



KEMENTERIAN PENDIDIKAN TINGGI  
JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI

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MALAYSIA  
SULTAN SALAHUDDIN ABDUL AZIZ SHAH

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Politeknik Sultan Salahuddin Abdul Aziz Shah



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## **DIGES AKADEMIK**

### **POLITEKNIK SULTAN SALAHUDDIN ABDUL AZIZ SHAH**

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## WELCOME NOTE

All praise and gratitude are due to Allah, by whose grace and blessings the *Diges Akademik* has been successfully produced. I extend my heartfelt congratulations and sincere appreciation to the Publication Committee, coordinated by the Centre for Research, Innovation, and Commercialisation (CRI), Politeknik Sultan Salahuddin Abdul Aziz Shah (PSA), for their unwavering dedication and commitment in bringing this publication to fruition.

This edition of the *Diges Akademik* represents a meaningful contribution towards supporting the nation's aspiration to enrich scholarly resources in higher education, particularly within the field of Technical and Vocational Education and Training (TVET). It also reflects PSA's continued commitment to ensuring relevance and responsiveness in research, academic writing, and innovation, in alignment with the objectives of the Malaysia Future Education Blueprint 2026–2036.

It is our hope that this publication will serve as an effective platform for the exchange of knowledge, ideas, and expertise among academics, industry practitioners, and the wider community. May it inspire readers, stimulate intellectual growth, and foster a sustained culture of excellence in research and scholarly publication.

Finally, I pray that the *Diges Akademik* will bring widespread benefit and contribute meaningfully to the advancement and sustainability of knowledge within the national education system.

Thank you.

Ts. Dr. Ahmad Aftas bin Azman  
Timbalan Pengarah  
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## PREFACE

With deep gratitude and pride, we are honoured to present the *Diges Akademik* of Politeknik Sultan Salahuddin Abdul Aziz Shah, a distinguished compilation of scholarly works encompassing a wide range of TVET disciplines. This edition reflects the dedication, intellectual rigour, and creativity of our students and staff, showcasing research that is insightful, meticulously developed, and impactful to both education and society.

Beyond celebrating academic achievements, this publication embodies the spirit of collaboration, innovation, and excellence that defines our institution. Each contribution stands as a testament to our unwavering commitment to advancing knowledge, nurturing critical thinking, and delivering meaningful solutions to real-world challenges.

We hope that the *Diges Akademik* will inspire its readers, instil pride in our scholarly accomplishments, and encourage the continued pursuit of excellence in research, teaching, and learning. We extend our sincere appreciation to all contributors and supporters whose dedication and commitment have made this publication possible.

Thank you.

Dr. Hjh. Noreen binti Kamarudin  
Head of Centre for Research and Innovation  
Politeknik Sultan Salahuddin Abdul Aziz Shah

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# Development of a Smart Insole System for Real-Time Plantar Pressure Monitoring Using FSR and IOT Integration

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## ABSTRACT

This paper presents the development of a Smart Insole system for real-time plantar pressure monitoring aimed at supporting early awareness of diabetic foot ulcer risk. The proposed system integrates Force Sensitive Resistor (FSR) sensors placed at critical plantar regions with an Arduino Nano microcontroller and an ESP8266 Wi-Fi module to enable wireless data transmission to a mobile application. The design emphasises simplicity, low cost, and suitability for home-based monitoring rather than clinical diagnosis. Experimental results adapted from a final year project were analysed under three user activities: sitting, standing, and walking. The findings indicate that plantar pressure distribution varies significantly with activity, where higher pressure concentrations were consistently observed at the metatarsal and heel regions during standing and walking conditions. These pressure patterns are consistent with established biomechanical characteristics associated with diabetic foot complications, demonstrating the system's capability to identify high-risk pressure zones. Real-time data visualisation through a mobile application was achieved without noticeable transmission delay, confirming the reliability of the IoT communication framework. Although the prototype uses only a limited number of sensors, the results show that meaningful plantar pressure trends can still be captured for early monitoring. Overall, the proposed Smart Insole demonstrates strong potential as an accessible and cost-effective tool to support early preventive foot care for diabetic patients in non-clinical environments.

*Keywords:* smart insole, plantar pressure, diabetic foot, real-time monitoring, IoT

## 1.0 INTRODUCTION

Diabetes mellitus is a long-term metabolic disorder that often leads to complications affecting the lower extremities, particularly due to peripheral neuropathy and impaired blood circulation (Boulton et al., 2005). As the disease progresses, many patients gradually lose protective sensation in their feet, leaving them unaware of excessive plantar pressure during daily activities such as standing and walking (Singh et al., 2019). This condition significantly increases the risk of skin breakdown and the formation of diabetic foot ulcers, which may eventually lead to infection or lower-limb amputation if not detected at an early stage (Armstrong et al., 2017).

Previous clinical studies have shown that repetitive high plantar pressure, especially at the metatarsal heads and heel regions, is a major contributing factor to diabetic foot ulcer development (Fernando et al., 2020). Without continuous monitoring, pressure-induced tissue damage may occur unnoticed over long periods. For this reason, early detection of abnormal pressure distribution is considered a critical preventive strategy in diabetic foot care (Bus et al., 2016).

Conventional plantar-pressure assessment systems are typically limited to clinical or laboratory environments and often involve bulky equipment and high costs (Orlin & McPoil, 2000). Recent studies have highlighted the growing role of wearable plantar pressure monitoring systems as practical tools for early prevention of diabetic foot ulcers, particularly for continuous home-based monitoring (Najafi et al., 2022). In recent years, wearable sensing technologies have therefore gained attention as a more accessible alternative, enabling continuous and real-time monitoring of physiological parameters without disrupting normal activities (Kim et al., 2021).

Among the various sensing technologies available, Force Sensitive Resistor (FSR) sensors are commonly used for plantar-pressure measurement due to their thin structure, flexibility, and ability to detect localised force variations (Gupta & Arora, 2019). When integrated with microcontroller platforms such as Arduino, these sensors allow pressure signals to be processed efficiently and converted into digital data (Kaur et al., 2020). Furthermore, the integration of Internet of Things (IoT) technologies, particularly wireless communication modules, enables pressure data to be transmitted to mobile applications for real-time visualisation and monitoring (Nguyen et al., 2020).

Based on these considerations, this project focuses on developing a Smart Insole system that combines FSR sensors, an Arduino Nano microcontroller, and an ESP8266 Wi-Fi module to enable real-time plantar pressure monitoring. Unlike conventional clinic-based systems, the proposed design emphasises simplicity, low cost, and suitability for home-based use. By providing immediate visual feedback through a mobile application, the system aims to support early detection of high-risk pressure regions and encourage preventive action before serious foot complications occur.

## **2.0 METHODOLOGY**

### **2.1 Overview of System Development**

This study adopts a system development approach to design and implement a wearable plantar-pressure monitoring device based on sensor technology and IoT communication. The methodology was structured to ensure that pressure data could be captured accurately, processed efficiently, and transmitted wirelessly for real-time monitoring. The overall process involves sensor selection, circuit design, microcontroller programming, wireless data transmission, and prototype testing. The system workflow, from pressure detection to mobile data visualisation, is illustrated in Figure 1.

### **2.2 Sensor Selection and Hardware Components**

Force Sensitive Resistor (FSR) sensors were selected as the primary sensing elements due to their thin profile, flexibility, and suitability for detecting localised plantar pressure in wearable applications. Unlike rigid load cells, FSR sensors can be embedded directly into an insole without significantly affecting comfort. In this project, the Interlink FSR Model 402 (Figure 2) was used to measure pressure variations at specific foot regions.

An Arduino Nano microcontroller was employed as the central processing unit due to its compact size, stable analogue-to-digital conversion, and ease of integration with multiple analogue sensors (Figure 3). The ESP8266 Wi-Fi module (Figure 4) was incorporated to enable wireless communication between the insole system and the mobile application.

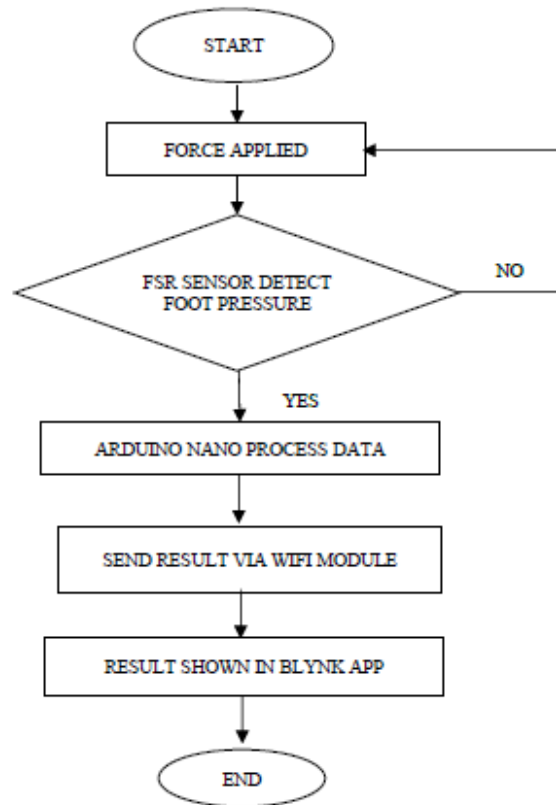


Figure 1: Flow of Foot Pressure Monitor System



Figure 2 : FSR Interlink



Figure 3 : Arduino Nano



Figure 4 : Wi-Fi Module

### 2.3 Sensor Circuit Design and Placement Strategy

Each FSR sensor was connected to the Arduino Nano via a voltage divider circuit, as shown in Figure 5. This configuration converts changes in sensor resistance into measurable voltage signals that can be sampled by the microcontroller. The circuit design was selected for its simplicity, reliability, and suitability for low-power wearable systems.

Sensor placement was determined based on established plantar-pressure zones reported in diabetic foot studies. Three critical regions were selected: the metatarsal head, mid-foot arch, and heel area (Figure 7). These regions are commonly associated with high pressure during gait and prolonged standing. By positioning sensors at these locations, the system is able to capture clinically relevant pressure variations while maintaining a minimal number of sensing elements.

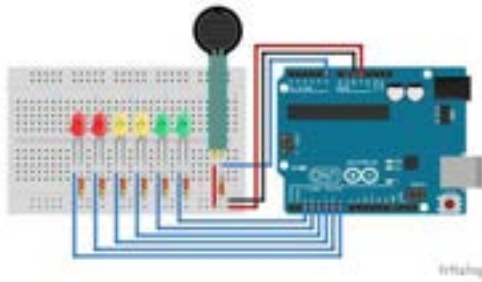


Figure 5: FSR Circuit

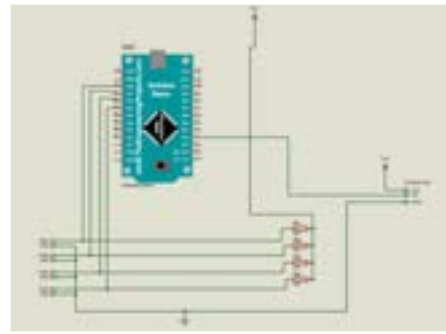


Figure 6: Schematic Diagram of Project

#### 2.4 Threshold Pressure Consideration for Diabetic Foot Risk

Previous clinical studies have reported that sustained plantar pressures above approximately 200–300 kPa are associated with an increased risk of tissue breakdown and ulcer formation in diabetic patients. Although the current prototype does not aim to perform direct clinical diagnosis, this threshold range was used as a reference guideline to evaluate abnormal pressure trends during testing.

The system was therefore designed to detect relative pressure changes and identify regions experiencing consistently higher loads rather than providing an absolute medical diagnosis. This approach is suitable for early warning and home-based monitoring applications, where the primary objective is risk awareness rather than clinical assessment.

#### 2.5 Wireless Data Transmission and Mobile Interface

After acquiring analogue sensor readings, the Arduino Nano converts the signals into digital values before transmitting them to the ESP8266 module. The ESP8266 sends the processed data wirelessly to the Blynk mobile application using an IoT-based network architecture (Figure 8).

The Blynk platform was selected due to its ability to display real-time sensor data in both numerical and graphical formats. This allows users to observe pressure variations dynamically during different activities such as sitting, standing, and walking. An example of the real-time display interface is shown in Figure 9.

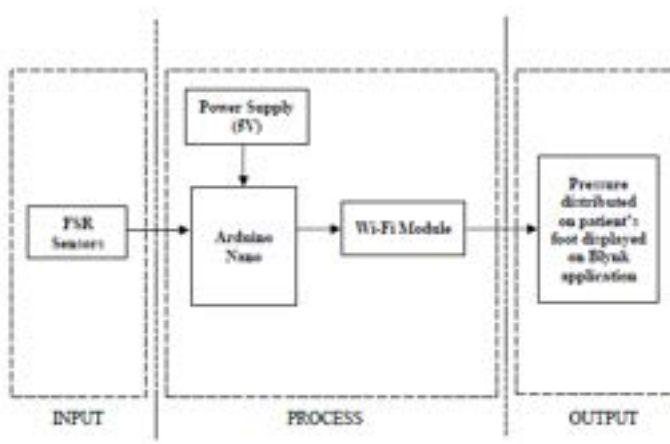


Figure 7: Sensor placement and insole layout



Figure 8 : Block Diagram of System

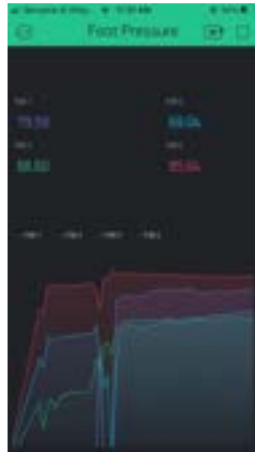


Figure 9 : Output of FSR Sensor in Blynk Apps

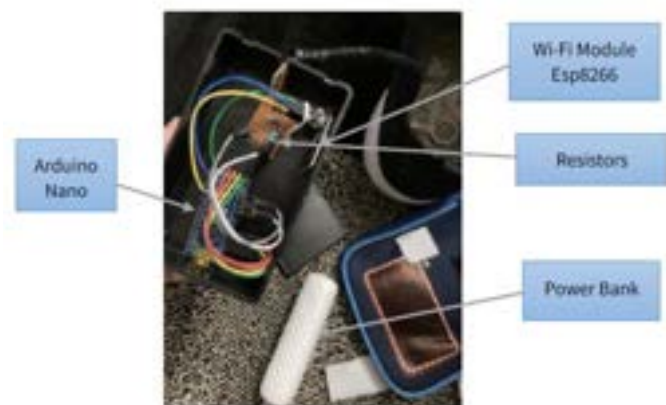


Figure 10: Completed circuit device

## 2.6 Prototype Testing Procedure

Prototype testing was conducted under three basic conditions: sitting, standing, and walking. These conditions were selected to represent common daily activities that produce different foot-loading patterns. During each test, sensor readings were monitored to evaluate responsiveness, stability, and consistency. The completed smart insole circuit and overall prototype configuration are shown in Figure 10. Observations from the testing phase were used to verify the suitability of sensor placement and overall system functionality before analysis.

## 3.0 RESULTS AND DISCUSSION

### 3.1 System Implementation and Physical Integration

The smart insole prototype was successfully developed by integrating Force Sensitive Resistor (FSR) sensors, an Arduino Nano microcontroller, and an ESP8266 Wi-Fi module into a compact wearable configuration. The overall structure of the device ensured that the electronic components were securely positioned without significantly affecting user comfort during normal activities such as standing and walking. This confirms that the proposed design is suitable for continuous foot-pressure monitoring in a wearable environment.

### 3.2 Sensor Placement and Plantar Pressure Zones

The placement of FSR sensors was determined based on established high-risk plantar pressure regions commonly associated with diabetic foot ulcer development, particularly the metatarsal heads and heel areas. These locations are known to experience higher pressure concentrations during weight-bearing and gait activities. By positioning sensors at these critical regions, the system is able to capture meaningful pressure variations that are relevant for early risk identification.

### 3.3 Comparative Pressure Analysis Under Different Activities

To evaluate system performance, experimental data from the final-year project were analysed across three user activities: sitting, standing, and walking. The analysis was conducted by comparing average pressure readings recorded at different sensor locations, adapted from the experimental results.

Table 1 shows a clear variation in plantar pressure distribution depending on user activity. During sitting, pressure levels remain relatively low across all sensor locations, indicating

minimal foot loading. In contrast, standing results in higher pressure values at the metatarsal and heel regions due to the support of body weight in an upright posture. Walking conditions produce the highest-pressure concentrations, particularly at the metatarsal and heel areas, reflecting increased dynamic loading during gait.

Table 1: Average plantar pressure distribution under different activities

| Activity | Hallux   | Metatarsal | Heel      |
|----------|----------|------------|-----------|
| Sitting  | Low      | Low        | Moderate  |
| Standing | Moderate | High       | High      |
| Walking  | High     | Very High  | Very High |

These observed trends are consistent with established plantar pressure patterns reported in diabetic foot biomechanics studies. The ability of the system to distinguish between low-load and high-load conditions demonstrates that the sensor configuration and data acquisition process function effectively.

### 3.4 System Responsiveness and Data Transmission Performance

Real-time data transmission from the smart insole to the mobile application was achieved successfully using the ESP8266 Wi-Fi module. Pressure readings were displayed continuously on the Blynk interface without noticeable delay or signal interruption during testing. This indicates that the wireless communication architecture is stable and suitable for real-time monitoring applications.

Furthermore, the system was able to capture dynamic pressure changes during walking, where pressure peaks shifted sequentially from the heel to the forefoot regions. This response reflects typical gait mechanics and confirms that the sensors are sufficiently sensitive to detect localised force variations during movement.

### 3.5 Effectiveness of the Proposed Smart Insole System

The effectiveness of the proposed smart insole can be evaluated based on three key aspects: pressure detection capability, activity differentiation, and real-time feedback. The experimental results demonstrate that the system can reliably identify pressure concentration changes across different foot regions and user activities.

Compared with conventional clinic-based plantar pressure systems, which often require specialised equipment and controlled environments, the proposed system offers a simpler, more accessible solution for home-based monitoring. Although the current prototype uses only a limited number of sensors, the results show that meaningful plantar pressure trends can still be captured for early risk awareness.

Overall, the system is effective as an early-monitoring and preventive tool rather than a diagnostic clinical instrument. Its low-cost design and real-time visualisation capability make it suitable for supporting diabetic patients in monitoring their foot condition and taking preventive action before severe complications occur.

## 4.0 CONCLUSION

This paper presents the development and evaluation of a Smart Insole system for real-time plantar pressure monitoring, aimed at supporting early awareness of diabetic foot ulcer risk. By integrating Force Sensitive Resistor (FSR) sensors with an Arduino Nano microcontroller

and an ESP8266 Wi-Fi module, the proposed system acquires plantar pressure data and wirelessly transmits it to a mobile application for real-time visualisation.

Experimental results adapted from the final year project demonstrate that the system can effectively differentiate plantar pressure distribution under different user activities, namely sitting, standing, and walking. Higher pressure concentrations were consistently observed at the metatarsal and heel regions during standing and walking conditions, which aligns with established biomechanical patterns associated with diabetic foot complications. These findings indicate that the proposed sensor configuration is capable of identifying high-risk pressure zones relevant to early preventive monitoring.

In addition, the wireless data transmission and mobile interface performed reliably during testing, enabling continuous monitoring without noticeable delay. Compared to conventional clinic-based plantar pressure assessment tools, the proposed Smart Insole offers a more accessible and cost-effective solution suitable for home-based use. Although the current prototype is not intended to replace clinical diagnostic systems, it demonstrates strong potential as an early-monitoring and preventive support tool for diabetic foot care.

Future work may focus on increasing the number of sensing points, improving sensor calibration, and incorporating alert mechanisms when pressure exceeds predefined safety thresholds. Overall, this study confirms that a low-cost IoT-based smart insole can provide meaningful plantar pressure information and contribute to early awareness and prevention of diabetic foot complications.

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# Electro Socks Massage: Development of a Portable Wearable Foot Therapy Device for Sepak Takraw Athletes

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## ABSTRACT

This study presents the development of the Electro Socks Massage, a portable IoT-enabled wearable device designed to support foot muscle recovery among Sepak Takraw athletes. The device integrates an ESP32 microcontroller, eccentric vibration motors, and a Blynk-based mobile application to deliver customizable vibration therapy through a modified sports sock. The methodology involved system design, hardware integration of miniature actuators and lithium-ion power modules, firmware programming for wireless control, and prototype construction using textile-embedded electronics. The developed prototype demonstrated stable wireless operation, accurate motor responsiveness, and an ergonomic wearable structure that ensured user comfort during use. User-based testing involving ten athletes indicated that approximately 80% of participants reported reduced foot fatigue after therapy sessions, while the system exhibited response times of less than one second during wireless operation. These results confirm the feasibility of delivering localised vibration therapy through a wearable IoT-controlled platform. Overall, the Electro Socks Massage prototype highlights the potential of IoT-driven wearable rehabilitation devices to enhance accessibility, portability, and personalisation in athlete recovery, serving as a practical complementary tool to conventional post-training therapy methods.

*Keywords:* Vibration Therapy, Athlete Recovery, Internet of Things (IoT), Mobile Application, Sports Rehabilitation.

## 1.0 INTRODUCTION

Foot injuries remain a common problem among athletes, particularly those involved in high-impact sports that place repetitive stress on the lower limbs. Continuous jumping, rapid directional changes, and forceful landings often expose the foot and ankle to excessive mechanical loading, increasing the risk of musculoskeletal injuries (Fong et al., 2017). If not properly managed, these injuries may lead to persistent pain, reduced mobility, and long-term performance decline.

Sepak Takraw is a physically demanding sport that relies heavily on the lower extremities' strength, flexibility, and endurance. Players frequently perform explosive kicking and jumping movements, which place significant strain on the foot and ankle structures. Previous studies have reported that foot and ankle injuries account for a substantial proportion of injuries among Sepak Takraw athletes, highlighting the need for effective recovery strategies (Azhar et al., 2019; Thanes et al., 2020).

Recovery methods such as manual massage, ice therapy, and compression are commonly used to manage post-training fatigue and minor injuries. Although these approaches can be effective, they often require professional assistance, are time-consuming, and may not be easily accessible outside training facilities (Dupuy et al., 2018). As a result, athletes may delay recovery treatment, which can prolong fatigue and increase the risk of injury recurrence.

In recent years, wearable technology has gained attention as a practical solution for athlete recovery. Wearable therapeutic devices allow users to perform recovery sessions independently while maintaining consistency in treatment intensity and duration. Vibration-based therapy, in particular, has been shown to improve local blood circulation, reduce muscle soreness, and support post-exercise recovery when applied to targeted areas (Lau & Nosaka, 2021).

The integration of Internet of Things (IoT) technology further enhances the functionality of wearable recovery devices. Microcontrollers such as the ESP32 enable wireless communication, low-power operation, and compact system design, making them suitable for wearable health applications (Almeida et al., 2022). Through mobile-based control interfaces, users can adjust therapy parameters according to their comfort and recovery needs, improving usability and personalisation.

Based on these considerations, the Electro Socks Massage project was developed to provide a portable and wearable foot therapy solution specifically designed for athletes. By embedding vibration motors into a sock-based structure and enabling wireless control through a mobile application, the system aims to support convenient, customizable, and accessible foot recovery. This approach aligns with current trends in athlete-centred rehabilitation technology and contributes to the growing field of wearable health engineering.

## **2.0 METHODOLOGY**

This project employed a structured development methodology to design and evaluate the Electro Socks Massage wearable device. The methodology was organised into four main stages: system design, hardware development, software and IoT integration, and prototype construction. This approach was selected to ensure systematic development, functional reliability, and user safety, which are essential considerations in wearable therapeutic systems (Almeida et al., 2022).

### **2.1 System Design and Architecture**

The overall system architecture of the Electro Socks Massage device is illustrated in Figure 1. The system is centred on the ESP32 microcontroller, which functions as the main control unit. The ESP32 receives user commands from a mobile application and controls the activation of vibration motors through a relay module.

The ESP32 was selected due to its compact size, low power consumption, and built-in wireless communication capabilities, making it suitable for wearable health applications (Lee & Kim, 2020). The block diagram highlights the interactions among the control unit, power supply, vibration actuators, and user interface, providing a clear overview of system operation.

### **2.2 Hardware Development**

The hardware components were designed with emphasis on portability and user comfort. Vibration motors were used as the massage actuators due to their effectiveness in providing localised stimulation and their suitability for wearable applications (Lau & Nosaka, 2021). The motors were connected to a relay module, which acts as a switching interface to safely control motor operation.

A rechargeable lithium-ion battery was integrated to supply power to the system, enabling fully portable operation. Battery-powered wearable devices are preferred for

applications because they offer greater flexibility without reliance on external power sources (Kim & Lee, 2019). Component placement was arranged to minimise bulk and maintain flexibility when integrated into the sock structure.



Figure 1: System Design and Architecture

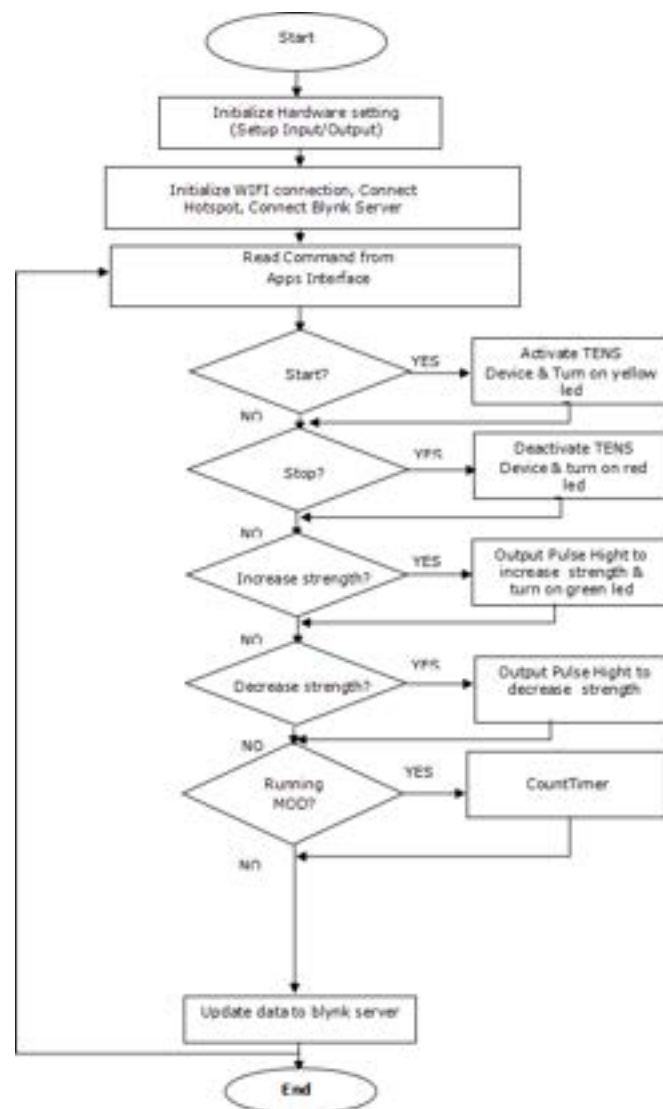


Figure 2: System Flowchart

## 2.3 Software and IoT Integration

The software development focused on enabling wireless control and reliable system operation. The ESP32 microcontroller was programmed with the Arduino IDE, and the Blynk platform was used to create a mobile user interface. Through the mobile application, users can adjust massage intensity and duration according to their comfort level.

The operational flow of the system is summarised in Figure 2, which shows the sequence from system initialisation to wireless connection, command reception, and vibration motor activation. This flowchart ensures that system operations follow a clear, logical sequence, thereby improving reliability and usability (Nguyen & Hallberg, 2021).

## 2.4 Prototype Construction and Functional Testing

The final prototype of the Electro Socks Massage device is shown in Figure 3. The vibration motors were embedded inside an elastic sports sock to enhance wearability and user comfort. Electrical wiring was carefully routed through the sock material to avoid discomfort during use.

The control module and battery were housed externally to reduce weight on the foot and protect electronic components. Functional testing was conducted to verify vibration responsiveness, wireless connectivity stability, and basic battery performance. The device was operated using the mobile application, and the system response was observed under normal operating conditions. Such functional validation is essential to ensure safe and reliable operation of wearable therapeutic devices (Lee & Wong, 2020).



Figure 3: Electro Socks Massage prototype

## 3.0 RESULTS AND DISCUSSION

This chapter presents and discusses the results obtained from the development and testing of the Electro Socks Massage device. The discussion focuses on system functionality, response performance, and preliminary user-based evaluation. The results are interpreted in relation to

the project objectives and supported by relevant recent studies in wearable therapy and sports recovery.

### 3.1 System Functionality and Prototype Performance

The completed Electro Socks Massage prototype is shown in Figure 3. The device successfully integrates an ESP32 microcontroller, vibration motors, a relay module, a rechargeable battery, and a mobile application interface within a wearable sock structure. During testing, the system demonstrated stable operation with no unexpected interruptions or component failures.

Activation of the vibration motors through the Blynk mobile application was immediate, indicating reliable wireless communication between the ESP32 and the user interface. The response time between user input and motor activation was observed to be less than one second, which is acceptable for wearable therapeutic applications. Similar response performance has been reported in recent IoT-based wearable recovery devices, where real-time feedback is critical for user satisfaction.

### 3.2 Evaluation of Vibration Control and Voltage Levels

The effectiveness of the vibration therapy was evaluated by varying the supplied voltage between 1 V and 20 V. The distribution of voltage levels used during testing is presented in a boxplot analysis in Figure 4. The results indicate that higher voltage levels produced stronger vibration intensity, which was perceived as more effective by the users.

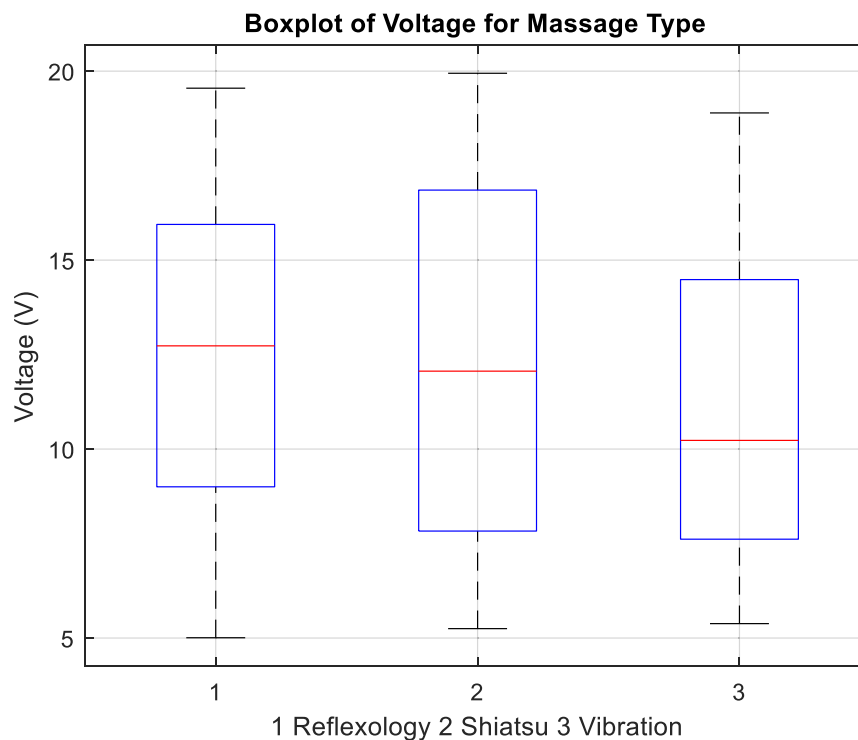


Figure 4: Boxplot of Voltage for Massage Type

Based on the analysis, voltage levels between 14 V and 20 V were found to provide the most effective massage sensation without causing discomfort. Lower voltage levels (below 8 V) produced minimal vibration and were generally reported as insufficient to achieve a therapeutic effect. These findings are consistent with previous studies, which reported that adequate vibration amplitude is necessary to stimulate blood flow and reduce muscle fatigue effectively.

### 3.3 Statistical Distribution of Therapy Parameters

Histogram and normal distribution plots were used to analyse the consistency of voltage application across different massage modes, as shown in Figures 5 to 7. The results demonstrate that voltage values were distributed within a controlled range, indicating stable system performance during repeated testing sessions.

The relatively symmetrical distributions in the histograms suggest that the system delivered consistent output across multiple trials. Consistency in therapeutic output is essential for wearable rehabilitation devices, as inconsistent stimulation may reduce treatment effectiveness and user trust.

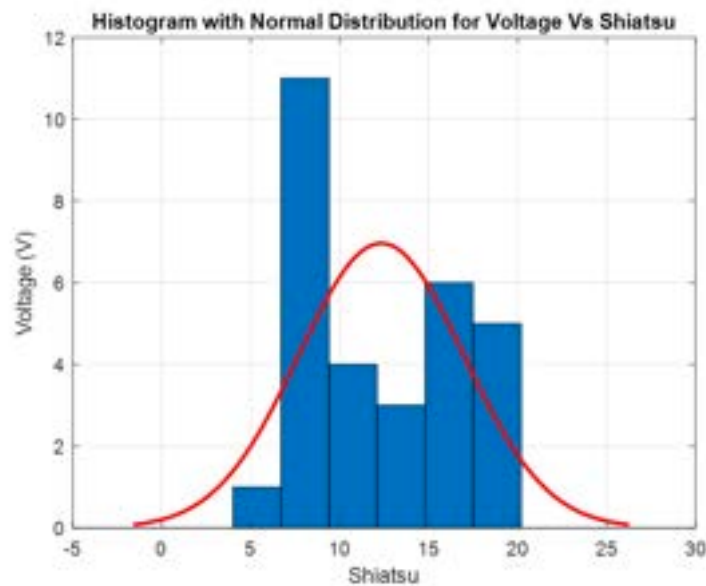


Figure 5: Histogram with normal distribution for voltage versus shiatsu

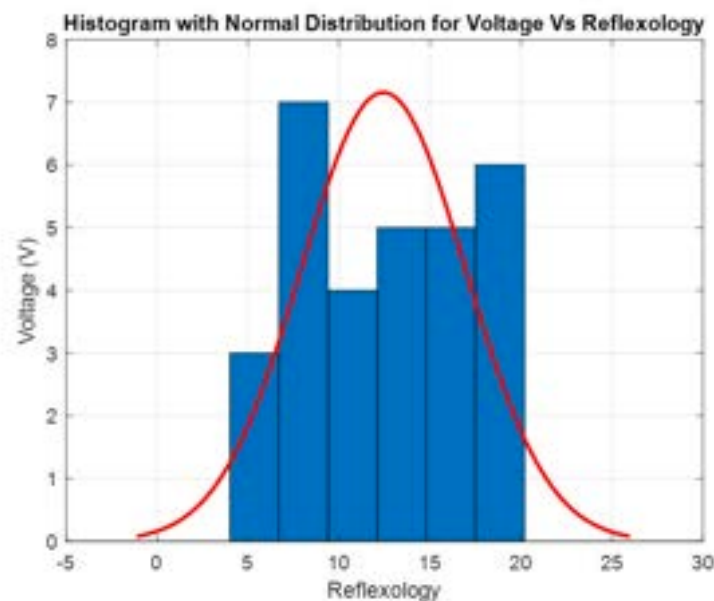


Figure 6: Histogram with normal distribution for voltage versus Reflexology

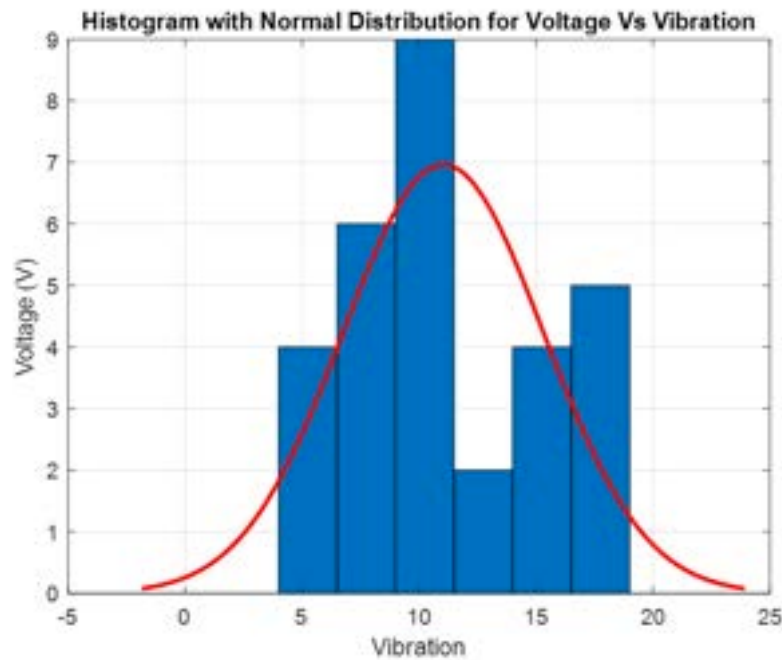


Figure 7: Histogram with normal distribution for voltage versus Vibration

### 3.4 User-Based Testing and Physiological Response

User-based testing was conducted involving 10 athletes who experienced foot discomfort or fatigue. Each participant completed three therapy sessions, with each session lasting 15 minutes. During the evaluation period, participants reported noticeable relaxation and reduced foot discomfort after therapy.

Physiological response was assessed using heart rate measurements before and after therapy sessions. Results showed an average reduction in heart rate of 5–8 beats per minute (bpm) after therapy, suggesting a relaxation response associated with vibration-based massage. Similar reductions in heart rate following massage therapy have been reported in sports recovery studies, indicating reduced sympathetic nervous system activity.

In addition, approximately 80% of participants reported a significant reduction in perceived foot pain and fatigue after completing the therapy sessions. These subjective responses align with findings from recent wearable vibration therapy studies, which emphasise the role of localised stimulation in enhancing recovery and user comfort.

### 3.5 Discussion

The results demonstrate that the Electro Socks Massage device successfully achieved its intended functionality as a wearable, IoT-enabled foot therapy system. The integration of the ESP32 microcontroller provided reliable wireless control and low-power operation, which are critical requirements for wearable health devices.

The identification of an effective voltage range (14–20 V) supports the importance of adjustable therapy intensity, allowing users to tailor massage strength according to individual comfort levels. This customisation is a key advantage of wearable recovery devices compared

to traditional manual massage, which may vary depending on the practitioner. From an engineering perspective, the consistency observed in voltage distribution and system response indicates that the hardware and software integration was successful. The use of boxplots and histograms provided a clear visualisation of system stability, reinforcing the reliability of the developed prototype.

Overall, the findings suggest that the Electro Socks Massage device offers a practical and accessible solution for post-exercise foot recovery. While the current evaluation was limited to a small group of users, the positive functional performance and user feedback indicate strong potential for further development and extended clinical testing.

#### **4.0 CONCLUSION**

This project successfully developed a wearable foot therapy device known as the Electro Socks Massage, designed to support post-exercise recovery among athletes, particularly those involved in high-impact sports such as Sepak Takraw. The project achieved its primary objective of integrating vibration-based massage therapy into a portable sock-based structure controlled through an IoT-enabled system.

The developed prototype demonstrated stable operation, effective wireless control, and consistent vibration output. The integration of the ESP32 microcontroller enabled reliable communication with the mobile application, allowing users to adjust massage intensity and duration according to their comfort level. Functional testing confirmed that the system responded promptly to user commands, indicating suitable performance for wearable therapeutic applications.

A user-based evaluation involving 10 athletes showed positive outcomes. Voltage levels between 14 V and 20 V were identified as the most effective range for delivering noticeable vibration therapy without causing discomfort. In addition, most participants reported reduced foot pain and fatigue after therapy sessions, while physiological measurements indicated a decrease in heart rate following treatment. These findings suggest that vibration-based massage delivered through a wearable device can support relaxation and recovery after physical activity.

From an engineering perspective, the project demonstrated successful integration of hardware, software, and wearable design considerations. The use of vibration motors, relay control, and battery-powered operation contributed to system reliability and portability. Overall, the Electro Socks Massage project confirms the feasibility of using IoT-enabled wearable technology as a practical tool for athlete recovery and foot care.

#### **4.1 Recommendations for Future Work**

Although the Electro Socks Massage project achieved its intended objectives, several improvements and extensions are recommended for future development. First, future versions of the device could incorporate more compact electronic components, such as flexible printed circuit boards (flexible PCBs) and thinner battery modules, to further enhance comfort and reduce overall weight during prolonged use.

Second, the inclusion of additional sensors, such as temperature or pressure sensors, could provide more objective data on foot condition and therapy effectiveness. This would allow the system to support basic biofeedback functions and enable more personalised therapy settings based on user response.

Third, future studies should involve a larger number of participants and longer evaluation periods. Extended testing would allow more comprehensive analysis of recovery effectiveness, durability, and user acceptance. Such studies could also compare the Electro Socks Massage device with conventional recovery methods to further validate its benefits.

Finally, advanced data analytics and machine learning techniques could be explored to improve therapy personalisation. By analysing user usage patterns and feedback, future systems could automatically adjust massage parameters to optimise recovery outcomes. These enhancements would strengthen the device's potential for broader application in sports rehabilitation and wearable health technology.

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# High Efficiency Series Parallel Loaded Resonant DC to DC Converter for Low Voltage Electronic Devices Applications.

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## ABSTRACT

The increasing demand for portable electronic systems has intensified the need for compact, high-efficiency low-voltage DC power converters. This paper presents the design, simulation, and experimental validation of a series–parallel loaded resonant DC–DC converter (SPLRC) intended for battery-powered low-voltage electronic applications. The proposed converter employs a half-bridge LCC resonant topology and operates under zero-voltage switching (ZVS) conditions to significantly reduce switching losses and enhance conversion efficiency. Comprehensive performance analysis was carried out using MATLAB Simulink and followed by hardware realization using PCB Wizard software. Simulation and experimental results demonstrate that the proposed SPLRC achieves a peak efficiency of 92–98% and delivers a regulated output voltage with voltage regulation within  $\pm 1$ –3% across nominal operating conditions. The results confirm that the SPLRC topology is well suited for high-efficiency, low-voltage DC power conversion in portable electronic applications.

*Keywords:* Loaded Resonant Converter, MATLAB Simulink, half bridge rectifier, LCC configuration, Zero Voltage Switching (ZVS).

## 1.0 INTRODUCTION

Battery-powered portable electronic devices, such as notebooks, digital trainer boards, mobile phones, hearing aids, and sonar transmitters, demand low-power operation while supporting varying processing speeds. In digital signal processing, a trade-off exists between speed and supply voltage, with modern devices often requiring supply voltages as low as 0.5 V. Analog circuitry, however, is constrained by external signals and load requirements.

Rechargeable batteries, particularly lithium-based chemistries, provide a maximum open-circuit voltage of approximately 4.2 V, whereas modern silicon VLSI circuits have a maximum usable voltage of around 2 V. To efficiently bridge this voltage gap, high-efficiency DC–DC converters are required, enabling multiple regulated supply voltages to optimize power consumption for different circuit blocks.

Among DC–DC converters, resonant converters are widely used in applications requiring fixed or regulated output voltages, such as induction heating, fluorescent lighting, sonar transmitters, and ultrasonic generators. [1] The Series–Parallel Loaded Resonant Converter (SPLRC), which employs two capacitors and one inductor in a half-bridge configuration, is particularly effective in providing high efficiency, low electromagnetic interference (EMI), zero-voltage switching (ZVS), and zero-current switching (ZCS) operation at high frequencies.

Despite extensive studies on resonant converters, a research gap remains in applying SPLRC topologies to battery-powered, low-voltage portable electronics, where stringent efficiency, voltage regulation, and compact design are critical. This study aims to design, simulate, and implement a high-efficiency SPLRC that provides a stable low-voltage output from a battery source, demonstrating its potential for modern low-power electronic applications.

## 1.1 Problem Statement.

The DC to DC converter is a part of a power electronic circuit that converts from one level DC voltage to a desired level DC voltage and usually with a regular output. DC to DC converters are widely used in switching power supply modes as found in computers, television receivers, battery chargers, DC motor driving and sometimes used as a supply voltage for IC in Digital trainer board. Among the DC-DC converter is a converter basis step-up and step-down converters, each known as a buck converter and a boost converter. Buck boost Converter also can raise and lower the voltage, however, is the opposite polarity of the output voltage from the input voltage. In addition, the problems faced by other converters are manufactured circuit is more complex and complicated. This causes difficulty and problems for converters. Although some output converter also generates a lot of noise. Among other problems, the converter will give a slow response time operation. This thus gives poor efficiency capabilities. Since the efficiency was very low, this problem can be solved by using a Series Parallel Loaded Resonant Converter (SPLRC).

## 1.2 Literature Review.

This research proposes to apply a several component half bridge series parallel resonant converters. Designing of SPLRC needed the value of the component, so MATLAB Simulink and programming is important medium to designing the series parallel resonant converter module. MATLAB is a high-level language and interactive environment for numerical computation, visualization, and programming. [2]The use of MATLAB and its companion toolboxes in teaching graduate and undergraduate control systems and signal analysis courses has long realized and reported by many educators. More recently, some have started using this package in undergraduate electrical engineering circuit courses. These works concentrate on the numerical capabilities of MATLAB for solving linear equations and its plotting capabilities.

Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) will be used to inject the high frequency of SPRC module. The characteristics of a high frequency power MOSFET are reviewed to design the SPRC module.[3]This inverter circuit includes the first resonant capacitor and that of the second resonant capacitor with a one-way short-circuit switch and can output the variable frequency from 160kHz to 400kHz by using power MOSFETs. The power MOSFET has the disadvantages of withstand voltage and current. To solve this problem by the methods of connecting the switching devices in series. The half-bridge circuit is an elegant solution for many switched-mode applications that offers many benefits. But these benefits are realizable only when the half-bridge circuit, the gate drive circuit, and layout, are all properly designed.[4]As in the half-bridge converter, the high-side and low-side power MOSFETs' complementary driving circuit is a common topology in many other power converters, such as synchronous buck converter, class-d power amplifier, brushless direct current (BLDC) motor driver, and full-bridge converter.

## 2.0 METHODOLOGY

### 2.1 Flow Chart Process.

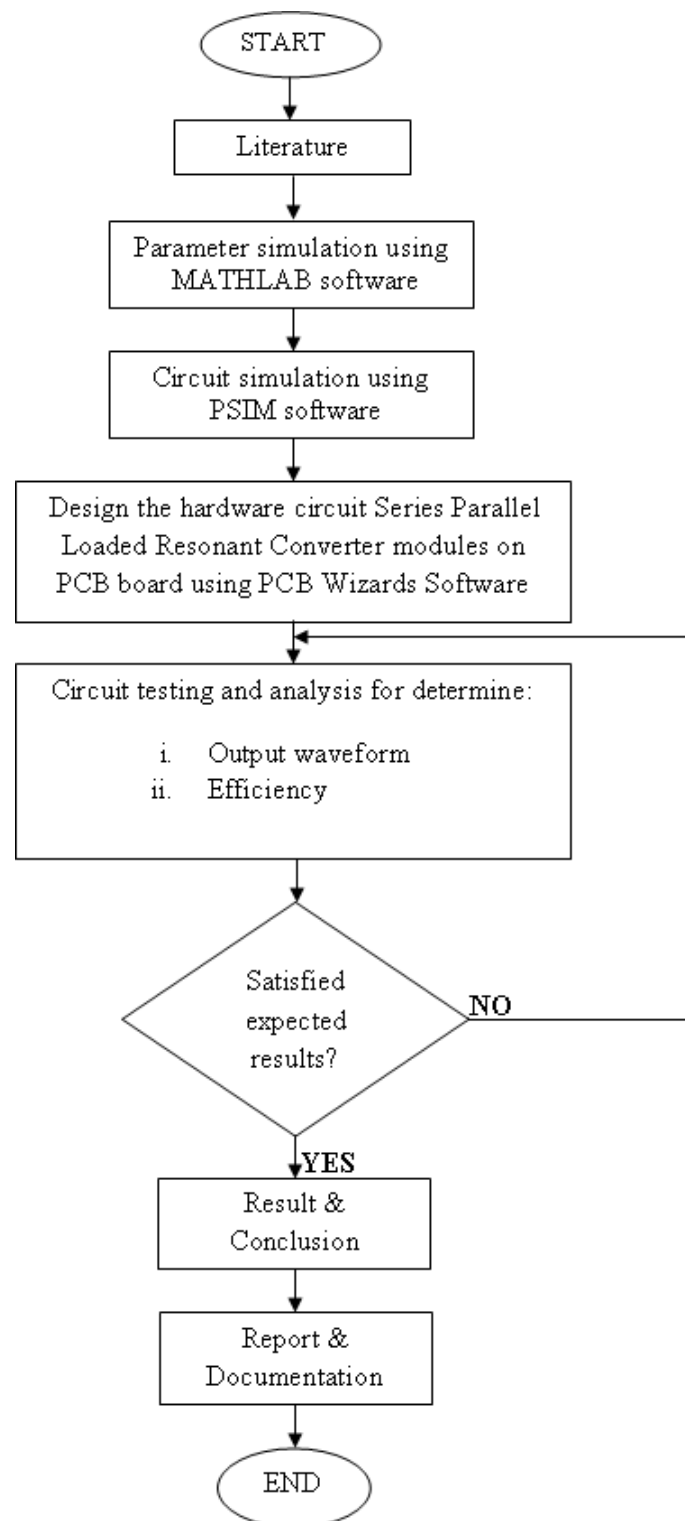


Figure 1.0: Flow chart process.

#### i. Literature.

The process that will involve work that makes it possible to study the relevant information about the resonant converter. Literature on the topic, all information about or related to resonant converters has been reviewed and analyzed to obtain accurate knowledge of resonant converters.

- ii. **Simulate.**  
This process is done to do the preliminary work for the circuit. Simulation will provide an accurate product and ensure that the circuit can operate well before the actual circuit formed.
- iii. **Design.**  
This work requires specific components, which refer to circuit simulation. Materials for producing PCB circuit design is also needed, so the possibility that this block requires capital and hard work.
- iv. **Testing.**  
Testing performed will also refer to the previous simulation circuit so the results will be correct and accurate in accordance with specifications. Testing the product including the efficiency and harmony.
- v. **Satisfied.**  
Testing the circuit to obtain correct results according to the specifications. If the results obtained in accordance with the specifications, the next process can be implemented.
- vi. **Analysis.**  
Analysis is commonly done in the form of computation. In addition, the results can be analyzed according to a schedule or arrange a specific graph.
- vii. **Report.**  
Documentation is to provide technical paper, slide presentations and project reports.

## 2.2 Block Diagram of SPRC.

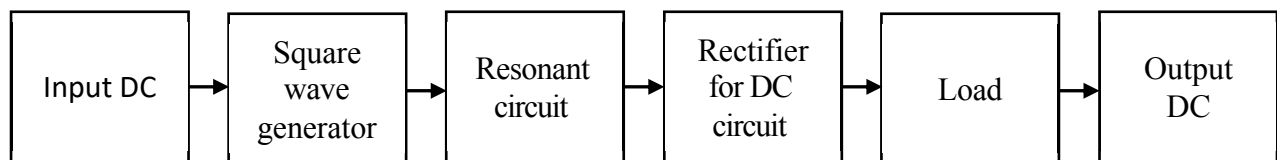


Figure 2: Block diagram of SPRC .

- i. **DC Input : 12v**
- ii. **Squarewave Generator.**  
In Squarewave generator block using two N-channel MOSFET connector in series each other. Inject the pulse signal at gate with frequency 20kHz each other.
- iii. **Resonant circuit.**  
The converter is produced by splitting the resonant capacitor into two component  $C_s$  and  $C_p$  with the load being connected in parallel with  $C_p$  . Therefore the circuit is suitable for high output current applications.
- iv. **Rectifier for dc output.**  
Diode is a component in rectifier where four diode connected in series and parallel.
- v. **Load.**

The inductor is connected in series, capacitor and resistor connected in parallel to produce a load.

- vi. Output  
Refer to the result section.

### 2.3 SPLRC circuit.

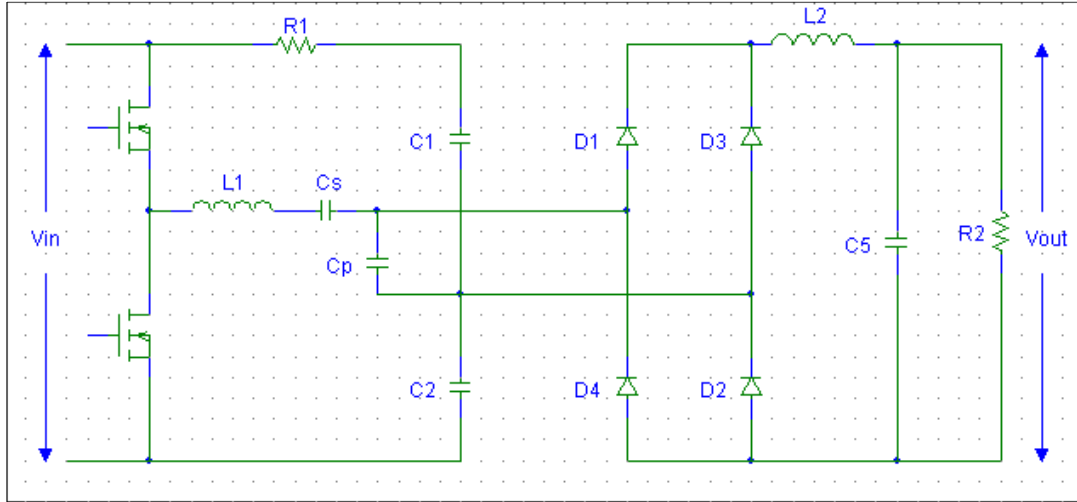


Figure 3: Series-Parallel resonant converter.

Figure 3 shows the combined series-parallel loaded converter is frequently used. The converter is produced by splitting the resonant capacitor into two components  $C_s$  and  $C_p$  with the load being connected in parallel with  $C_p$ . DC input voltage connected and at the same time injected pulse frequency, ( $f_s$ ) 10kHz at the MOSFET. MOSFET1 and MOSFET2 are connected in series. The output to the resonant tank connected between source MOSFET1 and drain MOSFET2. Resonant tank connected through L-C filter. The filter capacitor ripple current  $C_s$  controlled by the choice of the filter inductor. The parallel capacitor  $C_p$  is effectively shorted by relatively low input resistance of the rectifier circuit. The operation is dominated by L- $C_s$  and the converter takes on the characteristics of a series-loaded converter. The rectifier for output dc where the current flow through diode 1 and diode 4 for positive cycle while diode 2 and diode 3 is negative cycle in forward bias.

### 2.4 Equivalent Circuit and Analysis.

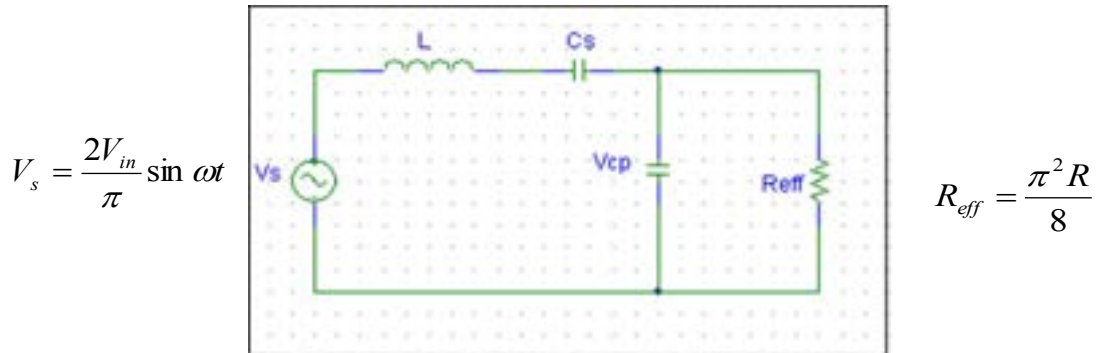


Figure 4: LCC configuration half bridge SPRC.

$$V_{in} = 12\text{V}, P_o = 200\text{W}, f_s = 10\text{kHz}$$

The equivalent circuit is shown in figure 4 as before sinusoidal input voltage and the voltage fed rectifier is replaced with an effective input resistance[5].

$$V_{in\_eq} = \frac{2V_{in}}{\pi} \sin \omega t$$

$$R_{eff} = \frac{\pi^2 R}{8}$$

$$V_o = \frac{C_p // R_{eff}}{(L + C_s) + (C_p // R_{eff})} \times V_{in}$$

$$\frac{V_o}{V_{in}} = \frac{C_p // R_{eff}}{(L + C_s) + (C_p // R_{eff})}$$

$$\left| \frac{V_o}{V_{in}} \right| = \frac{\frac{1}{2}}{\left| \frac{\pi^2}{8} \left[ 1 + \frac{C_p}{C_s} \left( 1 - \left( \frac{\omega}{\omega_o} \right)^2 \right) - jQ \left( \frac{\omega}{\omega_o} - \frac{\omega_o}{\omega} \right) \right] \right|}$$

In designing a converter,  $C_p = C_s$  is often chosen as a compromise limiting the operating frequency range but providing a reasonable variation in  $I_{xy}$  as load changes. The full-load  $Q$  is usually chosen to be around five since there is then 50% reduction in  $I_{xy}$  as the load is reduced.

$$C_p = C_s$$

$$\omega_n = \frac{\omega}{\omega_o} = \frac{2\pi f_s}{2\pi f_o}$$

$$\omega_o = \frac{1}{\sqrt{LC_s}}$$

Zero Voltage Switching where  $f_s > f_o$ ,

$$R_{eff} = \frac{\pi^2 R}{8}$$

$$Q = \frac{\omega_o L}{R}$$

(in practical,  $Q = 5$ )

The voltage conversion of the converter will be illustrated in graph where voltage conversion ratio plotted against  $\omega = \frac{\omega}{\omega_o}$  for a  $Q=5$  and ratio  $\frac{C_p}{C_s}$  equal to one.

## 2.5 Analysis and simulation.

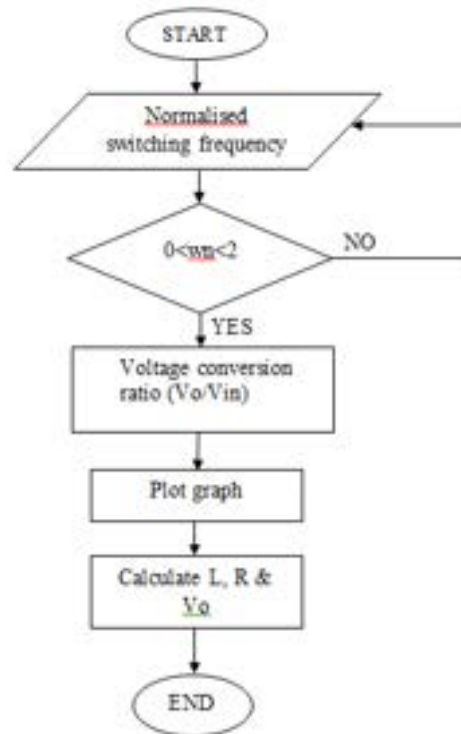


Figure 5: Flow chart for MATLAB calculation.

```

clear
clc

w=0.1:0.01:2.5;
wo=(2*pi*10e3) ./ w;
    display (w);
    display(wo);

    %Q=5;
    e=1./w;
    d=(5*(w-e)).^2;
    c=(1+(1*(1-w.^2))).^2;
    b=1.2347;
    a=0.5;
    f=(c+d).^(1/2);

    M=a./(b*f);
    display(M);

plot(w,M);
xlabel('Normalised swicthing frequency');
ylabel('Voltage conversion ratio');

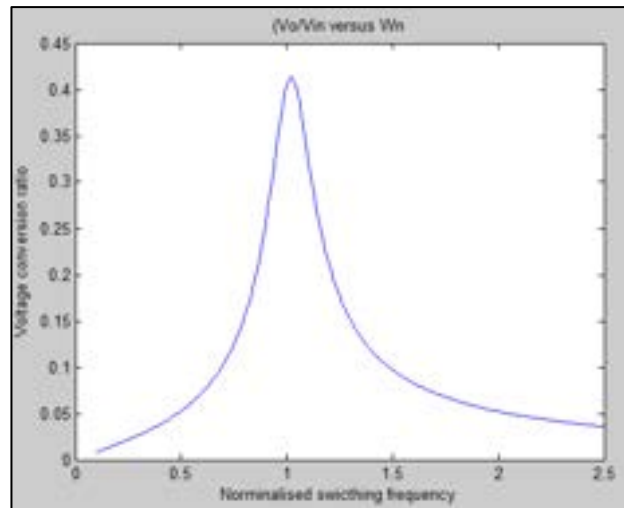
title('(Vo/Vin versus Wn)');
  
```

Figure 6: MATLAB programming for ratio versus resonant frequency.

Once the programming is completed then the code above will produce a graph of the ratio ( $V_o/V_{in}$ ) versus resonant frequency ( $\omega_n$ ) show in figure 7 below. From the graph, value of  $\omega_n$  suitable is 1.1 and table 1 below show calculation result using MATLAB.

Table 1: Plotting value.

| $\omega_n$           | 1.08   | 1.09   | 1.1    | 1.11   | 1.12   | 1.13   | 1.14   |
|----------------------|--------|--------|--------|--------|--------|--------|--------|
| $\frac{V_o}{V_{in}}$ | 0.3568 | 0.3418 | 0.3268 | 0.3122 | 0.2981 | 0.2846 | 0.2720 |
| $\omega_o$           | 58180  | 57640  | 57120  | 56610  | 56100  | 5560   | 55120  |

Figure 7: Graph  $V_o/V_{in}$  versus  $\omega_n$ 

From the table 1 above show  $\omega_n=1.1$  is suitable to choose and the results from the calculation of  $L$ ,  $R$  and  $V_o$  by MATLAB show table 2 below.

|                                                                                                                                                                                                                                                                                |                                                                                                                                  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| <pre>%Cp=Cs=3.07uF wn=1.1; Wo=57120;  %Wo=2*pi*fo fo=Wo/(2*pi); display (fo);  %Wo=1/(LCs)^(1/2) L=100e-6; display (L); Cs=1/((Wo^2)*100e-6); display(Cs);  Q=5; R=(Wo*L)/Q; display(R);  Reff=((pi.^2)*R)/8; display(Reff);  %M=Vout/Vin Vout=0.3268*12; display(Vout);</pre> | <pre>fo =     9.0909e+003  L =     1.0000e-004  Cs =     3.0650e-006  R =     1.1424  Reff =     1.4094  Vout =     3.9216</pre> |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|

Figure 8: Programming MATLAB for value of  $C_s$ ,  $L$ ,  $R$  and  $V_{out}$ .

Figure 8 above shows the results from MATLAB programming to achieve the value for  $C_s$  capacitor ( $C_s$ ), inductor ( $L$ ), resistor ( $R$ ) and the output voltage ( $V_o$ ). Once this information is obtained, the values of the components included in the circuit simulation using MATLAB Simulink and then the results are tabulated in the following table 2 for further discussion and make it easier to make referrals.

Table 2: Calculation from MATLAB

| $f_o$   | $L$   | $C_s = C_p$  | $R_{eff}$     | $R$           | $V_o (V_{out})$ |
|---------|-------|--------------|---------------|---------------|-----------------|
| 9.09kHz | 100mH | 3.07 $\mu$ F | 1.41 $\Omega$ | 1.14 $\Omega$ | 3.9216V         |

## 2.6 Hardware and Design.

Hardware design assisted by PCB layout software where the components suitable install at PCB. Figure 9 below show the layout for SPRC circuit.

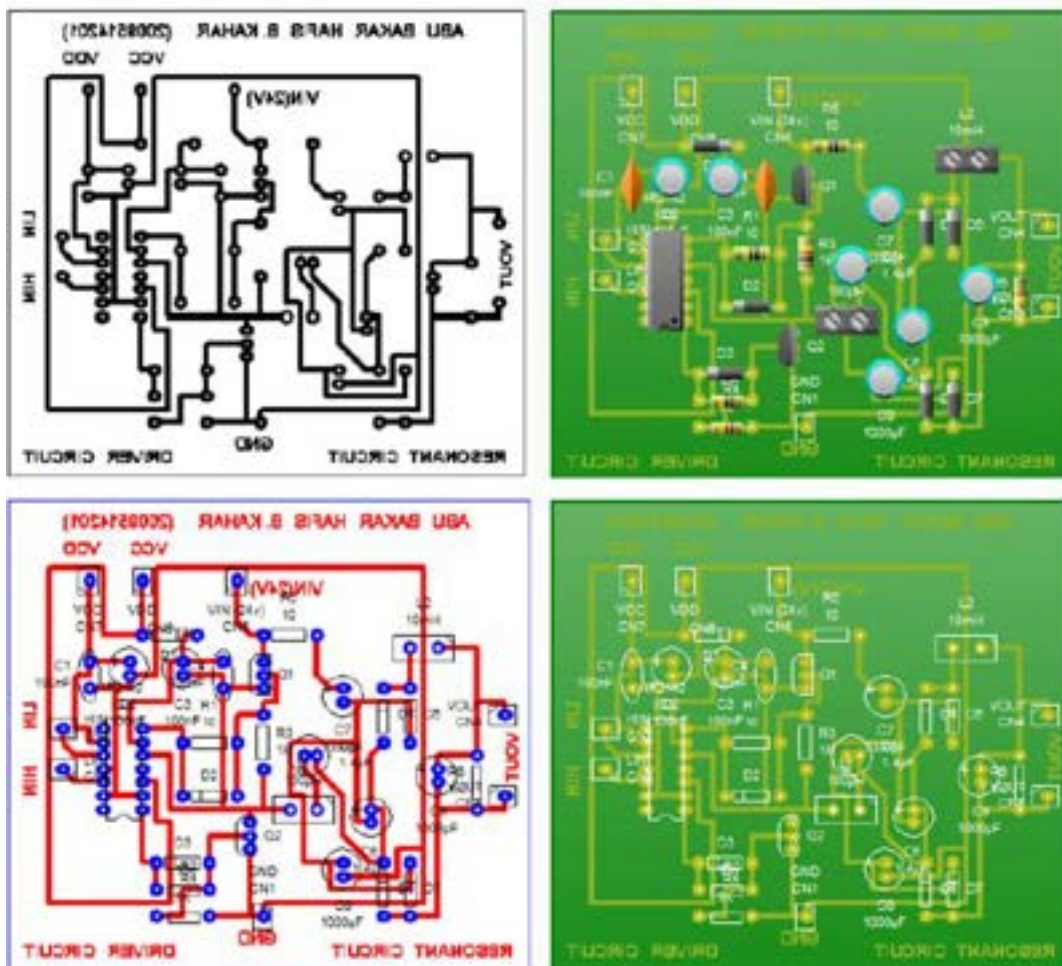


Figure 9: PCB layout design (hardware).

### 3.0 RESULTS AND DISCUSSION

#### 3.1 Result.

The results will be show in simulation and hardware testing. Figure 10 below show the input voltage and current form resonant tank.

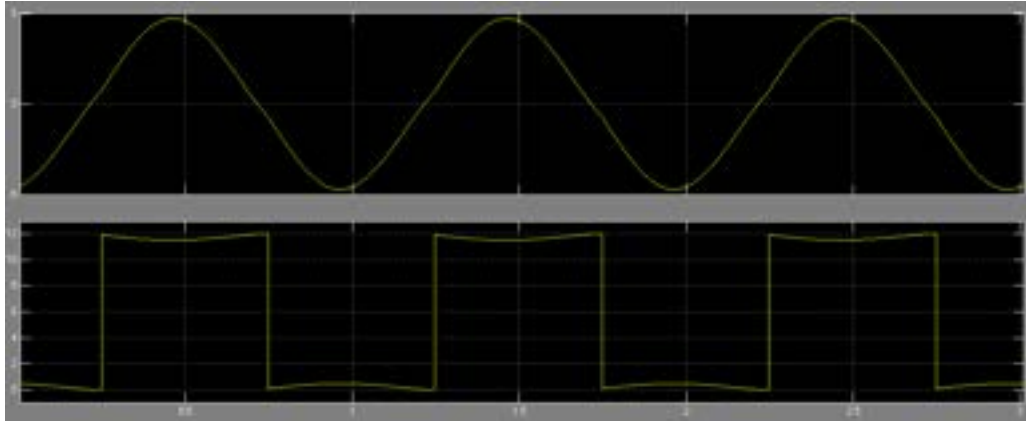


Figure 10: Input current and voltage resonant tank circuit.

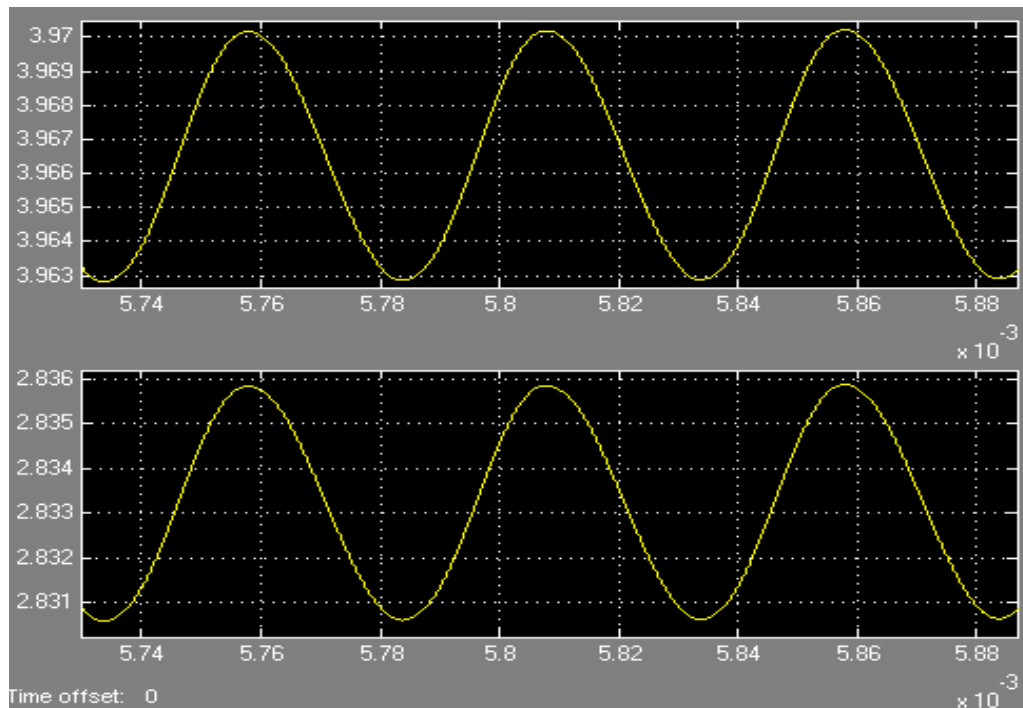


Figure 11: Output current and voltage resonant tank circuit.

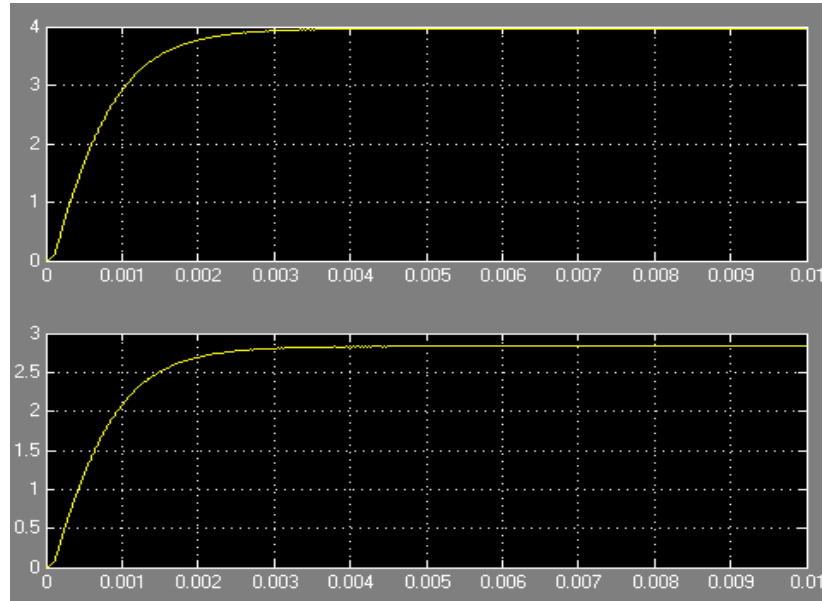


Figure 12: Output voltage ( $V_o$ ) after testing the result is 3.851V and current 2.836A.

From table2, the output voltage ( $V_o$ ) from calculation (simulation) given 3.921V and based on figure 12 the result (hardware) is 3.851V. The percent difference between calculation(simulation) and testing (hardware) around 1.78%.

$$\begin{aligned} \text{Voltage Efficiency}(\%) &= \frac{V_o(\text{measured})}{V_o(\text{simulation})} \times 100 \\ &= \frac{3.851}{3.921} \times 100 = 98\% \end{aligned}$$

Table 3: Output voltage from simulation and hardware.

| Result                   | Simulation | Hardware (measured) | Voltage Efficiency(%) |
|--------------------------|------------|---------------------|-----------------------|
| Output Voltage ( $V_o$ ) | 3.9216V    | 3.851V              | 98                    |

### 3.2 Discussion.

The difference between the output voltage obtained from hardware measurements and simulation is approximately 1.78%, which is acceptable in practical engineering applications. This difference occurs because simulations assume ideal components and operating conditions, whereas real hardware is affected by non-ideal factors such as component tolerances, unstable power supplies, parasitic resistance and capacitance in wiring and PCB traces, and temperature variations that influence device characteristics. Additionally, measurement instruments can slightly load the circuit and introduce small errors, while practical issues like wiring quality, grounding, and electrical noise further contribute to discrepancies. In contrast, simulations typically use exact component values, ideal power sources, and simplified models, leading to minor differences when compared to real measurements. Therefore, both the simulation and hardware results are accepted as valid references. From the hardware measurements, the input voltage at the resonant tank shown in Figure 10 is a square wave with a peak-to-peak voltage ( $V_{pp}$ ) of approximately 12V and a peak-to-peak current ( $I_{pp}$ ) of 5A. Figure 13 shows the output results of the SPLRC, where the output voltage is 3.851V and the output current is 2.836A. Based on these results, the system achieves a voltage efficiency of 98%, indicating that the converter operates with very high efficiency and minimal voltage

## 4.0 CONCLUSION

The objective of this project is to design, simulate, and experimentally validate a Series–Parallel Loaded Resonant DC–DC Converter (SPLRC) intended for battery-powered, low-voltage electronic applications, while gaining practical understanding of resonant converter technology. The SPLRC is a power conversion technique that operates by injecting a high-frequency pulse signal into a resonant tank circuit to regulate the output voltage. Depending on the circuit configuration, the SPLRC can function as either a step-up or step-down voltage converter, which represents its primary operating capability.

One of the main advantages of the series–parallel resonant converter is that the power switches, such as MOSFETs or IGBTs, can operate under Zero-Current Switching (ZCS) or Zero-Voltage Switching (ZVS) conditions. This significantly reduces switching losses, voltage and current stress on the devices, and improves overall efficiency. In addition, the sinusoidal resonant waveform reduces high-frequency harmonics, thereby lowering electromagnetic interference (EMI) and noise levels.

However, the SPLRC also has some disadvantages. The circuit topology is more complex compared to conventional DC–DC converters, and it tends to produce higher peak currents in the resonant tank. The efficiency of the SPLRC is highly dependent on the proper selection of the normalized switching frequency, which must be optimized to achieve the best output performance.

For future work, it is recommended to enhance the current protection mechanism in the switching stage. Improved protection circuitry would help safeguard power switches such as MOSFETs or IGBTs from damage caused by sudden overcurrent or fault conditions, thereby increasing the reliability and robustness of the converter system.

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# Hourly Acoustic Profiling of an Electrical Wiring Workshop Using Multi-Point LAeq Measurements

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## ABSTRACT

This study characterises the acoustic environment of the Electrical Wiring Workshop MC013 using hourly LAeq measurements collected from three strategically positioned monitoring stations: STA1 and STA2 located adjacent to the wiring bays, and STA3 positioned near the instructor's desk. Measurements were conducted from 08:00 to 16:00 across five working days in accordance with the workshop utilisation schedule, involving class sizes ranging from 10 to 34 students. Results reveal substantial noise variability, with hourly levels ranging from approximately 40 dB to 89 dB. The highest peak occurred on Tuesday during a large practical session, while Wednesday and Thursday exhibited the highest overall average noise levels. STA2 consistently recorded the highest noise exposure due to concentrated wiring activities, whereas STA3 showed more fluctuating levels influenced by intermittent external disturbances such as vehicular traffic. Several outliers were observed, attributed to sudden impacts and irregular student movement. Overall, the findings indicate that noise exposure within the workshop may approach or exceed recommended occupational limits specified by the World Health Organization (WHO) and the National Institute for Occupational Safety and Health (NIOSH) during intensive activities. This study provides a quantitative basis for acoustic risk identification and supports the development of noise mitigation and management strategies in technical and vocational training environments.

*Keywords:* workshop noise; LAeq; electrical wiring workshop; occupational noise exposure.

## 1.0 INTRODUCTION

Excessive noise exposure in technical workshops has become an increasingly significant occupational concern within engineering and vocational education environments. Noise levels exceeding 55 dB have been reported to impair concentration, reduce learning effectiveness, and compromise overall acoustic comfort in educational settings (World Health Organization [WHO], 2018). From an occupational safety perspective, the National Institute for Occupational Safety and Health (NIOSH) recommends an exposure limit of 85 dB for an eight-hour time-weighted average (TWA) (National Institute for Occupational Safety and Health [NIOSH], 1998), whereas the Occupational Safety and Health Administration (OSHA) permits a higher exposure limit of 90 dB under regulated occupational conditions (Occupational Safety and Health Administration [OSHA], 2008). In addition, the ISO 1996-1:2016 standard provides internationally recognised methodological guidelines for the measurement and assessment of environmental noise (International Organization for Standardization [ISO], 2016). In Malaysia, the Factories and Machinery (Noise Exposure) Regulations 1989 establish an action level of 85 dB to protect workers from hazardous noise exposure (Government of Malaysia, 1989).

Vocational workshops, such as electrical wiring laboratories, typically exhibit highly fluctuating noise patterns due to variations in practical activities, tool operation, student movement, and intermittent external noise intrusion. Previous studies have shown that technical training environments frequently record equivalent continuous sound pressure

(LAeq) ranging between 70 and 90 dB during intensive hands-on sessions (Ali et al., 2020). Such acoustic variability can adversely affect verbal communication, operational safety, and long-term auditory health among instructors and trainees.

This study evaluates the acoustic profile of the MC013 Electrical Wiring Workshop using hourly LAeq measurements obtained from three strategically positioned monitoring locations: STA1 and STA2 located near the wiring bays, and STA3 positioned at the instructor's desk. Measurements were conducted across five working days in accordance with the workshop timetable, involving class sizes ranging from 10 to 34 students. By integrating international and national noise exposure standards, this study provides a quantitative description of the workshop's acoustic conditions, identifies periods of elevated acoustic risk, and offers empirical evidence to support mitigation strategies aimed at enhancing safety and learning quality in vocational workshop environments. Although numerous previous studies have addressed noise exposure in technical training settings, investigations focusing on hourly and multi-point acoustic profiling within Malaysian technical training workshops remain limited.

## 2.0 METHODOLOGY

### 2.1 Research Design

This study adopts a quantitative approach based on continuous monitoring of equivalent continuous sound levels (LAeq) over one-hour intervals. Measurements were conducted over five working days (Monday to Friday) to capture temporal variations in noise associated with the operational schedule of the MC013 Electrical Wiring Workshop. The measurement protocol follows the guidelines outlined in ISO 1996-1:2016, which emphasise consistent temporal and spatial sampling for environmental noise assessment (International Organization for Standardization [ISO], 2016).

### 2.2 Measurement Locations

Three monitoring stations were selected based on workshop activity zones:

STA1: Located near the left wiring bay, a zone frequently used for basic wiring tasks.

STA2: Positioned near the right wiring bay, where the highest intensity of practical work occurs.

STA3: Installed near the instructor's table, representing a supervisory and communication area that also receives indirect external disturbances.

This spatial arrangement enables representative acoustic mapping across the workshop.

Table 1: Workshop utilisation schedule for Electrical Wiring Workshop (MC013)

| Class | No of Students | Day       | Time         |
|-------|----------------|-----------|--------------|
| DJK1A | 10             | Monday    | 2 PM – 6 PM  |
| DEP2A | 29             | Thursday  | 2 PM – 6 PM  |
| DEP2B | 30             | Tuesday   | 9 AM – 1 PM  |
| DEU2A | 34             | Wednesday | 8 AM – 12 PM |
| DEU2B | 31             | Friday    | 8 AM – 12 PM |
| DEU2C | 33             | Thursday  | 9 AM – 1 PM  |

### 2.3 Workshop Utilisation Schedule

Table 1: Workshop Utilizations Schedule for Electrical Wiring Workshop (MC013) shows differing activity densities across the week, with class sizes ranging from 10 to 34 students and practical sessions scheduled mainly between 08:00–13:00 and 14:00–16:00. Intensive morning sessions on Wednesday and Thursday, as well as the late-afternoon session on Monday, correspond to periods of higher expected noise, whereas some afternoon slots on Tuesday and

Friday exhibit lighter activity. The utilization schedule is used as contextual information to interpret temporal noise behavior.

## 2.4 Noise Data Acquisition

Noise measurements were collected at 15-minute intervals using standard LAeq procedures with a Class 2 sound level meter, with the microphone positioned at approximately ear height and oriented towards the primary activity zone, in accordance with the general recommendations of ISO 1996-1. Every four readings were averaged to obtain hourly noise levels. Data collection occurred from 08:00 to 16:00 daily, corresponding to the workshop's operational hours. The simplified hourly LAeq formula is:

$$LA_{eq, 1h} = \left( \frac{1}{4} \sum_{i=1}^4 LA_{eq, 15 \text{ min}, i} \right)$$

where  $LA_{eq, 15 \text{ min}, i}$  represents each 15-minute measurement. For pattern interpretation in this study, arithmetic averaging is applied, given that within-hour dynamic variations are moderate and the focus is on broader temporal trends rather than detailed spectral analysis. It is acknowledged that arithmetic averaging was applied to derive hourly LAeq values for simplified representation. While this approach does not fully capture short-duration impulsive noise events, it is adequate for identifying broader temporal patterns and relative acoustic risk periods within the workshop.

## 2.5 Data Analysis

Hourly LAeq values were plotted as line graphs for each day to identify temporal noise patterns, compare acoustic behaviour between monitoring stations, and relate noise variations to the class timetable and student numbers. Based on these profiles, periods of elevated acoustic risk were identified by comparing the observed noise levels with guideline limits established by the World Health Organization (WHO), the National Institute for Occupational Safety and Health (NIOSH), the Occupational Safety and Health Administration (OSHA), and the Malaysian Noise Exposure Regulations (Government of Malaysia, 1989; NIOSH, 1998; OSHA, 2008; WHO, 2018).

## 3.0 RESULTS AND DISCUSSION

This section presents hourly acoustic trends for STA1, STA2, and STA3 from Monday to Friday using line graphs (Figures 1–5). All hourly LAeq values were derived from averaged 15-minute recordings.

### 3.1 Monday

Figure 1 shows relatively low morning noise levels, mostly between 44 and 53 dB from 08:00–13:00 across all stations. A pronounced increase occurs between 14:00–16:00, when STA2 reaches 81 dB and STA1 and STA3 exceed 71 dB. This rise corresponds to the DJK1A practical session, illustrating the acoustic impact of late-afternoon wiring activities.

### 3.2 Tuesday

Figure 2 indicates a clear elevation from 09:00–12:00, with STA1–STA3 ranging between 65 and 80 dB. The highest recorded value for the entire week, 89 dB, occurs at STA2 between 11:00–12:00 during DEP2B's large practical group (30 students). After 12:00, noise levels drop and stabilise at approximately 46–50 dB, reflecting reduced workshop activity.

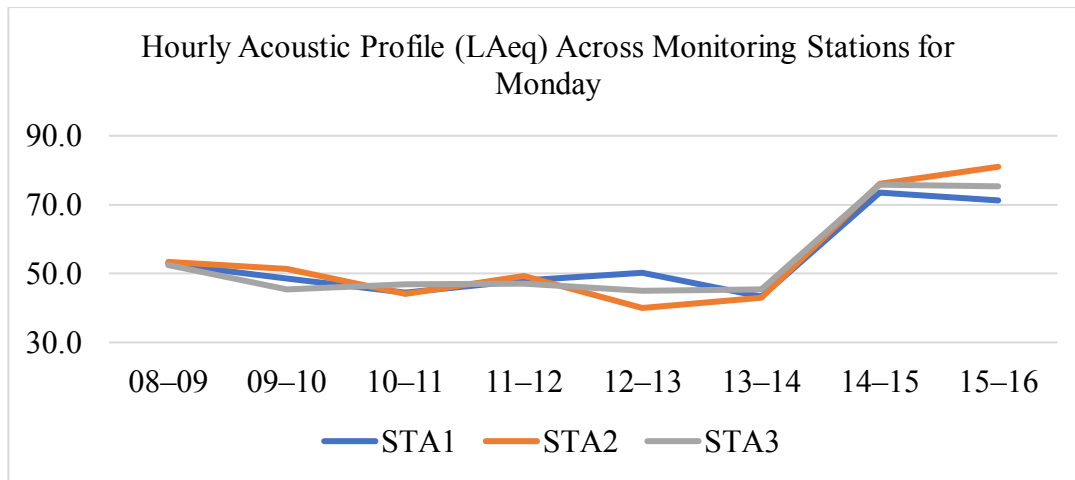


Figure 1: Hourly acoustic profile (LAeq) across monitoring stations for Monday.

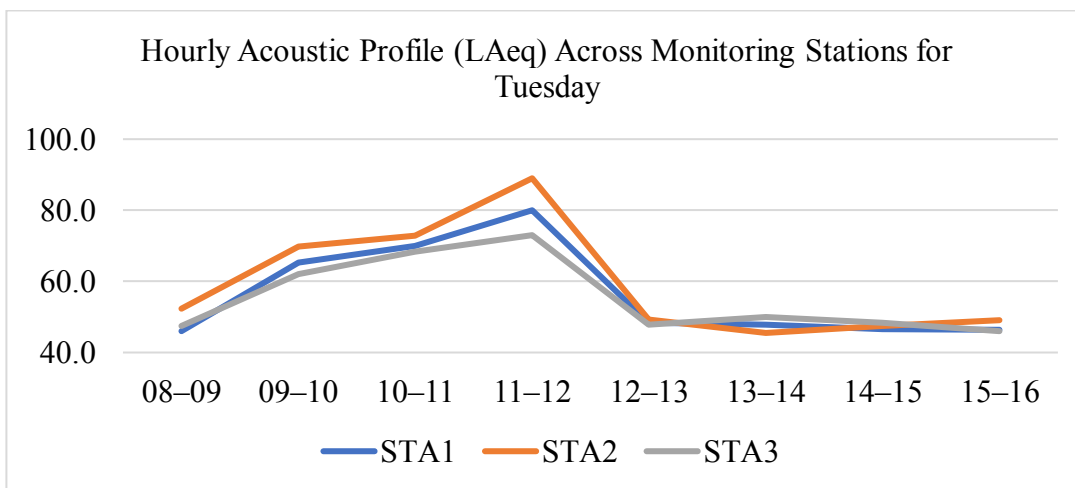


Figure 2: Hourly acoustic profile (LAeq) across monitoring stations for Tuesday

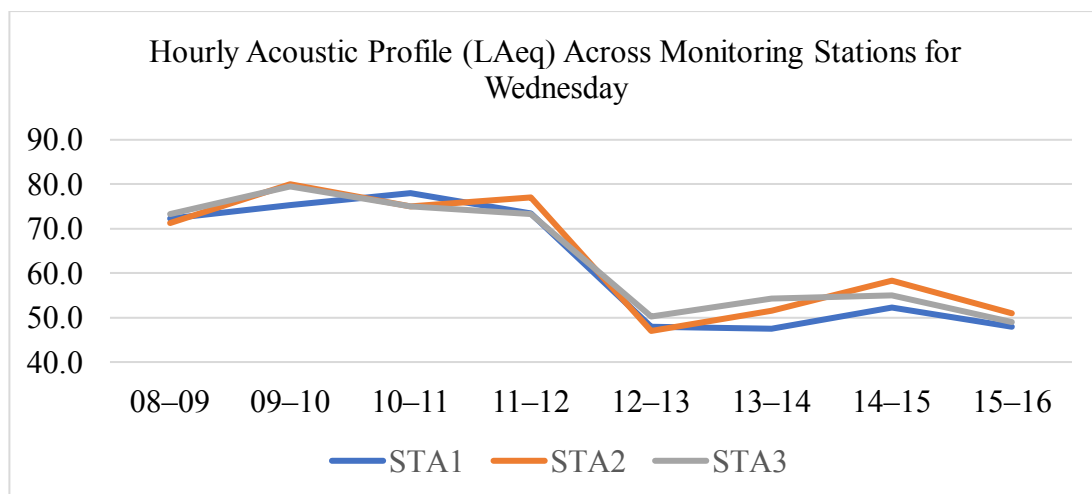


Figure 3: Hourly acoustic profile (LAeq) across monitoring stations for Wednesday

### 3.3 Wednesday

As shown in Figure 3, Wednesday exhibits consistently high readings between 08:00–12:00, where most hourly LAeq values lie between 73 and 80 dB across stations. These elevated levels are associated with DEU2A’s intensive practical class (34 students). After 12:00, noise levels decline to the 47–55 dB range, indicating a transition to lighter or non-technical activities.

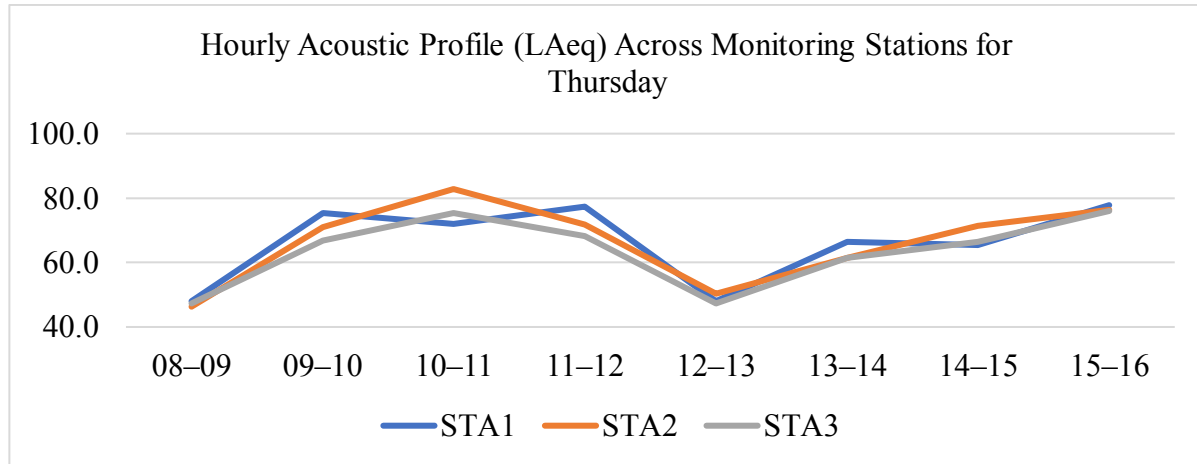


Figure 4: Hourly acoustic profile (LAeq) across monitoring stations for Thursday

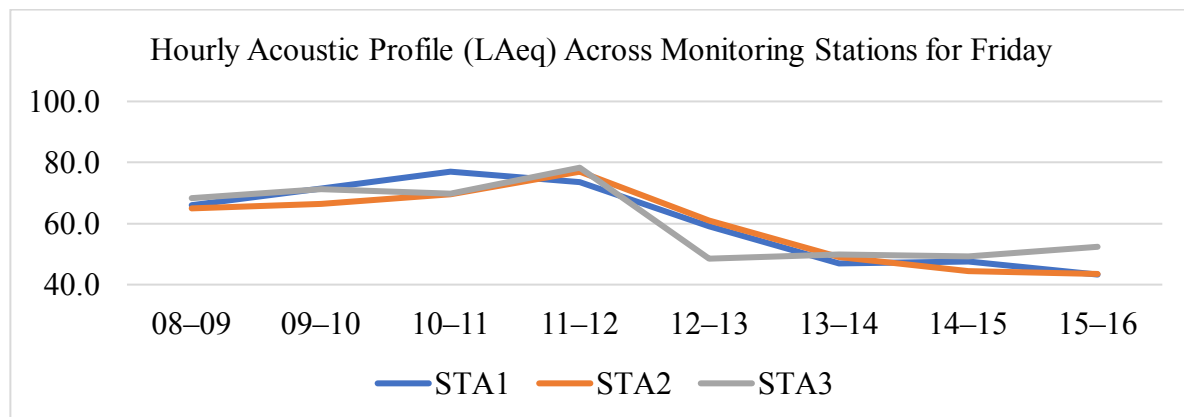


Figure 5: Hourly acoustic profile (LAeq) across monitoring stations for Friday

### 3.4 Thursday

Figure 4 presents two dominant high-noise periods: 09:00–11:00: STA2 peaks at 82.8 dB, while STA1 and STA3 remain above 66 dB, coinciding with DEU2C’s morning session. 14:00–16:00: All stations register levels above 65 dB, with STA1 approaching 78 dB, reflecting another intensive practical block. Considering both peak values and daily averages, Thursday emerges as one of the acoustically most demanding days in the workshop schedule.

### 3.5 Friday

Figure 5 shows moderate-to-high noise levels between 08:00–12:00, with STA1–STA3 mostly within 66–78 dB during DEU2B’s practical activities. After 12:00, levels decrease markedly: STA1 and STA2 fall into the 43–49 dB range, while STA3 remains slightly higher (up to 52 dB), influenced by intermittent external noise and residual movement in the workshop.

Comparison with international guidelines indicates that several measured noise levels exceeded recommended exposure thresholds. The World Health Organization (WHO) specifies a limit of 55 dB for educational settings to ensure effective communication and concentration (World Health Organization [WHO], 2018); however, many morning sessions on Wednesday and Thursday recorded LAeq values between 73 and 80 dB, which are substantially above this guideline. From an occupational safety perspective, the recommended exposure limit of 85 dB for an eight-hour time-weighted average proposed by the National Institute for Occupational Safety and Health (NIOSH) and the permissible exposure limit of 90 dB set by the Occupational Safety and Health Administration (OSHA) provide important benchmarks for risk assessment (National Institute for Occupational Safety and Health [NIOSH], 1998; Occupational Safety and Health Administration [OSHA], 2008). Notably, the maximum recorded value of 89 dB on Tuesday approaches the OSHA threshold and exceeds Malaysia's action level of 85 dB as stipulated under the Factories and Machinery (Noise Exposure) Regulations (Government of Malaysia, 1989).

Spatial analysis indicates that STA2 is the most acoustically vulnerable station. Its location adjacent to the primary wiring bay exposes it to intense practical activities such as cable cutting, component installation, and electrical testing. These tasks generate impact and mid-frequency noise, contributing to consistently elevated LAeq values. Additionally, higher student density in this zone amplifies the acoustic load through verbal communication and movement.

STA1 shows similar but slightly lower patterns, whereas STA3 displays more dynamic fluctuations. STA3 occasionally records elevated levels due to external disturbances such as nearby traffic or student movement, but generally remains lower than STA1 and STA2 as it is positioned further from hands-on tasks.

Overall, these results confirm that MC013 contains high-risk acoustic zones during morning hours (09:00–12:00) and selected afternoon periods (14:00–16:00). Such levels may lead to auditory fatigue, impaired verbal communication, and increased risk of error in tasks requiring precision. Mitigation strategies—including acoustic treatment, spatial restructuring, workload rotation, or administrative controls—should be considered to improve the learning and safety environment.

#### **4.0 CONCLUSION**

This study assessed the acoustic profile of the MC013 Electrical Wiring Workshop by analyzing hourly LAeq measurements collected from three strategically positioned monitoring stations across five working days. Findings confirm that noise levels within the workshop are strongly influenced by the intensity of hands-on activities, class size, and spatial characteristics of the measurement zones. The overall noise range of 43 dB to 89 dB reflects substantial variability consistent with technical training environments.

STA2 was identified as the most acoustically vulnerable location due to its proximity to high-intensity wiring activities. Morning sessions on Wednesday and Thursday frequently exceeded 75 dB, while the highest peak of 89 dB on Tuesday approaches OSHA's permissible limit and surpasses the NIOSH and Malaysian action levels. These results highlight the presence of high-risk acoustic zones that may compromise verbal communication, operational safety, and long-term auditory health.

In conclusion, the acoustic conditions in MC013 indicate the need for systematic mitigation and risk control. Recommended measures include the installation of sound-absorbing materials, reorganization of activity layouts, limiting class sizes during complex tasks, and the targeted use of hearing protection when necessary. The insights from this study provide a foundation for developing an effective noise management strategy to enhance safety and learning quality in vocational workshop environments while aligning with international and national acoustic standards.

Future work may extend this study by incorporating longer monitoring durations and frequency-weighted noise analysis to capture a wider range of acoustic characteristics. The effectiveness of specific mitigation measures, such as acoustic treatment or administrative controls, can also be evaluated. In addition, comparative studies across different technical and vocational training workshops are recommended to establish broader acoustic exposure benchmarks.

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## Smart 3R Bin

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### ABSTRACT

Inefficient manual recycling methods contribute to increasing waste generation and environmental pollution, necessitating innovative solutions to improve waste segregation accuracy and public participation. This project aims to develop a functional smart recycling bin prototype and evaluate its acceptance among users. The prototype was developed using the Arduino platform, integrated with ultrasonic sensors to accurately detect waste levels and a micro-servo motor for automated sorting of aluminum, paper, and plastic. An LED traffic light system was implemented to guide users to the correct bin compartment, while a Blynk application provides real-time waste level monitoring and full-bin alerts. Functional testing confirmed that the ultrasonic sensors accurately detected waste levels, the LED indicators successfully guided users, and data were transmitted reliably to the Blynk application. User feedback was overwhelmingly positive, indicating that the prototype was easy to use, visually appealing, and suitable for public areas. This analysis confirms the system's ability to operate effectively and reliably in a testing environment. The implementation of the bin has the potential to significantly enhance recycling efficiency and reduce landfill waste, fostering improved waste management habits. By providing clear guidance, the Smart 3R Bin encourages greater recycling awareness and promotes positive environmental practices within the community. In conclusion, the Smart 3R Bin successfully achieved its main objectives, resulting in a functional, user-friendly, and well-accepted solution for modernizing the recycling process.

*Keywords: Recycled bin, Arduino, ultrasonic sensor, micro-servo motor, Blynk.*

### 1.0 INTRODUCTION

The rapid escalation of global waste generation, driven by increased urbanization and consumption, presents a critical environmental challenge. Traditional manual recycling methods often lack efficiency, leading to contamination of recyclable materials and contributing to overflowing landfills and environmental pollution (e.g., poor waste segregation and wish cycling). In many regions, as mentioned by Hamsini et al. (2025), manual sorting in recycling processes is labour-intensive and error-prone, resulting in the misallocation of recyclables and increased operational costs.

To address these challenges, smart recycling systems have emerged as a promising innovation. Smart bins integrate sensor technologies and Internet of Things (IoT) capabilities to monitor fill levels, automate waste segregation, and provide real-time alerts for maintenance (Sunday et al., 2021). By using embedded devices such as ultrasonic sensors, microcontrollers (e.g., Arduino), and connectivity modules, smart bins can significantly improve waste management efficiency (Samann et al., 2017). Moreover, such systems can reduce collection frequency by ensuring bins are emptied only when necessary, thereby saving resources and minimizing environmental impact (Li et al., 2023).

Beyond technical performance, user interaction and acceptance are crucial for the success of smart recycling solutions. A people-centred design approach can enhance usability, encourage correct usage, and foster positive attitudes toward sustainable behaviour (Li et al., 2023). However, despite growing interest in the development of automated waste separation systems, there is comparatively less research on how users perceive and accept these technologies in real-world or semi-real-world settings.

This study aims to fill this gap by developing a Smart 3R (Reduce, Reuse, Recycle) Bin prototype using the Arduino platform, equipped with ultrasonic sensors, a micro-servo motor for sorting, and a user feedback system via an LED “traffic light” indicator and a Blynk mobile application. The prototype is designed to detect waste levels, automatically sort waste into aluminium, paper, and plastic compartments, and notify users and administrators of fill status in real time.

The objectives of this research are:

1. To design and build a functional smart recycling bin prototype that can accurately monitor waste levels and sort waste using sensor-based mechanisms.
2. To evaluate user acceptance of the developed prototype.

By addressing these objectives, the proposed Smart 3R Bin directly supports Sustainable Development Goal 12: Responsible Consumption and Production, emphasizing resource efficiency and waste minimization. The implementation of the prototype has the potential to encourage better recycling habits, reduce landfill dependency, and promote community engagement in environmental practices.

## **2.0 METHODOLOGY**

This methodology chapter describes the research design, prototype development, material selection, system integration, and data processing approaches employed in the construction of the Smart 3R Bin.

### **2.1 Product Design**

The methodology of this project outlines the processes involved in designing, developing, and testing the Smart 3R Bin prototype. Figure 1 illustrates the design dimensions of the Smart 3R Bin prototype alongside the actual product, providing sufficient space for three waste compartments dedicated to plastic, aluminium, and glass. Each disposal opening on the top has a dimension of 400 mm × 400 mm, allowing users to insert recyclable materials easily without obstruction. The slanted upper section, measuring 130 mm in height and 550 mm in slope length, is designed to create a modern and user-friendly appearance while enhancing accessibility. The proportional dimensions also ensure that all components (infrared sensors, LED indicators, and wiring systems) can be installed neatly inside the bin without affecting its external appearance.

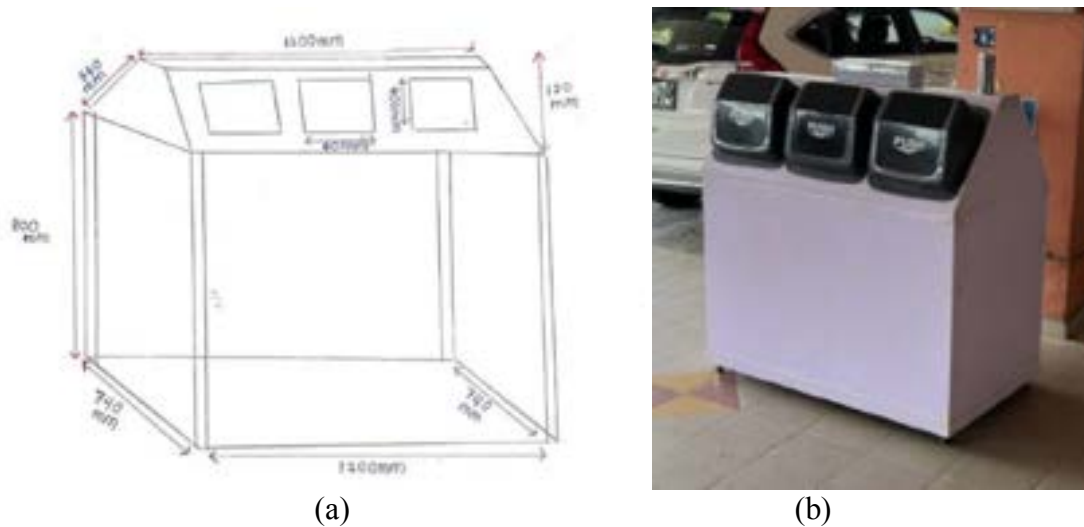


Figure 1: a) Dimensional size of Smart 3R Bin, b) The Smart 3R Bin prototype

## 2.2 Smart sensing system

The schematic diagram of the smart sensing system is presented in Figure 2. The increasing amount of waste generated daily has highlighted the need for an efficient waste segregation system. Traditional waste bins often lack proper separation mechanisms, leading to contamination of recyclable materials and increased handling and processing costs. To address this issue, the Smart 3R Bin was developed using sensor-based automation to improve segregation accuracy, promote recycling habits, and optimize waste collection.

The Smart 3R Bin utilizes an infrared sensor to classify aluminium, plastic, and paper waste based on light reflection, and an ultrasonic sensor to monitor the bin's fill level. LED indicators provide visual cues to users, while an automatic sorting mechanism directs waste into the correct compartment for plastic, aluminium, or paper. The system is further enhanced through integration with the Blynk IoT platform, which enables real-time monitoring and notifications when the bin reaches full capacity.

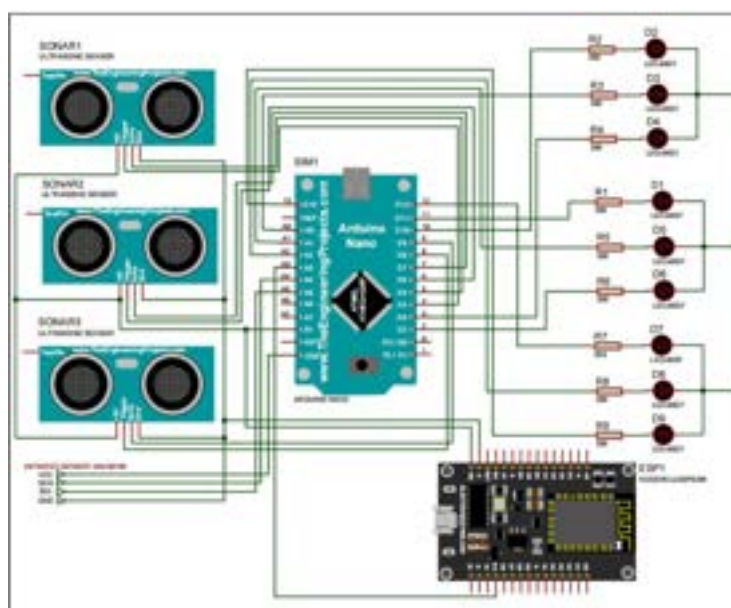


Figure 2: Schematic diagram of the smart sensing system

Figure 3: Smart sensing system setup

The system consists of an infrared sensor, an ultrasonic sensor, a microcontroller (ESP32), LED indicators, and the Blynk application. The infrared sensor detects the type of waste, while the ultrasonic sensor measures the bin's fill level. Data collected by these sensors are processed by the ESP32 microcontroller and transmitted to the Blynk application via a Wi-Fi connection. The following electronic components are housed inside an enclosure, as shown in Figure 3.



Figure 3: System architecture

Figure 4 shows the system architecture of the Smart 3R Bin. The diagram illustrates the flow of information from the input stage (waste detection) to the system components (ESP32, Arduino, and Blynk) and finally to the output stage, where LED indicators display the bin's status. The red light indicates that the bin is full, the green light shows that the bin is not full, and the yellow light represents ongoing waste detection activity.

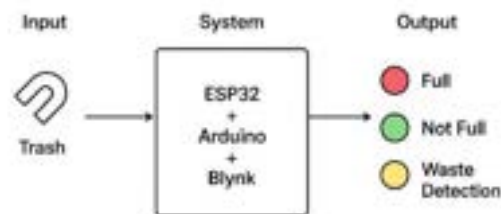


Figure 4: System architecture

The LED indication system provides immediate visual feedback to users regarding the bin's status and the type of waste being disposed of. Each LED colour represents a specific condition, enabling users to easily understand the bin's status. The yellow LED lights up when the sensor detects the type of waste being disposed of, such as plastic, paper, or aluminium, functioning as an indicator of the waste category. The green LED indicates that the bin's fill level remains within a safe range and is not yet full. When the bin reaches its maximum capacity, the red LED turns on as a warning that the bin is full and requires emptying. This system allows users to instantly identify the bin's status without consulting additional applications, thereby improving efficiency and convenience in daily waste management.

### 3.0 RESULTS AND DISCUSSION

#### 3.1 Object detection and LED light indicator

The Smart 3R Bin prototype, as shown in Figure 5(a), was functionally tested to evaluate the performance of its LED indication system and infrared-based object detection. The system was assessed using three types of recyclable materials: aluminium, plastic, and paper. During testing, each object was positioned at a minimum distance of 4.5 cm from the infrared sensor and held in contact with the sensor surface for approximately 15 seconds to ensure accurate detection.

Successful material detection was indicated by the activation of the yellow LED at the corresponding bin compartment, as shown in Figure 5(b). The results demonstrate that the sensor operated reliably within the defined proximity and detection duration. Following detection, the servo motor actuated to direct the waste into the appropriate compartment. The servo response times and detection outcomes are summarized in Table 1.

A *correct* condition was recorded when the yellow LED illuminated at the appropriate bin section corresponding to the detected material (e.g., plastic detected and plastic-bin LED activated). Conversely, an *error* condition occurred when the LED was activated at an incorrect bin section. Although minor variations in detection time were observed across different materials, these did not significantly affect overall sorting performance. Similar response delays have been reported in Arduino-based automated waste sorting systems and are generally attributed to sensor processing and actuator movement (Hassan et al., 2018).

Table 1: Time response result

| Waste object | Time Detection (second) | Sensor signal (Yellow lights on) |
|--------------|-------------------------|----------------------------------|
| Plastic A    | 10                      | Correct                          |
| Plastic B    | 15                      | Correct                          |
| Plastic C    | 8                       | Correct                          |
| Plastic D    | 9                       | Error                            |
| Plastic E    | 9                       | Error                            |
| Paper A      | 8                       | Correct                          |
| Paper B      | 15                      | Correct                          |
| Paper C      | 10                      | Correct                          |
| Paper D      | 8                       | Correct                          |
| Paper E      | 8                       | Correct                          |
| Aluminum A   | 7                       | Correct                          |
| Aluminum B   | 9                       | Correct                          |
| Aluminum C   | 9                       | Correct                          |
| Aluminum D   | 7                       | Correct                          |
| Aluminum E   | 23                      | Error                            |



Figure 5: a) The developed Smart 3R Bin, b) Object from plastic was detected and yellow LED lights up

The results shown in Figure 6 indicate that the infrared sensor consistently activated the yellow LED when waste materials were correctly detected and deactivated once the object was removed. These findings demonstrate that the infrared sensor provides reliable short-range detection and is suitable for smart waste segregation applications where direct object placement is expected.

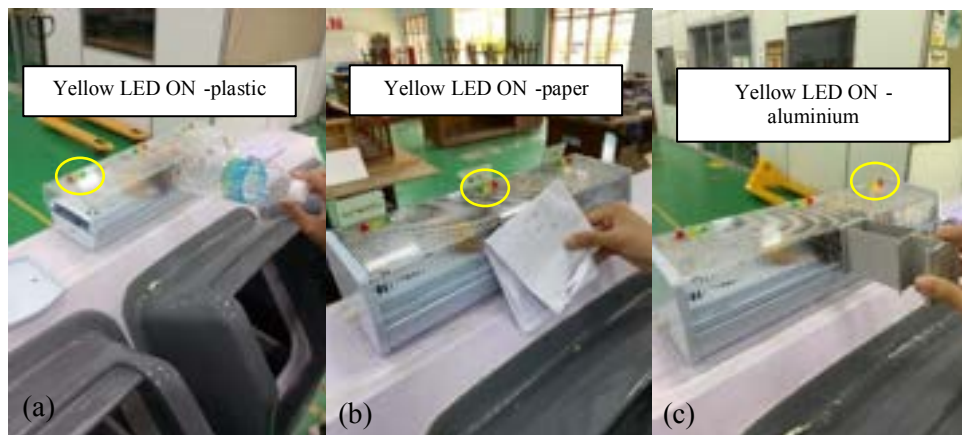


Figure 6: (a) Plastic, (b) paper and (c) aluminium identified, yellow LED lights up at each bin

### 3.2 Waste level detection using ultrasonic sensor

The primary purpose of this test was to verify the sensor's ability to accurately detect the fill level of waste in each bin compartment. The ultrasonic sensor was installed on the lid of the Smart 3R Bin and oriented downward to measure the fill level in each compartment. During testing, the bin-full condition was simulated by placing objects inside the compartments to gradually increase the waste height. The ultrasonic sensor measured the distance between itself and the waste surface and subsequently activated the corresponding LED status indicator.

The sensor accurately detected changes in waste level and triggered the appropriate LED indicators. The actual results confirmed that the system performed as intended: when the measured distance indicated available space, the green LED illuminated. Conversely, when the waste level approached the defined threshold, the red LED turned on, as shown in Figure 7, indicating that the bin was full. Based on these observations, the ultrasonic sensor successfully detected the waste level and met the functional requirements of the Smart 3R Bin.

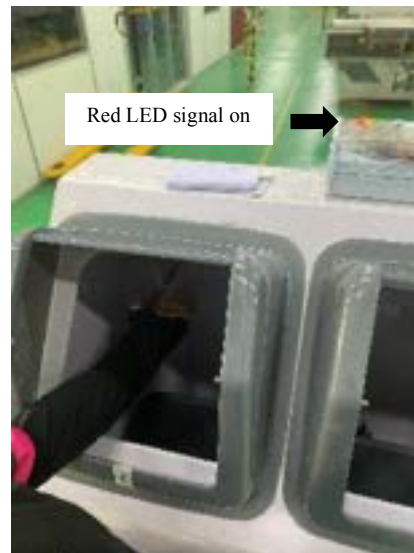


Figure 7: Waste level detection with red LED signal.

### 3.3 Blynk application test

The performance of the IoT monitoring system was evaluated using the Blynk application. As shown in Figure 8, the Blynk app successfully displayed the real-time status of the Smart 3R Bin and issued a notification when the ultrasonic sensor detected that the bin had reached its full level. This confirms that the communication between the hardware components and the Blynk cloud platform was stable and functioning as intended.

Figure 9 illustrates the trend of “critical events” recorded over time, representing the distance measurements collected from the ultrasonic sensor. Higher peak values in the graph correspond to shorter distances between the sensor and the waste surface, indicating that the bin was approaching full capacity. Conversely, the decline in the graph represents increasing distance values, signifying that the amount of waste in the bin had decreased, such as after manual emptying.

The observed fluctuations demonstrate that the ultrasonic sensor was capable of detecting continuous changes in the bin’s fill level. These real-time readings were transmitted accurately to the Blynk console, where they were processed and displayed for monitoring. Overall, the results confirm that sensor-to-platform data transmission is reliable and that the system can provide timely notifications regarding the bin’s status, thereby supporting efficient waste management operations.

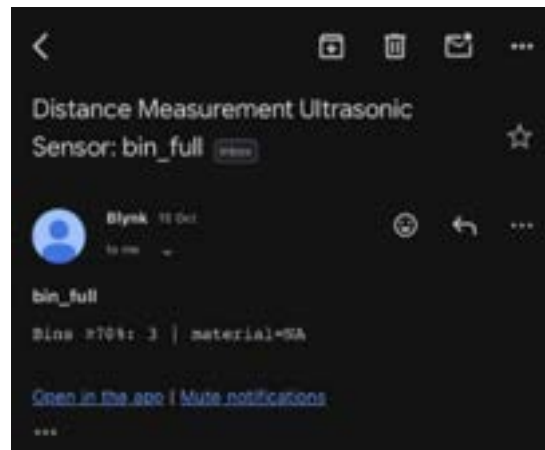


Figure 8: Notification of waste level detection when bin is full.

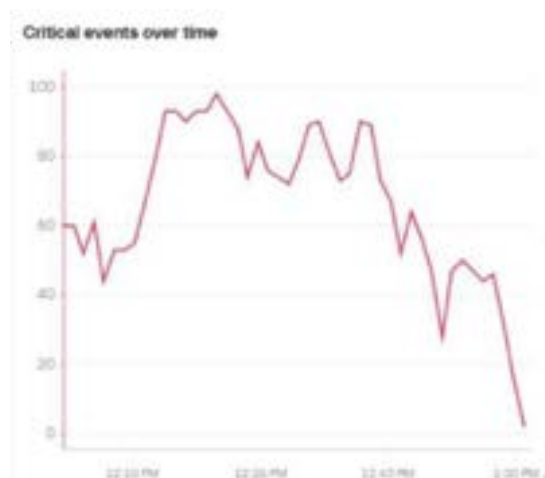


Figure 9: Waste level detection with red LED signal.

### 3.4 User feedback

As shown in Figure 10, the user evaluation results indicate a high level of acceptance of the Smart 3R Bin. Most respondents strongly agreed that the system is easy to use, enhances recycling convenience, and reduces the need for manual sorting. Positive feedback regarding the yellow LED indicator demonstrates that visual guidance effectively assists users in identifying the correct waste category, which aligns with findings that clear visual cues significantly improve waste segregation accuracy (Sankeerth et al., 2020). Additionally, users reported that the infrared sensor performs reliably in detecting waste materials, confirming the effectiveness of sensor-based detection for short-range applications, as supported by previous smart bin studies (Hassan et al., 2018). Overall, the results indicate that the Smart 3R Bin successfully integrates technical functionality with user-centered design to promote efficient and sustainable recycling practices.

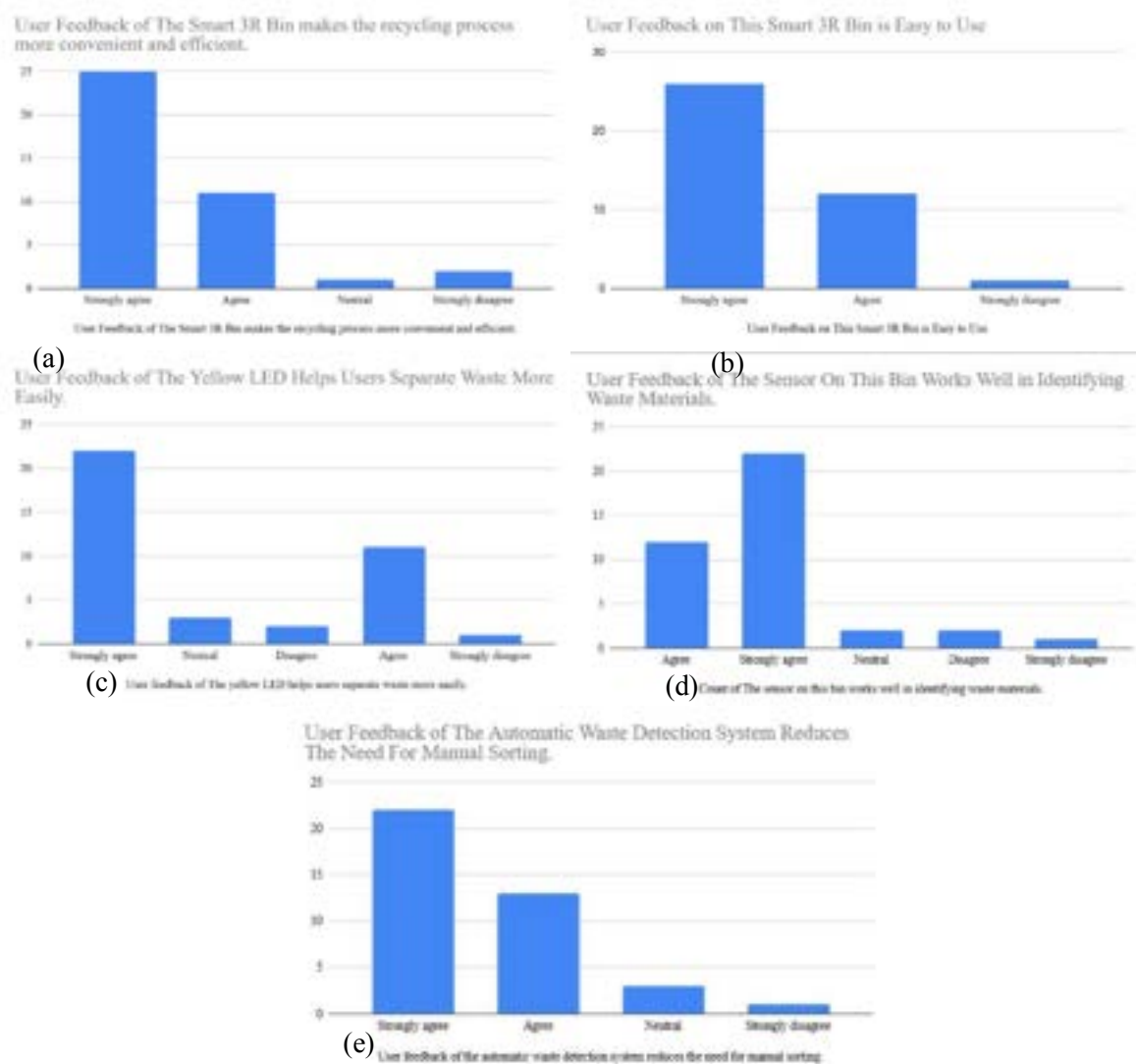


Figure 10: User evaluation results of the Smart 3R Bin: (a) ease of use, (b) recycling efficiency, (c) effectiveness of yellow LED indicator, (d) sensor performance in identifying waste materials, and (e) reduction of manual sorting

#### 4.0 CONCLUSION

This research successfully designed and developed a functional Smart 3R Bin prototype capable of monitoring waste levels and sorting recyclable materials using sensor-based mechanisms. System testing confirmed reliable object detection, LED guidance, and actuator response with acceptable processing delays. User evaluation results indicated a high level of acceptance, demonstrating that the system is easy to use, efficient, and suitable for public deployment. Overall, the Smart 3R Bin exhibits strong potential to improve waste segregation efficiency and support sustainable recycling practices through automated, user-centred design.

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# Application of Visual Observation Technique for Identifying and Categorizing The Timber Defects: A Case Study of TimTech House Design

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## ABSTRACT

The TimTech wooden house is located at Politeknik Sultan Salahuddin Abdul Aziz Shah and was constructed in 2022. After three years of exposure to environmental conditions, the structure has begun to exhibit signs of deterioration. This degradation is likely driven by a combination of biological and non-biological agents. The primary objective of this research was to investigate and identify the various types of wood defects present within the structure. A visual observation technique was employed in this study, and the analysis was conducted by identifying and categorizing the specific types of defects present in the TimTech house. Results from the study demonstrate that the house's wooden components suffer from deterioration caused by biological and non-biological factors, including fungal decay, timber fractures, and pigmentation changes. High average weekly rainfall, ranging from 33 cm to 49 cm, along with elevated moisture content (MC) levels ranging from 23% to 46%, also influenced the progression of these deteriorations. Therefore, it is highly recommended that a periodic maintenance framework is established as a preventive measure against progressive decay, thereby extending the service life of the timber components in the TimTech house.

*Keywords: Timber defects, Biology defects, Non-Biology defects, Timber house, SDG 12.*

## 1.0 INTRODUCTION

Building with wood is a key strategy for achieving SDG 12 (Responsible Consumption and Production) because it is sustainable, affordable, and visually appealing. Unlike steel or concrete, timber is a renewable resource with low embodied energy, stores carbon, and reduces waste through biodegradability. By employing modern construction methods and ensuring proper maintenance to extend the wood's lifespan, the industry can promote resource efficiency and more responsible consumption in the building sector (Isa, H. M., et al., 2025; Azzi, Z., et al., 2025). Wooden houses are traditional homes commonly found in Malay architecture (M. Nurfaizal et al., 2020). Wood is susceptible to damage from humidity, insects, and natural irregularities such as knots or grain slopes. When moisture levels exceed 20%, fungal decay becomes a major threat to structural integrity. Since timber is frequently used in homes and bridges, prolonged exposure to harsh weather can lead to staining, rot, insect infestation, and mechanical wear. To ensure safety and longevity, it is essential to monitor these environmental impacts and address deterioration caused by wood-destroying organisms (Azzi, Z., et al., 2025).

Wood is the primary material used in the construction of the TimTech House at Politeknik Sultan Salahuddin Abdul Aziz Shah, Shah Alam, Selangor. Wood defects can not only affect the durability and safety of the building but also compromise its structural quality and aesthetic value. Increased maintenance costs may also arise in the long term if the defects are not addressed at an early stage. To date, no comprehensive study has been conducted to assess the level of deterioration that may have occurred at the TimTech House after three years of construction. The deterioration of wood construction materials is a common issue that occurs over time, particularly when exposed to environmental factors such as humidity, weather, and biological agents (Bowyer, J. L., Shmulsky, R., & Haygreen, J. G., 1996). Therefore, this study aims to identify the types of wood defects present in the TimTech House. The findings from this study are crucial as a basis for recommending effective conservation measures and ensuring that the lifespan and safety of this wooden structure can be extended in the future.

### 1.1 History of Timtech House at Politeknik Sultan Salahuddin Abdul Aziz Shah (PSA)

The Timber Technology House (TimTechH) project at Politeknik Sultan Salahuddin Abdul Aziz Shah (PSA), completed in mid-2022, is a landmark initiative as the first wooden house in Malaysia constructed using the Industrialised Building System (IBS) concept. This project is the result of a collaboration between PSA and the Malaysian Timber Industry Board (MTIB) and integrates Industrial Revolution 4.0 (IR4.0) technologies, such as solar energy and smart home applications, into its structure. Primarily serving as a practical learning environment, TimTechH plays a key role in modernizing national Technical and Vocational Education and Training (TVET) by shifting the educational approach from "train and place" to "place and train," thereby enhancing students' skills and fostering future industry partnerships in advanced construction technology (Kosmo Online, 2023). Figure 1(a) shows the map location of the TimTechH House at PSA, while Figure 1(b) depicts the overall building structure of the TimTechH House.



Figure 1(a): Map location of TimTech House at PSA (Source: Google Map, 2025).



Figure 1(b): TimTech House at PSA

### 1.2 The Common Types of Timber Defects

The numerous types of wood defects, as categorized by M. Nurfaizal et al. (2020), Ridout (2000), and S. Johar et al. (2013), can be grouped into four main agents: Biological agents are

the most destructive, encompassing fungi (such as soft, brown, and white rot) and insects or small animals (including termites, beetles, and ants) that can cause catastrophic damage. Physical agents refer to aesthetic and inherent flaws arising from the tree's natural growth, including hollowness, knots, and pre-existing cracks. Chemical agents involve acids, typically present in polluted industrial areas, which render the wood brittle and cause surface fibers to separate into sharp filaments. Lastly, mechanical agents result from physical friction during processing (e.g., cutting and drying) or environmental stress from light, wind, and water, leading to surface checks and cracks. While physical, chemical, and mechanical damage is often superficial, the combination of biological agents and moisture problems represents the two most common factors causing serious and structural wood deterioration (S. Johar et al., 2013). Other causes of timber defects are also illustrated in Figure 2.

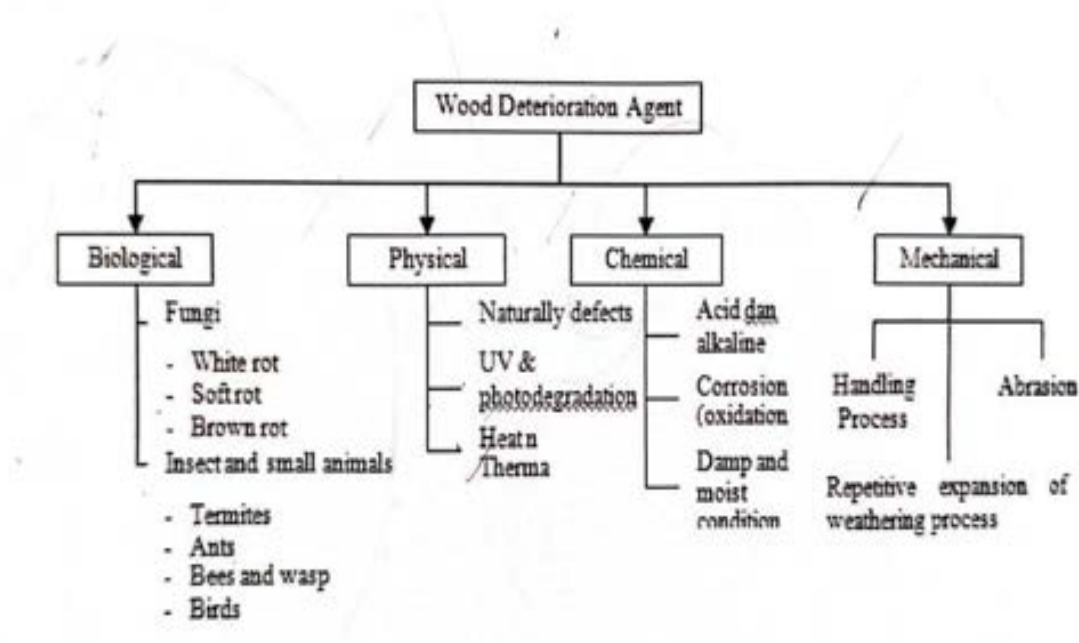


Figure 2: Common timber defects found in wooden house (S. Johar et al. 2013).

## 2.0 METHODOLOGY

### 2.1 Visual Observation Method

Visual inspection is the simplest and most fundamental method for examining an existing structure. However, this method may not detect defects that do not appear on the surface (Isa, H. M., et al., 2025). Visual inspection involves carefully examining the wood's surface to identify any visible defects, damage, or signs of deterioration. Although this method is limited to detecting surface-level or near-surface issues, it remains highly valuable because it is simple, cost-effective, and provides crucial initial information about the wood's structural health and integrity (Azzi, Z., et al., 2025).

A thorough visual inspection of wood requires several key tools. Basic equipment includes a magnifying glass, flashlight, ruler, and marking tools. A mirror is essential for checking hard-to-reach areas. To detect internal damage, tools such as a gimlet, awl, or chisel are used for

probing the surface, and a hammer is used to tap the wood to locate hidden voids. Additionally, a hygrometer and moisture meter are required to measure moisture content. Finally, a digital camera is used to accurately document all observations (Azzi, Z., et al., 2025).

This study was carried out at the TimTech House over an eight-week period from August to September 2025, primarily on weekdays (Tuesday and Thursday), with data collected twice weekly. The observation of wood defects was specifically limited to the main structural elements of the house: pillars, floors, walls, and windows, based on the TimTech plan drawing shown in Figure 4. Data were gathered and compiled for the project report using a Samsung A35 mobile phone camera, a vernier caliper (Anton), and a moisture meter. Weekly rainfall distribution was retrieved from the METMalaysia website (METMalaysia, 2025). Figure 3 illustrates the overall flow process of the research study for this project.

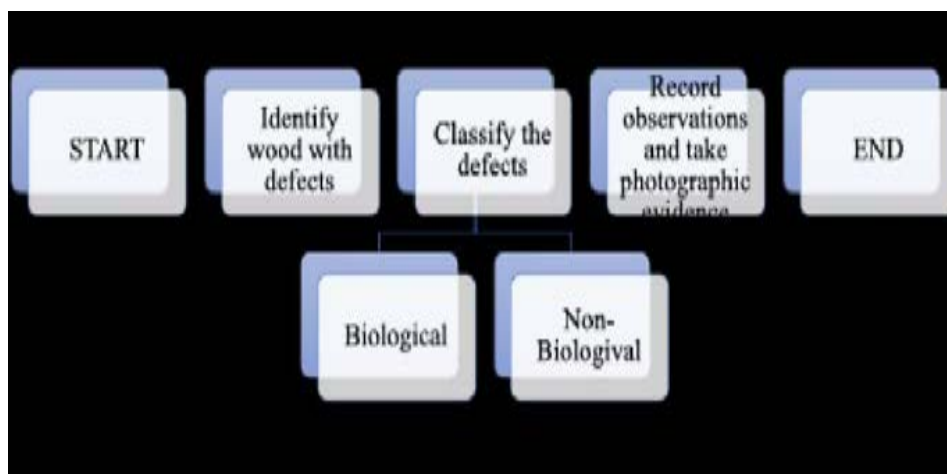


Figure 3: Flowchart of Research Study Workflow.

A Vernier caliper was used to measure changes in the size of the defects, and a digital moisture meter was employed to determine the wood's moisture condition during data collection. Rainfall data were used to assess whether changes in timber defects were influenced by weather and humidity.

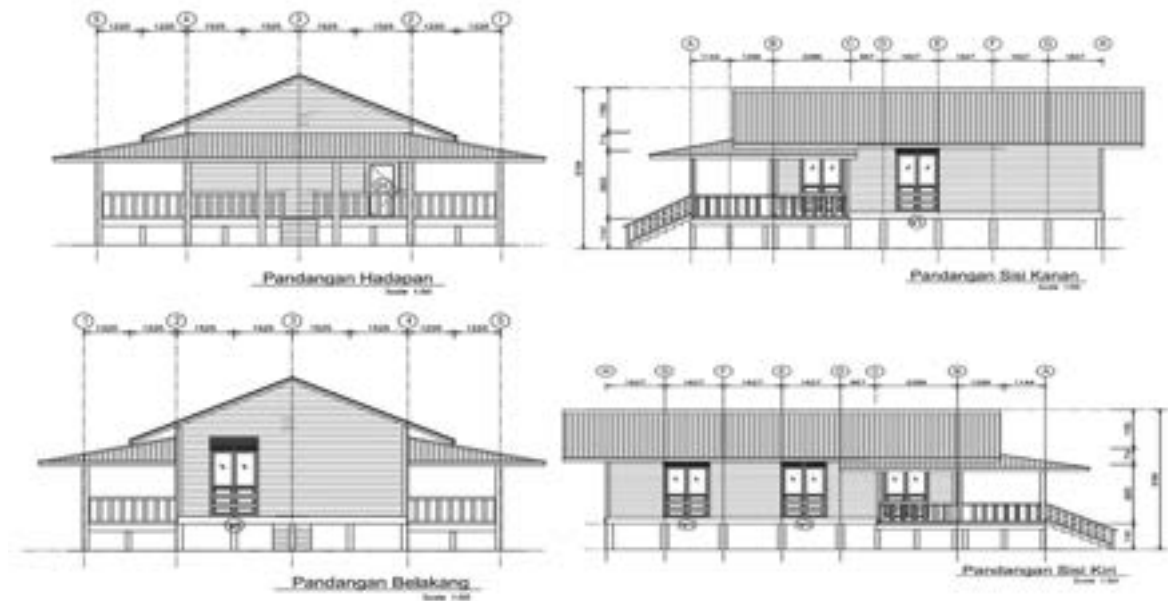


Figure 4: Timtech House Drawing Plan Structure in PSA (Mustazha H. A. T. (2022).

### 3.0 RESULTS AND DISCUSSION

The data gathered over the eight-week project indicates that the pillars, floor, and rear window were affected by timber defects. However, the house walls remained in good condition even after three years of construction. Three types of timber defects were identified, of which two were caused by biological factors and one by a non-biological factor. Detailed discussions of these findings are presented in Sub-topics 3.1 and 3.2, respectively.

#### 3.1 Timber Defects Caused by Biology Factor.

Tables 1–4 show the timber defect classified as brown rot fungi, which appeared on the rear window of the TimTech House.

**Table 1: Brown Rot Fungi (Biology) defects for Week 1 and Week 2.**

| Week 1 | Week 2 |
|--------|--------|
|        |        |

|                                                                                   |                                                                                    |
|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|  |  |
| Size : 4.35 cm<br>Rainfall : 33 cm<br>MC: 33.6 %                                  | Size : 4.39 cm<br>Rainfall : 42 cm<br>MC: 33.6%                                    |

From Table 1, it is shown that the timber defect size increased from 4.35 cm to 4.39 cm within the first two weeks. No change was observed in week 3; however, in week 4 (Table 2), the size increased by approximately 0.20 cm, representing a 20% increase from week 5 to week 6 (Table 3). Meanwhile, from week 7 to week 8, the defects increased from 7.8 cm to 10 cm, corresponding to a 22% increase, as shown in Table 4. The observed size increase may have been influenced by high and fluctuating humidity levels, as indicated by rainfall and moisture readings over the eight-week period.

**Table 2: Brown Rot Fungi (Biology) defects for Week 3 and Week 4.**

| Week 3                                                                              | Week 4                                                                               |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|  |  |
| Size : no size changes<br>Rainfall : 37 cm<br>MC: 35.78 %                           | Size : 4.59 cm<br>Rainfall : 49 cm<br>MC: 45.77 %                                    |

**Table 3: Brown Rot Fungi (Biology) defects for Week 5 and Week 6.**

| Week 5                                                                            | Week 6                                                                             |
|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|  |  |
| Size : 7.8 cm<br>Rainfall : 37 cm<br>MC: 26.0 %                                   | Size : 10 cm<br>Rainfall : 42 cm<br>MC: 25.0 %                                     |

**Table 4: Brown Rot Fungi (Biology) defects for Week 7 and Week 8.**

| Week 7                                                                              | Week 8                                                                               |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|  |  |
| Size : no size changes<br>Rainfall : 33 cm<br>MC: 23.5 %                            | Size : 10.9 cm<br>Rainfall : 44 cm<br>MC: 24.0 %                                     |

This finding is also in agreement with previous work by Isa, H. M., et al. (2025), which concluded that fungal attack on window surfaces is influenced by weather conditions.

**Table 5: Fungus (Biology) defects for Week 1 to Week 4**

| Week 1                                                                             | Week 2                                                                              |
|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
|  |  |
| Size : 3.69 cm<br>Rainfall : 39 cm<br>MC: 22.3 %                                   | Size : 3.79 cm<br>Rainfall : 33 cm<br>MC: 31.7 %                                    |

**Table 6: Fungus (Biology) defects for Week 5 to Week 8.**

| Week 3                                                                              | Week 4                                                                               |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|  |  |
| Size : 7 cm<br>Rainfall : 33 cm<br>MC: 27.0 %                                       | Size : no size changes<br>Rainfall : 42 cm<br>MC: 32.4 %                             |

|  |  |
|--|--|
|  |  |
|--|--|

**Table 8: Fungus (Biology) defects for Week 1 to and Week 4**

| Week 7                                                                                       | Week 8                                                                              |
|----------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
|  <p>UI</p> |  |
| <p>Size : 4.55 cm<br/>Rainfall : 42 cm<br/>MC: 26.9 %</p>                                    | <p>Size : 4.63 cm<br/>Rainfall : 47 cm<br/>MC: 36.5 %</p>                           |

**Table 6: Fungus (Biology) defects for Week 5 to Week 8.**

| Week 3                                                                            | Week 4                                                                             |
|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|  |  |
| Size : 8.50 cm<br>Rainfall : 47 cm<br>MC: 29.1 %                                  | Size : 8.83 cm<br>Rainfall : 39 cm<br>MC: 39.4 %                                   |

Tables 5 to 8 also show that two instances of fungal growth were observed on the pillar at the front of the TimTech House. The size of one fungus increased from 3.69 cm to 3.79 cm within a month, while another fungus detected on a different pillar grew from 7 cm to 8.83 cm over the same period. Temperature variations recorded during the eight-week study were caused by highly unpredictable weather and inconsistent rainfall patterns. Elevated moisture content also contributed to the growth of fungi in the pillars (Azzi, Z., et al., 2025).

### 3.2 Timber Defects Caused by Non-Biology Factor.

Besides the biological factors affecting the TimTech House at PSA, other types of timber defects were also observed. A crooked or bowed timber defect was identified in the main door frame, and discoloration or pigmentation changes in the timber were noted, as shown in Tables 9 to 12. Observations conducted over the eight-week period showed that the defect size increased from 3.65 cm in Week 1 to 4.75 cm in Week 8, with no change recorded in Week 5.

**Table 9: Structural Damage (Non-biology) defects for Week 1 and Week 2.**

| Week 1 | Week 2 |
|--------|--------|
|        |        |

|                                                                                   |                                                                                    |
|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|  |  |
| Size : 3.65 cm<br>Rainfall : 33 cm<br>MC: 22.3 %                                  | Size : 3.79 cm<br>Rainfall : 42 cm<br>MC: 31.7 %                                   |

**Table 10: Structural Damage (Non-biology) defects for Week 3 and Week 4.**

| Week 3                                                                              | Week 4                                                                               |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|  |  |
| Size : 4.55 cm<br>Rainfall : 37 cm<br>MC: 26.9 %                                    | Size : 4.63 cm<br>Rainfall : 49 cm<br>MC: 36.5 %                                     |

**Table 11: Structural Damage (Non-biology) defects for Week 5 and Week 6.**

| Week 5 | Week 6 |
|--------|--------|
|--------|--------|

|                                                                                   |                                                                                    |
|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|  |  |
| <p>Size : no size changes<br/>Rainfall : 37 cm<br/>MC: 22.5 %</p>                 | <p>Size : 4.67 cm<br/>Rainfall : 42 cm<br/>MC: 30.1 %</p>                          |

**Table 12: Structural Damage (Non-biology) defects for Week 7 and Week 10.**

| Week 7                                                                              | Week 8                                                                               |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|  |  |
| <p>Size : 4.73 cm<br/>Rainfall : 33 cm<br/>MC: 24.0 %</p>                           | <p>Size : 4.75 cm<br/>Rainfall : 44 cm<br/>MC: 46.9 %</p>                            |

The fracture of the timber frame and the pigmentation changes in the timber were caused by adverse weather conditions (Isa, H. M., et al., 2025). This is consistent with the findings of the present study, where rainfall was particularly high in Week 4 (49 cm). Continuous exposure to harsh weather also affected both biological and non-biological factors contributing to timber defects in the house (Nur Fadhilah et al., 2022). Another contributing factor to timber defects is poor maintenance by the house owner (Kay et al., 2023; Hassanain et al., 2021; Ortiz et al., 2020).

#### 4.0 CONCLUSION

In conclusion, visual inspection of the TimTech House confirmed that structural deterioration resulted from both biological and non-biological agents. Biological decay was primarily evidenced by the presence of brown rot fungi on the pillars and windows, while non-biological defects included bowing (crooking) and surface discoloration or pigmentation on the timber flooring. Notably, the cement board walls remained unaffected, highlighting the vulnerability of the timber components to moisture-driven decay. The study established that elevated moisture content (MC) and high rainfall frequency significantly accelerated these defects. Therefore, implementing a systematic preventive maintenance plan is essential to preserve the structural integrity of the house and extend its service life.

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# Students' Perceptions of the NYC English Mobile Application as a Supplementary English Language Learning Tool at Politeknik Sultan Salahuddin Abdul Aziz Shah

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## ABSTRACT

In the Malaysian Technical and Vocational Education & Training (TVET) context, English is critical for communication at the workplace. However, limited classroom hours and students' poor proficiency in the language at the entry level pose a challenge for students to achieve mastery. To address this, Politeknik Sultan Salahuddin Abdul Aziz Shah (PSA), in collaboration with SASBADI Malaysia Sdn. Bhd. introduced a supplementary tool for learning English. This study investigates student perceptions of the NYC English mobile application as a supplementary tool for English language learning at PSA. The research aimed to evaluate the application's general effectiveness in improving students' language skills, its alignment with students' diverse learning styles, and its overall accessibility, and to obtain students' suggestions to improve the application. Adopting a quantitative research design, structured questionnaires were administered to 92 Semester 1 students following a 14-week intervention period. Descriptive statistical analysis revealed that most of the respondents held positive perceptions of the application, particularly noting its user-friendly interface and the quality of its visual, audio, and grammar modules. Additionally, the application significantly boosted students' confidence in English usage and was compatible with their individual learning preferences. However, students expressed a need for more interactive speaking activities to improve their oral proficiency. The findings indicate that NYC English effectively complements conventional English instruction in Malaysian polytechnics. The study concludes that NYC English is effective and should be incorporated into curricula, with additional interactive features added.

*Keywords:* mobile-assisted language learning, English proficiency, student motivation, usability, NYC English

## 1.0 INTRODUCTION

English proficiency is a core requirement in Malaysian polytechnics, as graduates are expected to communicate effectively in academic, technical, and workplace contexts. At Politeknik Sultan Salahuddin Abdul Aziz Shah (PSA), English language courses such as Communicative English and Technical English are offered from Semester 1 to Semester 3, focusing on listening, speaking, reading, writing, and workplace communication skills. These courses typically carry two to three credit hours and aim to equip students with functional English for employment and further studies. However, most incoming Semester 1 students enter PSA with limited English proficiency, often holding minimal English qualifications from secondary school. This gap affects students' confidence, classroom participation, and ability to engage

with course content delivered fully in English. Traditional classroom instruction alone may not sufficiently address these challenges, particularly for students with diverse learning styles.

To address these challenges, mobile-assisted language learning (MALL) has increasingly been adopted as a supplementary strategy. One such tool is the NYC English mobile application (hereafter called NYC English), developed by SASBADI Malaysia Sdn. Bhd. The application provides thematic modules, grammar explanations, audio-visual learning materials, speech recognition features, and self-paced practice activities. It enables learners to access English learning materials at their convenience, promoting independent and personalised learning.

Therefore, at the end of its implementation, a survey is conducted to obtain students' feedback on the application. The objectives of the study are:

1. To examine students' general perceptions of NYC English.
2. To identify the extent to which the application supports students' learning styles.
3. To evaluate the usability and accessibility of the application.
4. To obtain students' suggestions and improvements for NYC English.

The following section reviews relevant literature on mobile-assisted language learning (MALL), usability, and learner engagement.

## 1.1 Literature Review

### **Mobile-Assisted Language Learning (MALL): Effectiveness and Autonomy**

Mobile-Assisted Language Learning (MALL) has received considerable research attention for promoting flexible and autonomous learning. Peng et al. (2021) reviewed various MALL studies and found that mobile learning typically yields small to moderate gains in second-language (L2) skills. They noted that design quality and effective implementation influence outcomes. Pedagogically sound and context-sensitive features are essential (Peng et al., 2021).

Longitudinal research supports the benefits of MALL. Lei et al. (2022) found that learners' vocabulary attitudes and self-regulation improved over time when using mobile apps. Their study suggests that frequent, student-driven use of mobile tools fosters good habits and persistence, both of which are important for language development.

Studies also demonstrate the effectiveness of mobile platforms. Smith, Jiang, and Peters (2024) investigated the use of Duolingo among university students over a 3-month period. They found statistically significant gains in both receptive and productive language skills. This indicates that well-structured apps, such as NYC English, can support gains when learners use them regularly.

### **Enhancing Speaking: Interactive Feedback in MALL**

One frequent gap in language apps is the enhancement of aural/oral productive skills. However, recent systematic reviews indicate encouraging results when mobile learning systems incorporate peer feedback or interactive speaking tasks.

Weng et al. (2025), in a Cogent Education review, concluded that mobile-assisted peer feedback mechanisms help improve speaking proficiency, particularly when accompanied by immediate and targeted feedback. Rajendran and Yunus (2021) reviewed studies on MALL

tools for EFL speaking and found that students improved when tasks used peer interaction, speech recognition, and scaffolded prompts.

These findings indicate that extending the NYC English application to include dynamic speaking modules with real-time feedback could address a limitation in many language applications and substantially improve learner outcomes.

### **Usability, Engagement, and Sustained Use**

Sustained engagement, critical for language learning, depends on user experience design. Stockwell's (2010) research found that ease of use, intuitive navigation, and accessibility encourage regular app use and satisfaction.

Faudzi et al. (2024) studied mobile learning UI design and found that a lower extraneous cognitive load, achieved with clear layouts and minimal distractions, improved usability and learner retention. Mohtar et al. (2022) noted that user-friendly features, such as progress tracking and visual cues, are positively associated with continued engagement.

NYC English incorporates several of these design principles through its conversational modules, grammar support, and interactive feedback. These features contribute to the high usability and engagement observed in the present study. Further refinement of the interface, including improved integration and accessibility of speaking tasks, may enhance consistent usage and overall effectiveness.

### **Contextual Insights from Malaysia and the Polytechnic Sector**

Reviews of MALL adoption in Malaysia (from 2019 to 2021) highlight positive attitudes among learners and instructors, while recommending greater curricular alignment and contextually relevant content (iJIM Review, 2022). Similarly, Azli et al. (2018) noted that Malaysian vocational learners perceived high usefulness and ease of use when engaging with mobile language tools.

Hashim's (2016) earlier study in Malaysian polytechnics found that students are open to technology-based learning. However, this is limited by infrastructure and the need for structured implementation. Local findings indicate that NYC English will succeed best with institutional support, guided use, and content tailored to students' vocational and language needs.

## **2.0 METHODOLOGY**

A quantitative research design, utilising an online survey, assessed the NYC English Platform among PSA students. The online survey allowed efficient access to many students. It collected data on students' views of the platform's features, its impact on their English skills, and their overall satisfaction with the platform. The survey data were analysed to evaluate how well NYC English supports English language learning for this student group.

### **2.1 Research Design**

This study adopted a quantitative research design using an online survey to collect data on students' perceptions of the NYC English application.

### **2.2 Participants**

The participants were 92 Semester 1 students from Politeknik Sultan Salahuddin Abdul Aziz Shah (PSA), aged 19 to 21, who willingly used the NYC English application as a supplementary tool, outside class hours.

### 2.3 Instrument

The instrument used was a structured online questionnaire developed using Google Forms. The survey consisted of four primary constructs aligned with the study objectives:

- Student general perceptions of NYC English
- Compatibility of NYC English to students' learning preferences and styles
- Usability and accessibility of NYC English
- Students' recommendations and suggestions to improve NYC English

A five-point Likert scale was used (1 = Strongly Disagree to 5 = Strongly Agree).

### 2.4 Data Collection and Data Analysis

The study was conducted over 14 lecture weeks. Students used the NYC English application as a supplementary learning tool alongside classroom instruction. At the end of the period, the online survey was administered. Data were analysed using descriptive statistics, including frequencies and percentages.

## 3.0 RESULTS AND DISCUSSION

Table 1 shows that a total of 92 Semester 1 students participated in the survey. Most respondents were 19 years old (51 students), followed by those aged 20+ (29 students), while fewer were 20 (11) and 18 (1). In terms of gender distribution, male students (58) outnumbered female students (34), reflecting common enrolment trends in technical and vocational programmes at polytechnics.

Table 1: Students' Demographics

| INDICATORS | JKE (7.6%) | JKM (18.5%) | JKA (26.1%) | JPG (47.8%) | TOTAL |
|------------|------------|-------------|-------------|-------------|-------|
| Male       | 5          | 16          | 20          | 17          | 58    |
| Female     | 2          | 1           | 4           | 27          | 34    |
| TOTAL      | 7          | 17          | 24          | 44          | 92    |

The respondents were Diploma students from 4 departments. The largest group of students came from the Commerce Department (JPG) (44 students), followed by the Civil Engineering Department (JKA) (24 students). There were 27 students from the Mechanical Engineering Department (JKM). The fewest students came from the Electrical Engineering Department (JKE), which amounted to 7 students. This diverse representation indicates that the findings reflect a broad cross-section of Semester 1 students at the polytechnic.

### 3.1 Students' General Perceptions of NYC English

As shown in Figure 1, there were 5 survey questions related to students' general perceptions of NYC English.

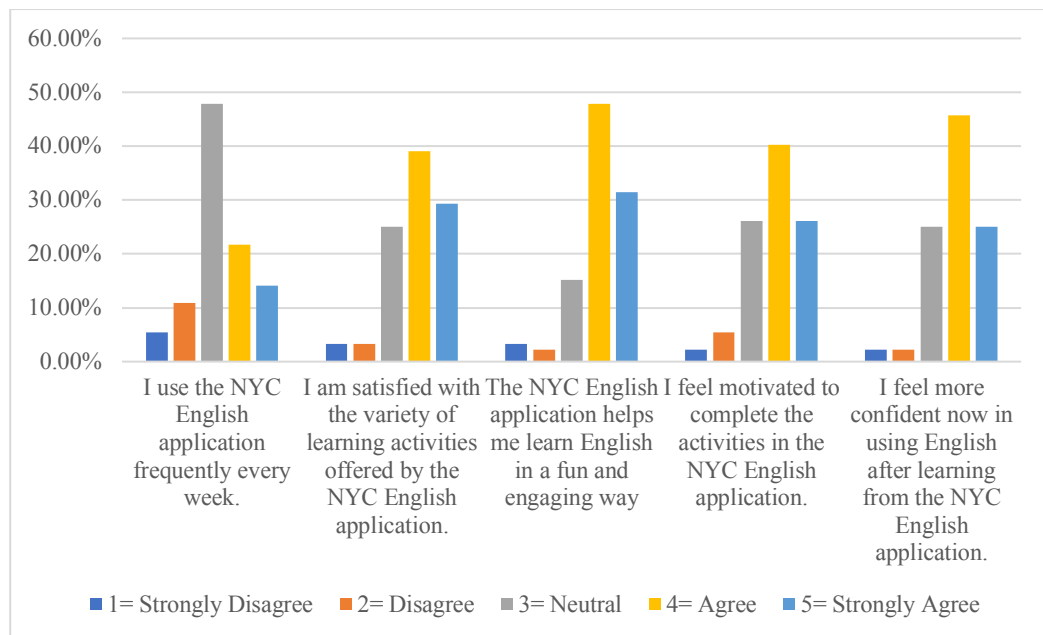


Figure 1: Students' General Perceptions of NYC English

Figure 1 shows students' general perceptions of the NYC English application across five aspects. In terms of frequency of use, responses were mixed, with 47.8% of students selecting neutral, indicating irregular weekly usage. Nevertheless, 35.8% agreed or strongly agreed that they used the application frequently, while 16.3% disagreed. Regarding the variety of learning activities, students responded positively, with 68.4% agreeing or strongly agreeing that the application offered a satisfactory range of activities, compared to 25% neutral responses and minimal disagreement.

Students also perceived the application as fun and engaging, with a high 79.3% agreeing or strongly agreeing that it helped them learn English in an enjoyable way. In terms of motivation, 66.3% of students agreed or strongly agreed that they felt motivated to complete the activities, while 26.1% remained neutral. Similarly, 70.7% reported increased confidence in using English after learning with the NYC English application. Overall, these findings indicate generally positive student perceptions, particularly in engagement, motivation, and confidence, despite moderate variation in usage frequency.

These findings are consistent with previous studies on Mobile-Assisted Language Learning (MALL). Peng et al. (2021) reported that well-designed mobile applications can elicit positive learner perceptions and modest improvements in second-language skills when integrated effectively. Similarly, Lei et al. (2022) found that sustained use of mobile applications supports learner autonomy and positive learning attitudes over time. The positive perceptions observed in this study indicate that NYC English functions effectively as a supplementary learning tool rather than a replacement for classroom instruction.

### 3.2 Compatibility of NYC English to students' learning preferences and styles

Table 2 shows that there were 9 questions related to the compatibility of NYC English to students' learning preferences and learning styles.

Table 2: List of Questions on the Compatibility of NYC English to Students' Learning Preferences and Styles

| Questions                                                                           |
|-------------------------------------------------------------------------------------|
| 1 The NYC English application suits my learning style.                              |
| 2 I enjoy the visuals in the NYC English application.                               |
| 3 I enjoy the audio in the NYC English application.                                 |
| 4 I like using this application to support my classroom learning.                   |
| 5 The NYC English application provides good explanation for grammar concepts.       |
| 6 The NYC English application helps to prepare me for my Semester 1 English topics. |
| 7 I am satisfied with the exercises in the NYC English application.                 |
| 8 I am satisfied with the activities in the NYC English application.                |
| 9 The NYC English application is effective to improve my English proficiency.       |

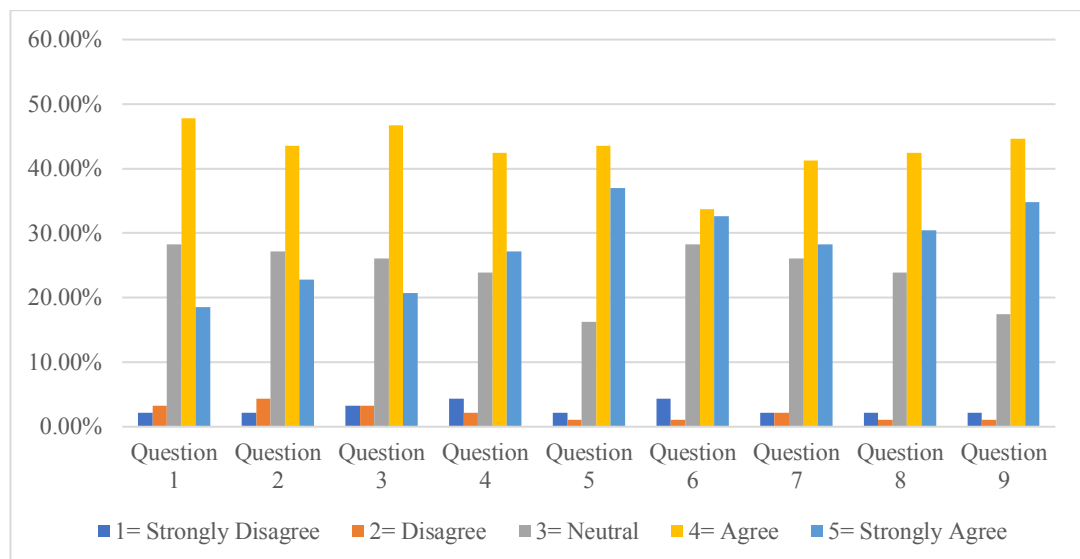


Figure 2: Students' Responses on Compatibility of NYC English to Students' Learning Preferences and Styles

Overall, students demonstrated positive perceptions across all items. For learning style suitability, 66.3% of respondents agreed or strongly agreed that the application suited their learning styles, indicating good alignment with individual preferences. With regard to visual elements and audio components, over 65% of students agreed or strongly agreed that they enjoyed these features, highlighting the effectiveness of the app's multimedia design. Students also responded positively to using the application as a support for classroom learning, with a majority indicating agreement.

In terms of content clarity, 77% of respondents agreed or strongly agreed that the application provided clear explanations of grammar concepts, suggesting that the structured presentation supported comprehension. 66.3% of students agreed or strongly agreed that the NYC English application helped prepare them for their Semester 1 English topics, while 28.3% were neutral and only 5.4% disagreed,

indicating overall positive perceptions of its relevance to course learning. However, some of the written feedback from students indicated that the app needs to be more interactive. Some of the comments are “Some words couldn't be recognize by system when we speak”, “It's a good application but need a huge improvement on speaking part. The apps couldn't catch up with what we are trying to say” and “The apps not detected what i really said”. Students expressed positive views of the activities provided, with most respondents agreeing that they were satisfactory and engaging. Finally, responses to the item on overall effectiveness in improving English proficiency were predominantly positive, with a clear majority agreeing or strongly agreeing that the application contributed to their language development.

The strong agreement on the clarity of grammar explanations further underscores the importance of structured, scaffolded content in mobile learning environments. This supports earlier research by Stockwell (2010), who emphasised that well-organised content and accessible explanations enhance learner engagement and sustained use. The findings also align with Faudzi et al. (2024), who noted that reduced cognitive load through effective interface and content design positively influences learner satisfaction and engagement.

### 3.3 Usability and Accessibility of NYC English

Table 3 shows that there were seven questions related to Usability and Accessibility to NYC English.

Table 3: List of Questions on the Usability and Accessibility of NYC English

| Questions |                                                                       |
|-----------|-----------------------------------------------------------------------|
| 1         | I find the NYC English application easy to use.                       |
| 2         | I find the application's features easy to navigate.                   |
| 3         | The grammar section in the NYC English application is easy to use.    |
| 4         | The vocabulary section in the NYC English application is easy to use. |
| 5         | The reading section in the NYC English application is easy to use.    |
| 6         | The listening section in the NYC English application is easy to use.  |
| 7         | The speaking section in the NYC English application is easy to use.   |

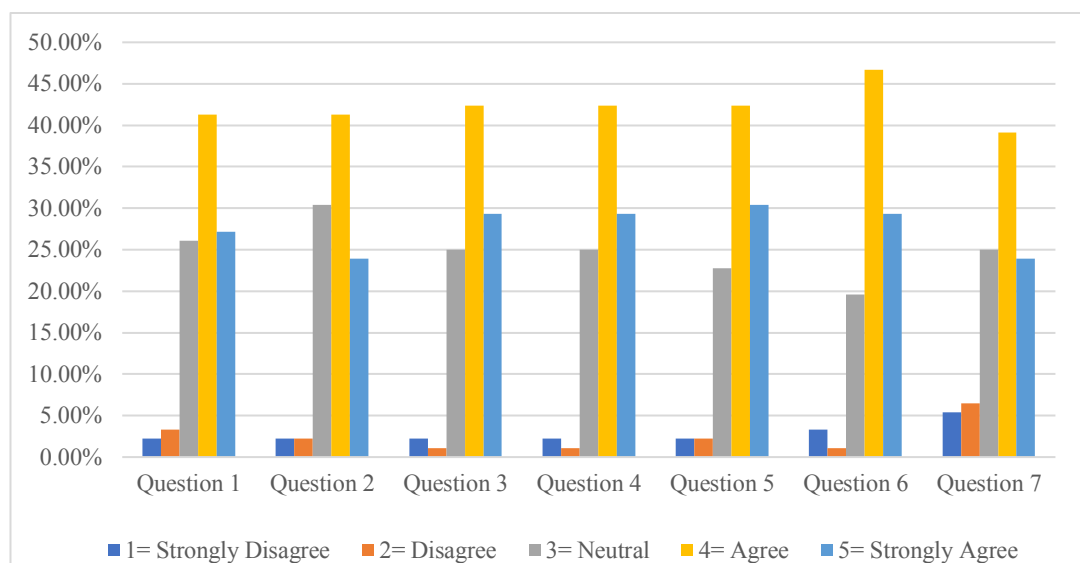


Figure 3: Students' Responses on the Usability and Accessibility of NYC English

As seen in Figure 3, 68% of respondents indicated that the application was user-friendly and easy to navigate. The grammar, vocabulary, reading, and listening sections specifically received high usability ratings, highlighting the application's overall accessibility and intuitive design for learners.

Usability emerged as a key strength of the NYC English application. Most students reported that the application was user-friendly and easy to navigate, particularly in the grammar, vocabulary, reading, and listening sections. High usability ratings indicate that students were able to engage with the application independently without experiencing significant technical barriers.

This finding reinforces the argument that usability is a critical determinant of sustained engagement in mobile learning (Mohtar et al., 2022). When learners can easily access and navigate learning materials, they are more likely to use the application consistently. The positive usability outcomes observed in this study suggest that NYC English meets fundamental design principles required for effective mobile-assisted learning in the polytechnic context.

### 3.4 Students' Recommendations and Suggestions to Improve NYC English

Table 4 shows the 7 questions on students' recommendations and suggestions to improve NYC English.

Table 4: List of Questions on Students' Recommendations and Suggestions to Improve NYC English Open Feedback Questions

| <b>Questions</b> |                                                                                                               |
|------------------|---------------------------------------------------------------------------------------------------------------|
| <b>1</b>         | I would recommend that better improvements be made for the grammar section in the NYC English application.    |
| <b>2</b>         | I would recommend that better improvements be made for the vocabulary section in the NYC English application. |
| <b>3</b>         | I would recommend that better improvements be made for the reading section in the NYC English application.    |
| <b>4</b>         | I would recommend that better improvements be made for the listening section in the NYC English application.  |
| <b>5</b>         | I would recommend that better improvements be made for the speaking section in the NYC English application.   |
| <b>6</b>         | I would recommend the NYC English application to other students in the future.                                |
| <b>7</b>         | I would recommend that the grammar section of the NYC English application be improved.                        |

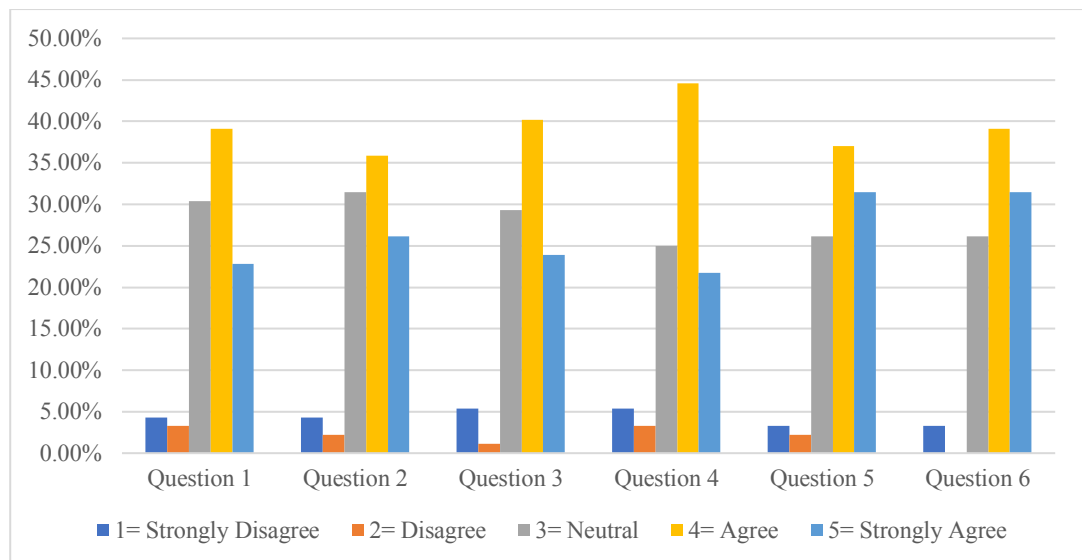


Figure 4: Students' Recommendations and Suggestions to Improve NYC English

Most students agreed or strongly agreed that improvements were needed for the grammar (61.9%), vocabulary (62.0%), reading (64.1%), and listening (66.3%) sections, indicating general support for content enhancement. The strongest recommendation concerned the speaking section, where 68.5% of students agreed or strongly agreed that improvements should be made, reflecting an apparent demand for more substantial support for productive skills. Despite these suggestions, overall acceptance of the application remained high, with 70.6% of students indicating they would recommend it to other students in the future. Among the written feedback provided by students were comments such as “This Nyc is good for our future student”, “Nyc is the one of the best for learning”, “nyc is very helpful for students and hopefully nyc can give more interesting questions”, “I'm strongly recommend the NYC application” and “i will use the NYC English application more in the future”.

This result aligns with findings by Rajendran and Yunus (2021), who reported that speaking proficiency improves more significantly when mobile applications incorporate interactive speaking tasks, peer interaction, and immediate feedback. Weng et al. (2025) similarly concluded that mobile-assisted peer feedback and speech recognition features can enhance oral proficiency when designed effectively. Therefore, expanding the speaking components of NYC English could substantially enhance its effectiveness as a comprehensive language-learning tool.

### 3.5 Overall Implications

Overall, the discussion indicates that NYC English effectively supports English language learning by enhancing motivation, confidence, usability, and learner engagement among Semester 1 polytechnic students. The application complements traditional classroom instruction by accommodating diverse learning styles and enabling flexible, self-paced learning. However, to maximise its impact, improvements in speaking modules and interactive features are necessary. These findings support the growing body of research advocating for structured integration of mobile learning tools within formal curricula, particularly in technical and vocational education contexts in Malaysia.

### 4.0 CONCLUSION

Based on the findings, the NYC English application effectively supports English language learning among Semester 1 students at PSA by enhancing motivation, confidence, and engagement. Students perceived the application's usability, visual and audio features, and grammar explanations positively. However, the findings also indicate a clear need for improved speaking components and more interactive oral practice.

Therefore, it is recommended that NYC English be used as a structured supplementary tool within English courses, with enhanced speaking modules and guided classroom integration. Overall, the study confirms that NYC English is a valuable mobile-assisted learning resource for technical higher education contexts.

### ACKNOWLEDGMENT

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# Pembangunan Peranti Pemantauan Kualiti Udara Mudah Alih Berasaskan Internet of Things (IoT) untuk Sokongan Keselamatan Pesakit COPD

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## ABSTRAK

Kualiti udara yang tidak baik merupakan antara faktor utama yang boleh menjejaskan kesihatan pernafasan, khususnya bagi individu yang menghidap Penyakit Paru-paru Obstruktif Kronik (COPD). Pesakit COPD lebih sensitif terhadap pendedahan kepada zarah halus, gas berbahaya serta perubahan suhu dan kelembapan persekitaran. Sehubungan itu, kajian ini bertujuan untuk membangunkan sebuah peranti pemantauan kualiti udara mudah alih berasaskan Internet of Things (IoT) yang mampu memberikan maklumat persekitaran secara masa nyata kepada pengguna. Peranti yang dibangunkan menggabungkan penderia PM2.5, penderia gas, serta penderia suhu dan kelembapan yang disambungkan kepada mikropengawal Arduino. Sistem ini turut dilengkapi dengan paparan skrin sentuh dan modul Wi-Fi bagi membolehkan data dipaparkan secara terus pada peranti dan dihantar ke aplikasi mudah alih. Selain itu, reka bentuk bekas peranti telah dibangunkan menggunakan teknologi percetakan 3D bagi memastikan aliran udara yang lebih baik serta perlindungan terhadap komponen dalaman. Pengujian peranti telah dijalankan di tiga jenis persekitaran berbeza, iaitu kawasan dalaman, luar bandar dan perindustrian. Keputusan menunjukkan bahawa peranti ini mampu memberikan bacaan yang stabil serta bertindak balas dengan baik terhadap perubahan kualiti udara. Secara keseluruhan, peranti ini berpotensi menjadi satu penyelesaian kos rendah dan praktikal sebagai alat sokongan pemantauan kualiti udara, khususnya untuk membantu pesakit COPD mengurus pendedahan harian mereka terhadap persekitaran yang berisiko.

**Kata kunci :** Pemantauan Kualiti Udara, Internet of Things (IoT), COPD, Peranti Mudah Alih, PM2.5, Pemantauan Masa Nyata

## 1.0 PENGENALAN

Pencemaran udara kini menjadi antara masalah utama yang sering dibincangkan kerana kesannya yang besar terhadap kesihatan manusia. Di kawasan bandar dan perindustrian, kualiti udara sering terjejas akibat pelepasan asap kenderaan, aktiviti kilang serta pembakaran terbuka. Antara bahan pencemar yang paling berbahaya ialah zarah halus PM2.5 kerana ia mudah memasuki sistem pernafasan dan boleh menyebabkan keradangan serta gangguan fungsi paru-paru (U.S. Environmental Protection Agency [EPA], 2022). Pertubuhan Kesihatan Sedunia turut melaporkan bahawa pendedahan berterusan terhadap zarah halus ini menyumbang kepada peningkatan kadar kematian pramatang di seluruh dunia (World Health Organization [WHO], 2021).

Bagi individu yang menghidap Penyakit Paru-paru Obstruktif Kronik (COPD), keadaan ini memberi kesan yang lebih serius. Pesakit COPD mempunyai saluran pernafasan yang sempit dan lemah, menyebabkan mereka mudah terjejas walaupun dengan perubahan

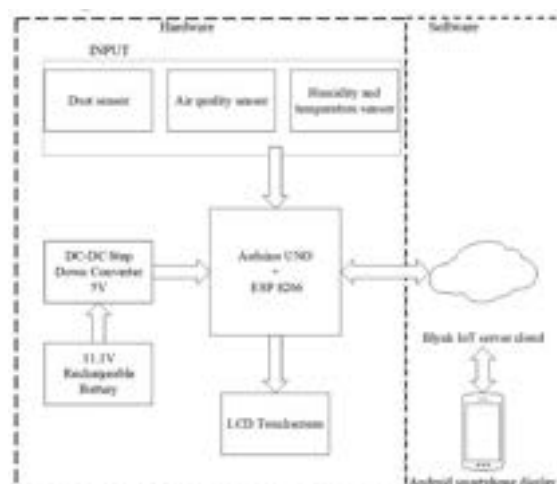
kualiti udara (Global Initiative for Chronic Obstructive Lung Disease [GOLD], 2023). Pendedahan kepada gas berbahaya, habuk halus serta perubahan suhu dan kelembapan boleh mencetuskan sesak nafas, batuk berpanjangan dan serangan akut yang memerlukan rawatan segera (Li et al., 2016). Keadaan ini menjadi lebih membimbangkan bagi pesakit yang tinggal berhampiran kawasan trafik sesak, kawasan perindustrian atau di ruang tertutup yang kurang pengudaraan.

Perkembangan teknologi masa kini, khususnya dalam bidang Internet of Things (IoT), telah banyak membantu dalam pelbagai aspek kehidupan termasuk pemantauan persekitaran (Xu et al., 2014). Melalui penggunaan penderia dan sistem tanpa wayar, maklumat berkaitan keadaan sekeliling seperti kualiti udara, suhu dan kelembapan boleh diperoleh dengan lebih mudah dan pantas (Kumar et al., 2015; Hossain et al., 2019). Data yang dikumpul juga boleh terus dipaparkan kepada pengguna melalui telefon pintar tanpa perlu bergantung kepada stesen pemantauan tetap yang biasanya terhad dari segi lokasi dan akses.

Oleh itu, satu peranti pemantauan kualiti udara yang mudah dibawa adalah sangat sesuai dibangunkan khusus untuk membantu pesakit COPD. Dengan adanya peranti yang boleh digunakan di mana-mana, pesakit dapat memeriksa keadaan udara di sekeliling mereka sebelum memasuki sesuatu kawasan. Ini dapat membantu mereka mengelakkan persekitaran yang berisiko dan seterusnya mengurangkan kemungkinan berlakunya serangan sesak nafas atau komplikasi kesihatan. Secara tidak langsung, peranti ini boleh menjadi alat sokongan harian kepada pesakit dalam menjaga kesihatan pernafasan mereka.

## 2.0 METODOLOGI

Bahagian ini menerangkan secara terperinci proses pembangunan peranti pemantauan kualiti udara bermula daripada peringkat reka bentuk sistem, pemilihan komponen, pembangunan perisian, sehinggalah kepada pengujian peranti dalam persekitaran sebenar. Kaedah yang digunakan adalah berasaskan pendekatan kejuruteraan praktikal bagi memastikan peranti yang dibangunkan berfungsi dengan baik dan sesuai digunakan oleh pesakit COPD dalam situasi harian. Rajah 1 menunjukkan gambaran keseluruhan seni bina sistem yang merangkumi penderia, mikropengawal, modul komunikasi, paparan dan aplikasi mudah alih.



Rajah 1 Block Diagram

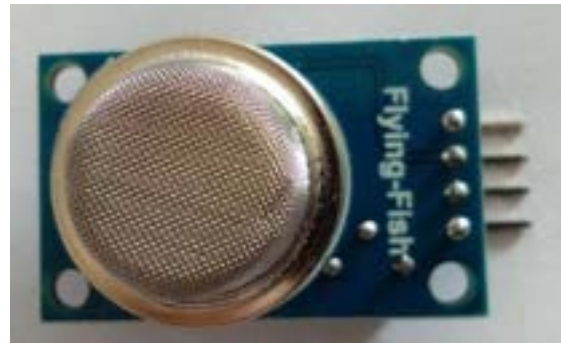
## 2.1 Pemilihan Penderia dan Reka Bentuk Sistem Perkakasan (versi disusun semula)

Sistem pemantauan kualiti udara yang dibangunkan menggunakan tiga jenis penderia utama, iaitu penderia habuk PM2.5, penderia gas serta penderia suhu dan kelembapan. Pemilihan penderia ini dibuat berdasarkan keperluan untuk memantau faktor persekitaran yang boleh memberi kesan langsung kepada kesihatan pernafasan, khususnya dalam kalangan pesakit Penyakit Paru-paru Obstruktif Kronik (COPD).

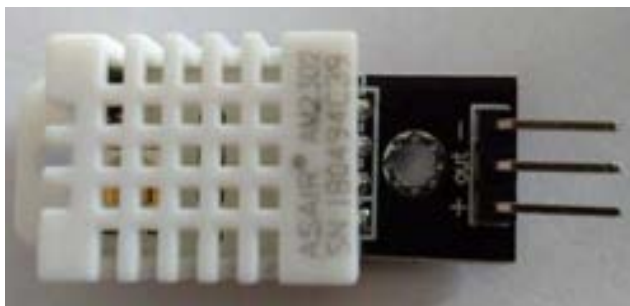
Penderia habuk Sharp GP2Y1010AU0F digunakan untuk mengesan zarah halus di udara seperti yang ditunjukkan dalam Rajah 2. Penderia jenis optik ini sesuai digunakan kerana keupayaannya mengesan zarah bersaiz kecil yang boleh menembusi sistem pernafasan dan menjejaskan kesihatan (Wang et al., 2015). Bagi pengesanan gas berbahaya, penderia MQ-135 digunakan seperti yang ditunjukkan dalam Rajah 3 kerana ia mampu mengesan pelbagai jenis gas seperti ammonia, benzena dan asap yang lazim terdapat di kawasan tercemar. Selain itu, penderia DHT22 digunakan untuk memantau suhu dan kelembapan seperti yang ditunjukkan dalam Rajah 4 kerana kedua-dua parameter ini turut mempengaruhi keselesaan pernafasan serta tingkah laku zarah di udara (Luo et al., 2019). Kesemua penderia ini disambungkan kepada mikropengawal Arduino Uno yang berfungsi sebagai pusat pemprosesan data sistem. Arduino dipilih kerana ia mudah diprogram, stabil dan sesuai digunakan dalam pembangunan prototaip sistem pemantauan berasaskan penderia (Banzi & Shiloh, 2014).



Rajah 2 GP2Y1010AU0F Dust Sensor



Rajah 3 MQ-135 Air Quality Sensor



Rajah 4 DHT 22 Temperature dan Humidity Sensor



Figure 5 : Arduino IDE antara muka

## 2.2 Pengaturcaraan Mikropengawal dan Pembangunan Perisian

Perisian sistem dibangunkan menggunakan Arduino IDE seperti yang ditunjukkan dalam Rajah 5. Atur cara ditulis bagi membolehkan bacaan daripada setiap penderia dibaca secara berkala, diproses dan dipaparkan kepada pengguna. Dalam proses ini, nilai analog daripada penderia akan ditukarkan kepada bentuk digital sebelum dihantar ke modul komunikasi dan paparan. Selain itu, had bacaan tertentu turut ditetapkan bagi tujuan amaran. Apabila bacaan melepasi paras yang ditetapkan, sistem akan memaparkan amaran kepada pengguna melalui skrin dan aplikasi mudah alih.

### 2.3 Sistem Komunikasi IoT dan Paparan Mudah Alih (versi kemas)

Bagi membolehkan penghantaran data secara tanpa wayar, modul ESP8266 digunakan seperti yang ditunjukkan dalam Rajah 6. Modul ini membolehkan sambungan Wi-Fi dibuat antara peranti dan rangkaian internet bagi menghantar data ke platform IoT. Aplikasi Blynk digunakan sebagai antara muka pengguna seperti dalam Rajah 7 bagi memaparkan bacaan PM2.5, gas, suhu dan kelembapan secara masa nyata. Melalui aplikasi ini, pengguna boleh memantau keadaan persekitaran walaupun tidak berada berhampiran peranti. Penggunaan sistem IoT dalam pemantauan persekitaran telah terbukti dapat meningkatkan kesedaran pengguna serta memudahkan akses kepada maklumat secara langsung (Hossain et al., 2019).

### 2.4 Paparan Skrin Sentuh

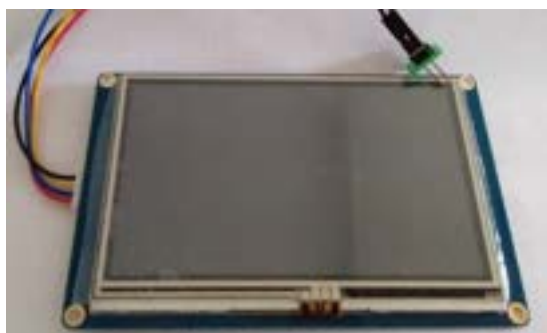
Selain paparan melalui telefon pintar, sebuah skrin sentuh Nextion 4.3 inci dipasang pada peranti seperti yang ditunjukkan dalam Rajah 8. Skrin ini membolehkan pengguna melihat bacaan secara terus tanpa perlu membuka aplikasi mudah alih. Antara muka skrin direka dengan susun atur yang ringkas, tulisan yang jelas dan penggunaan warna yang sesuai bagi memudahkan bacaan, khususnya untuk pengguna yang memerlukan maklumat dengan cepat.



Rajah 6 : ESP 8266 Wi-Fi Module



Rajah 7 : Blynk IOT Antara muka telefon pintar



Rajah 8 : Nextion 4.3 TFT LCD Touchscreen



Rajah 9 : Reka bentuk 3D

### 2.5 Reka Bentuk Bekas dan Percetakan 3D

Pada peringkat awal, peranti dipasang menggunakan bekas sedia ada. Namun, didapati aliran udara tidak optimum dan susun atur komponen agak terhad. Oleh itu, satu reka bentuk baharu telah dibangunkan menggunakan perisian Fusion 360 seperti yang ditunjukkan dalam Rajah 9. Reka bentuk ini kemudiannya dicetak menggunakan pencetak 3D dan hasil akhir ditunjukkan dalam Rajah 10.

Reka bentuk bekas baharu ini memberi perhatian kepada aliran udara, kedudukan penderia serta kemudahan pegangan bagi memastikan peranti lebih selesa dibawa dan digunakan. Aliran udara yang baik adalah penting terutamanya bagi penderia PM2.5 bagi memastikan bacaan yang lebih stabil dan tepat (Borghi et al., 2018). Selain itu, bekas ini juga direka untuk melindungi komponen dalaman serta meningkatkan keselamatan dan ketahanan peranti semasa penggunaan harian.

## 2.6 Penyediaan Ujian dan Pengujian Fungsi (versi kemas)

Bagi menilai prestasi peranti, ujian telah dijalankan di tiga jenis persekitaran berbeza, iaitu kawasan luar bandar (Rajah 11), kawasan perindustrian (Rajah 12) dan kawasan dalaman (Rajah 13). Pengujian di kawasan luar bandar bertujuan mendapatkan bacaan dalam persekitaran yang lebih bersih, manakala pengujian di kawasan perindustrian dilakukan bagi menilai keupayaan peranti mengesan perubahan mendadak dalam tahap pencemaran. Ujian di kawasan dalaman pula dijalankan bagi menilai kestabilan bacaan dalam ruang tertutup.

Bacaan yang diperoleh daripada paparan skrin sentuh kemudiannya dibandingkan dengan bacaan yang dipaparkan dalam aplikasi Blynk bagi memastikan keseragaman dan konsistensi data. Pengujian di pelbagai lokasi ini penting bagi mengesahkan kebolehpercayaan sistem pemantauan mudah alih yang dibangunkan (Kumar et al., 2015).



Rajah 10 : 3D Printed Case



Rajah 11 : Ujian di kawasan terbuka



Rajah 12: Ujian di kawasan Perindustrian



Rajah 13 : Ujian di dalam bilik

### 3.0 KEPUTUSAN DAN PERBINCANGAN

Bahagian ini membincangkan hasil pembangunan dan pengujian peranti pemantauan kualiti udara yang telah dibangunkan. Perbincangan tertumpu kepada prestasi sistem secara keseluruhan, keberkesanan reka bentuk perkakasan, fungsi paparan, serta tindak balas peranti terhadap perubahan kualiti udara di persekitaran yang berbeza.

#### 3.1 Reka Bentuk Akhir Peranti

Rajah 14 menunjukkan reka bentuk akhir peranti pemantauan kualiti udara yang telah siap dipasang. Semua komponen utama seperti penderia PM2.5, penderia gas, penderia suhu dan kelembapan, mikropengawal Arduino, modul ESP8266, bateri serta sistem penyejukan telah berjaya diintegrasikan ke dalam satu bekas yang padat dan mudah dibawa.



Rajah 14 : Air Monitoring



Figure 15 : Antara muka Nextion LCD



Rajah 16 : Antara muka utama



Figure 17 : Antara muka utama Skrin Sentuh

| 24-hr PM <sub>2.5</sub> [µg/m <sup>3</sup> ] | AQI Categories                 | AQI Values |
|----------------------------------------------|--------------------------------|------------|
| 0 - 12.0                                     | Good                           | 0 - 50     |
| 12.1 - 35.4                                  | Moderate                       | 51 - 100   |
| 35.5 - 55.4                                  | Unhealthy for Sensitive Groups | 101 - 150  |
| 55.5 - 150.4                                 | Unhealthy                      | 151 - 200  |
| 150.5 - 250.4                                | Very Unhealthy                 | 201 - 300  |

Rajah 18 : Jadual antara muka LCD AQI



Rajah 19: Antara muka LCD AQI Kategori

Perbandingan antara prototaip awal menggunakan bekas sedia ada dan bekas cetakan 3D menunjukkan peningkatan yang ketara dari segi aliran udara dan susun atur komponen. Reka bentuk baharu ini bukan sahaja lebih kemas, malah memberikan bacaan yang lebih stabil terutamanya bagi penderita PM2.5 yang memerlukan aliran udara yang konsisten. Dari segi kebolegunaan, peranti juga lebih selamat dan praktikal untuk digunakan oleh pesakit COPD dalam situasi harian.

### 3.2 Pembangunan Antara Muka Skrin Sentuh

Rajah 15 menunjukkan reka bentuk awal antara muka skrin sentuh yang dibangunkan. Walaupun fungsi asas dapat dilaksanakan, didapati paparan tersebut kurang jelas dari segi pemilihan warna dan saiz ikon. Berdasarkan pemerhatian ini, penambahbaikan telah dilakukan dengan memfokuskan kepada kejelasan visual dan kemudahan bacaan.

Versi antara muka yang ditambah baik seperti ditunjukkan dalam Rajah 16 dan Rajah 17 memaparkan bacaan PM2.5, gas, suhu dan kelembapan secara masa nyata dengan susun atur yang lebih ringkas. Selain itu, paparan tambahan seperti jadual rujukan AQI dan maklumat keselamatan (Rajah 18 dan Rajah 19) turut disediakan bagi membantu pengguna memahami tahap kualiti udara dan tindakan yang perlu diambil. Pendekatan ini sangat sesuai untuk pesakit COPD yang memerlukan maklumat yang mudah difahami dan boleh ditafsir dengan pantas.

### 3.3 Fungsi Aplikasi IoT

Rajah 20 menunjukkan antara muka aplikasi Blynk yang digunakan dalam sistem ini. Aplikasi ini membolehkan pengguna memantau bacaan penderita secara masa nyata melalui telefon pintar. Selain paparan data, fungsi notifikasi turut diaktifkan bagi memberi amaran sekiranya bacaan kualiti udara melepasi tahap yang ditetapkan. Keupayaan pemantauan jarak jauh ini memberi kelebihan kepada pengguna, terutamanya pesakit COPD, kerana mereka tidak perlu sentiasa berada berhampiran peranti. Aplikasi ini juga berfungsi sebagai sokongan tambahan kepada paparan skrin sentuh, sekali gus meningkatkan fleksibiliti penggunaan sistem.

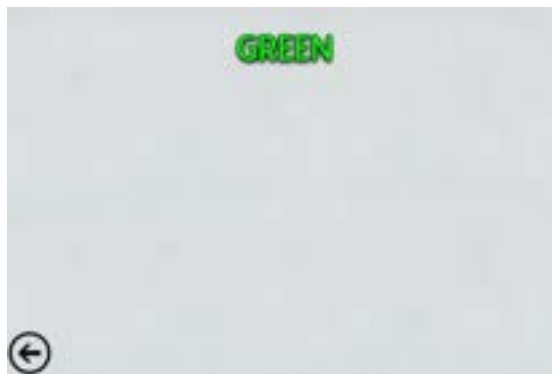


Figure 20 : Nextion LCD antara muka aplikasi Blynk

### 3.4 Prestasi Peranti di Persekitaran Berbeza

Pengujian peranti telah dijalankan di tiga jenis persekitaran berbeza bagi menilai tindak balas sistem terhadap tahap pencemaran yang berlainan.

#### (a) Persekitaran Dalaman

Ujian di kawasan dalaman seperti ditunjukkan dalam Rajah 13 menunjukkan bacaan PM2.5 dan AQI yang lebih stabil. Keadaan ini mencerminkan persekitaran yang kurang terdedah kepada pencemaran luaran, walaupun faktor seperti pengudaraan turut mempengaruhi bacaan.

**(b) Persekitaran Luar Bandar**

Ujian di kawasan luar bandar (Rajah 11) menunjukkan bacaan sederhana dengan sedikit variasi. Perubahan ini berkemungkinan disebabkan oleh aktiviti luar dan pergerakan udara semula jadi. Secara keseluruhan, bacaan yang diperoleh adalah lebih rendah berbanding kawasan perindustrian.

**(c) Persekitaran Perindustrian**

Pengujian di kawasan perindustrian (Rajah 12) menunjukkan bacaan PM2.5 dan AQI yang lebih tinggi serta perubahan yang lebih ketara. Peranti berjaya mengesan perubahan ini dengan pantas, sekali gus membuktikan kepekaan penderia dan keberkesanan sistem secara keseluruhan.

**3.5 Perbincangan Umum**

Secara keseluruhan, keputusan yang diperoleh menunjukkan bahawa peranti pemantauan kualiti udara yang dibangunkan berfungsi dengan baik dan responsif terhadap perubahan persekitaran. Reka bentuk bekas cetakan 3D telah meningkatkan kestabilan bacaan, manakala gabungan paparan skrin sentuh dan aplikasi IoT memudahkan pengguna mendapatkan maklumat secara langsung. Keupayaan peranti untuk berfungsi dengan konsisten di pelbagai persekitaran menunjukkan potensi penggunaannya sebagai alat sokongan harian, khususnya untuk pesakit COPD yang memerlukan pemantauan berterusan terhadap kualiti udara di sekeliling mereka.

**4.0 KESIMPULAN**

Kajian ini telah berjaya membangunkan sebuah peranti pemantauan kualiti udara mudah alih berasaskan Internet of Things (IoT) yang direka khusus untuk membantu pesakit Penyakit Paru-paru Obstruktif Kronik (COPD) serta pengguna umum memantau keadaan persekitaran mereka secara masa nyata. Peranti ini menggabungkan penderia PM2.5, penderia gas, penderia suhu dan kelembapan bersama mikropengawal Arduino, paparan skrin sentuh serta aplikasi mudah alih bagi menyediakan maklumat yang jelas dan mudah difahami oleh pengguna.

Hasil pengujian yang dijalankan di persekitaran dalaman, luar bandar dan perindustrian menunjukkan bahawa peranti ini mampu berfungsi dengan baik serta memberikan tindak balas yang konsisten terhadap perubahan kualiti udara. Penambahbaikan reka bentuk bekas melalui percetakan 3D telah membantu meningkatkan aliran udara dan kestabilan bacaan, manakala penggunaan sistem IoT membolehkan pemantauan dilakukan secara fleksibel tanpa had lokasi.

Secara keseluruhan, peranti yang dibangunkan ini berpotensi menjadi satu penyelesaian kos rendah dan praktikal sebagai alat amaran awal terhadap pencemaran udara. Melalui paparan bacaan masa nyata dan notifikasi amaran, pengguna khususnya pesakit COPD dapat mengambil langkah pencegahan yang sesuai bagi mengurangkan pendedahan kepada persekitaran yang berisiko. Dengan penambahbaikan lanjut seperti penentuan penderia dan ujian jangka panjang, sistem ini berpotensi untuk digunakan secara lebih meluas sebagai sokongan kepada pengurusan kesihatan pernafasan dan pemantauan kualiti udara harian.

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