Tunnel Electrification For Road Using Esp32 Based Smart Lighting And Safety System

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Abstract- *Road tunnels require continuous illumination for safe transportation; however, conventional tunnel lighting systems consume high energy and require manual monitoring, resulting in increased operating cost and reduced reliability. This project proposes an ESP32 based smart tunnel lighting and safety system that automatically controls tunnel lights based on vehicle movement and ambient light conditions. The system uses sensors to detect vehicles inside the tunnel and accordingly switches ON/OFF or adjusts intensity of LEDs. Additionally, safety features such as emergency alerts, smoke/fire detection support, and fault indication are incorporated. The proposed system reduces power consumption significantly and increases safety using automated and IoT-enabled monitoring. This model is suitable for smart city infrastructure, highways, and industrial tunnel applications.*

Keywords- ESP32, Tunnel Lighting, Smart Street Light, IoT, Automation, Safety System

I. INTRODUCTION

Tunnel electrification is essential for safe movement of vehicles in underground tunnels, flyovers, and enclosed highways. Proper lighting avoids accidents, improves visibility, and ensures smooth traffic flow. Traditional tunnel lighting systems operate continuously and consume high power even when vehicles are not present, resulting in unnecessary electricity waste.

With development in IoT and automation technologies, smart lighting systems are widely adopted in smart cities. ESP32 is a low-cost microcontroller with Wi-Fi and Bluetooth features which makes it ideal for real-time monitoring and remote control applications. By integrating sensors with ESP32, tunnel lighting can become energy-efficient, automated, and safer.

This project focuses on designing a smart tunnel lighting system that minimizes energy consumption, provides automated lighting control, and improves safety with monitoring and alerts.

II. IDENTIFY, RESEARCH AND COLLECT IDEA

The following study areas were explored before developing the project:

- Tunnel lighting challenges and electricity consumption problems
- Smart lighting systems in smart city projects
- IoT-based remote monitoring using ESP32
- Sensor-based automation
- Safety requirements in tunnels (smoke/fire/emergency)
- Key idea: Lights should operate only when needed (vehicle detected / low light condition) and system should provide safety alerts and remote monitoring.

III. WRITE DOWN YOUR STUDIES AND FINDINGS

A. Problem Statement

Conventional tunnel lighting remains ON continuously and wastes energy. Manual fault detection and poor safety alerts increase accident risk and maintenance cost.

B. Proposed Solution

A smart tunnel lighting system using ESP32 that detects vehicle movement using IR sensors, controls tunnel LEDs automatically, provides safety monitoring (smoke/fire alert support) and allows IoT based alert & status update.

IV. WORKING PRINCIPLE / SYSTEM OPERATION

- IR sensors detect vehicle entry into tunnel section
- ESP32 receives sensor signal
- LED lights of the detected section turn ON
- Other sections remain OFF / DIM to save energy
- When vehicle leaves the section, lights turn OFF after a delay
- If smoke/fire sensor detects abnormal condition, emergency alert can be triggered

V. BLOCK DIAGRAM (Description)

Power Supply (5V/12V) → ESP32 Controller → Sensors + Relay/Driver → LED Tunnel Lights

Main blocks: ESP32 microcontroller, IR vehicle detection sensors, LDR for ambient light detection, Relay module/MOSFET driver, LED lighting system, optional smoke sensor/buzzer.

VI. HARDWARE REQUIREMENTS

- ESP32 Development Board
- IR Sensors (Vehicle detection)
- LDR Sensor (Light intensity)
- Relay Module / MOSFET Driver
- LEDs / LED strip for tunnel lighting
- Buzzer (Alert)
- Smoke sensor (MQ series – optional)
- Power supply (5V/12V)

VII. SOFTWARE REQUIREMENTS

- Arduino IDE
- ESP32 Board Package
- Embedded C/C++ Programming
- IoT Dashboard support (optional): Blynk / Thingspeak / Firebase

VIII. ADVANTAGES

- Reduces power consumption (lighting only when necessary)
- Automatic system reduces manpower requirement
- Increased tunnel safety with alert mechanism
- Low-cost and scalable model
- Suitable for smart city infrastructure

IX. APPLICATIONS

- Road tunnels on highways
- Underground metro/rail tunnels (support lighting system)
- Industrial tunnels and mines
- Smart cities and smart roads
- Enclosed flyover passages

X. CONCLUSION

The project demonstrates an ESP32 based smart tunnel lighting and safety system that provides energy-efficient operation and improved safety. Automation using sensors reduces electricity wastage, ensures proper lighting in tunnel sections, and supports emergency alert mechanisms. The proposed model is reliable, low-cost, and can be implemented in real tunnel environments for smart infrastructure development.

XI. ACKNOWLEDGMENT

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