Enhancing Safety for High Ceiling Emergency Light Monitoring

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***Abstract*—The performance of information technology has gradually improved and advanced during this period for safety management. Nonetheless, there is no disputing that during power outages, emergency lights continue to be crucial to people's safety and comfort. Regrettably, businesses don't give emergency lighting in buildings enough thought. The primary causes of the problem are expensive spending and long-term management for high ceiling safety. Additionally, one aspect that must be considered and ensured is the safety of maintenance personnel when the light is installed in high-rise locations. Thus, by creating wireless global control and monitoring via Android mobile phones, our effort intends to increase the availability and reliability of the emergency light. The suggested light monitoring system collects information from Internet of Things devices and transmits it to users' mobile phones over the Internet. Moreover, the risk of employees keeping the emergency light will be significantly reduced because it is monitored via the Internet on mobile devices. Additionally, by using the information the sensor inside the emergency light collects, it is possible to estimate its current condition, including its battery life. This repair will also improve everyone's safety within the building by increasing the emergency light's dependability with good process innovation.**

Keywords—Safety management; Internet of Things; high ceiling safety; high building safety; safety; process innovation

I. Introduction

Buildings with several levels have been constructed more quickly and easily because of advances in current technology in the construction industry, which also included utilizing the power of materials and other clever technologies. Emergency lights are necessary to handle power outages in these facilities. The Department of Economic and Social Affairs' Goal 17 (2022) requires the installation of emergency lighting during building projects when a power outage could negatively affect the surrounding environment or even endanger human life. However, organizations may find it challenging to keep a sizable number of emergency lights maintained due to considerations including time consumption and safety. Furthermore, there is no denying that Internet of Things (IoT) technology has become indispensable in the current trend due to its automation and low participation control. Companies can get around these challenges by integrating Internet of Things technologies into emergency lighting systems. With Internet of Things capabilities, emergency lights may be remotely monitored and controlled, reducing the need for manual maintenance and ensuring quick problem-solving. Moreover, businesses can optimize power usage, save costs, and manage energy more effectively thanks to the automated features of IoT technology [1].

Building construction on a huge scale has become commonplace in the modern era, which is notable for its technological and economic advancements. However, it is imperative that emergency lights be installed in these structures because they are essential for surviving power outages. To prevent catastrophic catastrophes, emergency lighting must be provided in public or commercial buildings per government rules, with the preservation of human life and the environment receiving top priority [2, 3]. When there is a decrease in light or an emergency brought on by a power outage, emergency lighting turns on. Its primary job is to create enough light automatically so that everyone within the building can leave safely. Due to varying safety rules in different buildings and areas, there are numerous types of emergency lights available on the market. Dominik Pfaff has proposed four different types of emergency lights [2]. They are emergency escape lighting, which is designed to prevent dangerous accidents during emergencies; standby lighting, which continuously supports normal activities in specific locations and buildings; high-risk task area lighting, which is essential to the escape lighting system and provides enough illumination for people to reach specific areas; and escape route lighting, which guarantees clear visibility of evacuation routes.

It is obvious that emergency lights are necessary to guarantee people's safety in unexpected situations. Nonetheless, managing the availability and dependability of these lights is a big problem for businesses. The lack of practical means to ensure the continuous operation and reliability of emergency lights is one of the major problems [3]. Moreover, the financial aspect is a significant challenge since companies are often reluctant to bear the associated costs, such as wages, software development, and maintenance fees. Especially on construction sites where there are a lot of emergency lights, workers face several challenges throughout the maintenance process. Handling this big array is going to take a lot of work. The placement of emergency lights in elevated areas significantly increases the risk of injury or even death to a maintenance worker while they are performing their task. The last problem is that relying just on visual observation to assess emergency lights' functioning by personnel jeopardizes the accuracy of the test results and could lead to incorrect evaluations of the lights' operational state. Emergency lights play an important role in protecting and ensuring human safety during emergency events. However, companies often neglect the management of reliability and availability of emergency lights due to various challenges. Firstly, there is a lack of efficient ways to maintain the performance and reliability of emergency lights. Moreover, cost spending is also a factor that companies are unwilling to face, including employee fees, software development, and maintenance fees. In addition, there are various challenges that employees face during maintenance of emergency lights. For example, due to the large number of emergency lights on the construction site, it requires a lot of time to manage the lights. Some emergency lights are installed at higher locations, which may cause injury or even loss of life for maintainers if they fall while maintaining the emergency lights. Lastly, the accuracy of examination results is low because employees can only tell if the emergency lights are working by observation.

Consider a scenario where a maintainer is inspecting emergency lights that are located at a height to provide another example that will help clarify this idea. Because of how challenging it is to reach these areas; maintenance personnel may need to employ ladders or other risky climbing equipment. Such actions constantly increase the risk of injury to maintenance personnel. Should the ladder be unstable, or the process not be carried out correctly, maintenance personnel could fall from a height and suffer severe injuries or even lose their lives. Working at these high altitudes therefore necessitates extra safety procedures as well as personnel training to minimize potential hazards. In addition to highlighting the urgent need to address these problems, this example illustrates the dangers that maintainers may face during inspections. For companies that value the safety of their maintenance staff, it is imperative to establish strict protocols and norms for operating at elevated heights. protecting the emergency lighting. Routine maintenance and inspections should be performed to ensure the stability and dependability of ladders and other machinery. Companies can lower the risk of accidents and protect the health of their maintenance workers by implementing these safety precautions. Furthermore, ladders and other equipment need to have routine maintenance and inspections performed to guarantee their stability and dependability. Organizations can mitigate the likelihood of accidents and safeguard the welfare of their maintenance staff by implementing these preventive measures.

The IoT technology is a network of physical things that have related to sophisticated software and high-tech sensors to facilitate data interchange with other devices and computers over the internet [2]. IoT devices link to a cloud, like Google Firebase or an IoT gateway, to exchange the gathered data for local data analysis. The Internet of Things (IoT) system, which includes low-power sensor technology, cloud computing platforms, and sophisticated connectivity, can benefit from the integration of artificial intelligence and machine learning to improve the data collection process. As a concrete illustration of an IoT system, modern applications include supply chains, robotics, smartwatches, and health monitoring devices [1].

Several businesses could be revolutionized by IoT technology. IoT devices, for instance, may monitor machinery in real-time in the manufacturing industry, identifying any problems before they arise and enabling preventative maintenance. This can boost output and drastically cut down on downtime. IoT devices in the healthcare industry are able to monitor patient vitals and notify medical personnel in the event of an emergency. The Internet of Things (IoT), a revolutionary concept that connects diverse products and systems through the internet, has evolved with the rapid growth of technology. This network's interconnection makes data sharing and communication easy, which has several advantages for a range of sectors. IoT technology has the power to completely change the way we live and work, from increasing productivity and efficiency to boosting safety and convenience. The capacity of IoT technology to facilitate predictive maintenance is one of its main benefits. IoT sensors, for instance, can be mounted on machines in the manufacturing sector to track performance and identify possible problems before they cause a breakdown [4]. Real-time data on variables like temperature, vibration, and power usage may be gathered by these sensors, and artificial intelligence algorithms can be used to assess the results. This minimizes downtime and increases overall equipment effectiveness by enabling maintenance professionals to proactively arrange repairs or replacements. IoT technology may also notify technicians about certain maintenance requirements, guaranteeing that the appropriate resources are available when needed [5]. IoT technology also has the potential to gather and evaluate data in order to spot patterns and trends, which helps maintenance specialists maximize maintenance plans and raise equipment dependability. An illustration of an IoT system can be found in Fig. 1.

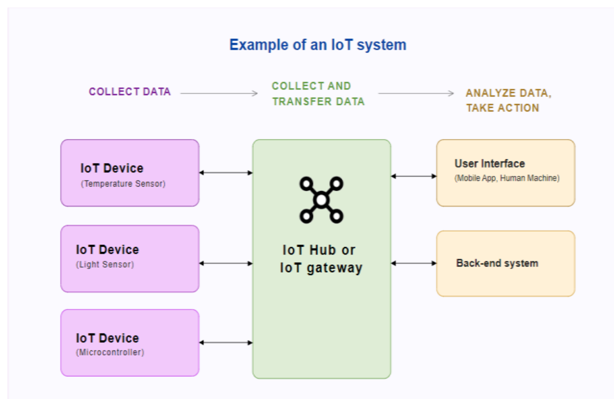

Fig. 1. Example of an IoT system.

The extensive attraction of IoT can be attributed to its pivotal role in intelligent management, which leverages automation to reduce human involvement and preserve time. This trend is further supported by the advantages it provides. Firstly, IoT increases productivity through task automation and simple connections between devices, systems, and processes. This reduces the requirement for manual intervention while optimising the utilisation of resources. Second, intelligent connectivity between IoT devices leads to enhanced decision-making capabilities and optimised operations. Real-time data monitoring and analysis enables people and businesses to respond swiftly to changing circumstances. Finally, IoT contributes to better resource management by enabling efficient asset monitoring and utilisation, which lowers costs and increases production. When everything is considered, the Internet of Things is not simply a fad but rather a revolutionary force that is facilitating state-of-the-art research and creating intelligent, effective, and adaptive products that satisfy the constantly shifting needs of our globalised society.

Large-scale construction projects are becoming more prevalent in the rapidly evolving 21st-century environment, which is characterized by economic growth and technological advancements. Installing emergency lighting is also necessary in these kinds of locations to ensure residents' safety during power outages. Moreover, given the critical role emergency lights play in averting serious repercussions for human life and the environment, it is important to resolve maintenance-related concerns surrounding them (Goal 17 | Department of Economic and Social Affairs, 2022). Firstly, the proposed system addresses these problems head-on by providing a unique solution: a smartphone app designed to monitor emergency light conditions without forcing users to approach close. This promises to address concerns related to safety and enhance the efficiency of maintenance protocols.

The core of this innovative system is the Internet of Things (IoT) technology, which generates critical data through sensors [6]. Long-distance monitoring and control are also made possible by the data that is safely kept on the Firebase server and sent. Furthermore, because of its low cost and the availability of open-source tools and software, Arduino is selected as the Internet of Things device for data collection. This solution guarantees affordability and provides a wealth of resources through open-source, comprehensive software development modules.

The proposed approach extends its UI to an Android app, going beyond only integrating hardware. Users of this app can also easily regulate operations and monitor the status of emergency lights. While speed of performance is not the primary factor, the Android operating system was specifically selected for the application, emphasizing its ability to display data in real-time [6]. Because it makes use of Google's Firebase cloud server and online storage platform, which are both efficient and readily available, the system is also the best choice. The platform's easy setup and installation processes, in addition to its free plan for students and learners, contribute even more to the overall effectiveness of the recommended system. In essence, this innovative strategy uses contemporary technology to support accessible, safe, and effective building management while concurrently solving issues with emergency light maintenance. To improve routine check efficiency and human safety, this project aims to develop a system that integrates Internet of Things (IoT) sensors with a smartphone application to remotely monitor emergency light status.

II. Methodology

The waterfall model is one of the straightforward techniques in the Software Development Life Cycle (SDLC), an organised methodology used to produce high-quality products. The requirement analysis, design, development, testing, deployment, and maintenance phases are the six stages that this paradigm usually entails. But just the first four stages of the project—analysis, design, development, and testing—have been completed thus far. The waterfall model is a step-by-step process where the output from one phase becomes the input for the subsequent phase. It's important to remember that a variety of factors, including stakeholder preferences and project complexity, influence the decision between the waterfall model and alternative techniques. Phase 1, data collection, which included requirements analysis and design; Phase 2, system development, which covered the development activities; and Phase 3, testing, which concentrated on the testing phase, comprised the three phases of the research approach. This methodology follows a step-by-step process, with each phase building on the output of the one before it. It is similar to the waterfall approach as mentioned by another team [7].

A. Phase 1: Data Collection

Initially, in-depth perspectives and opinions on the idea from Malaysian citizens were obtained through interviews, a qualitative data gathering technique. To ascertain whether the public appendices and papers in the report were acceptable to them, three individuals were interviewed. The purpose of this interview was to ascertain the significance of emergency lighting and the suggested system, as well as to assess people's comprehension of them. In addition, it aids in determining the qualities that people find appealing. Furthermore, the interviews also helped in identifying any potential concerns or issues that may arise with the proposed emergency lighting system. This feedback will be crucial in refining and improving the system before implementation. Overall, the interviews provided valuable insights that will inform the development and implementation of the emergency lighting system. By addressing any concerns raised and incorporating desirable features, the final product will be better tailored to meet the needs and expectations of the user.

Knowledge of the suggested high-ceiling emergency light monitoring system was obtained from talks with professionals in the field. An expert emergency light vendor stressed the significance of emergency lights in guaranteeing security during blackouts. The expert also voiced excitement about the potential advantages of an IoT system, emphasizing how it might improve system reliability by lowering the need for physical involvement during maintenance, thereby increasing safety. Furthermore, it highlighted how crucial practical aspects like battery life monitoring and long-distance control are in huge facilities. First, in a similar vein, an emergency mechanical engineer emphasized the need for emergency lighting for safe building evacuation in times of crisis. The engineer also said that the system would be more reliable and that inspectors would not have to be there in person as much. He suggested features like automated testing that could generate reports and long-range control by supporting the use of an IoT monitoring system. Finally, the suggestions made by industry professionals will have a significant impact on the design and development of the High Ceiling Emergency Light Monitoring System.

The use case diagram in Fig. 2, which is a representation of the functionality and extent of the system using the Unified Modelling Language (UML) language, then illustrates the interaction between the actors and various use cases [8]. The use case diagram provided below illustrates how actors and use cases relate to one another in the proposed system. The functioning of the high-ceiling emergency light monitoring system is also depicted in the diagram. It describes how communication between the three primary components—Firebase, IoT devices, and the Android app—works. The diagram emphasizes the seamless flow of commands and data between different components, highlighting their interconnectedness. It explains the intricate communication routes and shows how Firebase serves as a central hub for data storage and retrieval, enabling real-time control and monitoring.

As the system's senses, the Internet of Things devices communicate back and forth with Firebase and the Android app to maintain a continuous flow of critical data. [9]. Furthermore, the Android app acts as the user interface, facilitating a variety of operations for consumers. By illustrating the transparent communication channels and the relationship between user actions and system reactions, the graphic highlights the system's efficiency and eventually enhances the monitoring and control of emergency lights in situations with high ceilings.

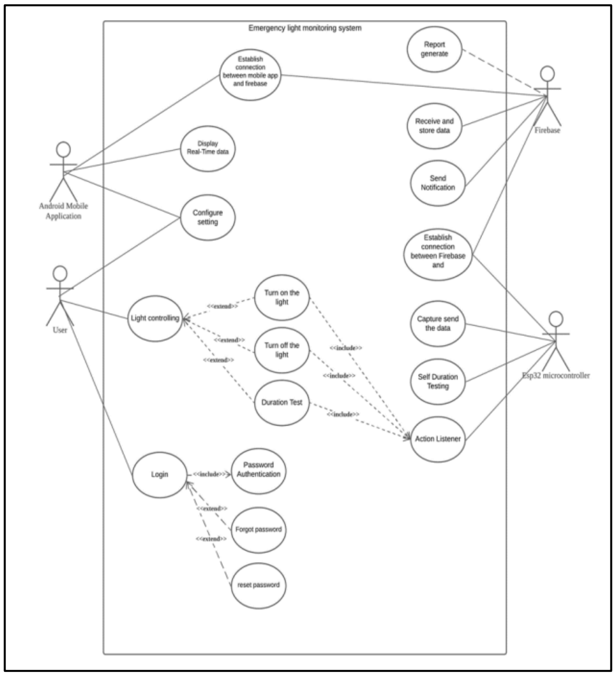

Fig. 2. Use case diagram for solid waste classification system.

B. Phase 2: System Development

Fig. 3 depicts the block diagram of the prototype system, which utilizes the ESP32 module as the core controlling and monitoring component. The system is composed of three distinct sections: the controlling board (navy blue), the controlling medium (green), and the original target device (orange).

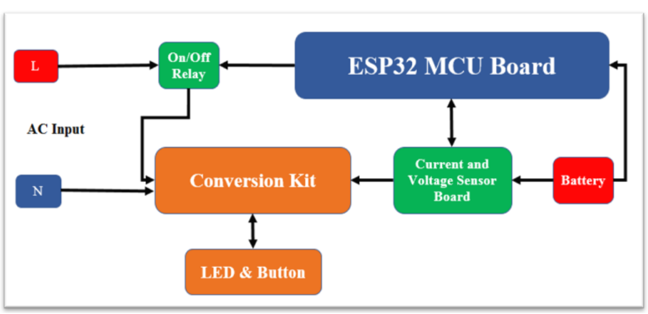

Fig. 3. Block diagram of prototype system.

As illustrated by Fig. 4, the suggested emergency light monitoring system is organized around three main elements: data display via Android mobile phones, data storage in Firebase, and data sensing through IoT devices [10]. Furthermore, the system uses the Arduino ESP32 module as its microprocessor, which makes data management and wireless network connections like Wi-Fi and Bluetooth possible. Furthermore, in order to improve its functionality, the ESP32 module supports a wide range of sensors, including voltage, light, and temperature. First off, the ESP32 may be connected to the internet and Firebase server networks thanks to Arduino's open-source software development tools, which include Wi-Fi, Bluetooth, and Firebase modules. Additionally, users can permanently store configuration data, such as the positions of emergency lights and Wi-Fi connections, using the ESP32's ROM storage. The ESP32's LED lights make effective performance testing possible [10]. After sensor data is gathered, it is sent over the internet to the Firebase server platform for real-time monitoring and archiving. In addition, the Firebase server has cloud messaging and cloud function messaging features that allow users to communicate with one another directly from the server [10]. The system's third component is an Android mobile application that lets users keep an eye on emergency light data. Additionally, the application gives users control over the emergency light switching during system inspections by displaying all collected data parameters saved in Firebase. The application also highlights the emergency light's condition with colour changes. Last but not least, since Google developed Android, connecting the Android application to Firebase is a simple process, ensuring seamless integration and user-friendly access to real-time emergency light monitoring [10, 11]. This comprehensive system design not only leverages IoT technology for efficient data sensing but also employs Firebase and Android integration to provide a user-friendly and effective emergency light monitoring solution [12].

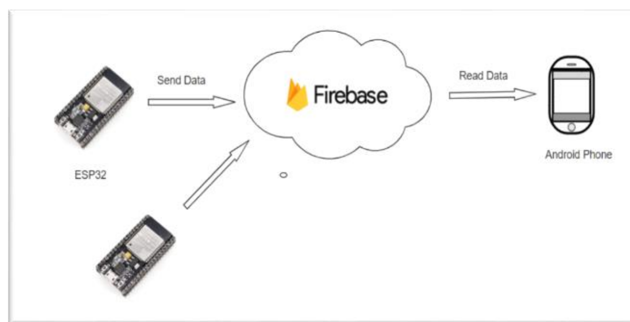

Fig. 4. Structure of proposed system development .

C. Phase 3: Testing

The High Ceiling Emergency Light Monitoring System went through a thorough testing process, including unit, integration, and acceptance testing to check its usability, reliability, and performance. In the unit testing phase, specific criteria for each component, from the ESP32 microcontroller [13] to various sensors and user interface activities, were carefully examined. Additionally, the successful completion of tasks, such as connecting to the internet, capturing sensor data accurately, and performing user actions, demonstrated the individual components' functionality. Moreover, integration testing further strengthened the system's robustness, ensuring smooth communication between modules. The system demonstrated cohesive behaviour and met the predetermined pass criteria, regardless of whether it was internet connectivity, real-time database interactions, or user interface functionalities. Furthermore, acceptance testing provided a complete evaluation, confirming that the system effectively met user requirements and expectations [14, 15]. Documented procedures and results from each testing phase attest to the system's overall success, confirming its high performance, reliability, and user satisfaction and highlighting its readiness for deployment in monitoring emergency lights in high-ceiling environments. The system's ability to meet the pass criteria in various areas demonstrates its robustness and adaptability. Additionally, the positive feedback received from users during acceptance testing further validates its effectiveness and usability in real-world scenarios.

III. Results and Discussion

The High Ceiling Emergency Lighting Monitoring System's useful features and characteristics make it a valuable tool for emergency lighting system maintenance is captured in Fig. 5.

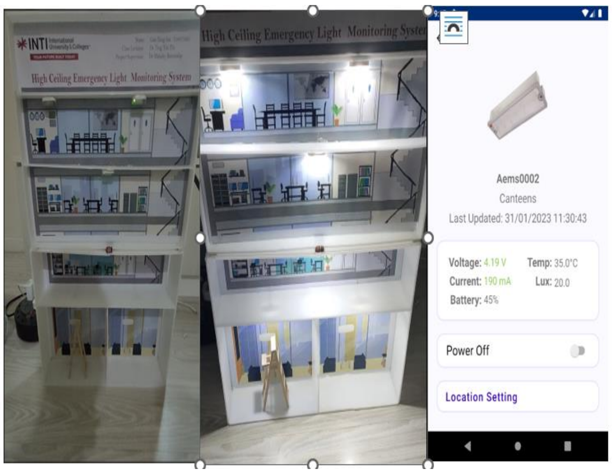

Fig. 5. High ceiling emergency light monitoring system prototype.

One notable feature that guarantees emergency light dependability during power outages is the automatic testing feature. This feature allows for regular assessments of emergency lights without requiring operator intervention. Additionally, maintenance staff can effectively operate emergency lights from a distance thanks to the system's support for remote control. Additionally, a reliable testing function tracks battery life in compliance with safety standards. As a result, real-time monitoring features give precise information about the state of the system and enable prompt problem identification. The report-generating capability also gathers diagnostic data to facilitate prompt remediation and ongoing enhancement. All these carefully thought-out features together increase the system's ability to dependable sustain emergency lighting systems in rooms with high ceilings. Furthermore, the sophisticated technology of the system guarantees effective coordination in emergency scenarios by enabling a smooth interface with other building management systems. Furthermore, the interface is easy to use, making it simpler to adjust settings to suit individual requirements and tastes. IoT based monitoring supports easily scalable and can handle expanding or complex systems without significant additional infrastructure. It also help to reduces maintenance efforts with automated alerts, predictive analytics, and remote management capabilities. Finally, IoT also adapts easily to changes in system requirements or facility needs with minimal adjustments.

Still, there are a few things that could be done better with the High Ceiling Emergency Light Monitoring System. The first requirement for the system's correct operation is a reliable internet connection. The Internet of Things devices accountable for gathering data, storing it in Firebase, and receiving commands require a dependable and continuous internet connection. Furthermore, because the system only supports Android devices at this time, users of other mobile operating systems may find their accessibility limited [13]. Because of this, the overall efficacy and viability of putting the High Ceiling Emergency Light Monitoring System into place should be carefully considered while weighing these limitations.

IV. Conclusion and Future Enhancement

As the High Ceiling Emergency Light Monitoring System is developed further, a few possible enhancements become apparent. Initially and foremost, it is necessary to tackle the significant issue of enhancing the status reporting procedure. The current system can identify defective circuits, for example, but it may be enhanced by providing more precise information, even though it already provides a rudimentary diagnosis report. In addition, this comprehensive information would enable maintainers to carry out repairs with greater accuracy and efficiency. In addition, it would be very important to have an urgent notification system. Ignoring the lack of a notification system for users in the event of an emergency, like a fire tragedy or ongoing issues, would be one method to ensure prompt remediation and enhance overall safety. This means that looking into more advanced IoT device connectivity perhaps through a mesh network like Bluetooth mesh for the ESP32 which might end up being a game-changer. In the end, this would increase system responsiveness by enhancing group control, saving energy, and reducing network traffic. The installation process also needs to be optimized for the user's convenience. Adding features like auto-configuration and self-diagnosis could improve the installation process' efficiency and usability in the future. Keeping the system at the forefront of emergency light monitoring technology is the goal of all these significant enhancements. All things considered, the suggested improvements present a system that could significantly improve emergency light performance and reliability, setting a higher standard for general human safety.

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