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Subway Flood Monitoring and Different Vehicle Allowance

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Abstract

Urban flooding in subway systems has become a major safety and transportation challenge in modern cities, particularly during periods of heavy rainfall and inadequate drainage conditions. Subways and underpasses are generally constructed below ground level, making them highly vulnerable to rapid water accumulation during storms and monsoon seasons. Waterlogging in such areas can lead to severe traffic congestion, vehicle breakdowns, infrastructure damage, economic losses, and life-threatening situations for commuters. In many cases, drivers unknowingly enter flooded subways, resulting in engine failure, vehicle stalling, and accidents that may cause injuries or fatalities. Therefore, there is a growing need for intelligent and automated flood monitoring systems capable of providing real-time information and controlling vehicle movement in flood-prone subway regions.

This research focuses on the design and development of a Subway Flood Monitoring System integrated with a Vehicle Allowance Mechanism to improve urban transportation safety and traffic management during flood conditions. The primary objective of the proposed system is to continuously monitor water levels in subway areas and automatically regulate vehicle entry based on real-time flood conditions. By integrating sensor-based water level detection with automated signaling mechanisms, the system aims to prevent vehicles from entering dangerous flooded zones and reduce the risk of accidents, property damage, and human casualties.

The proposed methodology utilizes ultrasonic sensors, Arduino-based microcontrollers, LED indicators, and buzzer alarm systems for automated monitoring and warning operations. Ultrasonic sensors are used to continuously measure the distance between the sensor and the water surface. As the water level rises, the measured distance decreases, and this information is transmitted to the Arduino microcontroller for processing. The controller compares the measured water level with predefined threshold values and activates corresponding indicators and warning mechanisms.

Different LED indicators are used to represent varying flood conditions. A GREEN indicator represents a safe condition where all vehicles are allowed to pass through the subway. A YELLOW indicator signifies moderate water levels where only certain vehicles, such as bikes or small vehicles, may be allowed. A RED indicator along with a buzzer alarm is activated when the water level becomes dangerous, completely restricting vehicle entry to prevent accidents and vehicle damage. This intelligent vehicle allowance mechanism improves traffic regulation by ensuring that vehicles are permitted only under safe conditions.

Keywords: Flood Monitoring; Subway Safety; Ultrasonic Sensor; Vehicle Control; Smart Traffic System

How to Cite This Article

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Introduction

Subway systems are an essential component of modern urban transportation infrastructure, providing efficient connectivity, reducing travel time, and minimizing traffic congestion in rapidly growing cities. These underground or low-lying transportation passages play a significant role in maintaining smooth vehicle movement and improving urban mobility. However, despite their advantages, subways and underpasses are highly vulnerable to water accumulation and flooding during periods of heavy rainfall, storms, and monsoon seasons. Due to their depressed structural design and low elevation, subways often act as collection points for rainwater runoff, making them one of the most flood-prone areas in urban environments.

One of the major challenges faced by urban transportation authorities is the rapid accumulation of water in subways caused by inadequate drainage systems, blocked water channels, sudden rainfall intensity, and poor stormwater management. During extreme weather conditions, the drainage capacity may become insufficient to handle the excess water flow, leading to severe waterlogging within a short period of time. As a result, subways become unsafe for vehicles and pedestrians, disrupting normal traffic movement and creating hazardous transportation conditions.

Subway flooding can lead to several serious consequences, including vehicle breakdowns, engine damage, traffic congestion, economic losses, and life-threatening accidents. Vehicles entering flooded subways may experience engine stalling, electrical system failure, brake malfunction, and loss of control due to water entering critical components. Two-wheelers, bicycles, and small vehicles are particularly vulnerable because even a small rise in water level can affect vehicle stability and cause accidents. In severe flood conditions, rising water levels may completely block the subway passage, trapping vehicles and passengers inside flooded areas. Such incidents can result in injuries, fatalities, rescue operation challenges, and significant financial losses for both vehicle owners and city authorities.

In many urban areas, flood management in subways still depends on manual observation and conventional warning methods such as barricades, caution boards, and traffic personnel. However, these traditional approaches are often unreliable, slow, and inefficient during sudden flood situations. Manual monitoring cannot provide continuous real-time information, and delays in issuing warnings may lead to vehicles entering dangerous flooded zones before preventive measures are taken. Therefore, there is a strong need for an intelligent and automated flood monitoring system capable of continuously measuring water levels and providing instant alerts and traffic control decisions.

To address these challenges, this project focuses on the design and development of a Subway Flood Monitoring System integrated with a Vehicle Allowance Mechanism. The proposed system aims to improve urban transportation safety by detecting rising water levels in real time and automatically controlling vehicle entry based on predefined safety thresholds. The system utilizes ultrasonic sensors, Arduino-based microcontrollers, LED indicators, and buzzer alarms to continuously monitor subway flood conditions and provide immediate visual and audio warnings to drivers.

The ultrasonic sensor measures the distance between the sensor and the water surface, allowing accurate monitoring of water level changes. The Arduino controller processes the sensor data and activates different warning signals depending on the flood severity. Green indicators represent safe conditions where all vehicles are allowed, yellow indicators warn of moderate water levels where only certain vehicles may pass, and red indicators along with buzzer alarms indicate dangerous flood conditions where vehicle entry is completely restricted.

The integration of automated vehicle allowance mechanisms with flood monitoring significantly improves traffic management efficiency and public safety. By preventing vehicles from entering flooded subways, the system can reduce accidents, minimize vehicle damage, prevent traffic congestion, and protect human life. The proposed model is cost-effective, energy-efficient, easy to install, and suitable for implementation in urban roads, tunnels, underpasses, and smart city infrastructures.

Furthermore, the system can be enhanced in the future using Internet of Things (IoT) technologies, cloud-based monitoring systems, wireless communication modules, mobile alert applications, and artificial intelligence-based flood prediction techniques. Such advancements can contribute to the development of intelligent urban transportation systems capable of managing flood risks more efficiently.

Overall, the proposed Subway Flood Monitoring and Vehicle Allowance System provides an innovative and practical solution for improving transportation safety, reducing flood-related risks, and enhancing the resilience of urban infrastructure during extreme weather conditions.

Literature Review

Flood monitoring and traffic safety management have become important research areas in urban infrastructure development due to increasing cases of waterlogging caused by heavy rainfall, climate change, rapid urbanization, and inadequate drainage systems. Many researchers have focused on developing intelligent systems capable of detecting rising water levels in flood-prone regions such as subways, underpasses, tunnels, and low-lying roads. The primary objective of these systems is to provide early flood warnings and reduce the risks associated with urban flooding.

Several existing flood monitoring systems use sensors such as ultrasonic sensors, float sensors, water level sensors, and pressure sensors to continuously measure water levels. These sensors are commonly integrated with embedded systems and microcontrollers such as Arduino, Raspberry Pi, and ESP8266 modules for real-time monitoring and automated alert generation. Ultrasonic sensors are particularly popular because they provide accurate non-contact water level measurement and are relatively low-cost and easy to implement.

Many researchers have developed Arduino-based flood detection systems capable of activating LED indicators, buzzers, and warning alarms whenever water reaches predefined danger levels. In some advanced studies, GSM and IoT technologies have been integrated into flood monitoring systems to send alert messages, mobile notifications, or cloud-based updates to users and authorities during flood situations. These technologies improve response time and allow remote monitoring of flood-prone locations. Some systems also use wireless sensor networks and cloud computing platforms to monitor multiple flood locations simultaneously.

Apart from flood monitoring systems, traffic management and intelligent transportation systems (ITS) have also gained significant attention in urban planning and road safety applications. Traffic control systems are widely used in cities to regulate vehicle movement, reduce congestion, and improve transportation efficiency. These systems mainly rely on automated traffic signals, CCTV monitoring, vehicle counting sensors, and smart signal timing algorithms. However, most conventional traffic management systems focus primarily on traffic density and signal control rather than environmental hazards such as flooding in subways and underpasses.

One major limitation of many existing flood monitoring systems is that they only provide warning alerts without taking further action to control vehicle movement. Although warning indicators and alarms may notify drivers about flooding, vehicles may still enter dangerous flooded areas due to driver negligence, poor visibility, lack of awareness, or delayed response. This can result in vehicle damage, traffic congestion, accidents, and life-threatening situations. Therefore, merely generating flood alerts is often insufficient for ensuring transportation safety in flood-prone areas.

Another challenge observed in previous studies is the lack of integration between flood monitoring systems and intelligent vehicle management mechanisms. Most existing systems are unable to differentiate between safe and unsafe vehicle movement based on varying water levels. In real-world conditions, different types of vehicles such as motorcycles, cars, buses, and heavy trucks have different water tolerance limits. Existing warning systems do not provide selective vehicle allowance or traffic restriction mechanisms based on actual flood severity.

The proposed project improves upon previous systems by integrating flood monitoring with an intelligent vehicle allowance mechanism. Unlike conventional systems that only detect water levels and generate alerts, the proposed system also controls vehicle entry based on predefined safety thresholds. The system determines whether all vehicles, only selected vehicles, or no vehicles should be allowed to enter the subway depending on the measured water level. This significantly improves traffic management and public safety during flood conditions.

The proposed model uses ultrasonic sensors, Arduino-based microcontrollers, LED indicators, and buzzer alarms to create a fully automated flood monitoring and vehicle control system. By combining real-time water level detection with automated traffic signaling, the system provides a more effective and practical solution for preventing accidents, reducing vehicle damage, and improving urban transportation safety.

Furthermore, the proposed approach is cost-effective, energy-efficient, easy to install, and suitable for implementation in smart city infrastructures, underpasses, tunnels, and flood-prone transportation networks. Future advancements may include IoT integration, wireless communication systems, cloud-based monitoring, mobile applications, and artificial intelligence-based flood prediction technologies to further enhance system performance and reliability.

Overall, the literature review highlights the importance of integrating flood monitoring systems with intelligent vehicle control mechanisms to develop safer, smarter, and more efficient urban transportation infrastructures capable of handling flood-related challenges effectively.

Methodology

The methodology of the proposed Subway Flood Monitoring and Vehicle Allowance System explains the design, operation, and implementation process of the automated flood detection and traffic control mechanism. The system is developed to continuously monitor water levels inside subway areas and regulate vehicle movement based on real-time flood conditions. The primary objective of the methodology is to prevent vehicles from entering dangerous flooded subways, thereby improving public safety, reducing accidents, and minimizing vehicle damage during heavy rainfall and urban flooding situations.

The proposed system operates using sensor-based water level detection, automated signal processing, and intelligent vehicle allowance mechanisms. The methodology consists of four major stages: component integration, water level monitoring, indication and alert generation, and vehicle allowance control.

Components Used

The proposed system uses simple, low-cost, and easily available electronic components for efficient implementation and operation. Each component performs a specific function within the flood monitoring and vehicle control process.

- Ultrasonic Sensor

The ultrasonic sensor is the primary sensing device used to measure the water level inside the subway. It continuously emits ultrasonic waves toward the water surface and measures the reflected signals to determine the distance between the sensor and the water level. As the water level rises, the measured distance decreases. Ultrasonic sensors are highly suitable for non-contact water level monitoring because they provide accurate and reliable measurements.

- Arduino Microcontroller

The Arduino microcontroller acts as the central processing unit of the system. It receives water level data from the ultrasonic sensor, processes the information, compares the measured values with predefined threshold levels, and controls the operation of LED indicators and buzzer alarms accordingly. The Arduino automates the entire system and ensures real-time monitoring and decision-making.

- LED Indicators (Green, Yellow, Red)

LED indicators are used to visually represent different water level conditions inside the subway.

- **Green LED:** Indicates safe water level conditions where all vehicles are allowed to pass.
- **Yellow LED:** Indicates moderate water level conditions where only selected vehicles are allowed.
- **Red LED:** Indicates dangerous water level conditions where vehicle entry is completely restricted.

These visual signals help drivers quickly understand the flood situation and make safe decisions.

- Buzzer Alarm

The buzzer is used to provide an additional audio warning whenever dangerous water levels are detected. When the water level reaches the critical limit, the buzzer activates along with the RED indicator to alert drivers and nearby authorities about hazardous flood conditions.

- Power Supply

The power supply unit provides electrical energy required for the operation of the ultrasonic sensor, Arduino controller, LEDs, and buzzer system. The system may also be connected to battery backup or renewable energy sources such as solar panels for uninterrupted operation during power failures.

Working Principle

The working principle of the proposed system is based on continuous water level monitoring and automated flood condition analysis. The ultrasonic sensor is installed at the top of the subway model or underpass structure to continuously monitor the distance between the sensor and the water surface below.

During normal conditions, when the subway is dry or contains a very low water level, the distance measured by the ultrasonic sensor remains high. As rainfall intensity increases and water accumulates inside the subway, the water level rises and the distance measured by the sensor decreases.

The measured distance values are continuously transmitted to the Arduino microcontroller. The Arduino processes the sensor data in real time and compares the measured water level with predefined threshold limits programmed into the system. Based on the comparison results, the Arduino automatically activates the corresponding indication and warning mechanisms.

The automated operation ensures quick response, accurate flood detection, and continuous monitoring without requiring human intervention.

Indication System

The indication system is designed to provide clear visual and audio warnings to drivers based on the detected water level conditions. Different LED indicators and buzzer alerts are used to represent varying flood severity levels.

Green Light (Low Water Level)

When the water level remains below the safe threshold, the GREEN LED indicator turns ON. This indicates that the subway condition is safe and all vehicles, including bikes, cars, and heavy vehicles, are allowed to pass through the subway safely.

Yellow Light (Medium Water Level)

When the water level rises above the safe limit but remains below the danger threshold, the YELLOW LED indicator turns ON. This represents a warning condition where only selected vehicles such as larger vehicles or vehicles with higher ground clearance may be allowed. Small vehicles and two-wheelers may be restricted due to safety concerns.

Red Light + Buzzer (High Water Level)

When the water level reaches a dangerous limit, the RED LED indicator and buzzer alarm are activated simultaneously. This indicates severe flooding conditions where no vehicles are allowed to enter the subway. The buzzer provides additional audio alerts to warn drivers and pedestrians about the hazardous situation.

Vehicle Allowance Logic

The proposed system controls vehicle movement based on predefined safety conditions and water level measurements. The vehicle allowance logic helps regulate traffic flow and prevents unsafe vehicle entry into flooded subway areas.

Table 1. Vehicle Allowance Based on Water Level Conditions in Subway Flood Monitoring System

Water Level Condition	**Vehicle Allowance**
Low Water Level	All Vehicles Allowed
Medium Water Level	Only Selected Vehicles Allowed
High Water Level	No Vehicles Allowed

Under safe conditions, all types of vehicles are permitted to pass through the subway. During moderate flooding, only certain vehicles with higher stability or clearance are allowed. Under dangerous flood conditions, the system completely restricts vehicle movement to avoid accidents, vehicle damage, and human casualties.

The integration of flood monitoring with intelligent vehicle control makes the proposed system highly effective for real-time urban traffic safety management and flood risk reduction.

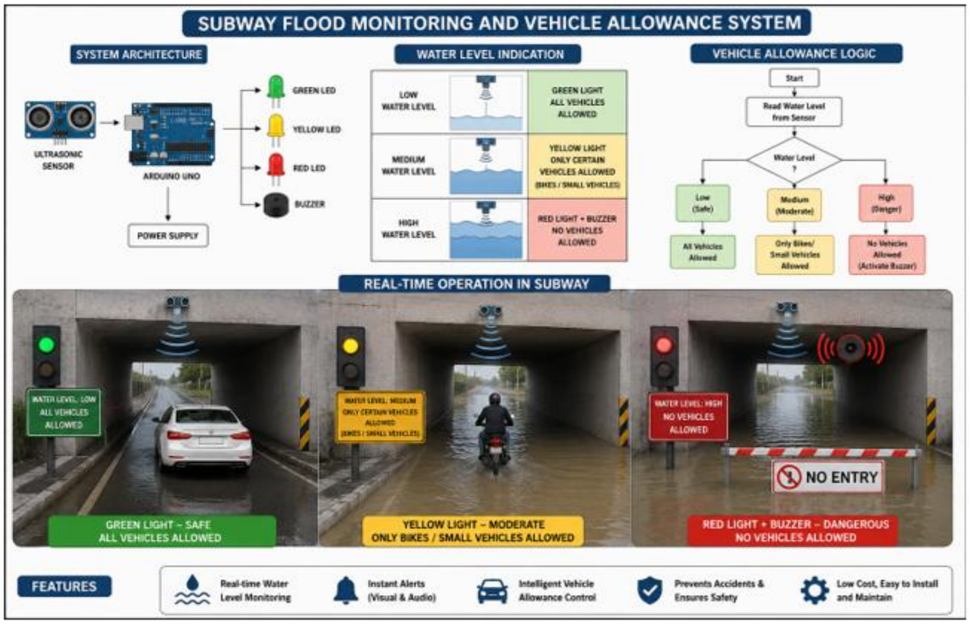

Table 2. Water Level Conditions and Vehicle Allowance Status

Water Level	**Condition**	**Vehicle Allowed**
Low	Safe	All Vehicles
Medium	Warning	Some Vehicles
High	Danger	No Vehicles

Results / Findings

The system was tested using a model setup by gradually increasing the water level in the container. It was observed that the ultrasonic sensor successfully detected the change in water level.

When the water level was low, the green LED turned ON, showing safe condition. At medium water level, the yellow LED turned ON, indicating warning and allowing only small vehicles. When the water level became high, the red LED and buzzer were activated, showing danger and stopping all vehicles.

The system responded quickly and accurately for all conditions. This shows that the model works properly and can be used for real-life applications.

Observation Table

Table 2. LED Indication, Buzzer Alert, and Vehicle Permission Based on Water Level

Water Level	**LED Indication**	**Buzzer**	**Vehicle Allowed**
Low	Green	OFF	All Vehicles
Medium	Yellow	OFF	Some Vehicles
High	Red	ON	No Vehicles

Discussion

The results show that the system is useful for detecting water levels in subways and controlling vehicle movement. It helps in preventing vehicles from entering flooded areas, which can reduce accidents and damage.

This system can be used in real-life locations like subways, underpasses, and low-lying roads. It provides clear signals to drivers, making it easy to understand the situation.

Advantages

- Simple and low-cost system
- Easy to operate
- Provides quick warning
- Improves safety Limitations
- Sensor accuracy may be affected by dirt or obstacles
- Requires proper power supply
- Works on limited range (model level)

Conclusion

The subway flood monitoring and vehicle allowance system is a simple and effective solution to reduce risks caused by waterlogging in subways. The system can detect water levels accurately and give proper signals to control vehicle entry.

It improves safety by preventing vehicles from entering dangerous flooded areas and helps in better traffic management.

Future Scope

- Can be connected to mobile apps for alerts
- Can be upgraded using IoT for remote monitoring
- Can be installed in real subways and smart cities

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