IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 6, Issue 11, May 2026

Impact Factor: 8.2

Autonomous Multi-Functional Robot for Drainage Line Inspection, Blockage Detection and Cleaning Operations

Swati Nehe[1], Gayatri Ghaywat[2], Vaibhav Fulsoundar[3], Dr. S. M. Turkare[4]

Department of Electronics and Telecommunication Engineering

Pravara Rural Engineering College (PREC), Loni, Maharashtra, India

SPPU, Loni, Maharashtra, India

swatinehe20@gmail.com[1] , gayatrighaywat2004@gmail.com[2] , fulsoundarvaibhav55@gmail.com [3],

turkanesm@pravaraengg.org.in [4]

Abstract: *The project aims to develop an autonomous multifunctional robot capable of navigating drainage lines, inspecting for blockages, detecting obstructions and executing cleaning operations. By integrating sensors, imaging, and actuators, the system reduces human exposure in hazardous drainage environments, enhances inspection accuracy and speeds up maintenance operations. The prototype design includes locomotion suited to drainage pipelines, live video feedback, blockage detection using ultrasonic/infrared sensors, and a mechanical cleaning mechanism. Drainage systems are vital to urban sanitation but often suffer from blockages that cause overflow, contamination and costly maintenance. To address this, the project presents an autonomous multifunctional robot designed for inspection, blockage detection and cleaning within drainage lines. The system integrates a locomotion platform tailored to pipeline traversal, ultrasonic and infrared sensors for obstruction detection, a camera module for live video feedback and a mechanical cleaning mechanism to remove debris. When deployed, the robot navigates autonomously through drainage pipelines, streams real-time video to operators, identifies blockages via sensor feedback and activates the cleaning module to restore flow. By reducing human entry into confined hazardous spaces and automating inspection and cleaning operations, the system significantly improves safety and operational efficiency. The prototype's performance in simulated drainage environments proves its potential for application in urban maintenance regimes*

Keywords: Drainage inspection robot, Autonomous robot, Blockage detection, Cleaning system

I. INTRODUCTION

Urbanization and rapid industrial growth have significantly increased the load on underground drainage, sewage, and pipeline infrastructure. Manual inspection and cleaning of sewer systems expose workers to hazardous gases, confined spaces, and unsanitary environments, leading to serious health risks and occasional fatalities. Traditional maintenance methods are also time-consuming, inefficient, and unable to provide continuous monitoring of underground pipelines. Hence, there is a growing demand for automated robotic systems capable of performing inspection, blockage detection, cleaning, and monitoring operations safely and efficiently. Recent advancements in robotics and embedded systems have enabled the development of in-pipe inspection robots and sewer cleaning mechanisms. Various researchers have proposed mobile robotic platforms equipped with cameras, sensors, and cleaning tools to identify blockages, cracks, and leaks inside pipelines [1]–[4]. IoT-based drainage maintenance robots further enhance system capability by enabling real-time data transmission and remote monitoring, thereby improving operational efficiency and response time [5], [8], [10]. Review studies highlight the importance of integrating sensing, navigation, and communication technologies for reliable sewer inspection and maintenance [6], [9], [15]. Artificial intelligence and computer vision

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 11, May 2026
Impact Factor: 8.2

techniques are increasingly being adopted for automated defect detection and damage assessment. CNN-based frameworks and AI-powered inspection robots have demonstrated promising results in identifying structural defects, leakages, and debris within sewer systems [11], [13], [14]. Additionally, ESP32-CAM and multisensor platforms have been utilized for pipeline leak localization and environmental monitoring, offering cost-effective and scalable solutions [7], [12]. Despite these advancements, challenges such as limited mobility in complex pipe geometries, insufficient cleaning efficiency, and lack of autonomous navigation still persist. Motivated by these limitations, this paper presents the design and implementation of an autonomous multi-functional drainage inspection and cleaning robot. The proposed system integrates embedded control, sensing modules, and wireless communication to perform real-time inspection, blockage detection, and cleaning operations. The objective is to reduce human intervention, improve safety, and enhance maintenance effectiveness in underground drainage systems. The developed prototype aims to provide a low-cost, reliable, and scalable solution suitable for smart city infrastructure.

II. RELATED WORK

Several researchers have explored robotic solutions for sewer, drainage, and pipeline inspection to overcome the limitations of manual maintenance. Shelke et al. [1] designed an in-pipe inspection robot capable of navigating pipelines and capturing visual data for fault identification. Jamadar et al. [2] proposed a pipe inspection and cleaning robot integrating mechanical cleaning mechanisms with camera-based monitoring to detect internal blockages. Student-level implementations such as manhole cleaning machines and sewage cleaning robots demonstrate the feasibility of low-cost robotic platforms for hazardous environments [3], [4]. Kumar and Gupta [5] introduced an AI-based smart drainage cleaning robot that incorporates automated decisionmaking for efficient waste removal. Deshmukh et al. [6] presented a comprehensive review of manhole monitoring systems, emphasizing the importance of real-time sensing and remote supervision. Recent studies have integrated IoT and embedded systems to enhance inspection capabilities. Shah and Patel

[7] developed a pipeline leak detection robot using ESP32-CAM for visual inspection and localization. IoT-enabled sewage cleaning and monitoring robots have been proposed to allow continuous data transmission and centralized control [8], [10]. Review works further highlight advancements in robotic navigation, sensing technologies, and automation trends in sewer maintenance [9], [15]. Machine learning and computer vision techniques are increasingly being adopted for defect detection. Melvin et al. [11] introduced a CNN-based remote drain inspection framework to automatically classify defects from captured images. Jung et al. [13] developed a multi-sensor robotic system for sewer damage inspection, improving detection accuracy through sensor fusion. Zholtayev et al. [14] proposed an AI-powered pipe inspection robot incorporating SLAM for autonomous navigation and defect recognition. Bommi et al. [12] designed a sewage pipe inspection robot capable of identifying blockages and assisting in clearance operations. Although existing systems demonstrate significant progress, most approaches suffer from limitations such as high system cost, complex hardware architectures, limited cleaning efficiency, or dependence on manual control. Moreover, fully integrated solutions combining inspection, blockage detection, and cleaning in a compact and economical platform remain limited. To address these challenges, the proposed project focuses on developing a multi-functional autonomous drainage robot that integrates inspection, cleaning, and wireless monitoring within a single system, aiming to provide a practical, low-cost solution suitable for real-world deployment.

III. PROPOSED SYSTEM OVERVIEW

The proposed system aims to develop an autonomous multifunctional drainage inspection and cleaning robot that integrates real-time monitoring, blockage detection, and debris removal within a compact robotic platform. Existing studies have demonstrated the effectiveness of in-pipe robots for visual inspection and fault identification [1], [2], while several educational and prototype-based systems focus on basic sewage cleaning mechanisms [3], [4]. However, many such systems operate with limited autonomy and lack integrated monitoring capabilities. Motivated by IoT-enabled drainage robots [5], [8], [10], the proposed system incorporates wireless communication to allow remote supervision

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 11, May 2026
Impact Factor: 8.2

and control. A camera module is employed to provide live video streaming for pipeline inspection, similar to ESP32-CAM–based approaches used for leak detection and localization [7]. Ultrasonic sensors are integrated for obstacle and blockage detection, supporting safe navigation inside narrow drainage paths. The robotic unit is driven by DC motors controlled through an embedded microcontroller, which acts as the central processing unit for movement coordination, sensor data acquisition, and cleaning activation. Upon detecting debris or blockage, the cleaning mechanism is automatically engaged to remove waste, inspired by earlier block detection and clearance systems [12]. This integrated inspection–cleaning framework addresses the limitations of traditional manual maintenance. Recent advancements in AI-based defect detection and multisensor inspection systems [11], [13], [14] highlight the importance of automation and intelligent monitoring. While advanced AI models can increase accuracy, they often increase system cost and complexity. Therefore, the proposed design emphasizes affordability and simplicity while maintaining essential inspection and cleaning functions. Review studies also indicate the growing need for scalable and economical robotic solutions for smart sewer infrastructure [6], [9], [15]. Overall, the proposed system combines inspection, blockage detection, cleaning, and wireless monitoring into a single low-cost robotic platform. This approach aims to enhance maintenance efficiency, reduce human exposure to hazardous environments, and provide a practical solution for modern drainage management systems.

IV. BLOCK DIAGRAM AND EXPLANATION

Power Supply and Battery Management: This block supplies regulated power rails (for example 12V/24V for motors and 5V/3.3V for electronics) coming from the rechargeable Li-ion battery pack. It contains DC–DC converters, a battery management system (BMS) for charging/discharging protection, current sensing for power monitoring, and fuses/emergency cutoffs. The BMS communicates status (voltage, current, stateof-charge, fault) to the controller so the robot can make safe decisions—e.g., abort a mission when battery falls below a threshold and return or pause operation. Main Controller (ESP32): The ESP32 is the central brain. It receives sensor data, runs control logic, executes autonomous

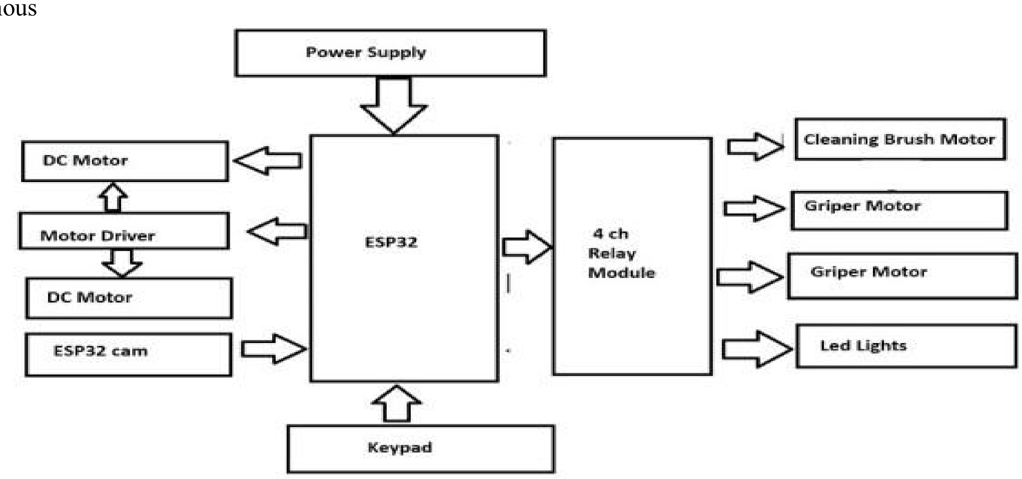

Fig. 1. Block Diagram

routines, and orchestrates actuators. It hosts the firmware that handles mode selection (autonomous/manual), sequencing (cap removal → inspection → cleaning → cap replacement), and real-time decision-making. It also interfaces to peripherals using GPIO, PWM, ADC, I²C, SPI, UART and handles Wi-Fi/RF stacks for telemetry and video streaming control signals. Mo motor Drivers Actuator Interface: This block contains motor driver ICs (H-bridges for DC motors, MOSFET drivers for brushed/BLDC motors, stepper drivers if used for arms) and any intermediate control logic (encoders, current sensors). The ESP32 sends PWM/speed commands and receives encoder ticks and

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 6, Issue 11, May 2026 Impact Factor: 8.2

motor health information. Motor drivers provide the required torque to the robotic arm, gripper actuator, mobility motors (tracks/wheels), and the rotating brush. Closedloop control (PID) runs on either the ESP32 or a dedicated motor controller for precise motion and torque limiting. Robotic Arm Gripper Mechanism: Mechanically, the arm and gripper are responsible for manhole cover manipulation. The arm block encompasses servos/geared motors, position/limit switches, and optionally encoders for joint angle feedback. The gripper includes force/torque sensors or current sensing to detect successful grasp and prevent over-torque. The arm receives motion trajectories or step commands from the main
controller; feedback ensures safe lifting and placing operations. Mobility Unit (Tracks / Wheels) Locomotion Control: This block covers the chassis, drive motors, suspension or track mechanisms, and local encoders/IMU for odometry. The locomotion controller uses sensor feedback (IMU, wheel encoders) to maintain stability while positioning for cap removal, lowering into the manhole, and retracting after cleaning. It also performs obstacle detection and short-range obstacle avoidance when moving on surface or inside shallow pits. Inspection Vision System (ESP32-CAM / Camera Module): The inspection unit carries the camera, LEDs for illumination, and optionally a pan/tilt mechanism. The ESP32-CAM streams live video to the main controller or directly to the web/app backend. Video frames are used for operator monitoring and (optionally) onboard image processing for blockage detection, alignment guidance, and autonomous decision making. The camera block also provides snapshots to the data logger for archival. Cleaning Mechanism (Brush
/ Water Jet / Suction): This block includes the rotating brush motor with gearbox, water pump and high-pressure lines (if water jet is used), valves, and a suction module (if incorporated). The cleaning controller manages brush speed and pump pressure according to the cleaning mode commanded by the main controller or operator. Sensors in this block (flow, pressure, RPM) provide feedback to optimize cleaning effectiveness and protect against jams. Sensor Suite: A set of environmental and proximity sensors feed situational awareness: ultrasonic or LiDAR for depth/obstacle detection, IR or proximity sensors for shortrange alignment, gas sensors (MQ series or electrochemical) for hazardous gas detection, temperature sensors, humidity sensors, and an IMU for orientation. These sensors stream real- time data to the ESP32 for safety checks (e.g., hazardous gas above threshold → abort) and navigation. Communication Module (Wi-Fi / RF / Telemetry): Although ESP32 includes Wi-Fi, the communication block may also include an RF transceiver or LTE/GSM modem for redundancy in lowcoverage zones. This block handles secure video streaming, telemetry (sensor data, battery status, operation logs), remote control commands, and OTA firmware updates. Communication protocols include TCP/UDP, MQTT for telemetry, and RTSP/HTTP for live video. Encryption and authentication are applied to avoid unauthorized control. Human Interface (Web/App UI Remote Control): This software block runs on a remote PC or mobile device. It receives live video, telemetry, and logs and allows the operator to switch modes, control arm motions, trigger cleaning, and view status. The UI also displays alerts (gas levels, low battery, motor faults) and provides manual overrides with safety interlocks such as deadman switches and confirmatory prompts before highrisk actions. Data Logger Cloud Integration: Operation logs, video clips, and sensor histories are stored locally (SD card) and optionally pushed to cloud storage for long-term archival, analytics, and maintenance scheduling. Cloud integration enables centralized fleet management, predictive maintenance analytics, and historical reporting for municipal authorities. Safety Fault-Handling Subsystem: This block comprises emergency stop circuitry, limit switches, watchdog timers, current/thermal monitors, and a failsafe routine in firmware. On detecting critical faults (e.g., gas threshold exceeded, motor overcurrent, comms loss), the system enters a safe state—halt motors, retract cleaning unit if possible, re-install cover if safe, and notify operator. Redundant checks and hardware kill switches ensure failsafe behavior.

V. HARDWARE DESIGN

The hardware design of the proposed drainage inspection and cleaning robot integrates multiple embedded and electromechanical components to perform inspection, movement, and cleaning operations. The system is centered around the ESP32 microcontroller, which serves as the primary control unit. 1. ESP32 Microcontroller The ESP32 acts

DOI: 10.48175/IJARSCT-35880

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 11, May 2026
Impact Factor: 8.2

as the central processing unit of the system. It controls motor operations, relay switching, camera interfacing, and keypad inputs. Additionally, the built-in Wi-Fi capability enables wireless communication for remote monitoring and control. 2. ESP32-CAM Module The ESP32-CAM module is used for real-time video streaming and image capture inside drainage pipelines. It allows visual inspection of blockages, debris, and internal pipe conditions. LED illumination assists in low-light environments. 3. Motor Driver and DC Motors Two DC motors are connected to the ESP32 through a motor driver module. These motors provide locomotion to the robot, allowing forward, backward, and directional movement. The motor driver enables safe current amplification and direction control based on ESP32 signals. 4. Relay Module A 4-channel relay module is employed to control high-power devices such as the cleaning brush motor, gripper motors, and LED lights. The ESP32 sends control signals to the relay module, enabling selective activation of each peripheral device.

5. Cleaning Brush Motor The cleaning brush motor removes accumulated waste and minor blockages within the drainage system. It is activated via the relay module when debris is detected or when commanded manually. 6. Gripper Motors Two gripper motors are used to hold or manipulate solid waste materials. These motors assist in removing larger debris that cannot be cleared by brushing alone. 7. LED Lighting LED lights are provided to illuminate dark pipeline environments, improving camera visibility during inspection. 8. Keypad Interface A keypad is used as a manual input device, allowing operators to issue movement and cleaning commands directly to the system. 9. Power Supply Unit The power supply provides regulated voltage to all system components. It ensures stable operation of the microcontroller, motors, camera, and relay module.

VI. SOFTWARE DESIGN

The software design of the proposed drainage inspection and cleaning robot is developed to coordinate sensing, motion control, video streaming, and cleaning operations through the ESP32 microcontroller. The system firmware is implemented using the Arduino IDE, which provides an efficient development environment for ESP32-based embedded applications. The software architecture is divided into several functional modules, including motor control, camera streaming, relay control, keypad input processing, and wireless communication. Each module operates under the supervision of the main control program. At startup, the ESP32 initializes all peripheral devices such as the motor driver, relay module, ESP32-CAM, keypad, and Wi-Fi interface. Once initialization is complete, the system establishes a wireless connection, enabling remote monitoring and command transmission. Motor control algorithms manage the movement of the robot based on user inputs received via keypad or wireless interface. Directional commands such as forward, reverse, left, and right are processed by the ESP32 and executed through the motor driver. The relay control module activates the cleaning brush motor, gripper motors, and LED lights as required. The ESP32-CAM module continuously captures video frames and streams them wirelessly to the monitoring device, allowing real-time visual inspection of drainage conditions. The software also handles manual override commands, enabling operators to directly control cleaning operations when necessary. A continuous loop structure is employed to monitor inputs, update motor states, manage relay outputs, and transmit video and system status data. Error handling routines are included to ensure safe operation in case of communication failure or power instability. Overall, the software design integrates inspection, mobility, cleaning, and communication functionalities into a unified embedded control system. This modular approach enhances system reliability, simplifies debugging, and supports future upgrades such as autonomous navigation or AI-based defect detection.

VII. METHODOLOGY

The methodology adopted for the proposed drainage inspection and cleaning robot focuses on integrating inspection, mobility, blockage detection, and cleaning operations into a single embedded robotic platform. Earlier studies have demonstrated the use of in-pipe robots for visual inspection and debris removal [1], [2], while IoT-based systems enable real-time monitoring and remote control [5], [8], [10]. Building upon these concepts, the proposed approach combines ESP32-based control, camera surveillance, motorized locomotion, and relaydriven cleaning mechanisms.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 11, May 2026
Impact Factor: 8.2

Initially, the hardware components including ESP32, ESP32- CAM, motor driver, DC motors, relay module, keypad, and power supply are assembled according to the designed block diagram. The ESP32 acts as the central controller, coordinating all sensing and actuation tasks. Similar to ESP32-CAM–based inspection systems reported in [7], the camera module provides live video streaming for monitoring internal pipeline conditions. After hardware integration, firmware is developed using the Arduino IDE. The software initializes all peripherals and establishes wireless communication. Movement commands are processed to control DC motors through the motor driver, allowing navigation inside drainage pipelines. Blockage identification is carried out using visual feedback and operator observation, as practiced in earlier inspection robots [3], [4], [12]. Cleaning operations are performed through a brush motor and gripper motors controlled via a 4-channel relay module. When debris is detected, the ESP32 activates the corresponding relay to initiate cleaning. LED lights are switched on to improve visibility in dark environments, supporting camerabased inspection similar to multi-sensor systems described in [13]. Manual input through a keypad and wireless control allows operators to guide the robot and trigger cleaning actions when required. Although advanced AI-based defect detection and SLAM navigation have been explored in recent research [11], [14], the proposed system emphasizes simplicity and cost-effectiveness while maintaining essential inspection and cleaning capabilities. This design choice aligns with review studies highlighting the need for affordable and scalable robotic drainage solutions [6], [9], [15]. Finally, real-time video and system status are transmitted to the monitoring interface, enabling continuous supervision. The integrated methodology ensures safe inspection, effective debris removal, and reduced human exposure to hazardous sewer environments.

VIII. IMPLEMENTATION DETAILS

The proposed drainage inspection and cleaning robot was implemented by integrating hardware components with embedded software to achieve real-time monitoring, mobility, and cleaning operations. The system is developed around the ESP32 microcontroller, which coordinates sensor inputs, motor control, relay activation, and wireless communication. Initially, all hardware components including the ESP32, ESP32-CAM, motor driver, DC motors, relay module, keypad, LED lights, and power supply were assembled according to the designed block diagram. Proper voltage regulation was ensured to protect sensitive components. The ESP32 was programmed using the Arduino IDE, where libraries for WiFi communication, camera interfacing, and motor control were integrated. The firmware begins by initializing peripherals and establishing a wireless connection. Once connected, the ESP32-CAM starts streaming live video, allowing operators to visually inspect drainage interiors. Robot movement is controlled through keypad inputs or wireless commands, which are processed by the ESP32 and executed via the motor driver. Relay modules are used to switch high-power devices such as the cleaning brush motor, gripper motors, and LED lights. When debris is observed through the camera feed, corresponding relays are activated to initiate cleaning operations. LED illumination enhances visibility in low-light pipeline environments. During testing, the robot demonstrated stable navigation in confined spaces and effective removal of minor blockages. Real-time video transmission enabled continuous supervision, reducing the need for direct human involvement. Manual override capability ensured operational safety during unexpected conditions. The implementation validates the feasibility of integrating inspection, cleaning, and wireless monitoring into a single embedded robotic platform. The modular design allows easy troubleshooting and supports future upgrades such as autonomous navigation and AI-based defect detection.

IX. WORKING ALGORITHM

Step 1: Switch ON the power supply and initialize all system modules.
Step 2: ESP32 establishes wireless connection and activates ESP32-CAM.
Step 3: Robot receives movement commands through keypad or wireless interface.
Step 4: DC motors drive the robot inside the drainage pipeline.
Step 5: Live video stream is monitored for debris or blockage detection.
Step 6: When obstruction is identified, ESP32 activates relay module.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 11, May 2026
Impact Factor: 8.2

Step 7: Cleaning brush motor starts removing accumulated waste.
Step 8: Gripper motors assist in handling solid debris if required.
Step 9: LED lights illuminate dark pipeline environment.
Step 10: After cleaning, robot resumes inspection or returns to start position. Step 11: System continuously transmits video and operational status.

X. RESULTS

The proposed ESP32-based drainage inspection and cleaning robot was successfully implemented and tested in a controlled environment. All hardware modules operated as expected, including the ESP32 controller, ESP32-CAM, motor driver, relay unit, and cleaning mechanism. The robot demonstrated smooth movement inside narrow paths, and real-time video streaming enabled effective visual inspection of internal drainage conditions. The cleaning brush motor efficiently removed light debris, while the gripper motors assisted in handling larger waste materials. LED illumination improved visibility in dark environments.

Wireless monitoring allowed remote supervision of robot operations, reducing the need for human intervention in hazardous areas. The system showed stable performance with minor communication delays that did not significantly affect functionality. These results confirm that the proposed system can effectively perform inspection, monitoring, and cleaning tasks, providing a low-cost and practical solution for drainage maintenance.

Fig. 2. Results

XI. CONCLUSION AND FUTURE WORK

This paper presented the design and implementation of an ESP32-based drainage inspection and cleaning robot aimed at reducing human involvement in hazardous sewer environments. The proposed system integrates real-time video monitoring, motorized locomotion, and relay-controlled cleaning mechanisms into a compact embedded platform. The experimental results demonstrate effective navigation in confined spaces and successful removal of minor debris, validating the feasibility of the proposed approach. Similar inspection and cleaning concepts have been explored in earlier robotic systems [1], [2], while IoT-enabled monitoring further enhances operational efficiency [5], [8], [10]. Recent advancements in AI-powered defect detection and multi-sensor inspection platforms show promising improvements in accuracy and autonomy [11], [13], [14]. However, such systems often increase hardware complexity and cost. In contrast, the proposed design emphasizes affordability and practical implementation, aligning with review studies that highlight the need for scalable and economical drainage maintenance solutions [6], [9], [15]. Future work will focus on incorporating autonomous navigation using SLAM, AI-based blockage and crack detection, and gas sensors for

hazardous environment monitoring. Integration of cloud-based data storage and mobile application interfaces is also planned to support smart city infrastructure and longterm pipeline health assessment

ACKNOWLEDGMENT

The authors would like to thank Pravara Rural Engineering College (PREC) and Savitribai Phule Pune University (SPPU) for their guidance and support throughout this research project. We extend our sincere gratitude to our project guide Dr.S.M.Turkane for his valuable insights, continuous encouragement, and practical guidance that helped shape the research direction and implementation approach. Special thanks to all the volunteers who participated in the testing phase and provided valuable feedback about system usability, comfort, and practical performance in real riding conditions. We also acknowledge the support of departmental staff and fellow students who contributed to various aspects of the project through discussions, technical assistance, and moral support during challenging phases of the development process.

REFERENCES

1. R. Shelke, D. Londhe, P. Gawade, and H. Patil, “Design and Implementation of In-Pipe Inspection Robot,” International Journal of Engineering Research and Technology (IJERT), vol. 12, no. 5, pp. 245–250, 2023.
2. P. Jamadar, P. Mali, M. W. Dilawar, and M. M. Jadhav, “Pipe Inspection and Cleaning Robot,” International Research Journal of Engineering and Technology (IRJET), vol. 10, no. 4, pp. 1–6, Apr. 2023.
3. “Design and Fabrication of Manhole Cleaning Machine,” Student Project Paper, India, 2023.
4. “Sewage Cleaning Robot,” Educational Project Publication, India, 2023.
5. A. Kumar and S. Gupta, “Artificial Intelligence-Based Smart Drainage Cleaning Robot,” International Journal for Research in Applied Science and Engineering Technology (IJRASET), vol. 12, no. 1, pp. 450–456, 2024.
6. S. Deshmukh, R. Patil, and K. Nair, “A Review on Manhole Monitoring System,” IJRASET, vol. 11, no. 7, pp. 870–875, 2023.
7. M. Shah and N. Patel, “Pipeline Leak Detection and Localization Robot with ESP32-CAM,” IJSRST, vol. 12, no. 2, pp. 100–106, 2025.
8. “Simulation and Development of Sewage Cleaning and Monitoring Robot using IoT,” Proc. National Conf. on Intelligent Systems and Automation, 2023.
9. “Pipeline, Sewage, and Manhole Cleaning Robotic Systems – A Review,” IRJMETS, vol. 9, no. 3, pp. 1120–1126, 2022.
10. S. Sharma and P. Agarwal, “IoT-Based Autonomous Drainage Maintenance Robot,” IEEE ICIRCA, 2023.
11. L. M. J. Melvin, A. Thomas, and J. George, “Remote drain inspection framework using CNNs,” Scientific Reports, vol. 11, no. 1, p. 10342, 2021.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 11, May 2026
Impact Factor: 8.2

12. R. M. Bommi, A. Kumar, and S. Varma, "Sewage pipe inspection robot for block detection and clearance," Proc. AIP Conf., pp. 145–150, 2022.
13. J. T. Jung, S. H. Park, and H. Y. Lee, "Improving sewer damage inspection using multi-sensor robotic system," Sensors, vol. 24, no. 3, p. 789, 2024.
14. D. Zholtayev, Y. Kim, and J. Park, "Smart pipe inspection robot with AIpowered defect detection and SLAM navigation," Journal of Intelligent Robotic Systems, vol. 112, no. 5, pp. 2201–2215, 2024.
15. M. Nashat and K. Rahman, "Hybrid review of sewer inspection tools and automated systems," Automation in Construction, vol. 162, p. 105992, 2025.