

**IOT BASED MANHOLE DETECTION AND MONITORING SYSTEM**

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Abstract:

Urban drainage systems play a crucial role in maintaining public safety and environmental cleanliness. However, damaged or open manholes, sewage overflow, hazardous gas leakage, and contaminated wastewater can lead to serious accidents, health hazards, and environmental pollution. To address these challenges, this project proposes an IoT-Based Smart Manhole Detection and Monitoring System that combines Artificial Intelligence (AI) and Internet of Things (IoT) technologies for continuous and automated monitoring of underground drainage infrastructure.

The proposed system is built around a Raspberry Pi 4 Model B, which serves as the central processing unit. A camera module captures real-time images of the manhole, and the YOLO (You Only Look Once) deep learning CNN algorithm detects whether the manhole cover is secure, damaged and open. Along with AI-based image analysis, the system uses an Ultrasonic Sensor to monitor the water level, an MQ-2 Gas Sensor to detect hazardous gases, a Turbidity Sensor to measure water quality, and a pH Sensor to monitor the acidity or alkalinity of wastewater. A GPS module provides the exact location of the monitored manhole.

All sensor readings and AI detection results are processed by the Raspberry Pi and displayed on a web-based monitoring dashboard, allowing authorities to observe real-time system status and historical sensor trends. Whenever abnormal conditions such as an open manhole, high water level, hazardous gas concentration, poor water quality, or abnormal pH values are detected, the system



automatically sends an email alert containing the fault details, sensor readings, and GPS location to the concerned municipal authorities. This enables rapid response, reduces manual inspection, improves worker and public safety, and minimizes the risk of accidents and environmental damage.

The proposed system provides a smart, automated, reliable, and cost-effective solution for intelligent urban drainage monitoring. It supports preventive maintenance, improves infrastructure management, and contributes to the development of safe, sustainable, and smart cities.

Keyword: Manhole Detection, Pollution Monitoring, Artificial Intelligence (AI), YOLO Algorithm.

1. INTRODUCTION

The rapid growth of urban populations has increased the demand for efficient and reliable drainage infrastructure. Manholes are important access points for the inspection, maintenance, and repair of underground drainage systems; however, open, damaged, or displaced manhole covers can create serious safety risks for pedestrians, vehicles, and maintenance workers, especially during nighttime and heavy rainfall. Drainage blockages can also cause wastewater levels to rise, resulting in sewage overflow, waterlogging, environmental pollution, and unpleasant odors. In addition, hazardous gases accumulated inside manholes can pose serious health risks to maintenance personnel. Traditional monitoring mainly depends on manual inspection, which is time-consuming, requires significant manpower, and cannot provide continuous real-time information. To overcome these limitations, the proposed IoT-Based Smart Manhole Detection and Monitoring System uses Raspberry Pi 4, Artificial Intelligence, IoT sensors, and a web-based monitoring platform for continuous monitoring. A camera module with AI-based computer vision is used to detect open or abnormal manhole conditions, while an ultrasonic sensor measures the wastewater level inside the manhole. A gas sensor detects hazardous gases, and pH and turbidity sensors monitor the chemical and physical quality of wastewater. The system also uses GPS to determine the exact location of the monitored manhole and abnormal conditions. All sensor readings are collected and processed by the Raspberry Pi 4 and displayed on a web-based dashboard for real-time monitoring. The system continuously compares the sensor readings with predefined threshold values and identifies abnormal conditions such as high water levels, dangerous gas concentrations, abnormal pH values, and excessive turbidity. When a critical condition is detected, the system automatically generates email alerts containing relevant sensor information, time, and GPS location, allowing maintenance authorities to respond quickly. The proposed system reduces dependence on manual inspection, supports early detection of drainage problems, improves preventive maintenance, and enhances the safety of both the public and maintenance workers. Overall, the system provides a smart, reliable, real-time, and scalable solution for urban drainage management, while contributing to improved infrastructure monitoring, environmental protection, and safer smart-city development.



2. LITERATURE SURVEY

Harish Ragavendra M. (2026) [1] proposed an IoT-based smart manhole monitoring system for detecting hazardous gases and temperature inside underground drainage systems. The system utilized methane (CH₄), hydrogen sulfide (H₂S), and carbon monoxide (CO) gas sensors along with a temperature sensor to continuously monitor manhole conditions. The collected data was transmitted through an IoT platform, enabling real-time monitoring and timely alerts to improve worker safety and prevent accidents.

Praveenkumar, Praveen Takhar, Sathvik N. G., Thokchom Mobisana, and Mrs. Thrisha V. S. (2025) [2] developed an IoT-based manhole detection and monitoring system for urban safety using Arduino Uno/ESP32, MQ-series gas sensors, ultrasonic sensors, DHT sensors, and wireless communication technologies such as GSM, Wi-Fi, and LoRa. The system also integrated Firebase and ThingSpeak dashboards to provide continuous monitoring, detect gas leakage, sewage overflow, and manhole cover displacement, and send instant alerts to the concerned authorities.

Rasel Hossen, Diptajoy Mistry, Mushiur Rahman, Waki As Sami Atikur Rahman Hridoy, Sajib Saha, and Muhammad Ibrahim (2025) [3] introduced a deep learning approach for road damage and manhole detection using the YOLOv9 object detection algorithm. Their work employed polygonal image annotation, Roboflow, Ultralytics, Python, and computer vision techniques to accurately identify damaged roads and open manholes. The proposed AI-based model improved detection accuracy and supported smart city applications by enabling automatic hazard identification.

S. Manikanta Swamy and E. Hari Chandana (2024) [4] proposed a smart manhole surveillance system using IoT technology. The system incorporated a camera module and LoRa-based communication to monitor manhole conditions continuously. It enabled remote surveillance, early fault detection, and long-distance communication, thereby improving maintenance efficiency and enhancing public safety.

Guru Prasath V.A. and Sowmya H.D. (2022) [5] presented an IoT-enabled manhole detection and monitoring system using NodeMCU (ESP8266), MQ-2 gas sensor, ultrasonic sensor, infrared sensor, GPS, GSM module, and ThingSpeak cloud platform. The system continuously monitored toxic gases, sewage level, and manhole cover status while providing real-time notifications through cloud services and SMS alerts to municipal authorities.

Abhishek Natu, Chaitanya Deshpande, Prof. Gajanan Chavhan, and Prof. Ketki Kshirsagar (2024) [6] designed an IoT-based manhole monitoring system using ESP8266 NodeMCU, SIM800L GSM module, waterproof ultrasonic sensor, KY-017 tilt sensor, MQ-2 gas sensor, GPS module, and the Blynk IoT platform. Their system monitored manhole cover displacement, gas leakage, water level, and geographical location while providing live monitoring through a mobile application.



M. S. Monishree and B. Maneshwaran (2023) [7] developed an IoT-based manhole monitoring system that utilized pH and gas sensors to monitor underground sewer conditions. The proposed system focused on detecting hazardous gases and measuring wastewater quality, enabling authorities to receive early warnings regarding abnormal sewer conditions and improving maintenance planning.

P. Kumar and S. Singh (2022) [8] proposed a solar-powered IoT-based smart manhole monitoring system that addressed the power requirements of conventional monitoring systems. By integrating solar panels with IoT sensor nodes, the system achieved continuous monitoring using renewable energy while reducing operational costs and improving energy efficiency.

Ruheena M. A., Rukhayia Sheereen, Sheeba Kulsum, and T. Komala (2021) [9] developed a manhole detection and monitoring system using Arduino Uno, DHT11 temperature sensor, MQ-2 gas sensor, water level sensor, GSM module, GPS, LCD, relay module, and IoT technology. The system continuously monitored environmental parameters inside the manhole and transmitted warning messages whenever dangerous conditions such as toxic gas leakage or water overflow were detected.

Wesam Moneer Rasheed, Raed Abdulla, and Low Yee San (2021) [10] proposed a computer vision-based manhole cover monitoring system over IoT. Their system combined MATLAB, HOG feature extraction, Naïve Bayes classification, Arduino Mega, SIM808 GSM/GPRS module, GPS, and the Blynk IoT platform to detect missing or displaced manhole covers automatically. The proposed approach demonstrated that integrating computer vision with IoT significantly improves the accuracy and efficiency of manhole monitoring systems.

Table 1 Comparative review of Manhole Detection and Monitoring System

Sr. No	Authors	Year	Title	Journal / Conference	Technology Used
1	Harish Ragavendra M.	2026	IoT-Based Smart Manhole Monitoring System for Gas and Temperature Detection	Modernization in Engineering Technology and Science (IRJMETS)	Gas sensors (CH ₄ , H ₂ S, CO), Temperature sensor, IoT system
2	Praveenkumar, Praveen Takhar, Sathvik N. G., Thokchom Mobisana, Mrs. Thrisha V. S.	2025	IoT-Based Manhole Detection and Monitoring System for Urban Safety	International Journal of Innovative Research in Technology (IJIRT), Vol. 11, Issue 12..	Arduino Uno/ESP32, MQ-2/MQ-7/MQ-135 Gas Sensors, HC-SR04 Ultrasonic Sensor, DHT11/DHT22, GSM/Wi-Fi/LoRa, Node.js/Firebase/ThingSpeak Dashboard, IoT Platform.



3	Rasel Hossen, Diptajoy Mistry, Mushiur Rahman, Waki As Sami Atikur Rahman Hridoy, Sajib Saha, Muhammad Ibrahim	2025	Road Damage and Manhole Detection using Deep Learning for Smart Cities: A Polygonal Annotation Approach	ArXiv Research Paper	YOLOv9, Deep Learning, Polygonal Annotation, Ultralytics Framework, Roboflow, Computer Vision, Python, Image Dataset (1022 images).
4	S. Manikanta Swamy and E. Hari Chandana	2024	Smart Manhole Surveillance System Using Io	Modernization in Engineering Technology and Science (IRJMETS)	Camera module, Lora based System
5	Guru Prasath V.A., Sowmya H.D.	2024	Smart Manhole Surveillance System Using IoT	International Research Journal of Modernization in Engineering Technology and Science (IRJMETS), Vol. 6, Issue 3, March2024	NodeMCU (ESP8266), MQ-2 Gas Sensor, HC- SR04 Ultrasonic Sensor, IR Sensor, NEO-6M GPS Module, GSM Module, I2C LCD, ThingSpeak Cloud, ThingView Application.
6	Abhishek Natu, Chaitanya Deshpande, Prof. Gajanan Chavhan, Prof. Ketki Kshirsagar	2024	IoT-Based Manhole Monitoring System	International Journal for Multidisciplinary Research (IJFMR), Vol. 6, Issue 2, March–April 2024	NodeMCU (ESP8266), SIM800L GSM Module, MQ-2 Gas Sensor, JSN- SR04T Waterproof Ultrasonic Sensor, KY-017 Tilt Sensor, Temperature Sensor, NEO-6M GPS Module, Blynk IoT Platform, Arduino IDE, 18650 Battery.
7	M. S. Monishree, B. Maneshwaran	2023	Manhole Detection and Monitoring System Using IoT	International Journal of Advanced Research in Science	PH Sensor, Gas Sensor
8	P. Kumar and S. Singh	2022	Solar Powered IoT-Based Smart Manhole Monitoring System	International Journal of Innovative Research in Science	Solar panel, IoT sensors, Renewable energy system
9	Ruheena M. A., Rukhayia Sheereen, Sheeba Kulsum, T.	2021	Manhole Detection and Monitoring System	International Journal of Engineering Research &	Arduino Uno, DHT11 Temperature Sensor, Water Level Sensor, MQ-2 Gas



	Komala			Technology (IJERT), NCCDS 2021 Conference Proceedings, Vol. 9, Issue 12	Sensor, GSM (SIM800), GPS, LCD, IoT, Relay Module, DC Motor.
10	Wesam Moneer Rasheed, Raed Abdulla, Low Yee San	2021	Manhole Cover Monitoring System over IoT	Journal	MATLAB, Naïve Bayes Classifier, HOG Feature Extraction, Computer Vision, Logitech Camera, Arduino Mega, SIM808 GSM/GPRS Module, GPS, Blynk IoT Platform.

3. PROPOSED METHODOLOGY

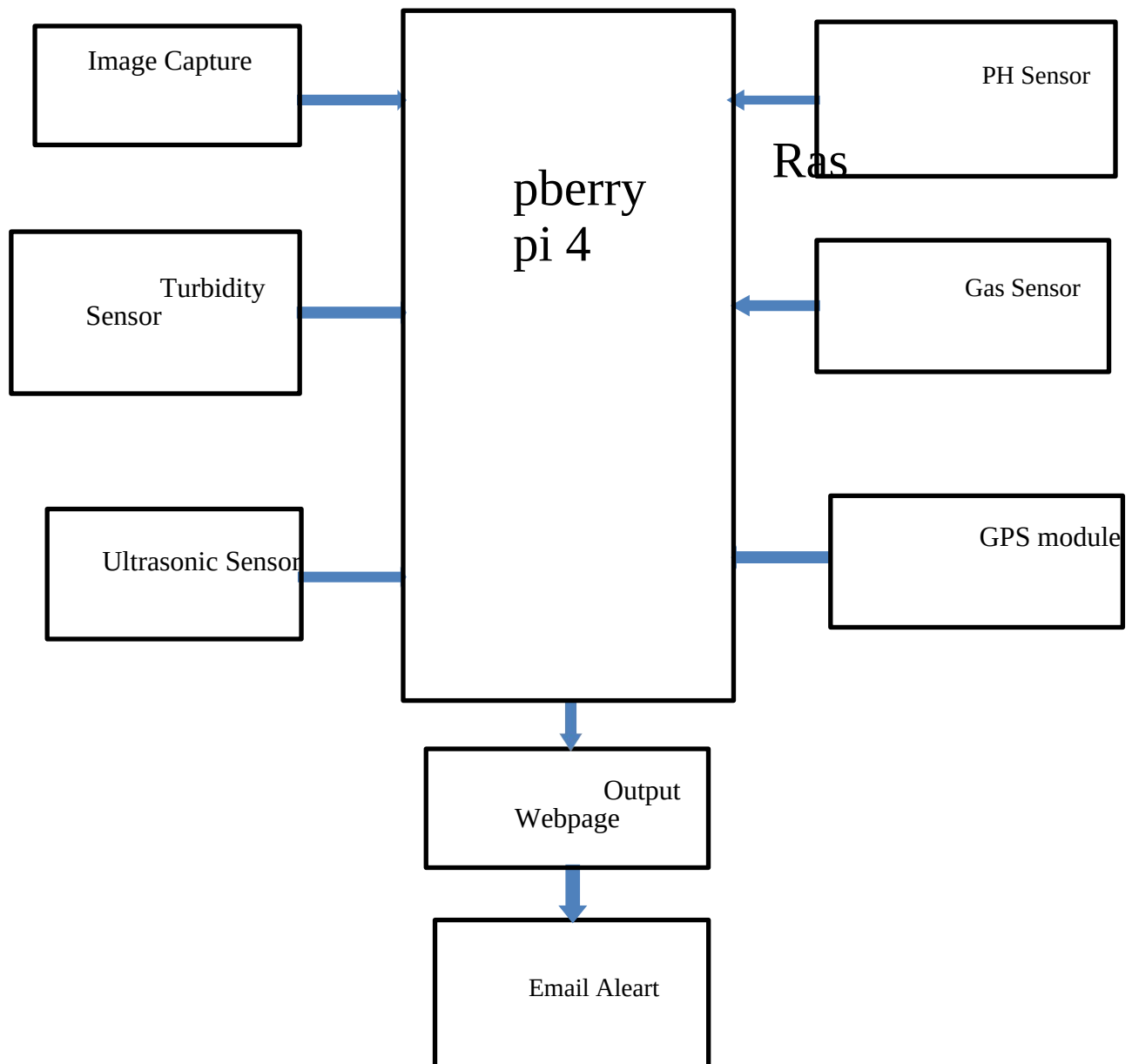


Figure.1 Block Diagram of Manhole Detection

The proposed IoT-Based Manhole Detection and Monitoring System is designed to provide intelligent infrastructure monitoring using computer vision, cloud computing, and IoT integration. The system follows a structured workflow consisting of image acquisition, classification, real-time analysis, cloud-based processing, automated documentation, and alert generation. The methodology begins with continuous image acquisition using CCTV cameras installed in urban areas. These cameras capture live video feeds in formats such as MJPEG or H.264.



The video feed is transmitted to the processing unit where frames are extracted and analyzed. The purpose of this stage is to ensure uninterrupted monitoring of manhole locations without manual supervision. Once the video frames are captured, the system performs manhole detection using computer vision algorithms. Artificial Intelligence (AI) models are trained to identify the presence of manholes within the video feed. The detection algorithm locates the coordinates of the manhole and isolates it from the background.

This step ensures that only relevant regions of interest are processed further, improving efficiency and accuracy. After detection, the system proceeds to image classification. In this stage, the visual features of the detected manhole are analyzed to determine its condition. The AI model classifies the manhole into categories such as Secure (closed and safe) or Damaged/Open. Feature extraction techniques evaluate surface structure, lid alignment, cracks, displacement, or open gaps. Based on trained data patterns, the system assigns a confidence score to the classification result.

The next stage involves real-time analysis. The classification results are processed immediately to identify whether the detected condition represents a normal or critical state. If the manhole is classified as secure, the system logs the status as normal. However, if the manhole is detected as damaged or open, the system flags it as a critical issue. This real-time processing ensures that hazardous situations are identified without delay. All processed data is then transmitted to the cloud server for centralized AI analysis and database management.

The cloud server acts as the core control unit of the system. It stores image data, classification results, timestamps, location details, and confidence levels. The cloud infrastructure allows scalable data storage and enables remote access to information. IoT data and visual confirmation are integrated at this stage to enhance reliability. In parallel, IoT sensors installed within or near the manhole monitor environmental parameters. These sensors detect status conditions and confirm whether the manhole environment is stable.



4. RESULT

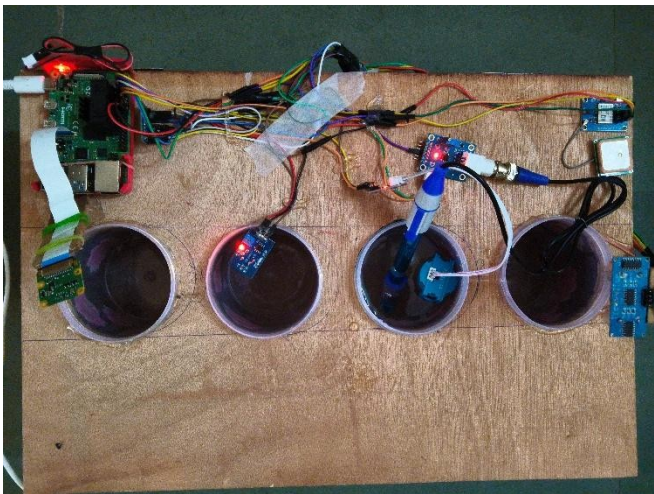


Figure 2 Project Setup



Fig.3 Overall, Sensor Analysis

Fig.4 PH Sensor Value Graph

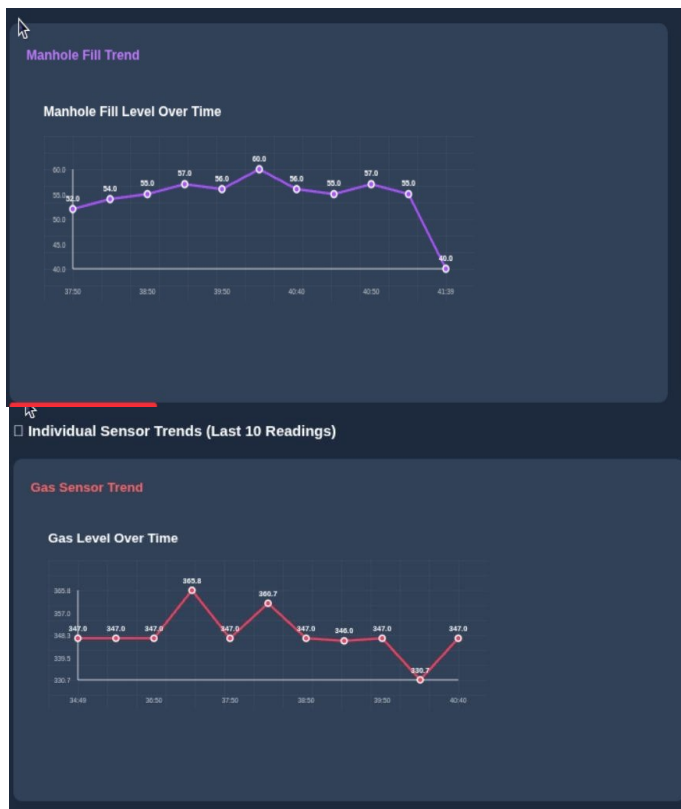


Fig.5 Manhole Filled Graph

Fig.6 Gas Level Value Graph

The system operates through a dual-layered approach that integrates Computer Vision and IoT based environmental sensing to ensure urban safety. The process begins with continuous image acquisition via a Raspberry Pi Camera module, which feeds live video to the Raspberry Pi 4. Using the YOLO (You Only Look Once) algorithm, the system performs real-time object detection to identify manholes and classify their state as either "Secure" or "Damaged/Open" based on visual features like lid alignment or cracks. Simultaneously, the hardware utilizes MQ-series gas sensors and air quality sensors to monitor for hazardous emissions such as methane and carbon monoxide within the manhole environment. All collected data—both visual confirmation and sensor readings—is transmitted to a Cloud Server for centralized analysis. If the AI detects an open manhole or the sensors identify toxic gas levels exceeding safety thresholds, the system flags a "Critical Alert" and instantly triggers an SMS notification to government authorities via an API like Twilio, while also updating a live map dashboard for real-time operator monitoring.

Graphical Analysis of Sensor Trends: -

The software dashboard includes a "Individual Sensor Trends" module that visualizes the last 10 readings to help operators identify patterns rather than isolated spikes.

1. Gas Sensor Trend: - Metric: Monitors toxic/combustible gas concentration, Observation: The readings show a baseline at approximately 347.0, with significant upward spikes reaching 365.8,



Explanation: These fluctuations represent the changing air quality within the manhole. Sharp spikes indicate periodic releases of hazardous gases like methane or carbon monoxide, which trigger a software-based threshold alert if they exceed safe limits.

2. pH Sensor Trend Metric: Measures the chemical acidity or alkalinity of the drainage water, Observation: The trend displays values fluctuating between 6.1 and 7.7, Explanation: A value of 7.0 is neutral. The software identifies levels dipping toward 6.1 as slightly acidic, potentially signaling industrial runoff. This continuous tracking helps in detecting illegal chemical discharges into the sewer system.

3. Turbidity Sensor Trend Metric: Measures the cloudiness or clarity of the water (particulate matter), Observation: Data points vary between 1.5 and 3.4, Explanation: Higher values (such as the peak at 3.4) indicate highly opaque water. The software uses this data to identify heavy sludge or sediment buildup, which often precedes physical blockages in the drainage network.

4. Manhole Fill Trend Metric: Tracks the sewage water depth using the Ultrasonic sensor, Observation: The fill level remains steady at 55%–60% before a sharp drop to 40%, Explanation: This trend is crucial for urban flood prevention. The software monitors these levels to ensure capacity remains safe; a sudden drop to 40% may indicate that a blockage downstream has cleared, restoring normal flow.

5. CONCLUSION

The IoT-Based Manhole Detection and Monitoring System provides a smart and efficient solution to improve urban safety. By integrating Artificial Intelligence, computer vision, IoT sensors, and cloud computing, the system can detect open or damaged manholes in real time and monitor environmental conditions effectively. It helps authorities receive instant alerts and access real-time data, reducing the need for manual inspections. This system improves public safety, prevents accidents, and supports better infrastructure management. Overall, it contributes to smart city development by providing a reliable, automated, and technology-driven approach for monitoring urban infrastructure

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