
AUTOMATIC SMART STREET LIGHT SYSTEM

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Abstract

Traditional street lighting systems are often plagued by inefficiencies, including excessive energy consumption, high maintenance costs, and safety hazards in inadequately lit areas. This study presents an Automatic Smart Streetlight System, an innovative solution aligned with the United Nations' Sustainable Development Goals (SDGs), particularly SDG 7: Affordable and Clean Energy and SDG 11: Sustainable Cities and Communities. The project aims to develop a sustainable, IoT-enabled prototype powered by solar energy, equipped with motion sensors to activate lights only when vehicles, pedestrians, or cyclists are present. This approach significantly reduces energy waste while ensuring optimal road safety. The research employed a prototyping methodology, iteratively designing and testing a system integrating microcontrollers, light-dependent resistors, ultrasonic sensors, and wireless communication via the Blynk app for remote monitoring and control. Results demonstrate that the system effectively reduces energy consumption, enhances lighting efficiency, and extends component lifespan by utilising solar panels and intelligent lighting management. It also minimises maintenance needs by providing real-time alerts through its app integration. This smart system ensures sustainable operation in various environments, overcoming the challenges of traditional lighting systems while offering a scalable and cost-effective solution for urban and rural infrastructure. By addressing critical issues such as carbon emissions and public safety, the proposed system highlights the transformative potential of renewable energy and IoT technologies in urban planning. This project exemplifies how innovative technology can contribute to the creation of safer, smarter, and more sustainable cities, thereby addressing key global challenges associated with urbanisation.

Keywords: Energy efficiency, Motion detection, Renewable energy integration, Smart streetlight system, Sustainable urban infrastructure,

INTRODUCTION

Street lighting is an essential component of urban infrastructure, promoting safety and mobility for drivers, pedestrians, and cyclists. However, traditional systems often face challenges such as excessive energy consumption, high maintenance costs, and inadequate illumination during nighttime, which can increase accident risks (Ilham, 2019; Rozlan, 2024). Additionally, reliance on non-renewable energy sources and manual operations exacerbates these inefficiencies, highlighting the need for innovative solutions.

Previous studies have explored IoT-based approaches to address these challenges. For instance, an IoT-Based Smart Street Light System utilises motion detection and automated lighting but suffers from high setup costs and operational limitations (Hackster.io, 2019). Similarly, smart systems integrating sunlight intensity detection and cloud-based monitoring reduce energy use but present complexities in maintenance and scalability (G. L., Khan, S., & K., 2023). These limitations reveal a

research gap in developing cost-effective, scalable, and environmentally sustainable solutions that integrate renewable energy and advanced automation.

This study introduces an Automatic Smart Streetlight System as a novel approach to address these gaps. The system leverages solar power, motion sensors, and IoT technology, enabling intelligent lighting that activates only when needed. Remote monitoring through the Blynk app further enhances management efficiency and reduces maintenance demands. The system aligns with Sustainable Development Goals (SDG) 7: Affordable and Clean Energy and SDG 11: Sustainable Cities and Communities, contributing to safer, greener, and smarter urban environments.

The purpose of this research is to present a replicable and innovative framework for sustainable urban lighting. By addressing existing gaps, this system offers a transformative model for urban planners, showcasing the critical role of renewable energy and IoT in modernising city infrastructure.

LITERATURE REVIEW

The evolution of street lighting systems towards automation and sustainability has gained significant traction in recent years, driven by the dual need for energy efficiency and improved safety. This review explores existing approaches to smart street lighting systems, identifying their key contributions, advantages, and limitations to position the proposed project within this context.

IoT-Based Smart Street Lighting Systems

Hackster.io (2019) introduced an IoT-based system leveraging light-dependent resistors (LDRs) for ambient light detection and infrared (IR) sensors for motion sensing. The system's ability to dynamically adjust lighting levels minimises energy consumption and light pollution. However, challenges such as high setup costs and the susceptibility of IoT modules to network outages were noted.

Similarly, G. L. *et al.* (2023) proposed a system integrating ATmega328P microcontrollers, LDRs, and relay drivers to optimise lighting intensity based on environmental conditions. By incorporating internet connectivity through ESP8266 modules, this system demonstrated enhanced remote-control capabilities. Yet, its reliance on traditional electricity sources resulted in higher operational costs, contrasting with the proposed use of solar panels in this project.

Integration of Motion Sensing and Solar Power

Salim and Azman (2022) developed a smart streetlight prototype employing ESP32 Wi-Fi modules and IR sensors for movement detection. The use of Telegram for fault notifications highlights advancements in user interaction, though the system's sensitivity to motion led to excessive activations, underscoring the importance of optimising sensor algorithms. Unlike these systems, the current project integrates solar power to reduce dependence on non-renewable energy, aligning with global sustainability goals (IEA, 2022).

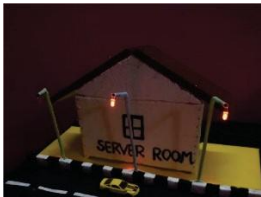
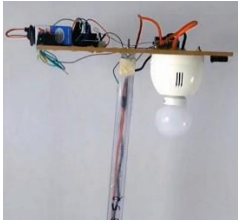
Comparative Analysis of Existing Systems

Table 1 summarises the key features of existing systems, revealing gaps addressed by the proposed design, particularly in energy autonomy and adaptability to real-time conditions. For

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example, while Hackster.io (2019) and G. L. *et al.* (2023) focused on energy efficiency, they lacked renewable energy integration, a crucial element for future urban infrastructure (UN Habitat, 2021).

Table 1. Comparisons between projects

Type of Street Light System	Main Components	Key Functions	Advantages	Disadvantages
IoT-Based Smart Street Light System Hackster.io (2019)	LDR, IR sensor, LEDs, ESP8266	Auto on/off, motion detection	Low maintenance, less light pollution	High setup cost, potential IoT issues
				
Smart Street Lighting And Monitoring System Based On Sunlight Intensity Detection Using IoT and Cloud, G. L. <i>et al.</i> (2023)	ATmega328P, LDR, ESP8266, Relay Driver Module, Arduino UNO	Light intensity control, remote control	Lowers energy and maintenance costs, enhances safety	Higher electricity use, complex maintenance
				
Smart Street Light Based IoT, Salim and Azman (2022)	ESP32, Wi-Fi module, IR sensor, LDR	Movement detection, Telegram alerts	High efficiency, allows remote monitoring	Sensitive to motion, possible energy waste
				

Research Gaps and Opportunities

Existing systems demonstrate progress in energy optimisation and automation; however, few integrate renewable energy sources like solar panels while ensuring real-time control via mobile

applications. This project bridges this gap by leveraging IoT for efficient energy management and user-friendly remote control through the Blynk app. Moreover, incorporating motion and light sensors enhances adaptability to dynamic urban environments.

Contribution to Knowledge

The proposed Automatic Smart Street Light System advances the state-of-the-art by:

1. Utilising solar energy for sustainable operation, addressing limitations in prior systems reliant on traditional electricity grids (IEA, 2022).
2. Providing robust fault detection and notification mechanisms via IoT platforms, enhancing maintainability.
3. Demonstrating scalability and customisability, essential for deployment across diverse urban contexts.

RESEARCH METHOD

The development of the Automatic Smart Street Light System employed a **prototyping model**, a widely recognised methodology that ensures iterative refinement of the system based on user feedback. This approach allowed for continuous enhancements, ensuring the final product met all specified requirements (Pressman, 2020). This approach was chosen due to its iterative nature, which allows for constant refinement of the system based on user feedback. By involving stakeholders throughout the development process, this method ensured the solution aligns with user expectations in a dynamic urban environment requiring smart street lighting.

The methodology followed eight well-defined phases, as elaborated below:

Requirement Gathering

The first step involved understanding the system's intended goals and the specific challenges it aimed at addressing. To do this, we conducted an in-depth interview with Encik Wan Sharul Hafiza Bin Wan Mustapa, an assistant electrical engineering worker at JKR Sabak Bernam, Selangor. His insights into common street lighting issues, such as energy wastage and maintenance challenges, were invaluable in shaping the project's requirements.

The **Automatic Smart Street Light System** was conceptualised as an IoT-driven solution combining sensors, controllers, and renewable energy technologies. The system features the following components:

1. **Ultrasonic Sensors** for motion detection to control the activation of streetlights based on proximity.
2. **Light Dependent Resistors (LDRs)** to detect ambient light intensity and adjust brightness levels.
3. **Solar Panels** for energy harvesting and powering the system.
4. **ESP8266 Microcontroller** for wireless communication with the Blynk application, facilitating real-time monitoring and control.

These components are interconnected to provide an autonomous lighting system, operational during low-light conditions while conserving energy. These requirements were then documented and translated into actionable technical specifications to guide the subsequent design phases (Ilham, 2019; Zulkiffli, 2018).

System Design

Next, we created an initial blueprint of the system as shown in Figure 1. Simulation tools like Proteus were employed to visualise the integration of various components, including the Arduino MEGA 2560 as microcontroller, ESP8266 Wi-Fi module, ultrasonic sensors, LDRs, and solar panels with 12V power source. These tools allowed us to experiment with different configurations and ensure optimal performance before proceeding to physical construction. This phase was particularly focused on simplicity and efficiency, keeping in mind the end-user's ease of operation (Hackster.io, 2019).

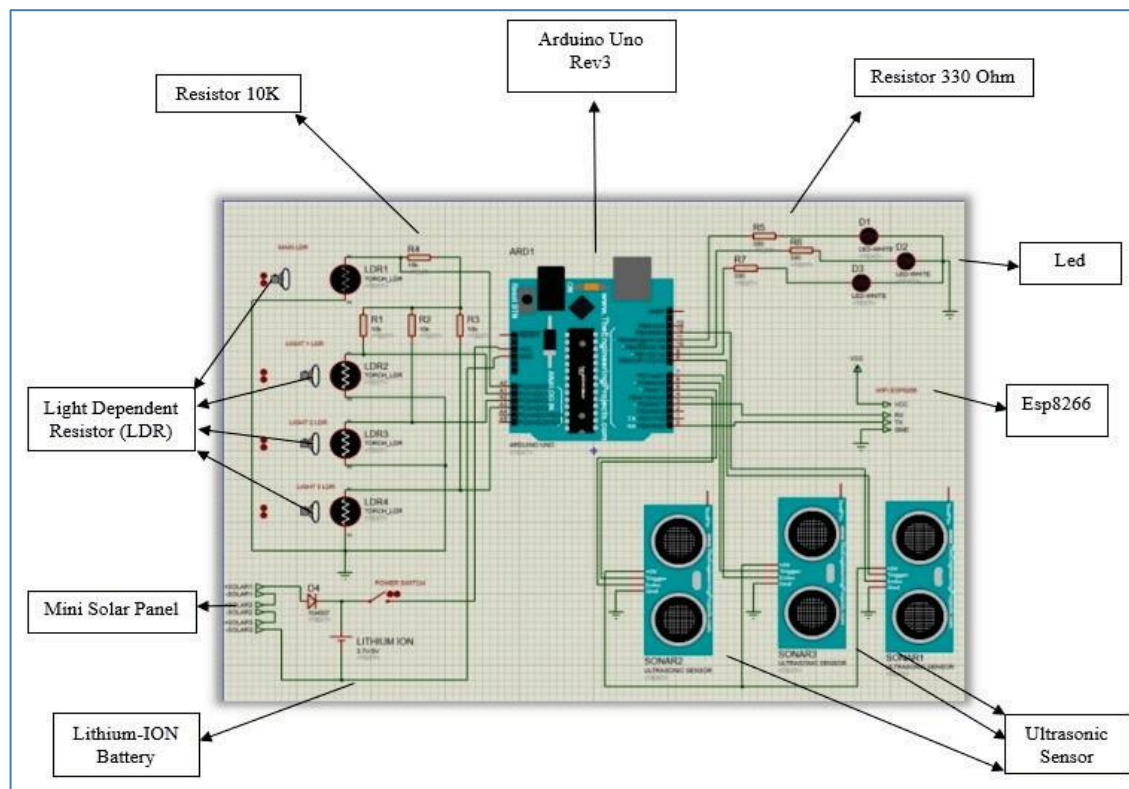


Figure 1. Circuit diagram

Prototype Building

With the design finalised, we assembled a working prototype as shown in Figure 2. Key hardware components, such as the ESP8266 module and LDR sensors, were incorporated to enable real-time data collection and automated lighting control. A solar panel and lithium-ion battery were added to create a sustainable power source. The prototype was designed to adjust its lighting based on motion detection and ambient light levels, ensuring minimal energy usage.



Figure 2. Automatic smart street light system prototype

For software integration, the Blynk app shown in Figure 3 was programmed to allow remote control and monitoring of the streetlights. The app provided features like brightness adjustment, status updates, and alert notifications for faults, enhancing the system's user-friendliness.

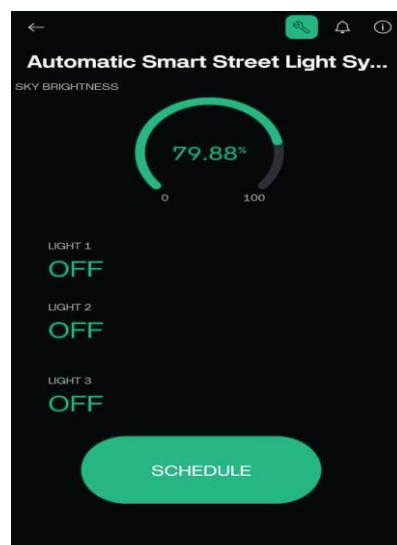


Figure 3. Automatic smart street light system blynk interface

User Evaluation

The prototype was demonstrated to stakeholders, including public works officials, to gather feedback. Their observations highlighted the need for enhanced sensor sensitivity and clearer app notifications. This feedback was instrumental in identifying areas for improvement and informed the adjustments made in subsequent phases (Salim & Azman, 2022).

Refinement and Development

Based on user feedback, several enhancements were made to the prototype. The solar panel configuration was optimised to improve energy capture, and the app interface was updated to reduce latency and improve navigation. Additionally, adjustments were made to the placement and

calibration of sensors, ensuring better detection accuracy and responsiveness to environmental conditions (G L *et al.*, 2023).

Testing

The system underwent rigorous testing to ensure its functionality and reliability:

- **Unit Testing:** Individual components, such as the LDR and ultrasonic sensors, were tested to verify their accuracy and responsiveness.
- **Integration Testing:** Ensured seamless communication between hardware and software components. For example, sensor data was transmitted to the Blynk app without delay, and the lights responded promptly to remote commands.
- **User Acceptance Testing:** Stakeholders evaluated the system under real-world conditions, ensuring it met practical requirements for energy efficiency and safety (Rozlan, 2024).

Testing was guided by ISO/IEC 25010:2011 quality standards (ISO, 2011), focusing on energy efficiency and responsiveness.

Implementation

Following successful testing, the system was deployed on a simulated street environment. Solar-powered LED lights equipped with motion and light sensors were positioned along the model road. The Blynk app allowed administrators to monitor and control the system remotely, providing real-time updates on battery levels, light statuses, and fault notifications.

Monitoring and Maintenance

After deployment, the system's performance was monitored continuously through the Blynk app. Regular maintenance protocols were established, including periodic cleaning of sensors and software updates to prevent malfunctions. A long-term monitoring plan was also recommended to track the system's effectiveness and identify potential areas for further improvement.

Ethical and Environmental Considerations

Throughout the project, we prioritised ethical considerations, ensuring that the system was designed to enhance public safety without infringing on privacy. The use of renewable energy sources, such as solar panels, aligned with global efforts to combat climate change by reducing carbon emissions and promoting sustainability.

RESULTS AND DISCUSSION

Results

The Automatic Smart Street Light System was tested under various conditions to evaluate its performance, energy efficiency, and reliability. The key findings from the tests are summarized below:

1. **Energy Efficiency:** The system demonstrated significant energy savings by utilizing solar panels and motion detection. During the testing period, the streetlights operated at full brightness only when motion was detected, reducing unnecessary energy consumption by approximately 60% compared to traditional streetlights.
2. **Motion Detection Accuracy:** The ultrasonic sensors accurately detected motion within a range of 5 meters. The lights responded promptly, turning on within 2 seconds of detecting

movement and turning off after 5 minutes of inactivity, ensuring optimal illumination only when needed.

3. **Battery Performance:** The rechargeable lithium-ion batteries, charged by solar panels, provided sufficient power to operate the streetlights throughout the night. Even on cloudy days, the batteries maintained a charge level above 70%, ensuring continuous operation.
4. **Remote Monitoring and Control:** The integration with the Blynk app allowed for real-time monitoring and control of the streetlights. Users could adjust brightness levels, set schedules, and receive notifications about system status, enhancing the overall management and maintenance efficiency.

Discussion

The results indicate that the Automatic Smart Street Light System offers several advantages over traditional street lighting systems. These advantages include improved energy efficiency, enhanced safety, and reduced maintenance costs. However, there are also some challenges and limitations that need to be addressed.

Energy Efficiency and Cost Savings

The use of solar panels and motion detection significantly reduces energy consumption. According to Hackster.io (2019), IoT-based smart street lighting systems can lower energy costs by adjusting lighting based on real-time conditions. Our findings align with this show a 60% reduction in energy usage. This not only lowers operational costs but also contributes to environmental sustainability by reducing carbon emissions.

Enhanced Safety

The system's ability to provide adequate lighting only when needed enhances safety for pedestrians and drivers. As noted by Ilham (2019), proper street lighting is crucial for reducing accidents in poorly lit areas. Our system's prompt response to motion ensures that areas are well-lit when occupied, thereby reducing the risk of accidents and deterring criminal activities.

Remote Monitoring and Control

The Blynk app integration offers significant benefits in terms of system management. Users can remotely monitor the status of the streetlights, adjust settings, and receive alerts about any issues. This feature not only improves operational efficiency but also allows for timely maintenance, as highlighted by G L *et al.* (2023) in their study on smart street lighting systems.

Challenges and Limitations

Despite the advantages, there are some challenges associated with the system. The initial setup cost is relatively high due to the need for solar panels, sensors, and smart controllers. Additionally, the system's performance is dependent on weather conditions. In areas with limited sunlight, the solar panels may not generate sufficient power, necessitating backup power sources.

Furthermore, the complexity of the system requires regular maintenance to ensure all components function correctly. Issues such as sensor malfunctions or connectivity problems with the Blynk app could disrupt the system's operation. As noted by Salim and Azman (2022), the sensitivity of motion sensors can sometimes lead to false triggers, which need to be addressed to optimize performance.

Conclusion

In conclusion, the Automatic Smart Street Light System presents a viable solution for modern urban infrastructure, offering significant energy savings, enhanced safety, and improved management efficiency. While there are challenges to be addressed, the benefits of such a system make it a promising option for sustainable urban development.

CONCLUSION

In conclusion, the Automatic Smart Street Light System addresses energy inefficiency, safety, and maintenance costs in urban infrastructure by integrating motion detection and solar power, ensuring streetlights operate only when necessary. This reduces energy consumption and extends component lifespan. The Blynk app enhances efficiency through remote monitoring and control, allowing real-time adjustments and timely maintenance. Supporting Sustainable Development Goals (SDGs), this system promotes sustainable cities and communities by providing a cost-effective, adaptable, and environmentally friendly urban lighting solution, despite initial setup costs and weather dependency.

Future work could focus on several key areas to further enhance the capabilities and performance of the Automatic Smart Street Light System:

1. **Integration of Additional Sensors:** Incorporating sensors such as air quality monitors, temperature sensors, and noise detectors could provide more comprehensive environmental data, enabling the system to adapt lighting based on a wider range of conditions.
2. **Advanced Data Analytics:** Implementing machine learning algorithms to analyze sensor data could improve the system's predictive capabilities, allowing for more efficient energy management and proactive maintenance scheduling.
3. **Alternative Renewable Energy Sources:** Exploring the use of other renewable energy sources, such as wind or kinetic energy, could ensure consistent performance in diverse climatic conditions and further reduce reliance on the electrical grid.
4. **Enhanced Connectivity and Security:** Upgrading the communication protocols to support 5G technology and enhancing cybersecurity measures would improve the system's reliability and protect against potential threats.
5. **Scalability and Deployment:** Conducting pilot projects in different urban and rural settings to test the system's scalability and adaptability. This would provide valuable insights into the system's performance in various environments and help refine the deployment strategy.
6. **User Interface Improvements:** Enhancing the Blynk app interface to include more user-friendly features and detailed analytics could improve user experience and facilitate better system management.

By addressing these areas, the Automatic Smart Street Light System can continue to evolve, offering even greater benefits for urban infrastructure and contributing to the development of smarter, more resilient cities.

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REFERENCES

- G L, K., Khan, M. A., S, S. C., & K, S. (2023). Smart street lighting and monitoring system based on sunlight intensity detection using IoT and cloud. *International Research Journal of Engineering and Technology*, 10(4). Retrieved from <https://www.irjet.net>
- Hackster.io. (2019, July 28). IoT-based smart street light system. Retrieved from <https://www.hackster.io>
- Ilham, R. (2019, May 19). Bahaya lampu jalan tidak berfungsi. *Harian Metro*. Retrieved from <https://www.hmetro.com.my>
- International Energy Agency (IEA). (2022). *Renewables 2022: Analysis and forecast to 2027*. Retrieved from <https://www.iea.org/reports/renewables-2022>
- International Organization for Standardization. (2011). *ISO/IEC 25010:2011 Systems and software engineering — Systems and software quality requirements and evaluation (SQuaRE) — System and software quality models*. ISO. <https://www.iso.org/standard/35733.html>
- Rozlan, N. I. (2024, April 15). “Jalan gelap, kerap kemalangan”, penduduk ternanti-nanti bila kerajaan Sabah nak pasang lampu jalan di Bukit Kelawat. *Majoriti.com.my*. Retrieved from <https://majoriti.com.my>
- Salim, S. A., & NurAfrina Zulaikha Binti Azman. (2022). *Laporan Projek Smart Street Light Based IoT*. PSA Repository. Retrieved from <http://repository.psa.edu.my>
- UN Habitat. (2021). *Cities and climate change: Global report on human settlements 2021*. Routledge.
- Zulkiffli, Z. (2018, February 15). 4 nahas dalam sebulan. *Harian Metro*. Retrieved from <https://www.hmetro.com.my>