Monitoring The Real-Time Level of Liquefied Petroleum Gas in A Cylinder

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ABSTRACT
This study presents a real-time LPG monitoring and alert system tailored for homes and restaurants, countering the drawbacks of manual monitoring. Gas sensors offer live gas supply data, and mobile alerts promptly notify users of critical levels. The user-friendly interface optimizes gas usage, bolsters safety, and fosters sustainability. Respondents' feedback underscores the system's potential to enhance safety through efficient refill planning and early leak detection. Despite concerns about initial costs and technology disruptions, participants support the system's implementation. Recommendations encompass regular maintenance and tamper-proof sensors. This innovation marks a pivotal step towards safer and more efficient LPG management, promising a substantial impact on residential and commercial sectors alike.
Keywords: *Liquefied Petroleum Gas, Gas Level Monitoring, Mobile Alert System, Gas Leak Detection*

1. INTRODUCTION

The increasing use of Liquefied Petroleum Gas (LPG) as a prominent energy source in residential homes and restaurants has brought about safety and management challenges, particularly concerning the potential risks of gas leaks and shortages (Mensah, 2023). Traditional manual methods of monitoring LPG levels and detecting leaks have proven to be inefficient and often lead to delayed identification of hazards, resulting in an escalation of accident risks (Khan, 2020). To address these limitations and enhance the safety and management of LPG usage, the current project proposes the development of an innovative Internet of Things (IoT) based system for real-time monitoring of LPG levels and timely mobile alerts (Economy, 2022). It is crucial to ensure accurate and effective monitoring and management of LPG levels, especially considering the increasing adoption of LPG as a cleaner fuel source in regions like Ghana, where the Ministry of Energy has actively encouraged its use to reduce reliance on traditional fuels (WLPGA & GLPGP, 2019). Therefore, the successful implementation of this project is of paramount importance to foster a safer and more sustainable environment for LPG utilization (Mensah, 2023).
The traditional method of manually weighing LPG cylinders for monitoring purposes has proven to be inefficient and wasteful, as it may lead to the unnecessary release of gas into the atmosphere during measurements (Zakaria et al., 2017). In contrast, the proposed IoT-based system offers a technologically advanced and environmentally friendly alternative, enabling users to remotely and accurately monitor LPG levels in real-time, without the need for manual intervention or gas wastage (Economy, 2022). This real-time data empowers users to proactively plan gas refills, thereby preventing shortages or leaks and enhancing overall safety. The mobile alert feature is a

critical component of the system, providing users with timely notifications on their smartphones or other devices, even when they are away from the location. This capability ensures that users stay informed about their gas levels at all times, promoting effective management and preventing potential accidents (Economy, 2022).
Enabling remote and accurate monitoring, proactive gas supply management, and timely notifications, this project seeks to enhance safety, optimize gas usage, prevent accidents, and promote sustainability in LPG utilization (Economy, 2022). The development and successful implementation of this innovative system have the potential to foster a culture of efficacy and environmental consciousness in the way LPG is utilized, contributing to a safer and greener environment (Mensah, 2023).

2. LITERATURE REVIEW

This section gives a summary of the relevant literature.

2.1 RELATED LITERATURE

The literature review explores existing research and projects related to monitoring and detecting gas leakage in LPG cylinders. Al Abdullah and Hussein (2021) proposed a smart home safety system for monitoring LPG concentration in the kitchen and providing alerts when gas levels reach a threshold. However, it lacks a mobile alert system and smart actions to eliminate gas leakage. In contrast, this study emphasizes a mobile alert system and proactive smart actions to enhance safety and efficiency in gas monitoring. Potdukhe and Gawai (2013) introduced a microcontroller-based system for LPG leak detection using the MQ6 gas sensor. It triggers alarms and alerts individuals via cellular networks when detecting LPG leakage. However, it lacks continuous monitoring and real-time gas level updates, which this study focuses on. It also lacks a mobile alert system, a key feature of this project for enhancing remote monitoring and response. Juvanna et al. (2014) proposed a system addressing the need to detect LPG cylinder weight decrease, notifying users when gas is running out. However, it relies solely on weight decrease rather than real-time monitoring and lacks a mobile alert feature that this study aims to incorporate.
Zakaria et al. (2017) introduced a non-invasive ultrasonic instrumentation system offering real-time LPG level data. However, it focuses only on one-cylinder size, while this project aims for a versatile solution usable with various cylinder sizes. The ultrasonic system may also require precise sensor positioning, making it less user-friendly than the comprehensive mobile alert system included in this project. Muthuvinayagam et al. (2014) developed a gas leakage detection system that activates an alarm when concentrations exceed normal levels. However, it lacks continuous gas level monitoring, unlike this study that aims for real-time tracking and mobile alerts for comprehensive LPG monitoring. This study by Jebaraj et al., (2023), highlights the significance of Liquefied Petroleum Gas (LPG) in everyday life and its various applications. To address safety concerns related to gas leakage, the researchers have developed a system that automatically detects leaks and alerts users through an LCD display. Additional safety features like automatic electricity cut-off and exit door opening are included. The system also monitors room temperature, and all status parameters are conveniently displayed on the LCD. Despite its benefits, the study acknowledges limitations, such as gas sensor accuracy and GSM network coverage issues. Addressing these limitations will enhance the system's efficiency and ensure safe LPG usage.
The creation of a Smart LPG Monitoring and Automatic Booking System based on IoT is discussed to address typical LPG use concerns. These concerns include gas cylinders running out of gas at inopportune times, a lack of information about gas levels, and the inability to estimate the cylinder's working days. The suggested Smart Gas Kit makes use of IoT to continually measure and show the gasoline level of LPG cylinders, booking a new cylinder when necessary.

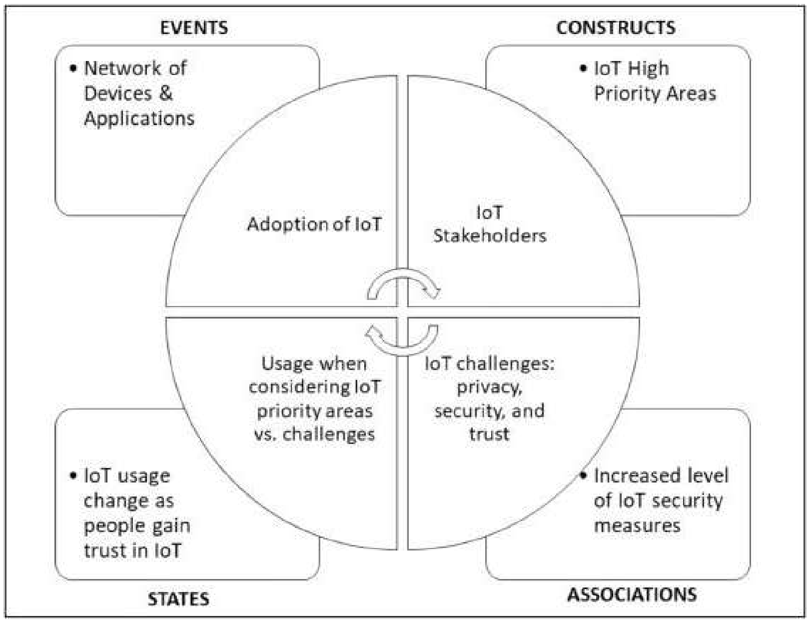
For weight measurement, the system utilizes a load cell interfaced with a microcontroller and transmits notifications to the user's mobile phone through Bluetooth module (Gupta et al., 2021). The study on IoT-based LPG monitoring systems shows a growing interest in enhancing user safety and convenience. The study identified challenges like lack of awareness about gas levels and timely refills. IoT technology offers real-time updates via mobile apps, accurate LPG level measurement, and predictive algorithms for refill needs. Safety features like gas leakage detection are emphasized. However, further research is needed on algorithm performance and mobile app security. Addressing these gaps will improve the system's efficiency and safety for LPG consumers (Arpit et al., 2019). Varma and Jayavel (2018) conducted a study on gas detectors' applications in various industries, categorizing them based on gas type and sensor technology. However, the effectiveness of the IoT-based gas leakage detection system for real-time LPG monitoring in cylinders may be influenced by factors like sensor accuracy, internet connectivity, and prompt response to alerts by authorities. Thorough testing and consideration of these factors are crucial to ensure reliable performance and user satisfaction.

Zhang Jiankun and Huang Lei's (2014) study presents an innovative gas sensor monitoring system using IoT technology. The system's strengths include low power consumption, cost-effectiveness, and high reliability. However, limitations include the lack of real-world performance data, insufficient security analysis, and comparison with other systems. Addressing these would enhance understanding of the system's capabilities and challenges. Nagib et al., (2020) proposed an IoT-based smart gas system using a sensor to measure and display cylinder content. It enables automatic booking via notifications. Limitations include potential inaccurate measurement due to sensor calibration, reliance on stable internet connectivity, and need for cooperation from distributors and consumers. It does not address security and privacy concerns. However, it provides insights into IoT for gas management and automated monitoring. Despite offering gas leakage and fire detection solutions, Sony et al., (2019)'s IoT-based system has limitations. Effectiveness relies on sensor accuracy and reliability. SMS and call notifications rely on stable internet connection. Successful implementation requires user and agency cooperation to embrace IoT. Considering these limitations is crucial to optimize functionality and ensure efficiency.

2.2 THEORETICAL FRAMEWORK

The study adopted the Internet of Things (IoT) framework, which seeks to effectively implement real-time monitoring of LPG levels using gas sensors, understanding the communication protocols and data flow involved in transmitting real-time data to the central monitoring system. This study analyzes the essential features required to develop a mobile alert system within the IoT network, ensuring timely notifications regarding critical gas level situations to users' smartphones or mobile devices. The IoT framework theory serves as a foundational framework for the study, guiding the design and development of a comprehensive gas monitoring system that enables users to make informed decisions, enhance safety, and efficiently manage their gas supply. Observers in the emerging digital landscape have recently experienced the widespread presence and influence of IoT-enabled devices. This technology has opened up fresh possibilities in the tech industry, while also presenting a range of challenges that demand heightened attention and consideration (Nord et al., 2019). Moreover, the Internet of Things (IoT) technology is at the core of the project's aim to provide real-time monitoring and mobile alerts, making it the most appropriate theory to guide the study's implementation and ensure successful development of the LPG gas level monitoring system.

Fig. 1:



IoTtheoretical framework and conceptual model

Source: (Norda, 2019)

The theoretical framework, depicted in Figure 1, consists of four key parts, which will be discussed in the following sections. In the lower-left section, the concept of "States" refers to the range of values that each construct in the theory might encompass. This includes the inside boundary state, denoted as "Usage," which explores the priority areas and challenges associated with the Internet of Things (IoT). Uncertainties, particularly concerning privacy and security, can influence usage, and users may be willing to take risks if the benefits are substantial. On the other hand, the outside boundary state encompasses "IoT usage change" as users gain trust in the IoT system, leading to potential usage increases that require further investigation (Forbes Insights Team, 2017).

2.2.1. DEFINITION OF CONSTRUCTS

The study adopts the Internet of Things (IoT) framework to achieve its objectives of optimizing gas usage, enhancing safety in LPG utilization, and implementing real-time monitoring using gas sensors. The framework encompasses various constructs: states, events, constructs, and associations. States involve identifying priority areas and challenges in IoT adoption specific to LPG gas monitoring, including real-time monitoring, data security, and user convenience. Events center around the adoption of IoT technologies in the gas monitoring system, integrating gas sensors, mobile alert systems, and data transmission protocols. Constructs represent individuals impacted by or interested in the IoT, such as end-users, homeowners, and regulatory authorities, whose perspectives are vital in system development. Associations focus on increased IoT security measures to safeguard sensitive data and ensure user safety. Leveraging the IoT framework and exploring these constructs, the study aims to design a comprehensive gas monitoring system that optimizes usage, enhances safety, and provides timely alerts to users, enabling efficient gas management (Weber, 2012).

3. RESEARCH METHODOLOGY

The study employed a qualitative research design and a purposive sampling technique to sample 10 respondents (8 females and 2 males). Data collection was conducted using interview guides, allowing for in-depth exploration of Respondents' perspectives, experiences, and opinions regarding LPG gas usage and safety measures. This systematic approach ensured that the study gathered relevant and valuable insights to address the research questions and objectives effectively. The data collection process spanned from July 2022 to December 2022, providing ample time to gather comprehensive data from the Respondents. Thematic analysis was employed to identify recurring themes and patterns in the Respondents' responses and observations of existing gas management practices. This analysis, along with a thorough review of relevant literature, ensured the comprehensive development of the real-time gas monitoring system.

4. RESULTS

The software development approach used in this study is the Rapid Application Development (RAD) methodology. RAD is a structured and iterative software development process which enabled the delivering of a working prototype, gather valuable user feedback, and make necessary adjustments along the way. By using qualitative methods and the Rapid Application Development (RAD) approach to efficiently design and develop a real-time gas level monitoring system. The RAD methodology consists of four stages: Requirements Gathering, User Design, Construction, and Cutover. The subsequent sections delved into a detailed analysis of each stage within the RAD model, illustrated in figure 2.

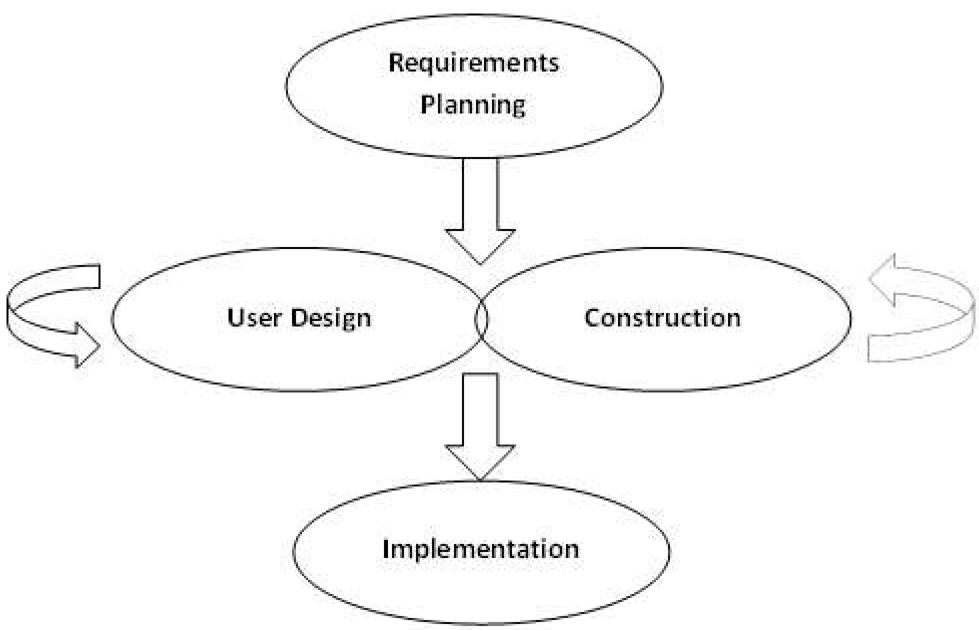


Figure 2 Rapid Application Development Model
Source: (Software Engineering, 2016)

4.1 REQUIREMENT PLANNING

The study chose a group of Respondents from various backgrounds, including students living in Pentecost University hostels, as well as households and eateries located in Sowutuom, within the Greater Accra Region of Ghana. These selected Respondents actively utilize LPG in cylinders, making them valuable contributors to the study's data collection process. The primary was utilized for the study. Semi-structured interview guides were used to collect qualitative data from homeowners, students, and restaurant managers. The interviews were to explore their experiences with LPG usage, gas monitoring practices, and perspectives on essential features for a mobile alert system.

4.1.1 INTERVIEW RESULT AND ANALYSIS

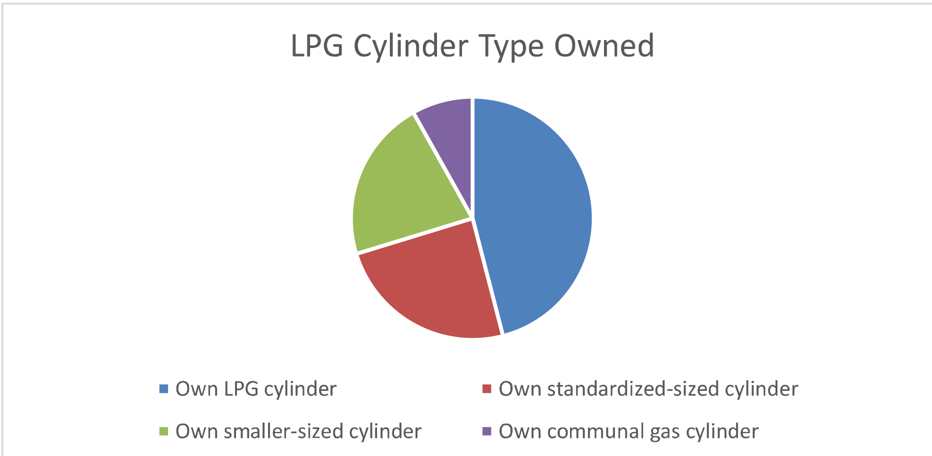


Figure 3. Representation of LPG Cylinder Owned by Respondents
Source: (Field, 2022)

Respondents were asked about their ownership of gas cylinders and their sizes. The majority of respondents (85%) reported owning gas cylinders, with 45% having standard-sized cylinders (e.g., 14 kg) and 40% having smaller-sized cylinders (e.g., 6 kg). Respondents highlighted several benefits of using LPG compared to traditional means of cooking and heating. The primary advantages reported were cleaner combustion, reduced pollution, faster cooking, convenience, and cost-effectiveness. When discussing the proposed LPG monitoring system, respondents expressed optimism about its potential positive impact through real-time monitoring to efficiently plan refills and enhance safety by early leak detection. However, concerns were raised regarding initial costs for low-income households and potential technology disruptions. Certain Respondents expressed concerns about their limited technological proficiency, underscoring the need for intuitive, user-friendly interfaces.

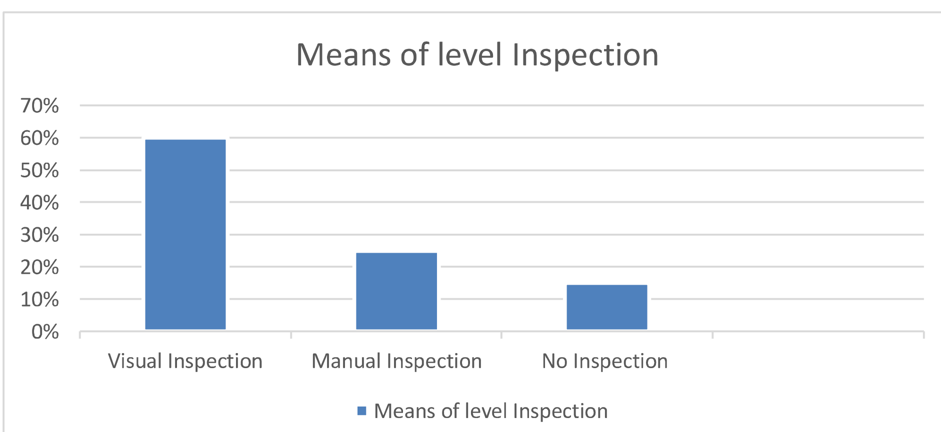


Figure 4. Representation of Means of Level Inspection
Source: (Field, 2022)

Most Respondents (60%) relied on visual inspection to gauge gas levels, while 25% used manual indicators, but acknowledged these methods' unreliability. Recommendations included regular maintenance, accurate level data, and durable tamper-proof sensors to optimize usage and ensure reliability. Respondents expressed interest in the proposed monitoring system for more reliable gas level information. Incorporating mobile applications for notifications and remote monitoring was suggested.

4.1.2 USER DESIGN

The User Design phase visualized the system's framework using UMLs like Use Case, Data Flow, and Context Diagrams. These structurally portrayed system aspects aligning with user requirements. Design objectives and architecture were outlined to guide development. The database structure was defined through an Entity-Relationship Diagram elucidating table relationships, streamlining data storage and retrieval. Prototype interfaces were refined based on usability feedback to ensure user-friendliness. This iterative visualization and refinement bridged the concept-execution gap. The stage precisely outlined structural aspects and database relationships to guide development towards the user requirements.

4.1.3 CONSTRUCTION PHASE

During the construction, task of transforming prototypes into a fully functional working model. The team delved into the creation of programs and applications, followed by the coding phase where the logical blueprints were translated into executable code. The valuable insights of respondents played a vital role and preparation for swift construction, the development of programs and applications, the coding process, and comprehensive testing procedures encompassing unit, integration, and system levels. Tools and techniques were employed to bring the proposed system to life in alignment with the study's objectives. Visual Studio, equipped with its Visual Basic component, played a pivotal role in this process. It was used to design the Graphical User Interfaces (GUIs) of the system and to write the necessary codes. This tool facilitated the development of a user-friendly interface and the implementation of essential functionalities.

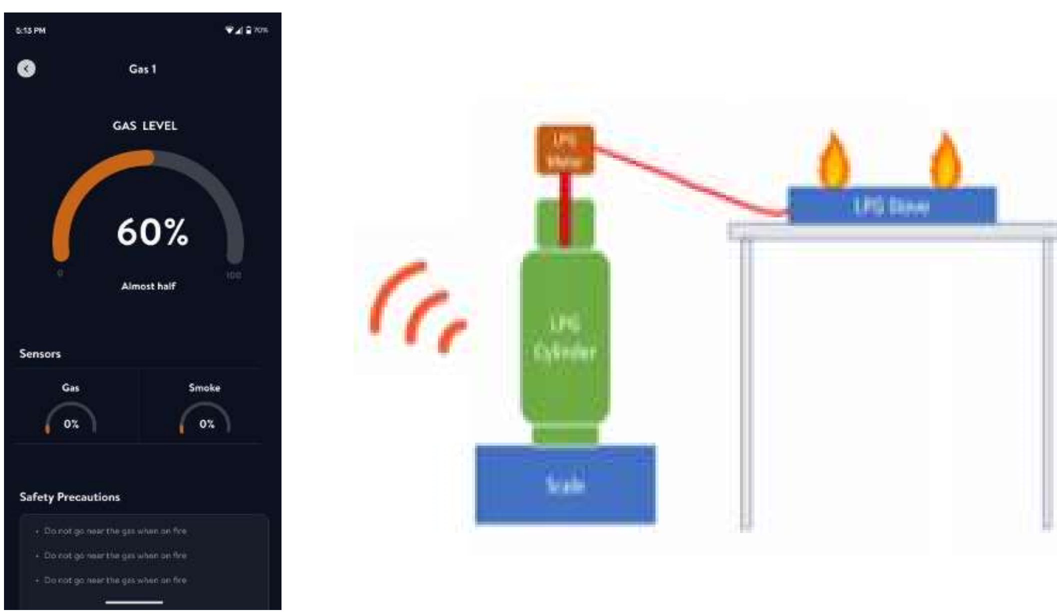


Fig. 6. Real-time LPG cylinder monitoring system: Scenario

4.1.4 CUTOVER PHASE

The real-time LPG monitoring system was deployed in households and restaurants to evaluate practical performance (Leung et al., 1997). User training ensured effective adoption and utilization. Continuous monitoring and feedback enabled addressing issues and enhancements for optimal performance, aligning with study objectives. System and user acceptance testing using the User Acceptance Testing method verified it met expected standards before deployment (Leung et al., 1997). Testing engaged participants like students and managers to evaluate usability and alignment with requirements, identifying discrepancies between system functionalities and user expectations. This ensured user-friendliness while providing insights to refine safety features and optimize gas use. The maintenance stage focuses on sustaining operational efficiency, performance, and effectiveness to ensure the system continues fulfilling real-time monitoring and timely notification objectives for safe LPG utilization.

Fig. 6. Sensors

Fig. 7. Load cell sensor

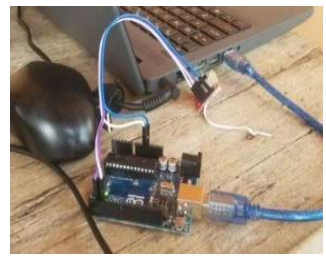


Fig. 8. Arduino Uno R3

4.1.5 DESIGNING TOOLS

The integrated tools enabled real-time LPG monitoring system development. Flutter and Dart crafted an intuitive app interface. Firebase enabled prompt alert data synchronization. Blynk Cloud facilitated hardware data acquisition. Arduino microcontroller with C programming-controlled sensor-app communication. Together, they enabled efficient real-time monitoring, synchronization, control, and alerts. The load cell, gas sensors, WiFi module, buzzer, and controller tracked LPG levels, detected leaks, transmitted data, and activated hazard alerts. Their synergistic integration enabled comprehensive real-time monitoring, connectivity, and automated safety features for efficient LPG management.

5. CONCLUSION

This study successfully realized its objectives by conceptualizing, developing, and implementing a real-time LPG gas level monitoring and mobile alert system tailored for both residential homes and restaurant environments. The study's findings emphasize the importance of user-friendly interfaces to accommodate varying technological proficiency and laid a foundation for the implementation of a safer and more sustainable LPG management system that will benefit an entire community. This study was another step toward home automation and reduced human intervention in monitoring the level of LPG in the gas cylinder, increasing the urgency in ordering a refill of the LPG cylinder. It was a dependable system, limiting the number of inconvenient scenarios of gas shortage in the middle of cooking. The system's potential for remote access and management opened avenues for commercialization, where the generated revenue was channeled back into refining the system and addressing any limitations it encountered. In essence, this initiative symbolized the fusion of home automation, practical utility, and innovative business prospects, poised to revolutionize LPG management practices within a well-defined context.

5.1 RECOMMENDATIONS

Continuous user training and feedback loops are crucial to ensure the LPG monitoring system remains user-friendly as proficiency varies. Partnerships with local LPG suppliers could streamline timely refills, enhancing practicality. Collaborating with manufacturers could enable sensor integration in new cylinders, expanding. Addressing power challenges through energy efficiency and alternative sources would improve sustainability. Comprehensive market research and targeted marketing strategies are needed to tap the system's commercial potential. Reinvesting profits into research and development would optimize the system. Overall, adhering to these recommendations can enhance user-friendliness, accessibility, and efficacy, contributing to a safer and more efficient approach to LPG management.

5.2 SUGGESTIONS FOR FUTURE STUDIES

Future research can enhance LPG management and home automation by incorporating automatic leak detection through advanced sensors and algorithms to promptly identify and mitigate hazards. Expanding the geographic scope by implementing the system in diverse regions could provide comprehensive insights on usability and effectiveness across contexts. Exploring partnerships with government and utility companies could enable widespread adoption. Investigating AI and machine learning to analyses patterns and optimize refill schedules could improve predictive capabilities. By refining safety features, broadening reach, and integrating cutting-edge technologies, future work can significantly advance LPG management practices, home automation, and integration of smart technologies, reshaping LPG utilization within a broader societal context.

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