

Design And Automatic of an Emergency Staircase System for High-Rise Building

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Abstract—High-rise buildings present significant challenges during emergency evacuations, particularly in situations such as fires, earthquakes, or power failures. Conventional staircase systems, while essential, often become congested, poorly illuminated, or difficult to access under emergency conditions. This project proposes the design and automation of an intelligent emergency staircase system aimed at improving evacuation efficiency, safety, and accessibility in high-rise structures.

The proposed system integrates advanced technologies such as IoT-based sensors, automated lighting, smoke detection, and real-time monitoring to enhance the functionality of emergency staircases. Sensors are deployed to detect fire, smoke density, temperature, and human movement, enabling dynamic control of staircase access and guidance systems. Automated features include adaptive LED lighting, voice-assisted evacuation instructions, and directional indicators that guide occupants toward the safest exit routes based on real-time hazard analysis.

Index Terms—emergency staircase, Highrise Building, safety, Smoke Detection.

I. INTRODUCTION

The rapid growth of urbanization has led to the construction of high-rise buildings, increasing the complexity of ensuring safety during emergency situations such as fires, earthquakes, and power failures. One of the most critical components of building safety is the emergency staircase system, which serves as the primary evacuation route for occupants. However, conventional staircase systems often lack intelligent features, leading to issues such

as overcrowding, poor visibility, and confusion during emergencies.

To address these challenges, this project focuses on the design and automation of an advanced emergency staircase system. The proposed system integrates modern technologies such as sensors, automated lighting, and real-time monitoring to enhance evacuation efficiency and safety. By detecting hazards like smoke, heat, and human movement, the system can provide dynamic guidance and ensure safer evacuation paths.

II. FUTURE SCOPE

the system can be expanded to coordinate with other building safety systems such as fire suppression and elevator control for a more comprehensive emergency response. The inclusion of biometric or wearable device integration can further improve occupant tracking and safety. With continuous advancements in smart building technologies, the system can be scaled and customized for various types of infrastructures, making it more efficient, intelligent, and widely applicable

III. METHODOLOGY

- Analyse emergency evacuation requirements in high-rise buildings.
- Identify key issues such as congestion, low visibility, and delayed response.
- Design the overall system architecture for the automated staircase system.
- Select and integrate sensors (smoke, temperature, motion).

- Connect sensors to a microcontroller or control unit for data processing.
- Develop algorithms to detect emergency conditions in real time.
- Implement automated features like emergency lighting and alarm systems.
- Install directional indicators to guide occupants toward safe exits.
- Integrate a voice alert system for evacuation instructions.
- Provide connectivity with a centralized monitoring or control system.
- Include a backup power supply for uninterrupted operation.
- Build a prototype model of the system.
- Test the system under simulated emergency conditions.

Evaluate performance based on response time, accuracy, and reliability.

1. Working of the System

The emergency staircase automation system works to provide safe evacuation during fire, smoke, earthquake, or power failure in high-rise buildings.

2. SensorDetection:

Smoke sensor, temperature sensor, and gas sensor continuously monitor the environment.

3. EmergencySignalActivation:

If smoke, high temperature, or gas is detected, the sensors send a signal to the microcontroller/PLC.

4. AutomaticAlarmSystem:

The controller activates buzzer, siren, and warning lights to alert all people inside the building.

5. AutomaticEmergencyLighting:

If power fails, battery backup automatically turns ON emergency staircase lights.

6. AutomaticDoor Opening System:

The controller operates a motor-based door mechanism to open emergency exit doors quickly.

7. Ventilation / Smoke Control:

Exhaust fan or pressurization system starts automatically to reduce smoke inside the staircase.

8. Real-TimeMonitoring:

Status information is displayed on LCD or sent to the control room using IoT / wireless system.

SafeEvacuation:

People use the staircase safely with proper lighting, alarms, and smoke-free environment.

IV. HELPFUL HINTS

A. THEORY

A. Design and Automation of an Emergency Staircase System for High-Rise Building

- Use fire, smoke, and temperature sensors for automatic emergency detection.
- Provide automatic emergency LED lighting with battery backup.
- Install alarm system (buzzer + flashing lights) for warning people.
- Use EXIT sign boards and direction indicators for safe evacuation.
- Add automatic door unlocking/opening system during emergency.
- Use staircase pressurization fans to stop smoke entry.
- Include manual override switch in case automation fails.
- Use Arduino/PLC controller for reliable automation control.
- Ensure fire-resistant materials for doors, wiring, and staircase structure.

Follow fire safety rules and building codes for proper design.

B. Abbreviations and Acronyms

- Emergency Staircase System – A dedicated escape route designed for safe evacuation during emergencies in buildings.
- Automation – Use of control systems and technology to operate staircase features automatically without human intervention.
- High-Rise Buildings – Multi-storey structures where efficient evacuation systems are critical for safety.

- IoT (Internet of Things) – Network of connected devices and sensors used for real-time monitoring and control.
- Fire and Smoke Detection – Systems that identify hazardous conditions and trigger safety responses.
- Smart Evacuation System – Intelligent system that guides occupants using real-time data and dynamic instructions.
- Sensor Technology – Devices used to detect motion, temperature, smoke, and occupancy levels.
- Emergency Lighting – Backup or automated lighting system that ensures visibility during power failure or emergencies.
- Safety and Accessibility – Design considerations ensuring safe evacuation for all individuals, including disabled persons.

Building Management System (BMS) – Centralized system used to monitor and control building operations during emergencies.

C. Equations

1) Stair Step Design Equation

$$2R + T = 600 \text{ to } 650 \text{ mm}$$

R = Riser height, T = Tread depth

2) Number of Risers

$$N_r = \frac{H}{R}$$

H = Floor height

3) Number of Treads

$$N_t = N_r - 1$$

4) Total Stair Run Length

$$L = N_t \times T$$

5) Stair Angle / Slope

$$\tan(\theta) = \frac{R}{T}$$

$$\theta = \tan^{-1}\left(\frac{R}{T}\right)$$

6) Total Load on Staircase

$$W_T = W_D + W_L$$

Dead load + Live load

7) Motor Torque (Automatic Door/Stair System)

$$\tau = F \times r$$

F = Force, r = radius

8) Motor Power

$$P = \tau \times \omega$$

9) Battery Backup Time

$$t = \frac{\text{Battery Capacity(Ah)}}{\text{Load Current(A)}}$$

10) Evacuation Time

$$T_e = \frac{N_p}{F}$$

Np = People, F = Flow rate

V. CONCLUSION

The design and automation of the emergency staircase system for high-rise buildings provide a significant improvement over conventional evacuation methods. By integrating sensors, automated controls, and real-time monitoring, the system enhances safety, reduces evacuation time, and minimizes confusion during emergency situations. The implementation of features such as emergency lighting, alarms, and guided evacuation ensures a more organized and efficient response.

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