



# **“Geo-tagging and Maintenance Monitoring of Manholes” A Smart Infrastructure Monitoring System for Nagpur Municipal Corporation (NMC)**

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**ABSTRACT:** Urban manholes play a vital role in drainage and sewer networks by providing access for inspection, maintenance, and ensuring the safe functioning of underground infrastructure. However, conventional monitoring methods are primarily manual, making them slow, inefficient, and susceptible to human errors, which often result in delayed maintenance and increased safety hazards. This paper proposes a smart manhole monitoring system that combines geo-tagging, artificial intelligence, and cloud-based analytics to enable automated detection, condition evaluation, and efficient maintenance management. The proposed system employs computer vision techniques to detect manholes from road images and classify their condition into categories such as maintained, damaged, or critical. Each identified manhole is geo-tagged with precise GPS coordinates and stored in a centralized cloud platform, allowing real-time monitoring through a web-based dashboard and mobile application. Additionally, the system facilitates maintenance workflow management by supporting task allocation and verification through image-based closure validation. The system is validated using real-world data collected from the Laxminagar zone of Nagpur Municipal Corporation, covering approximately 600 km of road network and 18,654 manholes. The analysis revealed 1,971 defective manholes, including 1,383 critical cases requiring immediate intervention. The findings indicate that the proposed system enhances inspection efficiency, supports real-time decision-making, and improves transparency in infrastructure management. Overall, the proposed solution offers a scalable and effective approach for smart city applications, contributing to improved safety, operational efficiency, and sustainable urban development

**KEYWORDS:** Geo-tagging, Manhole Maintenance, GPS, Sewer System, Urban Infrastructure, Monitoring System, Smart City.

## **I. INTRODUCTION**

Urban sewer and drainage systems form a vital part of city infrastructure, ensuring proper sanitation, minimizing waterlogging, and supporting environmental sustainability. Within this framework, manholes act as critical access points that enable inspection, cleaning, and maintenance of underground pipelines. These structures are distributed throughout urban road networks and play an essential role in maintaining the efficiency of wastewater management systems. Failure to properly maintain manholes can lead to serious issues such as sewer blockages, overflow of wastewater, foul odors, road surface damage, traffic disruptions, and even life-threatening accidents for pedestrians and motorists, as highlighted in urban infrastructure studies [6], [9]. Despite their importance, the monitoring and maintenance of manholes in many urban areas still rely heavily on traditional manual methods. In such systems, field workers are required to physically locate manholes, assess their condition, and document findings using paper-based records or fragmented digital tools. This approach is not only time-consuming and labor-intensive but also highly prone to human errors and inconsistencies. Studies on conventional monitoring systems indicate that the absence of a centralized and continuously updated database significantly affects maintenance planning and resource allocation [7].

As cities continue to expand and infrastructure becomes more complex, these conventional methods are increasingly unable to meet modern urban demands, leading to inefficiencies in inspection and delayed maintenance actions [12]. A significant drawback of manual monitoring is the lack of real-time information regarding the condition of manholes. Problems such as open covers, structural damage, clogging, or misalignment are often identified only after they result in visible consequences like flooding or accidents. This reactive approach has been widely criticized in literature for increasing operational costs and reducing system reliability [3]. Additionally, manual inspections expose workers to hazardous environments, including toxic gases and confined spaces, which pose serious health risks, as discussed in safety-related studies [8]. With rapid advancements in digital technologies, new opportunities have emerged to improve the management of urban infrastructure. Geo-tagging and geographic information systems (gis) enable accurate mapping and visualization of infrastructure assets, allowing authorities to maintain a reliable digital inventory of manholes [13]. At the same time, developments in artificial intelligence, particularly in computer vision, have enabled automated detection and analysis of objects from images and video data. Deep learning models such as convolutional neural networks (cnn) and object detection algorithms like yolo have demonstrated high accuracy in identifying infrastructure defects and classifying their conditions [1], [5]. These technologies provide a strong foundation for building intelligent monitoring systems.

The integration of these technologies with cloud computing further enhances system capabilities by enabling centralized data storage, real-time processing, and remote accessibility. Cloud-based platforms allow large volumes of geo-tagged data to be efficiently processed and visualized through interactive dashboards, supporting data-driven decision-making [10]. Additionally, mobile applications enable field engineers to update maintenance records, upload images, and verify completed tasks, thereby improving transparency and accountability in the maintenance process [11]. In addition to improving operational efficiency, modern monitoring systems also support predictive maintenance strategies. By analyzing historical data and identifying patterns in infrastructure failures, authorities can anticipate potential issues before they occur. Research shows that integrating ai with geo-spatial data significantly enhances the ability to detect high-risk zones and prioritize maintenance activities effectively [2], [4]. This shift from reactive to proactive maintenance plays a key role in reducing long-term costs and improving system reliability. Moreover, the adoption of smart monitoring systems aligns with the broader vision of smart city development. Governments and municipal authorities are increasingly focusing on digital transformation initiatives to improve urban governance and service delivery. Intelligent infrastructure monitoring systems contribute to this vision by enabling data-driven decision-making, improving service efficiency, and enhancing public safety. The scalability of cloud-based solutions further allows these systems to be deployed across large urban areas with minimal additional infrastructure [11], [13]. Furthermore, the system incorporates a structured digital workflow for maintenance management, where tasks can be assigned based on severity levels and completion can be validated using image-based evidence. This approach improves operational efficiency, ensures accountability, and reduces the likelihood of unresolved issues. By transitioning from a reactive to a proactive maintenance strategy, the system facilitates early detection of potential problems, thereby minimizing risks and reducing long-term operational costs. The effectiveness of the proposed approach is demonstrated using real-world data collected from urban environments, highlighting its practical feasibility and scalability. The adoption of such systems can significantly enhance municipal efficiency, improve public safety, and support the development of smart and sustainable cities. Overall, the integration of geo-tagging, artificial intelligence, and cloud computing represents a transformative advancement in modern urban infrastructure management.

## II. LITERATURE REVIEW

The management of urban manholes has undergone significant transformation, shifting from conventional manual inspection techniques to more advanced digital and intelligent monitoring approaches. Earlier systems primarily depended on manual surveys and paper-based documentation, which were not only time-consuming and labor-intensive but also susceptible to errors and inconsistencies. Research indicates that such traditional practices often lead to delayed fault detection, inefficient scheduling of maintenance activities, and increased operational expenses [6]. Moreover, the absence of a centralized database in these systems makes it difficult to maintain records and prioritize critical maintenance tasks effectively [7].

To address these challenges, researchers have introduced internet of things (iot)-based monitoring systems for manhole management. These systems employ various sensors to monitor parameters such as water levels, gas concentration, and

blockages in real time. For example, muralidharan and balasubramanian [9] developed an iot-based smart monitoring system capable of detecting hazardous conditions within manholes. Similarly, menakadevi et al. [7] proposed an automated system that generates alerts when abnormal conditions are detected. Although iot-based solutions enhance real-time monitoring capabilities, they often face limitations such as high deployment costs, maintenance complexity, and challenges in scaling across large urban areas.

With the rapid growth of artificial intelligence, especially in computer vision, more efficient solutions have been developed for infrastructure monitoring. Deep learning techniques, particularly convolutional neural networks (cnn), have proven to be highly effective for image-based defect detection. Varsha et al. [2] demonstrated that deep learning models can accurately identify manhole defects with high precision. Likewise, amalraj victorie et al. [4] proposed a visual inspection system based on deep learning that effectively classifies different manhole conditions. In addition, object detection algorithms such as yolo have significantly improved detection speed and accuracy, enabling real-time analysis of road images [5]. Ding et al. [1] further enhanced this approach by using an improved yolo model for efficient detection and classification of manhole cover defects in urban scenarios.

Alongside ai-based solutions, geo-tagging and geographic information systems (gis) have become essential tools for modern infrastructure management. Geo-tagging facilitates accurate mapping of manhole locations, while gis platforms provide powerful visualization and analysis capabilities for spatial data. Hassan et al. [13] emphasized that integrating geo-tagging with gis enables better urban asset management by providing a comprehensive view of infrastructure. Such systems assist authorities in planning maintenance operations more effectively and responding quickly to emergencies. Cloud computing has also played a significant role in enhancing smart monitoring systems by enabling centralized data storage and real-time data processing. Kumar and singh [12] highlighted that cloud-based analytics are effective in handling large volumes of infrastructure data and supporting real-time decision-making processes. Similarly, patel and gupta [11] demonstrated that integrating cloud technologies into smart city systems improves scalability, transparency, and overall operational efficiency. Furthermore, the use of mobile applications in conjunction with cloud platforms allows field personnel to update maintenance data, upload images, and validate completed tasks, thereby ensuring accountability and system reliability.

Despite these technological advancements, most existing solutions tend to focus on individual components such as iot sensing, ai-based detection, or gis mapping, rather than offering a comprehensive and integrated system. Many of these approaches lack seamless coordination between detection mechanisms, geo-tagging, real-time monitoring, and maintenance workflow management. Additionally, issues related to scalability and real-world implementation continue to pose significant challenges, particularly in densely populated urban environments. Therefore, there is a clear need for a unified and integrated system that combines artificial intelligence, geo-tagging, and cloud-based analytics into a single framework. The system proposed in this study aims to bridge these gaps by integrating computer vision-based detection, gps-enabled geo-tagging, and cloud-based monitoring with a structured maintenance workflow. This holistic approach provides a scalable, efficient, and practical solution for smart manhole monitoring and urban infrastructure management.

### III. RESEARCH GAP

Despite notable advancements in manhole monitoring and urban infrastructure management, several challenges continue to persist in existing approaches. Conventional manual inspection methods remain inefficient, time-intensive, and lack real-time monitoring capabilities, which often results in delayed detection of faults and higher operational costs. Although IoT-based systems enable real-time data collection through sensors, they are often associated with high deployment and maintenance expenses, making them less suitable for large-scale urban implementation. Recent developments in artificial intelligence and computer vision have significantly enhanced the capability to detect and classify manhole conditions. However, most of these approaches are primarily limited to image-based analysis and do not effectively integrate accurate geo-tagging or real-time monitoring features. In a similar manner, GIS and geo-tagging technologies provide precise location tracking but fail to incorporate intelligent detection mechanisms and automated maintenance workflows. Moreover, a major limitation of current solutions is their fragmented nature, where individual components such as detection, monitoring, and data visualization operate independently rather than as part of a cohesive system. The lack of seamless integration between AI-driven detection, geo-tagging, cloud-based data management, and maintenance workflow systems reduces overall efficiency and restricts their applicability in real-

world urban environments. In addition, challenges such as insufficient transparency, lack of proper closure validation, and limited scalability continue to hinder effective infrastructure management. Therefore, there is a critical need for a unified and scalable solution that integrates artificial intelligence, geo-tagging, and cloud-based analytics within a structured maintenance framework. The system proposed in this study aims to address these limitations by providing automated detection, real-time monitoring, precise location mapping, and streamlined maintenance management in a single integrated platform.

#### IV. PROPOSED WORK

The proposed work introduces a smart and integrated framework for monitoring and managing urban manholes by leveraging artificial intelligence, geo-tagging, and cloud-based analytics. The main goal of this system is to automate the processes of detection, condition evaluation, and maintenance tracking of manholes, thereby minimizing reliance on manual inspection methods and enhancing overall operational efficiency. The system is structured as a multi-layer architecture that integrates data acquisition, AI-driven processing, geo-tagging, cloud-based storage, and monitoring modules. These layers operate collaboratively to deliver a comprehensive end-to-end solution for real-time infrastructure monitoring and efficient maintenance management.

##### A. System Architecture:

The process begins with data acquisition, where a vehicle-mounted camera continuously captures images or video streams of road surfaces. At the same time, a GPS module records the geographical coordinates corresponding to each captured frame. This enables simultaneous collection of visual and spatial data in real time. The acquired images are then analyzed using deep learning techniques. A YOLO-based object detection model is utilized to identify manholes within the captured frames. After detection, the extracted region of interest is processed by a Convolutional Neural Network (CNN) to determine the condition of the manhole. The classification model categorizes the manholes into different states such as maintained, damaged, or critical, facilitating accurate condition assessment. Once detection and classification are completed, each manhole is geo-tagged using GPS coordinates. The system stores this information, along with timestamps and condition labels, in a centralized cloud database. This ensures scalable storage, secure data access, and efficient management of infrastructure information.

##### B. Block Diagram of Proposed System:

The diagram illustrates the integrated architecture of the proposed smart manhole monitoring system, which combines image acquisition, cloud computing, artificial intelligence, and municipal management modules. The process begins with the image capture and upload stage, where inspection devices or vehicles capture images of manholes and transfer them to a cloud-based platform. The cloud platform acts as a centralized system for data storage, processing, and communication between different modules. The uploaded images are forwarded to the AI processing pipeline, where preprocessing techniques such as image cleaning and resizing are applied. The processed images are then analyzed using a Convolutional Neural Network (CNN) to extract features and classify the condition of manholes into categories such as good, moderate, poor, or critical. Based on the prediction results, the system generates alerts and notifications, which are sent to the municipal office for further action.

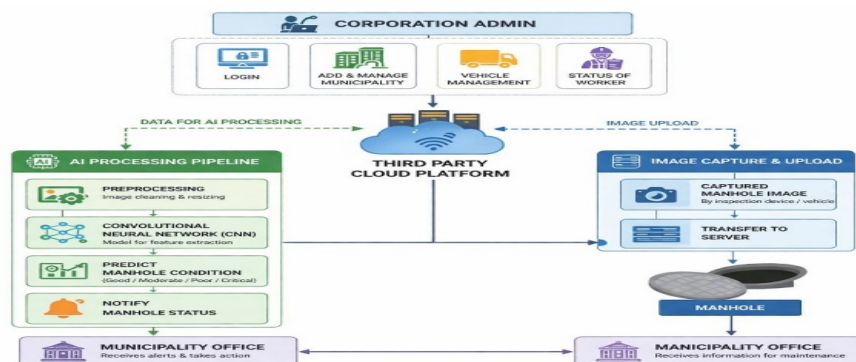


Fig. 1. Integrated Architecture of AI-Based Smart Manhole Monitoring System

The municipality authorities can monitor the status, manage maintenance activities, track workers, and update system records through the administrative interface. This integrated workflow ensures real-time monitoring, efficient decision-making, and improved maintenance of urban infrastructure.

### **C. Working of the System**

The operation of the system begins with continuous image acquisition through a vehicle-mounted camera. The captured data is processed using AI models to detect and classify manholes based on their condition. The output is then combined with GPS data to generate geo-tagged records, which are stored in the cloud database. The cloud platform functions as a centralized repository that enables real-time data access and monitoring. A web-based dashboard displays all geo-tagged manholes on a GIS-enabled map, using color-coded indicators to represent their condition. This allows authorities to quickly identify critical areas and prioritize maintenance activities. Additionally, a mobile application is integrated into the system for field engineers and maintenance personnel. The application enables users to receive assigned tasks, navigate to specific manhole locations, update maintenance status, and upload before-and-after images as proof of completion. This enhances transparency, ensures accountability, and improves the efficiency of maintenance operations.

### **D. Key Features of the Proposed System**

- Automated detection of manholes using deep learning techniques
- Reliable classification of manhole conditions
- GPS-based geo-tagging for accurate location identification
- Cloud-based storage for scalable and secure data management
- Real-time monitoring through a web-based dashboard
- Task prioritization and maintenance workflow management
- Closure verification using image-based evidence

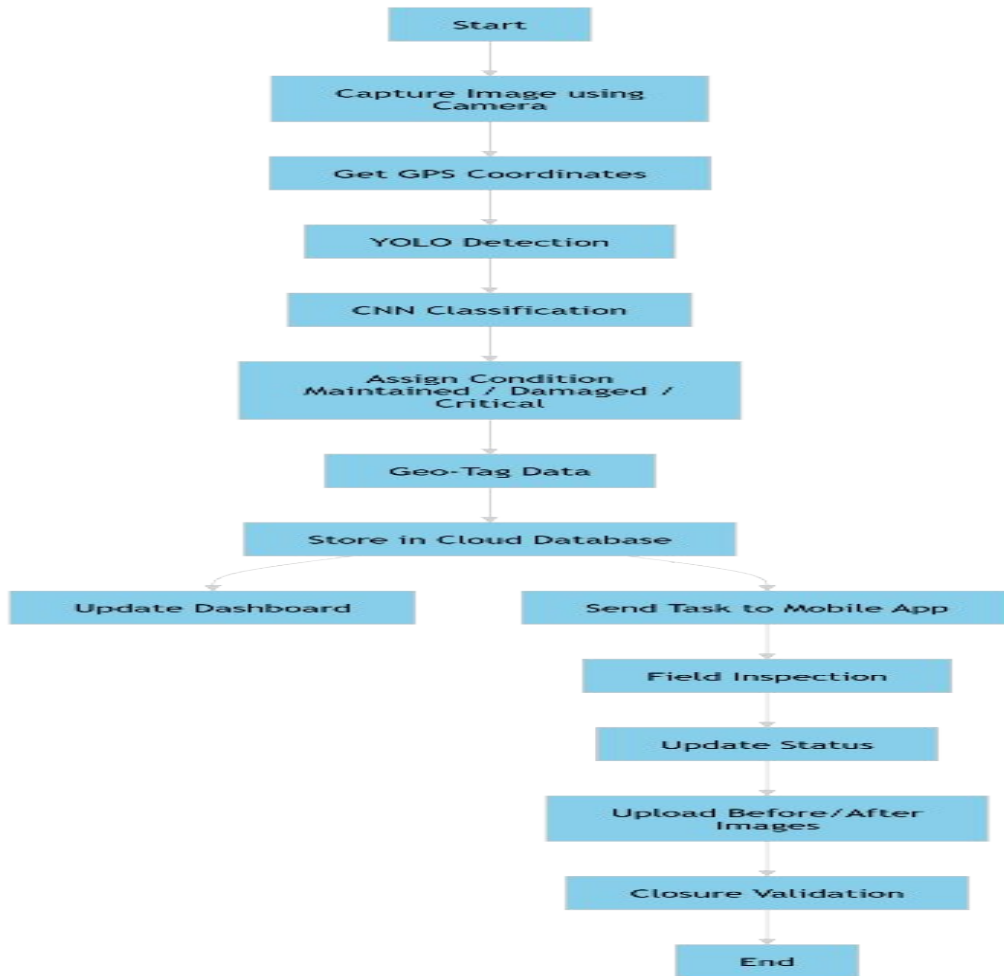
## **V. IMPLEMENTATION**

### **A. System Implementation**

The proposed smart manhole monitoring system is developed by integrating hardware devices, artificial intelligence techniques, and cloud-based technologies to facilitate real-time monitoring and effective maintenance of urban infrastructure. The implementation aims to automate the entire process, starting from data collection to maintenance verification, thereby minimizing manual effort and enhancing operational efficiency. The data acquisition stage is performed using a vehicle-mounted camera that continuously captures images or video of road surfaces while traversing urban areas. This approach enables large-scale data collection without requiring manual inspection. In parallel, a GPS module is incorporated into the system to capture precise geographical coordinates corresponding to each frame. This ensures accurate geo-tagging of detected manholes and supports location-based analysis.

The captured image data is processed using advanced deep learning algorithms. A YOLO-based object detection model is utilized to identify manholes in real time due to its speed and accuracy. After detection, the identified manhole regions are passed to a Convolutional Neural Network (CNN) for condition analysis. The CNN model classifies the manholes into different categories such as maintained, damaged, or critical. This automated classification process reduces dependency on manual inspection and ensures consistent and reliable outputs. Following detection and classification, the results are integrated with GPS data to generate geo-tagged records for each manhole. These records include latitude, longitude, timestamp, and condition status. The generated data is stored in a centralized cloud database, which serves as a scalable and secure platform for data management. The use of cloud technology enables efficient handling of large datasets, real-time accessibility, and smooth integration with other system components. A web-based dashboard is designed to provide monitoring and visualization capabilities. The dashboard displays geo-tagged manholes on a GIS-enabled map, where different colors indicate different condition categories. This allows authorities to easily identify critical issues and prioritize maintenance tasks. Additionally, the dashboard supports data filtering, reporting, and analysis, which aids in informed decision-making and optimized resource allocation. Furthermore, a mobile application is incorporated into the system for use by field engineers and maintenance staff. The application enables users to receive assigned tasks, navigate to specific manhole locations using GPS, update maintenance status, and upload before-and-after images as proof of completion. This enhances transparency and ensures proper tracking of maintenance activities.

**B. Flowchart of System Implementation**



**Fig. 2. Flowchart of Proposed System**

The flowchart illustrates the complete operational sequence of the proposed system. The process begins with capturing images of road surfaces using a vehicle-mounted camera, followed by obtaining GPS coordinates for accurate location identification. The captured images are then analyzed using a YOLO model to detect manholes. Once detection is completed, a CNN model is applied to classify the condition of each manhole into categories such as maintained, damaged, or critical. The classified output is combined with GPS data to create geo-tagged records, which are stored in a centralized cloud database. This data is then used to update the web dashboard, allowing authorities to monitor the condition of manholes in real time. At the same time, maintenance tasks are assigned to field engineers through a mobile application. The field personnel carry out inspections, update the maintenance status, and upload before-and-after images as evidence of completed work. The process concludes with closure validation to ensure that maintenance tasks have been successfully completed.

**C. Tools and Technologies Used**

Layer	Technology / Tool
Data Acquisition	Vehicle-mounted Camera, GPS Module
AI Processing	YOLOv8, CNN, OpenCV

Backend	Python, Flask
Database	PostgreSQL with PostGIS
Cloud	AWS / Cloud Storage
Frontend	Web Dashboard (React/Angular)
Mobile App	Android / Flutter

**Table I. Tools and Technologies Used**

#### D. Implementation Features

- Automated real-time data collection using camera-based systems
- Fast and efficient detection using YOLO deep learning model
- Reliable classification of manhole conditions using CNN
- GPS-based geo-tagging for accurate location tracking
- Cloud-based storage for scalable and secure data management
- GIS-based visualization for effective monitoring and analysis
- Maintenance workflow management with task assignment
- Closure validation using image-based verification

### VI. RESULTS AND ANALYSIS

The proposed smart manhole monitoring system was assessed using real-world data collected from the Laxminagar zone of Nagpur Municipal Corporation (NMC). The data acquisition process covered approximately 600 km of road network, during which both image data and corresponding geographical coordinates of manholes were recorded using a vehicle-mounted camera and GPS module. The collected dataset was then processed using artificial intelligence techniques to detect, classify, and geo-tag manholes with high accuracy.

During the survey, a total of 18,654 manholes were identified and analyzed. Among these, 16,683 manholes (around 90%) were found to be in maintained condition, while 1,971 manholes (around 10%) were classified as not maintained. Within the defective category, 1,383 manholes were categorized as critical, requiring immediate repair, whereas 588 manholes were identified as moderately damaged, requiring scheduled maintenance and monitoring.

The obtained results demonstrate that the proposed system is capable of performing accurate and efficient detection and classification of manhole conditions in real time. The integration of deep learning models with geo-tagging significantly improves both condition analysis and location accuracy. Compared to traditional manual inspection methods, the system reduces inspection time, minimizes human error, and ensures consistent reporting. As a result, maintenance planning becomes more efficient, and decision-making is significantly accelerated.

Category	Count	Percentage
<b>Total Manholes</b>	18,654	100%
<b>Maintained</b>	16,683	~90%
<b>Not Maintained</b>	1,971	~10%
<b>Critical Issues</b>	1,383	~7.4%
<b>Moderate Issues</b>	588	~3.1%

**Table II. Manhole Condition Analysis**

The data presented in Table II illustrates the distribution of manhole conditions across the surveyed region. Although a large percentage of manholes are in maintained condition, a considerable number still require attention. The presence of a high number of critical cases highlights the importance of continuous monitoring and timely maintenance to avoid potential risks and hazards.

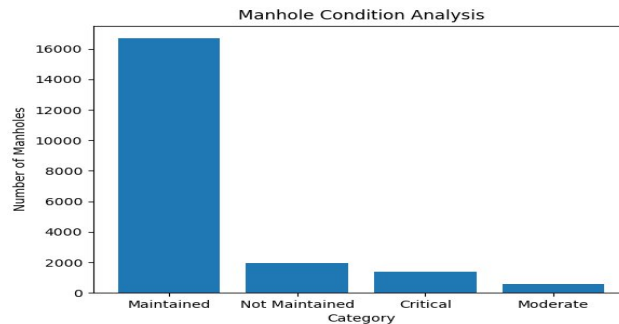


Fig. 3. Graphical Representation of Manhole Condition Analysis

The graphical representation shown in Fig. 3 provides a clear and intuitive visualization of the distribution of manhole conditions. It clearly indicates that the number of maintained manholes is significantly higher than defective ones, while also highlighting the proportion of critical and moderately damaged cases. This visual representation enhances data interpretation and enables quick identification of priority areas, thereby supporting effective decision-making and efficient allocation of resources. Furthermore, the integration of cloud-based storage and GIS-based visualization enables real-time access to infrastructure data. Authorities can monitor the condition of manholes, track ongoing maintenance activities, and allocate resources more effectively. The inclusion of a mobile application further strengthens the system by allowing field engineers to update maintenance status and upload image-based evidence, ensuring transparency and accountability throughout the maintenance process. Overall, the results validate that the proposed system is scalable, efficient, and well-suited for large-scale deployment in urban environments. The combined use of artificial intelligence, geo-tagging, and cloud-based analytics significantly improves operational efficiency and supports data-driven decision-making for smart city infrastructure management.

## VII. CASE STUDY: LAXMINAGAR ZONE IMPLEMENTATION

To assess the practical feasibility of the proposed system, a real-world case study was carried out in the Laxminagar zone of Nagpur Municipal Corporation (NMC). This region is a densely populated urban area with a complex drainage infrastructure, making it an appropriate environment to evaluate the performance of the smart manhole monitoring system.

The deployment covered approximately 600 km of road network, where a vehicle-mounted camera along with a GPS module was used to capture road images and corresponding location data. The collected information was processed using the proposed AI-based system to detect, classify, and geo-tag manholes, leading to the development of a detailed and structured digital database. During the survey, a total of 18,654 manholes were identified and examined. The system effectively classified these manholes based on their condition, providing a clear overview of the infrastructure status. While the majority of manholes were found to be in maintained condition, a notable portion was categorized as defective, including several critical cases that required immediate attention.

Parameter	Value
Area Covered	600 km
Total Manholes	18,654
Maintained	16,683
Not Maintained	1,971
Critical Cases	1,383
Moderate Cases	588

Table III. Case Study Summary (Laxminagar Zone)

The information summarized in Table III provides a concise overview of the case study findings. It reflects both the scale of the survey and the distribution of manhole conditions within the selected region. The presence of a significant number of defective and critical manholes highlights the necessity for continuous monitoring and timely maintenance interventions. A key outcome of this case study was the system’s ability to prioritize maintenance activities based on the severity of issues. Critical manholes were automatically detected and flagged, allowing authorities to take immediate corrective measures. The geo-tagging capability ensured accurate location identification, thereby reducing the time and effort required for field inspections. Furthermore, the integration of a cloud-based dashboard enabled real-time visualization of geo-tagged manholes on a GIS platform. This allowed authorities to monitor infrastructure conditions, analyze data trends, and optimize resource allocation effectively. The mobile application also played a vital role in field operations by enabling engineers to receive task assignments, update maintenance status, and upload before-and-after images as proof of completion. The results of the case study demonstrate that the proposed system performs effectively in real-world scenarios and can be scaled for deployment across larger urban areas. By integrating detection, geo-tagging, monitoring, and maintenance workflows into a unified platform, the system enhances efficiency, reduces operational delays, and improves infrastructure management. Overall, the successful implementation in the Laxminagar zone confirms the practicality and scalability of the proposed approach. The system not only improves maintenance efficiency but also contributes to enhanced safety and sustainability in urban environment.

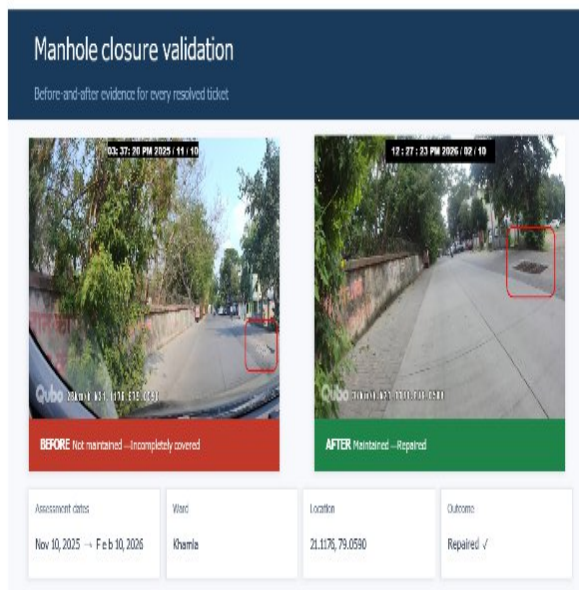


Fig.4. Before – After Manhole Closure Detection



Fig.5. Zonal Survey Analysis Dashboard (NMC)

**VIII. CONCLUSION**

This paper proposes a smart and integrated approach for monitoring and managing urban manholes by leveraging artificial intelligence, geo-tagging, and cloud-based analytics. The developed system overcomes the shortcomings of conventional manual inspection methods by automating the processes of detection, condition assessment, and maintenance tracking, thereby enhancing efficiency and minimizing human involvement. The system employs advanced computer vision techniques, where YOLO is used for detecting manholes and Convolutional Neural Networks (CNN) are applied for classifying their conditions. The incorporation of GPS-based geo-tagging ensures accurate location identification, while cloud-based storage and visualization enable real-time access to infrastructure data. Additionally, the integration of a web-based dashboard and mobile application improves system functionality by supporting real-time monitoring, task allocation, and maintenance verification. The effectiveness of the proposed system was demonstrated using real-world data from the Laxminagar zone of Nagpur Municipal Corporation. The results indicate that the system can reliably detect and classify manhole conditions with high accuracy, significantly reducing inspection time and improving decision-making processes. The capability to identify critical cases and provide real-time updates facilitates timely maintenance and enhances overall operational performance. Moreover, the proposed system offers a scalable and practical solution for modern urban infrastructure management. By combining artificial intelligence, geo-tagging, and cloud technologies into a unified framework, the system supports data-driven decision-making and aligns with the objectives of smart city development. In summary, the proposed smart manhole monitoring system provides an efficient, reliable, and scalable solution to address urban infrastructure challenges. It improves maintenance efficiency, ensures transparency, enhances public safety, and contributes to the advancement of sustainable and intelligent urban environments.

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