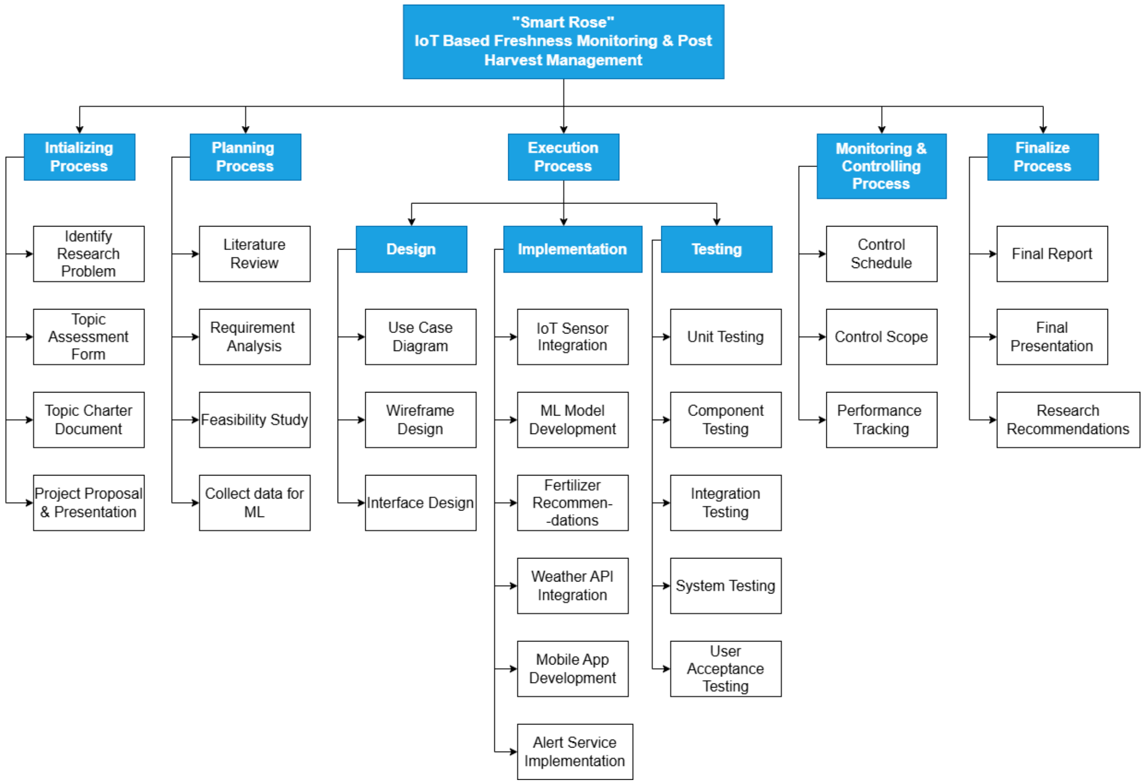

Figure 1: Work Breakdown Structure (WBS)

3.3. PROJECT TIMELINE (GANTT CHART)

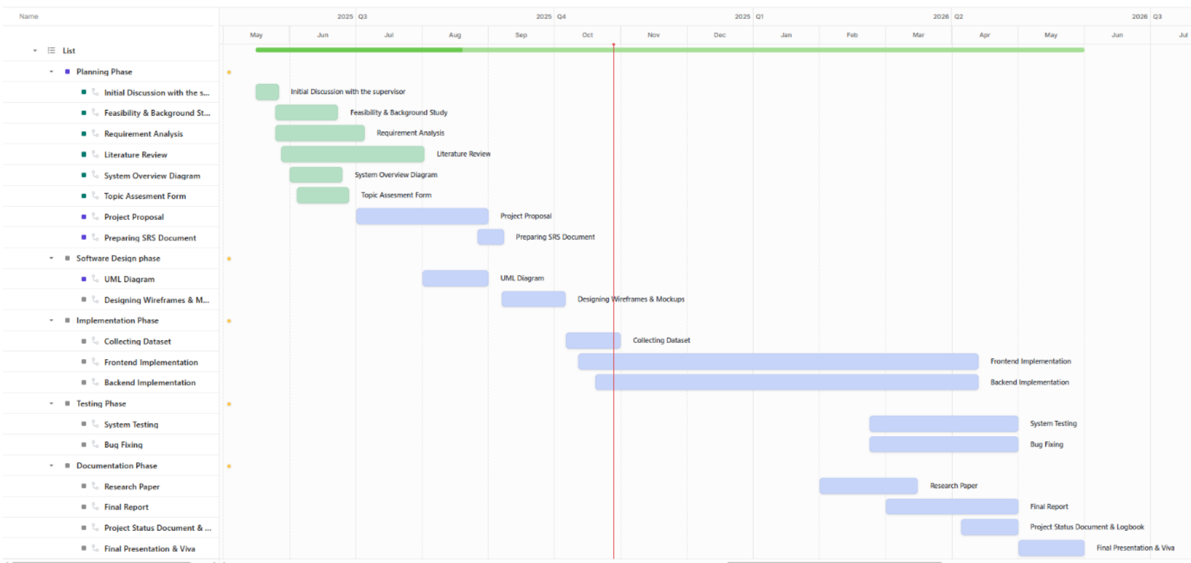

Figure 2: Project Timeline (Gantt Chart)

3.4. DATA REQUIREMENTS & COLLECTION

The system relies on real-time environmental data collected from IoT-based sensors distributed across multiple rose greenhouse zones. These data are used both for training a machine learning (ML) model that predicts plant stress conditions and for generating live, actionable insights through the centralized dashboard.

3.4.1. SENSOR DATA REQUIREMENTS

Each LoRa-connected node will gather and transmit the following key environmental parameters:

Parameter	Sensor Type	Purpose
Temperature (°C)	DHT22 or BME280	Influences transpiration and heat stress
Humidity (%)	DHT22 or BME280	Affects moisture retention and misting logic
Soil Moisture (%)	Capacitive Moisture Sensor	Determines irrigation need and root health
UV Intensity (μW/cm²)	GY-8511 or VEML6070	Guides artificial lighting optimization
Air Quality (ppm)	MQ-135 or CCS811	Detects harmful gases and ventilation need

Each sensor node transmits data via LoRa to an ESP32-based gateway at configurable intervals (e.g., every 1–5 minutes). The gateway logs this data locally for offline operation and pushes it to the cloud when a connection is available.

3.4.2. MACHINE LEARNING TRAINING DATASET

To build the ML-based stress prediction model, a dataset containing multiple days of sensor readings will be collected. Each data instance will include:

- Timestamp
- Sensor readings (temperature, humidity, UV, soil moisture, air quality)
- Corresponding label: Low Stress, Moderate Stress, or High Stress

In the absence of annotated field data, stress levels will be defined using domain expert knowledge, literature guidelines, or simulated thresholds derived from agronomic studies on rose physiology.

3.4.3. DATA PREPROCESSING TASKS

- Handling missing or inconsistent sensor values using interpolation or dropout removal
- Normalizing data ranges for consistency across feature types
- Encoding stress labels for classification model compatibility
- Splitting the dataset into training, validation, and test sets (e.g., 70/15/15 split)

All preprocessed data will be stored in structured CSV format or sent to a cloud platform such as Firebase or Google Sheets for visualization and analysis.

3.4.4. PRIVACY AND ETHICS CONSIDERATION

Since this project does not involve human subjects or private data, ethical concerns are minimal. However, all experimental deployments will be conducted in a controlled greenhouse setting to ensure safety and environmental compliance.

4. PROJECT REQUIREMENTS

4.1. FUNCTIONAL REQUIREMENTS

The SmartRose Centralized Stress Prediction and Energy Optimization System shall provide the following functions:

- Real-time Environmental Monitoring: Collect temperature, humidity, UV intensity, soil moisture, and air quality data from multiple flower beds using LoRa-enabled IoT sensor nodes.
- Long-Range Data Transmission: Transmit sensor data reliably from distributed greenhouse zones to a centralized gateway using LoRa communication.
- Offline Data Storage: Store sensor data locally at the gateway during internet outages and synchronize with the cloud when connectivity is restored.
- Stress Prediction: Analyze fused sensor data using a machine learning model to predict flower bed stress levels (Low, Moderate, High).
- Energy Optimization Recommendations: Generate actionable recommendations to optimize the use of grow lights, misting systems, and ventilation based on predicted stress conditions.
- Centralized Dashboard Visualization: Display real-time and historical data, stress alerts, and energy-saving suggestions through a web-based dashboard.
- Alert Notification System: Notify farmers when critical stress thresholds are detected in specific greenhouse zones or beds.

4.2. NON-FUNCTIONAL REQUIREMENTS

- Performance: Stress prediction and recommendation generation should occur within 5 seconds of receiving sensor data.
- Scalability: The system should support multiple greenhouses and up to 100 sensor nodes without performance degradation.
- Availability: The system should operate continuously with at least 95% uptime, including offline functionality.
- Reliability: Sensor data transmission and storage should be resilient to temporary network failures.

- Security: Access to the dashboard and system configurations should be protected through authentication mechanisms.
- Usability: The dashboard interface should be simple and understandable for farmers with minimal technical expertise.
- Maintainability: The system should allow easy replacement of sensors, firmware updates, and ML model improvements.

4.3. USER REQUIREMENTS

4.3.1. FARMERS / GREENHOUSE OPERATORS

- Monitor real-time environmental conditions across multiple greenhouses.
- Receive early warnings about plant stress conditions.
- View energy optimization recommendations to reduce electricity usage.
- Access historical data for decision-making and trend analysis.
- Use the system without requiring continuous internet connectivity.

4.3.2. SYSTEM ADMINISTRATOR

- Configure sensor nodes and communication parameters.
- Manage gateway synchronization and data storage settings.
- Monitor system health and performance.
- Update machine learning models and thresholds when required.

4.4. SYSTEM REQUIREMENTS

4.4.1. HARDWARE

- Sensor Nodes: ESP32 microcontroller with LoRa transceiver and environmental sensors (temperature, humidity, UV, soil moisture, air quality).
- Central Gateway: ESP32 or Raspberry Pi with LoRa receiver, local storage (SD card / flash), and optional internet connectivity.
- Power Supply: Stable power source or solar-assisted power for sensor nodes.

4.4.2. SOFTWARE

- Firmware: Arduino / ESP-IDF firmware for sensor data acquisition and LoRa communication.
- Backend / Processing: Python-based ML inference and data handling (Flask / Node-RED).
- Dashboard: Web-based interface using Node-RED, React, or similar frameworks.
- Database: Local storage (CSV / SQLite) with optional cloud synchronization (Firebase / MQTT).
- ML Frameworks: Scikit-learn or TensorFlow Lite for stress prediction.

5. BUDGET AND BUDGET JUSTIFICATION

Table 1: Estimated Budget

Item	Purpose	Estimated Cost (LKR)
IoT Device Hardware	Design and implementation of sensor nodes and central gateway for real-time greenhouse monitoring and LoRa communication	33,600
Travelling	Field visits to greenhouses, component purchasing, system testing and validation	8,000
Data Collection	Experimental setup, test measurements, logging, and documentation	3,000
Internet & Utilities (Development Phase)	System development, testing, dashboard access, cloud synchronization	6,000
Contingency (≈10%)	Unexpected hardware replacement or operational expenses	3,800

Total Estimated Budget: LKR 54,400

5.1. BUDGET JUSTIFICATION

- **IoT Device Hardware**: Covers all electronic components required to develop the SmartRose prototype, including ESP32 development boards, LoRa communication modules, antennas, environmental sensors (temperature, humidity, soil moisture, UV, and air quality), power regulation modules, storage units, protective enclosures, and assembly components.
- **Travelling**: Allocated for visits related to greenhouse observation, prototype testing, component sourcing, and validation activities.
- **Data Collection**: Supports experimental measurements, sensor calibration, and systematic data logging required for machine learning model training and system evaluation.
- **Internet & Utilities**: Includes connectivity and electricity costs incurred during development, testing, and cloud synchronization.
- **Contingency**: Provides flexibility for unforeseen expenses such as sensor damage or additional testing requirements.

6. REFERENCE LIST

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7. APPENDICES

1) APPENDIX A: SYSTEM COMPONENT DETAILS

This appendix outlines the main hardware and software components used in the SmartRose prototype implementation.

- ESP32-based IoT sensor nodes with LoRa communication
- Environmental sensors for temperature, humidity, soil moisture, UV intensity, and air quality
- Central gateway with offline data storage and cloud synchronization capability
- Machine learning model for stress prediction based on fused sensor data
- Web-based dashboard for visualization and decision support

Detailed circuit diagrams, firmware code snippets, and dashboard screenshots will be developed during the implementation phase and included in the final dissertation report.