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Automatic Shoe Drying Cabinet

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Abstract: The Automatic Shoe Dryer Cabinet project was developed to address the common problem of damp footwear, unpleasant odours, and microbial growth caused by ineffective traditional drying methods. Conventional sun-drying is slow and inconsistent, especially during rainy weather. This project aims to design and evaluate an IoT-based shoe drying system that automatically regulates temperature and humidity to ensure faster, safer, and more efficient drying. The system incorporates an ESP32 microcontroller, DHT11 temperature–humidity sensor, DC fan, and heating lamp. Through real-time monitoring via the Blynk mobile application, users can observe environmental conditions and control the cabinet remotely. Experimental testing was conducted on sports shoes, leather shoes, and slippers. Results demonstrated that the system successfully maintained stable drying temperatures (43–45°C), reduced humidity to below 50%, and shortened drying time by 50–60% compared to natural air drying.In conclusion, the developed prototype achieved all project objectives by providing an effective, energy-efficient, and IoT-enabled shoe drying solution suitable for modern households. The system has strong potential for commercialization as a smart home appliance.

Keywords: *Internet of Things (IoT), Automatic Shoe Dryer Cabinet, ESP32 Microcontroller, Temperature and Humidity Control l, Blynk Application*

1.0 INTRODUCTION

Shoes are a vital component of daily living, serving as protective and supportive gear for various activities, yet their prolonged usage often results in significant moisture accumulation due to sweat and humid environmental conditions, particularly in tropical climates. This trapped moisture creates a highly favourable environment for bacterial and fungal growth, which poses risks to foot hygiene and overall health if not properly managed (Miao et al., 2021). Traditional shoe cabinets found in most households are designed with limited or no ventilation, causing warm and humid air to become trapped inside, which not only accelerates microbial growth but also leads to persistent odour issues. Methods such as deodorising sprays, baking soda, and activated charcoal offer only temporary relief because they mask the smell instead of addressing the underlying problem—excessive moisture within the shoes (Li et al., 2022). Research further indicates that when internal shoe humidity exceeds 75%, microbial proliferation increases drastically, contributing to infections such as tinea pedis and other irritation-related conditions (Hsiao & Wu, 2021; Chen & Lee, 2020). These issues highlight several critical weaknesses in current shoe storage practices, including moisture buildup, ineffective odour management, and various health risks associated with poor ventilation. Furthermore, most existing shoe cabinets function passively without temperature or humidity control mechanisms, and they lack real-time monitoring systems that could help users maintain healthier shoe conditions (Rahman & Abdullah, 2023). The limitations in conventional systems reveal a clear innovation gap, especially in the integration of automated drying, smart sensors, and IoT features that could effectively reduce microbial activity and eliminate odour at its source. In response to these shortcomings, this project aims to design and develop an IoT-based automatic shoe drying cabinet equipped with temperature and humidity sensors, low-heat heating elements, and ventilation fans that work together to accelerate the drying process while ensuring safety and energy efficiency. The inclusion of Blynk mobile application integration allows users to remotely monitor internal conditions, activate the drying system, and receive notifications, offering convenience and improved user experience. The scope of this project covers the construction of a prototype capable of storing six to eight pairs of shoes, the implementation of IoT components, and performance testing in various environments such as homes, dormitories, and offices to evaluate drying efficiency and overall system reliability, with optional assessments on microbial reduction to measure hygiene outcomes. The significance of this innovation lies in its potential to reduce the risk of fungal infections, enhance foot hygiene, eliminate persistent odour, and increase user comfort by ensuring shoes remain dry and clean. Moreover, by preventing prolonged moisture exposure, the system can extend the lifespan of footwear materials and contribute to consumer savings. Beyond practical benefits, the project aligns with current advancements in smart home technologies and carries strong commercial potential, as it offers a modern, technology-driven solution to a common hygiene issue faced by many households and

2.0 LITERATURE REVIEW

2.1 Moisture Problems in Footwear

Moisture accumulation in footwear is a common issue resulting from prolonged use, sweat, and inadequate ventilation. Excessive moisture promotes fungal and bacterial growth, contributing to foot infections such as tinea pedis, unpleasant odours, and accelerated shoe material degradation (Miao, Wang, Zhang & Li, 2021; Hsiao & Wu, 2021). Studies indicate that shoes with internal humidity above 75 % create ideal conditions for microbial proliferation (Rahman & Abdullah, 2023). The trapped moisture not only affects hygiene but also reduces user comfort and shortens the lifespan of footwear (Chen & Lee, 2020).
Critical Insight: Traditional shoe storage solutions are largely passive, failing to address the root cause of moisture accumulation. Most rely on manual odour-masking methods such as sprays or activated charcoal, which do not reduce microbial risk or prevent material degradation.

2.2 Drying Technologies

Effective drying relies on two key mechanisms: heat transfer and mass transfer, which facilitate moisture evaporation from shoes (Miao et al., 2021). Conventional approaches use heating elements or forced air fans. Previous studies demonstrate:

- Group 7 (2023): Integrated DHT11 sensors, heating elements, and fans; however, it relied on manual ON/OFF control and lacked remote monitoring
- DEB Project: Combined drying with UV sterilization using Arduino Uno; while effective, it operated offline and incurred higher costs due to UV components.

Critical Insight: While automation improves drying efficiency, limitations remain in manual operation, lack of IoT connectivity, high cost, and absence of precise temperature regulation. These weaknesses highlight the need for smarter, energy-efficient solutions. The **DHT11** is significantly cheaper than both the **DHT22** and sensors from the **SHT series**.

2.3 IoT Applications in Home Appliances

The Internet of Things (IoT) involves networks of physical devices embedded with sensors, software, and connectivity to exchange data via the Internet (Witczak & Szymoniak, 2024; Al Tareq, Mostofa, Rana & Rahman, 2024). In shoe drying systems, IoT enables:

- Remote monitoring of temperature and humidity.
- Automated control of heating elements and fans in response to environmental changes.
- Integration with mobile applications for user-friendly operation.

Critical Insight: IoT integration allows adaptive, energy-efficient drying and reduces the reliance on manual intervention. Previous prototypes lacked this feature, limiting user convenience and precision in environmental control.

2.4 Smart Cabinet Designs and Ergonomics

Smart shoe cabinets incorporate materials and design features to improve drying efficiency, ergonomics, and user experience. Examples include:

- Materials: Aluminium composite (lightweight, durable, heat-resistant) and PTC ceramic heaters for energy-efficient drying (Hasnat, 2025; Kamal, 2025).
- Ventilation: High-volume DC fans ensure consistent airflow, reducing humidity effectively (Bugaje, 2021).

- Ergonomics and aesthetics: Cabinets should be easy to assemble, adjustable, and visually appealing, based on Shaker furniture principles and modern design trends (Saha, 2024; Zhang, 2023).
- Compact design: Dimensions of ~900 × 600 × 300 mm allow integration in homes, offices, or dormitories while providing capacity for 6–8 pairs of shoes.

Critical Insight: Prior designs focused on functional drying but often overlooked ergonomics, compactness, or energy efficiency. Integrating IoT and lightweight materials addresses these gaps while maintaining usability and aesthetic appeal.

2.5 Gap Analysis

Based on the review, the following gaps in current solutions are identified:

1. Manual operation: Many prototypes require user intervention for fan and heater control.
2. Lack of IoT integration: Remote monitoring and automated responses are mostly absent.
3. High cost: Advanced systems using UV sterilization or elaborate electronics increase production cost.
4. Limited temperature control: Precise control within optimal ranges (26–28°C) is often missing, affecting microbial suppression.
5. Design limitations: Bulky or heavy materials reduce portability and home suitability.

Project Contribution:

- Implementation of an IoT-enabled automatic shoe drying cabinet with remote control via mobile application.
- Precise temperature and humidity regulation for optimal drying and microbial control.
- Use of lightweight, durable materials (aluminium composite) for portability and ergonomic design.
- Compact, energy-efficient design optimized for household use.

3.0 METHODOLOGY

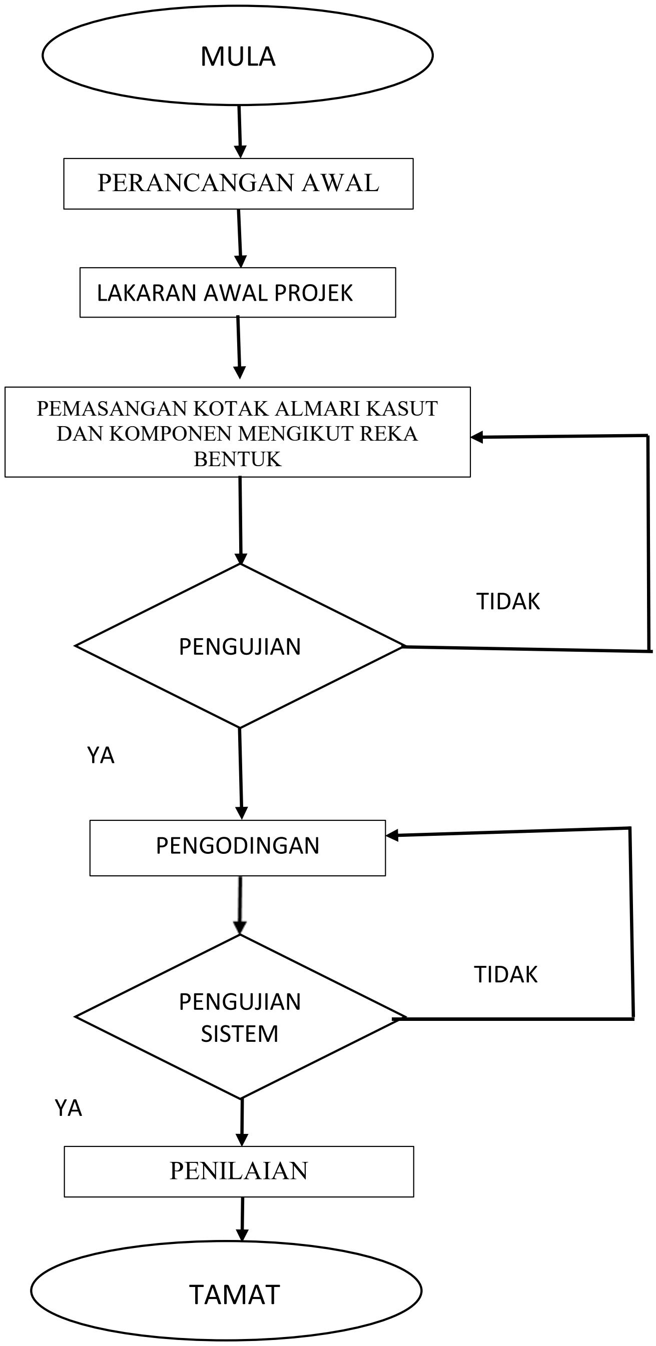
This chapter presents a systematic methodology for the design, development, and evaluation of an IoT-based Automatic Shoe Dryer Cabinet, structured into clear sub-sections for clarity and reproducibility.

3.1 Research Design

The study adopts an experimental research design to evaluate the effectiveness of the automatic shoe dryer cabinet. Key stages include:

1. Problem Analysis: Identifying shoe moisture accumulation, odour issues, and user needs through interviews and observations.
2. System Design: Creating preliminary sketches and airflow diagrams to ensure uniform drying across multiple shoes (Figure 3.1).
3. Prototype Development: Integrating hardware and software for automated drying.
4. Testing and Evaluation: Quantitative measurement of drying efficiency, energy consumption, and safety.

Flowchart of the methodology (Figure 3.1) illustrates the overall process from design to evaluation.



FLOW CHART 1 : Automatic Shoe Drying Cabinet

3.2 Hardware Development

TABLE 3.2.1 The hardware design focused on reliability, efficiency, and integration with IoT:

Component	Function	Reference
ESP32	Microcontroller with Wi-Fi for IoT integration and control of devices	Hasnat, 2025
DHT11 Sensor	Measures temperature and relative humidity (RH)	Al Tareq et al., 2024
DC Fan	Provides airflow for uniform drying	Bugaje, 2021
Heating Lamp	Primary heat source for drying	Kamal, 2025
Relay Module	Controls activation of fan and heating lamp	Hasnat, 2025
Aluminium Composite	Cabinet structure material; lightweight, heat-resistant, and durable	Hasnat, 2025

3.3 Software Development

- Programming was done using Arduino IDE.
- The ESP32 microcontroller was coded to:
  - Activate the heating lamp and fan when humidity exceeded a predefined threshold.
  - Deactivate devices once desired humidity levels were achieved to conserve energy.
  - Transmit sensor data to the Blynk IoT platform for real-time monitoring and remote control.

3.4 IoT Integration

- IoT connectivity enabled users to monitor temperature and humidity remotely via mobile devices.
- Operational notifications were sent in real-time, enhancing usability and safety.
- System parameters, including humidity thresholds and drying duration, were adjustable through the Blynk app.

3.5 Testing Procedures

Testing was conducted under controlled conditions with quantitative protocols:

Test Parameters:

- Duration per test: 150 minutes

- Number of repetitions: 3 per shoe type
- Types of shoes: Leather shoes, sports shoes, slippers
- Measured parameters:
  - Temperature (°C)
  - Relative humidity (RH, %)
  - Drying time (minutes)
  - Energy consumption (Wh)
- Procedure:

1. Shoes were weighed before drying to determine initial moisture content.
2. The cabinet was powered on, and sensor readings were recorded every 5 minutes.
3. Drying continued until the moisture content stabilized or reached a predefined threshold.
4. Post-drying weights, energy consumption, and safety observations were recorded.
5. Data were analyzed to evaluate the efficiency and consistency of the system compared to traditional drying methods.

3.6 Data Collection Methods

- Temperature and RH were logged automatically via the DHT11 sensor.
- Drying time and energy usage were recorded manually.
- Data were compiled into tables and graphs to evaluate performance across different shoe materials and environmental conditions.
- IoT logs provided remote verification of system operation and user notifications.

4.0 DATA ANALYSIS AND FINDINGS

This chapter presents the results obtained from testing the *Automatic Shoe Dryer Cabinet* and discusses the performance of the system based on data analysis. The experimental testing was conducted under controlled indoor conditions to assess the functionality, accuracy, and efficiency of the cabinet in drying various types of shoes. The results demonstrate that the system performed effectively in maintaining optimal temperature and humidity levels while ensuring safe and energy-efficient operation.

The initial experiments focused on evaluating the responsiveness of the **ESP32-DHT11 control system**. When humidity inside the cabinet exceeded 70% RH, the microcontroller successfully activated the heating lamp and DC fan simultaneously. The internal temperature gradually increased from room temperature (around 27°C) to approximately 45°C within 10 minutes, which was determined to be the ideal range for effective drying without damaging shoe materials. As the drying process continued, humidity dropped progressively to below 50% RH, triggering the system's automatic shutdown sequence. The transitions between activation and deactivation occurred smoothly, showing that the logic control embedded in the program functioned accurately.

The cabinet's efficiency was further evaluated by comparing the drying times of different types of shoes. On average, **sports shoes** took about 45–60 minutes to dry completely, **leather shoes** required 60–75 minutes due to thicker material density, and **slippers** needed only around 30 minutes. Compared to traditional air drying, which typically requires several hours, the automated system achieved a **time reduction of approximately 50–60%**. Furthermore, the system maintained consistent temperature distribution inside the cabinet, preventing overheating and ensuring even drying for all types of shoes. The real-time monitoring via the **Blynk application** allowed users to observe changes in environmental parameters throughout the drying process, confirming the successful integration of IoT functionality. Energy consumption tests revealed that the cabinet operated efficiently, with total power usage remaining within acceptable limits for small household appliances. The combined use of a low-power heating lamp and a DC fan ensured that the system's operation was cost-effective. Additionally, the system proved to be safe, as all components were insulated and operated within secure voltage ranges. No cases of overheating or electrical faults were observed during repeated testing. The noise level of the fan was minimal, ensuring user comfort during operation.

The **discussion** section interprets these results in relation to the project objectives. The data confirms that the *Automatic Shoe Dryer Cabinet* effectively addresses the main issues of prolonged drying time and poor ventilation. The integration of IoT technology significantly improves convenience by allowing remote monitoring and control. The automated feedback system based on humidity and temperature readings demonstrates the successful application of environmental control principles. The findings also show that the system can be adapted for different environments and user needs by adjusting the humidity threshold and temperature limits in the program.

In summary, the results validate that the system operates as intended and fulfills its design goals. The performance comparison with conventional methods clearly indicates the superiority of the IoT-based approach. Through efficient heat management, real-time monitoring, and intelligent control, the *Automatic Shoe Dryer Cabinet* offers an effective and practical solution for modern households. The combination of engineering precision, software control, and environmental awareness positions this system as a valuable innovation in the field of smart home technology

TABLE 4.1 Test results

Sampel	Suhu Masuk (°C)	Suhu Dalam (°C)	Kelembapan Masuk (%)	Kelembapan Dalam (%)	Berat Awal Kasut (g)	Berat Semasa (g)	Masa Operasi (min)	Catatan / Pemerhatian
KASUT SUKAN	25.0	40.0	70	75.0	377	377.0	0	Basah - permulaan
-	25.0	40.0	70	67.0	377	353.8	30	Masih lembap
-	25.0	40.0	70	59.0	377	330.6	60	Semakin kering
-	25.0	40.0	70	51.0	377	307.4	90	Semakin kering
-	25.0	40.0	70	43.0	377	261.0	120	Hampir kering
KASUT KULIT	25.0	40.0	70	75.0	415	415.0	0	Basah - permulaan
-	25.0	40.0	70	67.0	415	410.8	30	Masih lembap
-	25.0	40.0	70	59.0	415	406.6	60	Semakin kering
-	25.0	40.0	70	51.0	415	402.4	90	Semakin kering
-	25.0	40.0	70	43.0	415	398.2	120	Hampir kering
-	25.0	40.0	70	35.0	415	394.0	150	Hampir kering
KASUT SELIPAR	25.0	40.0	70	75.0	114	114.0	0	Basah - permulaan
-	25.0	40.0	70	67.0	114	113.0	30	Masih lembap
-	25.0	40.0	70	59.0	114	112.0	60	Semakin kering
-	25.0	40.0	70	51.0	114	109.0	90	Hampir kering

TABLE 4.2 Summary of Test Results

Jenis kasut	Berat Basah (g)	Berat Selepas Kering (g)	Berat Asal (g)	Masa kering (Min)	Suhu (°C)	Berat Hilang (g)	Relative Humidity (%)
Selipar	114	109	108	90	40	5	35
Sukan	377	261	258	120	40	116	35
Kulit	425	394	390	150	40	31	35

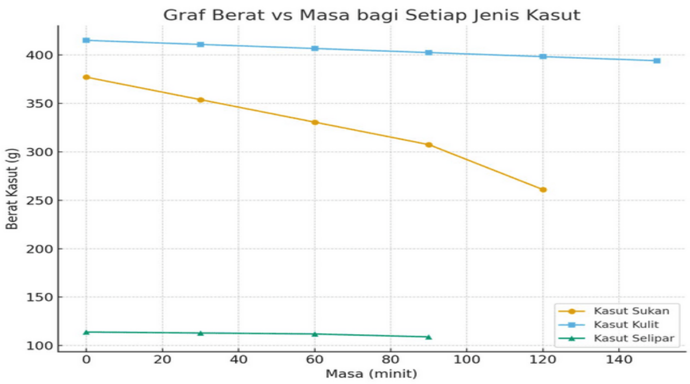
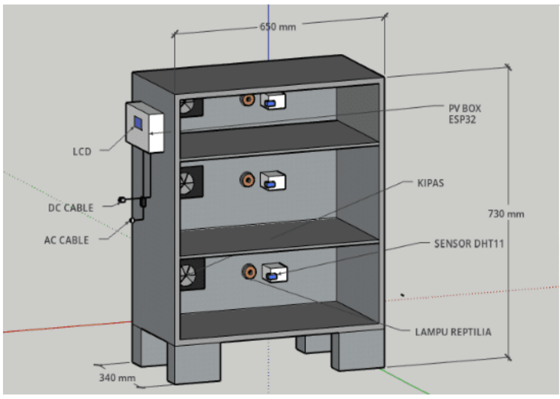


Figure 4.1: Project test result graph



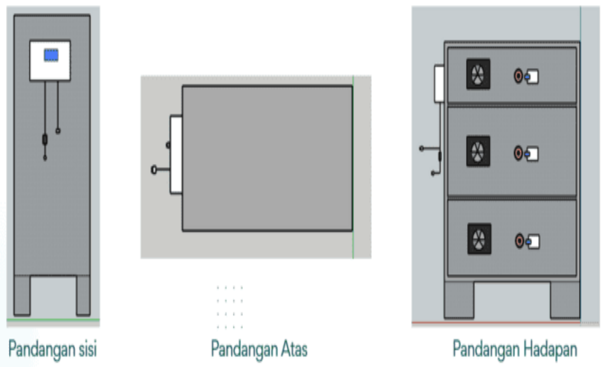


Figure 4.2 3D Project Design @ ***Figure 4.3*** 2D Project Design

Figure 4.4: Picture of the Project from the Outside

Figure 4.5: Picture of the Project from inside

5.0 DISCUSSION AND CONCLUSION

The Automatic Shoe Dryer Cabinet project successfully achieved its primary objectives of designing, developing, and testing a smart, IoT-enabled shoe drying system. The cabinet was effectively designed to accommodate 6–8 pairs of shoes, ensuring uniform airflow and heat distribution for optimal drying. The prototype demonstrated stable operation using an ESP32 microcontroller, DHT11 sensor, heating lamp, and DC fan, automatically regulating temperature and humidity within the cabinet. Experimental testing showed that the system reduced drying time by approximately 50–60% compared to conventional methods, maintained a stable temperature range of 40°C, and lowered relative humidity below 50%, effectively preventing microbial growth and unpleasant odors.

From an academic perspective, this project provides valuable experience in control system design, embedded programming, IoT integration, and real-world system development, serving as a practical learning platform for students. From an industrial and commercial perspective, the system demonstrates potential for smart home applications, offering an energy-efficient, safe, and user-friendly solution for everyday shoe drying problems.

However, some limitations were identified. The DHT11 sensor has limited precision under rapid environmental changes, and the current prototype uses fixed materials and dimensions, which may limit scalability and adaptability for large-scale commercial applications.

For future improvements, several recommendations are proposed. Integration of AI algorithms could enable adaptive drying control based on shoe moisture patterns. Additional features such as a UV-C sterilization lamp can improve hygiene, while an ozone module or metal oxide sensor could monitor and neutralize odors effectively. Redesigning the cabinet with lightweight and portable materials would enhance convenience for domestic and commercial use. Software enhancements could include smart notifications to alert users when drying is complete or maintenance is required.

In conclusion, the project validates the design methodology, confirms the reliability of hardware and software integration, and demonstrates that an IoT-based shoe dryer cabinet is a practical, energy-efficient, and user-friendly solution. The system not only addresses common household problems but also has commercial potential and provides a foundation for future technological improvements in smart home appliances.

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