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Research Article

IoT-Based Gas Alert Monitoring System (GAMS) Using ESP32 Technology

Dayangku Nurhayati Awangku Morni[1,*], Eliza Annis a/p Thangaiah[2], Ixora Nur Balqis Asrol Aidil[3] and Siti Nur Nabilah Yaki[4]

[1] Kolej Vokasional Shah Alam; g-52367876@moe-dl.edu.my

[2] Kolej Vokasional Shah Alam; g-68522763@moe-dl.edu.my

[3] Kolej Vokasional Shah Alam; m-7697311@moe-dl.edu.my

[4] Kolej Vokasional Shah Alam; m-8349528@moe-dl.edu.my

* Correspondence: g-52367876@moe-dl.edu.my

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Abstract: *The Gas Alert Monitoring System (GAMS) is an innovative Internet of Things (IoT) safety solution developed to monitor Liquefied Petroleum Gas (LPG) usage and mitigate risks in residential environments. Addressing the dual challenges of undetected gas leakages and unmonitored fuel depletion, the system integrates an ESP32 microcontroller with an MQ-6 gas sensor for real-time leak detection and a load cell to measure remaining gas mass continuously. When a hazardous threshold is reached, GAMS deploys a multi-layered warning mechanism comprising a local buzzer, LED status indicators and instant remote notifications via a Telegram bot. Furthermore, an integrated ESP32-CAM captures situational visuals during a leak event to provide immediate safety evidence for remote users. Evaluation results indicate excellent technical reliability and high user acceptance, demonstrating that GAMS offers a proactive, dependable domestic security standard that minimizes potential accidents, injuries and property damage.*

1. INTRODUCTION

Liquefied Petroleum Gas (LPG) is a liquefied gas consisting of hydrocarbons such as propane and butane. It is widely used globally as an essential domestic fuel for cooking and heating, as well as in commercial and automotive sectors. LPG is a flammable substance and a leak can cause dangerous incidents such as fire or explosion if there is an ignition source nearby. Accidents due to LPG explosions are increasing nowadays, posing a threat to human life (Raj, A., Viswanathan, A., & Athul T., S., 2015). Beyond fire hazards, an undetected leak in an enclosed space carries severe health risks. High concentrations of LPG displace oxygen in the air, acting as an asphyxiant that can cause dizziness, headaches, loss of consciousness, or suffocation for residents and domestic pets.

To address this threat, the Gas Alert Monitoring System (GAMS) project was developed as a smart security system based on the Internet of Things (IoT) and powered by an ESP32 microcontroller. This system integrates an MQ-6 gas sensor to detect leaks and a load cell sensor to monitor the mass of

the remaining gas in real time, thereby serving as an early-warning mechanism via a buzzer, LED, and Telegram application.

The background of this study is the high frequency of fire and explosion incidents caused by LPG gas leaks in Malaysia, which often threaten lives and property. In addition to safety issues, domestic consumers often face difficulties when the gas supply runs out suddenly due to a lack of an accurate monitoring system for the tank's remaining contents. Most existing detection devices on the market offer only basic functions and lack smart notifications or additional safety features, making it difficult for users to take quick action in an emergency when they are away from home.

The development of GAMS aims to improve the functions of existing monitoring systems by introducing more practical and efficient IoT innovations. Unlike previous studies that relied on SMS or latency-prone applications, GAMS offers real-time notifications via Telegram and the unique ESP32-CAM feature that automatically records video of incident locations as safety evidence. Through this approach, GAMS not only increases safety awareness but also facilitates the daily management of gas usage for domestic users.

2. LITERATURE REVIEW

The development of the Gas Alert Monitoring System (GAMS) requires a thorough analysis of historical and modern gas monitoring methodologies to overcome existing functional constraints. Over the past decade, residential gas protection systems have transitioned from basic localized hardware toward globally interconnected frameworks.

Early foundational work by Arun Raj et al. (2015) introduced an "LPG Gas Monitoring System" that leverages a PIC16F877A microcontroller, an MQ-6 gas sensor, and a strain-gauge load cell. While this prototype successfully initiated localized alarms and handled autonomous supplier bookings via a dedicated Global System for Mobile Communications (GSM) module, it relied heavily on traditional Short Message Service (SMS) messages. Empirical findings reveal that SMS-based warning architectures suffer from severe message transmission latency, unpredictable cellular service fees, and the absence of a visual channel for remotely verifying an ongoing emergency.

To establish continuous remote oversight, Manuel Taning et al. (2021) developed a "Smart Monitoring and Gas Leakage Detector for LPG Gas" using the NodeMCU ESP8266 platform connected to the Blynk cloud ecosystem. This design achieved a remarkable 99.97% sensor reading accuracy by passing MQ-9 gas and HX711 amplified load cell inputs to a specialized smartphone application dashboard. Despite its precision, extensive system evaluation showed that Blynk-reliant IoT implementations are vulnerable to deep internet data latency, making real-time warnings highly dependent on stable web bandwidth. Furthermore, the system lacked a secondary validation layer, such as real-time imaging, leaving users unable to distinguish genuine physical leak developments from false sensor fluctuations when away from home.

Recent advancements have attempted to bridge these communication and validation gaps by using decentralized social media interfaces and embedded imaging peripherals. For instance, empirical research by Robalino P (2024) demonstrates that modern dual-core microcontrollers like the ESP32 achieve system response times under 2 seconds, thereby proving highly reliable for handling

multitasking operations in residential gas safety ecosystems. Furthermore, the feasibility of pairing localized vision chips with instant messaging networks is strongly supported by Veeraboyina (2023), who demonstrated that an ESP32-CAM combined with the Telegram Bot API significantly reduces remote alerting latency and provides immediate visual confirmation. By integrating these specific mechanisms, the GAMS prototype moves beyond standalone alert or weight-tracking frameworks to build a comprehensive, visual and highly responsive security solution.

To visualize how GAMS establishes a unique, balanced framework amidst these shifting technologies, a technical feature matrix is structured in Table 1.

Table 1. Comparison of GAMS Features with Previous Studies

Characteristics	Legacy SMS Systems	Recent IoT Systems	GAMS
Notification method	SMS via GSM Module	Blynk App / Cloud Dashboards	Telegram Application Bot
Core Components	PIC16F877A, MQ-6	NodeMCU / ESP32, MQ-2, Load Cell	ESP32, MQ-6, ESP32-CAM, Load Cell
Visual Monitoring	None	Web-based Analog Gauge Stream	Automatic Event-triggered Captures
Strength	Basic functional alarm	High cloud sensor accuracy	Real-time visual confirmation and zero-app overhead alerts
Weakness	Message delays and carrier costs	Dependent on app latency and constant web hosting	Dependent on stable local Wi-Fi connectivity

Table 1 shows that the Gas Alert Monitoring System (GAMS) stands out as a proactive and practical domestic safety solution by resolving the direct functional limitations identified in earlier research. While legacy SMS architectures introduce unwanted carrier expenses and message transmission delays, and modern application dashboards require third-party web hosting or suffer from interface latency, GAMS utilizes an optimized Telegram bot interface to deliver secure, real-time remote alerts with zero application overhead for the user.

The technical novelty of GAMS lies in its hybrid, multi-layered validation architecture. By replacing low-power 8-bit microcontrollers with a powerful ESP32 microcontroller, the system seamlessly coordinates localized sensors with wireless media routines. Unlike previous systems that lack physical visualization or rely on heavy, continuous web streaming, GAMS introduces an automated, event-triggered ESP32-CAM script. The camera remains idle during standard operations but immediately captures and transfers high-definition situational visuals to the user's Telegram interface, the exact moment the MQ-6 sensor registers an LPG leak. Coupled with continuous, accurate load-cell weight tracking for gas depletion budgeting, this integrated IoT layout ensures high domestic security standards while remaining lightweight, practical and highly responsive.

3. METHODOLOGY

The development of the Gas Alert Monitoring System (GAMS) uses an Agile methodology with six main phases: planning, design, development, testing, end-user testing, and feedback and improvement. This methodology was chosen for its flexible, iterative nature, which enables more effective analysis and improvement of the prototype than traditional methods.

The initial phase begins with planning, including generating ideas, determining the project's scope for domestic users and preparing technical components and budget estimates. Next, the design phase produces physical sketches of the prototype and circuit diagrams, ensuring that the connections of electronic components, such as the MQ-6 sensor and load cell, are accurate before the construction phase begins. In the development phase, the initial prototype is built using a breadboard and an ESP32 microcontroller programmed via the Arduino IDE to integrate the communication module with the Telegram application. This process is followed by a rigorous testing phase to assess the gas sensor's sensitivity, the accuracy of the gas tank mass measurement, and the speed at which warning notifications are sent to the user's smartphone. The hardware modules used to develop GAMS are presented in Table 2.

Table 2. GAMS Hardware Module Function.

No	Name	Description
1	ESP32 CP2102	Main control unit
2	MQ-6 Gas Sensor Module	To detect the presence of LPG, butane and propane gas
3	Load Cell Sensor (50kg)	To detect and measure the remaining mass or weight
4	ESP32-Cam	To record photos and visuals of the location
5	Active buzzer 5V	To produce a physical alarm sound
6	LED light	Visual status indicator

Figure 1 shows the GAMS in a preliminary circuit sketch that connects all the hardware modules and Figure 2 shows the GAMS components placed in the temporary casing.

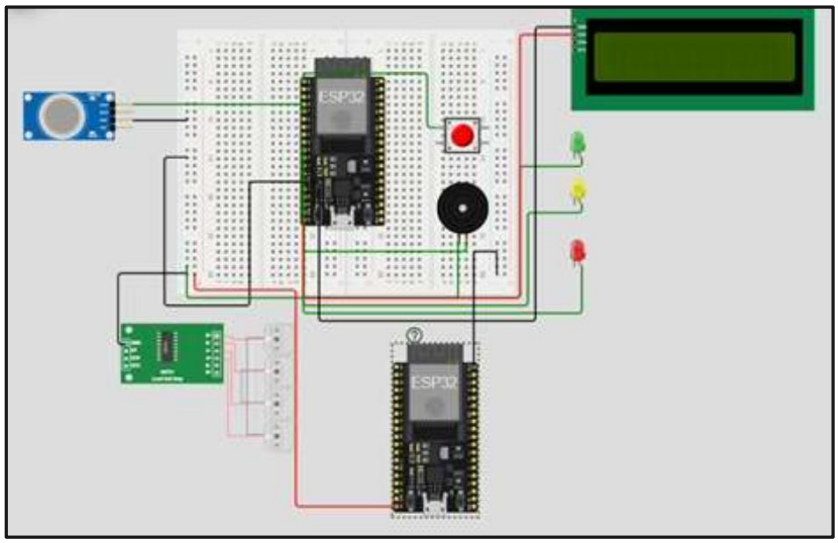


Figure 1. GAMS in preliminary sketch.

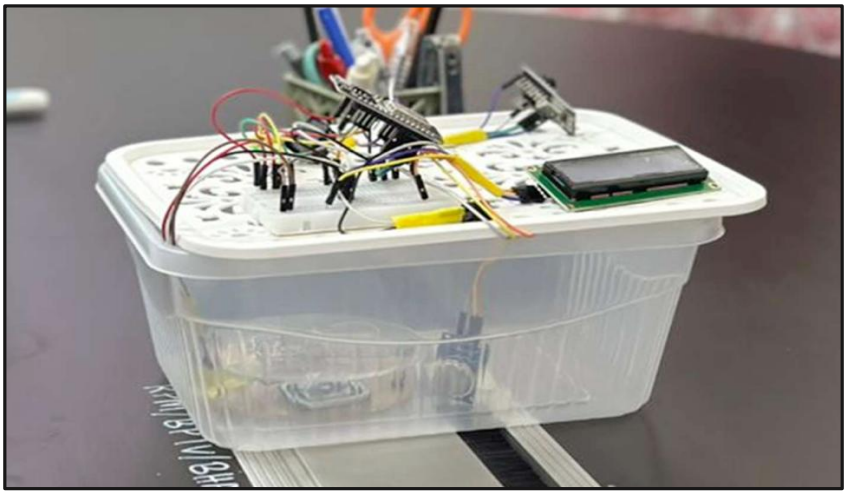


Figure 2. GAMS in temporary casing.

Finally, end-user testing is conducted by distributing User Acceptance Test (UAT) forms to 40 respondents to evaluate the system's functionality and effectiveness in real-world scenarios. Feedback from users is used to inform improvements, ensuring that the GAMS system optimally meets the set security objectives.

4. FINDINGS

The findings show a very high level of acceptance and awareness among 40 respondents of the importance of the GAMS system. Based on the questionnaire analysis, 100% of respondents agreed that a security system to detect LPG gas leaks is very important for every home. The majority of respondents (67.5%) expressed a strong willingness to consider installing GAMS in their homes and 95% fully supported using real-time notifications via the Telegram application as a key security feature. In addition, the functions of monitoring the gas cylinder's remaining weight and providing physical warnings via buzzer sounds and LED lights received 100% support from respondents, as they not only help daily management but also provide more effective early warnings.

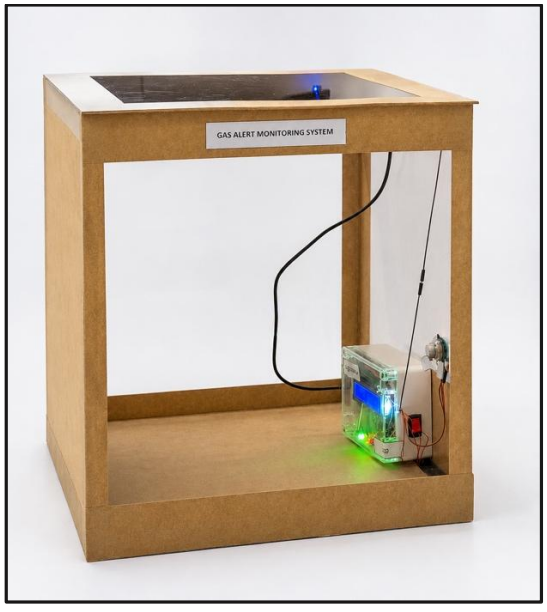


Figure 3. Final look GAMS.

In terms of technical functionality, system testing through the User Acceptance Test (UAT) phase proved that GAMS successfully achieved all the objectives set. This system can automatically detect LPG leaks via the MQ-6 sensor and measure the remaining gas mass in real time using a load cell with stable, accurate readings.



Figure 4. Telegram bot.

IoT integration enables alert notifications to be sent directly to the user's smartphone via a Telegram bot, while the ESP32-CAM function records video of the incident location as additional safety evidence. Overall, the analysis shows that GAMS has great potential as a practical and effective domestic security system for minimizing the risk of fire or explosion caused by gas leakage.

5. DISCUSSION

The implementation of the GAMS project has successfully achieved all three main objectives set during the initial planning phase. The LPG gas leak detector has functioned effectively, using sensors sensitive to propane and butane, thereby minimizing the risk of fire or explosion in homes. In addition, the integration of the load cell sensor enables real-time monitoring of gas cylinder mass, with data displayed directly to the user for more efficient gas balance management. The system's ability to send phased warning notifications via the Telegram application, as well as physical warnings via a buzzer and an LED, demonstrates that GAMS is a proactive and effective early warning system.

Analysis of responses from 40 respondents showed a very high level of acceptance of GAMS's functions and safety features. The majority of respondents (77.5%) considered the automatic gas leak detection function the most attractive feature because it provides users with peace of mind. The main

factors influencing their decision to use this system were its variety of functions and quality (80%). A summary of the study findings from respondents is as follows.

Table 2. A summary of the study findings.

No	Items	Result
1	The importance of a gas detector security system at home	100%
2	The use of the function of monitoring the remaining weight of the gas barrel	100%
3	Support for physical alerts	100%
4	Real time notification	95%
5	Readiness to install GAMS at home	67.5%

Although this project has achieved success in terms of functionality, some limitations have been identified that require improvements to enhance the system's reliability in the future. Among the main innovation proposals is the addition of an automatic shut-off valve that can independently cut off the gas flow when a leak is detected, preventing more serious incidents. In addition, using a battery power supply as additional support is highly recommended to ensure the system continues to operate in the event of an electrical failure. The development of dedicated mobile applications is also seen as a strategic step toward providing a more user-friendly and systematic monitoring interface than existing messaging platforms.

6. CONCLUSION

In conclusion, GAMS has successfully met its primary objectives, offering a robust and proactive solution for domestic safety. The system effectively detects LPG leaks using sensitive gas sensors, significantly reducing the risk of fire or explosion in residential settings. Furthermore, the integration of a load cell allows users to monitor the remaining mass of their gas cylinders in real-time, with data displayed on an LCD screen for efficient management. The development of a multi-layered notification system comprising physical buzzers, colored LEDs, and tiered alerts via the Telegram app ensures that users are promptly informed of any danger, even when they are away from home.

Looking ahead, GAMS represents a significant advancement in smart home safety technology, though there is room for further innovation. To enhance its reliability, future versions could include an automatic shut-off valve to immediately stop gas flow in the event of a leak, a dedicated mobile application for a more integrated user experience, and a battery backup system to ensure functionality during power outages. By addressing the limitations of previous technologies through IoT integration, GAMS serves as a vital tool for protecting lives and property from gas-related hazards.

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