

Ladies Washroom Maintenance System Using AI and IOT

V.D. Vaidya¹, More Arati², Raut Pooja³, Kaduskar Ishwari⁴, Karpe Sayali⁵

¹Professor, Dept. of Cloud Computing and Big Data, P.Dr.V.V.P. Institute of Technology and Engineering, Loni, Maharashtra, India

^{2,3,4,5}Final year Diploma Student, P.Dr.V.V.P. Institute of Technology and Engineering, Loni, Maharashtra, India

Abstract - Standard manual inspection and cleaning procedures are frequently time-consuming and ineffective, making it extremely difficult to maintain cleanliness in public restrooms, especially in heavily populated locations. Using Internet of Things (IoT) and sensor monitoring, this project demonstrates a smart public restroom maintenance system that can automate maintenance tasks and control hygiene in real-time. Equipped with sensors that track occupancy, water and soap levels, odor, and cleanliness, the system instantly notifies users when actions are needed. Predictive maintenance and effective resource allocation are made possible by transmitting data generated by Internet of Things devices to a central platform for monitoring and analysis. By keeping the facilities clean and sanitary, the suggested approach not only increases operating efficiency and decreases maintenance costs, but it also increases user happiness. In line with present needs for smart urban infrastructure and public health safety, this system offers a sustainable and scalable method for maintaining public washrooms by combining automation, the internet of things (IoT), and hygiene management concepts.

Key Words: *IoT, Sensor Monitoring, Hygiene Management, Automated Maintenance*

1.INTRODUCTION

It is essential for the efficient running of urban infrastructure that big public areas, such as train stations, airports, shopping malls, schools, and government buildings, have access to public bathrooms. Public restrooms are notoriously difficult to maintain in a clean and sanitary state, despite the fact that they are quite important. The conventional methods of maintenance rely mainly on hand examination and cleaning, which is labor-intensive, random, and inefficient. The result of this is that there is a dearth of basic supplies such as soap, water, and tissue paper, as well as dissatisfaction among users and conditions that are not sanitary. There is a potential threat

to the health of the general public when public restrooms are not properly maintained. This can lead to the spread of diseases as well as other health issues.

Because of the growing number of people living in metropolitan areas and the increased utilization of public facilities, there is a larger demand than ever before for bathrooms that are always clean and well-maintained. Maintenance practices that have been around for a long time are typically reactive rather than proactive. For instance, a maintenance worker might simply clean the restroom once or twice a day, despite the fact that the restroom is utilized on a regular basis. Inefficient use of labor and resources could occur if restrooms that are used frequently were allowed to remain in a state of disrepair while those that are used infrequently were cleaned without any necessity. It is also possible for users to feel discomfort and aggravation if essential items such as soap, hand sanitizer, and toilet paper are missing during times of high demand.

One possible technological answer to these issues is provided by monitoring systems that are connected to the Internet of Things (IoT). The utilization of public restrooms, the levels of water in water tanks, the availability of soap and tissue, the detection of odors, and the signs of cleanliness can all be monitored in real time with the assistance of sensors. Maintenance workers are able to receive real-time warnings as a result of the analysis of this data, which allows them to swiftly clean and replenish supplies. The utilization of automated monitoring systems not only results in an improvement in hygiene standards, but it also optimizes the workloads of cleaning workers, reduces the amount of resources that are squandered, and makes maintenance more efficient and responsive.

Using solutions that are made available by the Internet of Things, it is possible to significantly enhance the quality of maintenance performed on public restrooms, as indicated by a number of studies and deployments. Through the integration of sensors, cloud-based monitoring, and smartphone notifications, maintenance

workers are able to receive real-time updates whenever a restroom requires repair. Data that is collected over a period of time can also reveal patterns of use, which can lead to more efficient resource allocation and maintenance that includes predictive maintenance. Taking this proactive strategy results in an increase in the overall happiness of the public, a decrease in the chance of unhygienic conditions, and a reduction in the number of user complaints.

[1] The goal of Amar Lokman et al. proposed smart toilet scheduling is to make the most optimal use of author limited resources. You can see author updated ARIGA model right here. Because it employs both scheduling and prediction algorithms, ARIGA is able to plan and anticipate maintenance for a building's Internet of Things (IoT) sensors. Because of this, ARIGA can plan and anticipate when building IoT sensors will need maintenance. To accomplish the second objective, genetic algorithms are employed to modify the janitor's shift schedule. Experiments on different floors and user populations showed that the suggested method reduced the number of cleaners by an average of 24.7% and an overall reduction of 15%. This was established by comparing the outcomes of the experiments. At the moment, the model is testing two scheduling methods: baseline and the greedy algorithm. The approach is outlined in Section III. Predictive maintenance on smart toilet systems is the intended use of the offered technology in this study. Researchers from all walks of life are getting into the latest developments in machine learning, especially deep learning algorithms. It is crucial to evaluate the unique approaches' efficiency and precision in comparison to the conventional method. Two well-known time series prediction algorithms, ARIGA and LSTM, will be compared in the next section to determine which one is superior. The data collected from the identical set of Internet of Things sensors was used by both models. Prediction accuracy was improved by the ARIGA model, which reduced RMSE, MAE, and MAPE. To reduce AIC and BIC, the ARIGA needs to be adjusted to the correct AR value.

[2] Novie R. A. Palar et al. presented that service goods alone do not reveal how well public services are implemented. However, it's also important to have amenities that let each person work smoothly. Workers in government offices require access to restrooms in order to defecate and urinate while performing office duties. Anyone visiting a government office is subject to the same rules. Therefore, a clean and functional restroom is essential. It is clear from the state of cleanliness and the availability of facilities that

government offices' toilet sanitation management has been lacking up until this point. When it comes to cleanliness and hygiene, the majority of government restrooms are far from adequate. Poor toilet sanitation management is due to the lack of a dedicated team whose sole purpose is to ensure that all restrooms are kept clean and sanitary at all times. It is essential for a government office to have a dedicated work unit responsible for managing restroom sanitation. Through a cleaning service workforce outsourcing system, the government can collaborate with third parties to ease the development of work units. Government agencies will have an easier time providing adequate restrooms and meeting health regulations when they outsource cleaning services to private companies.

[3] Isabel Wagner et al. described that there are situations in which smart toilets are really useful. In cases where alternative methods of monitoring would be excessively burdensome (such as when traveling) and if continuous monitoring of particular health parameters is medically necessary, this would be the case either the patient's fault (forgetting to record) or the hospital's fault. It is important to weigh the potential health benefit against the hazards to privacy and other areas. It appears that the health benefit is probably too modest for widespread and universal use, considering the potential privacy problems and negative impacts. Nevertheless, there are measures that smart toilet manufacturers can do to mitigate privacy concerns. Technical safeguards, such as local data processing and the pseudonymization of recorded data, can be put in place by them. There are two major problems with this: first, manufacturers of smart toilets are unlikely to be interested in implementing privacy-preserving measures because their business model likely depends on some form of health data exploitation, and second, there is a lack of evidence in published designs and academic literature of sufficient expertise in privacy-by-design and data protection during the toilets' design.

The second section of this research analyzes prior studies classified as Literature Surveys. In Section 3, the course of action is detailed in great detail as Proposed methodology. Part 4 delves into the experimental examination, while Section 5 considers alternative revisions before concluding the essay with a statement on the existing plan.

2. LITERATURE SURVEY

[4] Kavita V. Horadi et al. examined for an IoT-based toilet monitoring system as a game-changer for India's public sanitation infrastructure, which has been plagued by ongoing problems. It is critical to find new

solutions quickly because open defecation, inadequate facilities, and badly maintained public restrooms are widespread problems. There is a need for a centralized monitoring mechanism to ensure that current sanitation measures are effective, despite noble endeavors such as the Swacch Bharat Mission Urban. By utilizing cutting-edge technology, such as a web server and a mobile cleaning application, the suggested IoT-based system fills this void. Through the implementation of real-time cleaning metric tracking, the system creates a two-way feedback loop between administrators and cleaners, allowing for timely interventions in response to user input. Public restroom upkeep is made more efficient and environmentally friendly with this system's innovative features, which include automatic water flush, UV sanitization, and other cutting-edge functionality. An effective and practical intervention, the IoT-based system has the ability to scale and be used in a wide variety of places, such as homes, schools, hospitals, companies, and enterprises. Through its cost-effective and efficient solution, the system serves as a driving force for positive transformation, paving the way for improved and long-lasting public sanitation infrastructure. Overarchingly, the suggested system is an innovative and realistic solution to India's long-standing sanitation issues, which would help create a better and more sustainable future.

[5] Kahpi Baiquni Arifani et al. demonstrates that an automated system may be created by integrating the Internet of Things (IoT), fuzzy logic, and a user interface built on the Flutter framework. This technology, which has room for improvement, provides a novel approach to managing energy use in public buildings, lends credence to the sustainability movement, and opens the door for the introduction of related technologies in other fields. Particularly in communal spaces like restrooms, the device significantly aids in the fight for better energy management. The system enhances user comfort while supporting environmental sustainability objectives because to its flexible control and great energy economy. Applications that necessitate intelligent control based on IoT and fuzzy logic, such as smart buildings or smart homes, can also benefit from the results.

[6] Jingye Xu et al. discussed in implementing a touchless toilet monitoring system was to enhance patient care while simultaneously protecting their privacy. A preliminary experiment proved the system's usefulness for managing tasks associated to the restroom, as it accurately inferred real-time actions and recognized different movements. When it comes to additional

reminder and monitoring apps, author system offers a versatile solution that prioritizes privacy protection while detecting presence and tracking activities. author plan to continue investigating the following areas, building on author initial study: To better understand how to identify subjects and improve activity recognition models, author intend to collect additional data. author system's future expansion into a full-fledged home assistive monitoring and reminder framework for effortless task management is also in the works. The possibilities for improved functionality, customization, and user engagement can be explored by integrating an LLM-powered agent into the reminder system.

[7] Haiyong Shen et al. explored on the third restroom, a significant public area that represents social care and service offering. It follows a systematic design research pathway of requirement identification, indicator construction, scheme evaluation, and optimization recommendations in order to address diverse user needs and optimize design decision-making. An analytical framework is developed by integrating the TOPSIS method with the Fuzzy Kano model. The Fuzzy Kano model was used to identify the multi-level functional demands of third restroom users. This allowed us to prioritize requirements and increase the design's relevance. At the same time, a thorough system of evaluation was built, with twenty subsidiary indications that had been developed and seven main dimensions. In order to ensure the suggested framework is both practical and logically sound, the study used the TOPSIS approach to rank three sample design schemes for public facility evaluations.

[8] F. I. Azman et al. accomplished all of authors research goals. Based on real-time data including ammonia levels, humidity, temperature, and occupancy, the suggested system optimizes cleaning operations by deploying janitorial personnel only when needed. Restroom conditions can be accurately assessed thanks to the high relationships found between environmental elements and IAQ markers. Even with a large number of users, the ammonia levels are kept safe by the efficient ventilation. Nevertheless, air quality could be significantly affected by the overuse of cleaning products. All things considered, the technology shows promise as a means to better control toilet hygiene, lower operational expenses, and increase user safety and comfort.

[9] Ahmet Karagoz et al. elaborated a single inexpensive ultrasonic sensor has allowed for the

realization of a system design that can identify and classify things; this sensor can be included into autonomous and robotic systems. The software architecture, preprocessing, feature extraction, and classification procedures, as well as the fast and secure data collecting system, provide an alternate solution to the object recognition problem, which is still an issue today. Its substantial addition to the field is due to its real-time object information retrieval, tracking, and interpretation capabilities through an interface, which enable object recognition. The ultrasonic sensor's embedded hardware provides a dependable data set creation infrastructure, in contrast to market-available unreliable sensor systems. With these new features, it's easy to see how ultrasonic sensors might help with practical issues. The study stands out and is significant since it uses raw ultrasonic signal data, statistical characteristics for feature extraction, and input features like distance and angle information. As the number of items increases, the suggested ANN architecture is fine-tuned to improve classification success. Consequently, it outperformed all other machine learning algorithms in terms of classification accuracy. In cases where camera systems are inadequate, this study could be utilized. Using signal information from ultrasonic sensors, object classification can be achieved. Additionally, a framework can be set up to enable control mechanisms, cross-validation, and integration with camera systems in security systems. The study's strength and uniqueness are highlighted by the high rate of categorization success attained even if the objects are close to each other

[10] Ayu Mika Sherila et al. showcased the development and assessment of a Smart Trash Bin System with two sensors that utilizes a Sugeno-type Fuzzy Logic Controller (FLC) to facilitate eco-friendly and contactless garbage collection. With the help of the MQ-2 gas sensor and the HY-SRF05 ultrasonic sensor, the system is able to adaptively control the bin lid in five different states, from completely closed to completely open. High dependability was shown during experimental validation using 25 test scenarios. All cases yielded less than 9% error and the average deviation was only 1.91%. Confirming the system's accuracy and mechanical stability under various conditions, the servo mechanism closely matched the projected output angles. The findings demonstrate fuzzy logic's potential as an adaptable and versatile control approach that can deal with uncertainty and sensor imprecision. Thanks to its lightweight implementation on Arduino, the proposed framework achieves performance that approaches ANN-level

accuracy without the high computing demands of AI-based systems. It also offers improved adaptability compared to conventional threshold-based controllers. Fuzzy sensor fusion offers a well-rounded solution that is both efficient and cost-effective, thanks to these benefits.

[11] Debanjon Dutta Purkaystha et al. introduced optimal hygiene and meeting the demand for sustainable sanitation solutions, an eco-friendly bio-toilet with an IoT-based hygiene maintenance system offers numerous advantages. To treat human waste in an eco-friendly manner, the bio-toilet uses bio-digesters. This reduces water consumption and eliminates the need for harmful chemicals. Integrating IoT devices allows for efficient regulation and monitoring, which in turn improves efficiency and decreases the need for maintenance. With real-time data, this system can detect possible malfunctions, track waste levels, and monitor temperature, all of which help with strategic maintenance and performance improvement. Reliability of the system and continuity of operations are guaranteed by this proactive approach. A cleaner, more sustainable environment is promoted by technology through water conservation and pollution prevention. An effective and convenient toilet system is made possible through the combination of cutting-edge technology, environmentally conscious waste treatment, and automated hygiene maintenance. Modern sanitation needs are met by this innovative approach to operational efficiency and resource management, which also helps to improve hygiene standards and reduces environmental impact.

[12] Ali Emre Öztürk et al. demonstrated a secure and privacy-aware deep learning system for monitoring restrooms using audio. Including complex faucet configurations and flow rates, it can accurately and generically categorize eleven separate hygiene and water-usage events. The suggested system employs a unique third-channel generation approach that makes use of stereo audio recordings converted to Mel spectrograms. In this approach, a trainable 1D-CNN adaptively fuses spatial audio cues in order to enhance discriminative capacity. Under rigorous domain shift conditions, with training and testing environments that were acoustically separate, author final ensemble model—which consisted of two RegNetY-008 networks that received complementary third-channel inputs—achieved a 97.8 percent accuracy and a macro-averaged F1-score of 0.966. Improved model robustness was achieved without the need for extra human annotation by combining targeted data augmentation techniques with semi-

supervised learning through pseudo-labeling. Most importantly, author offer a stereo audio dataset that has been curated, labelled, and unlabeled, and that has been gathered from five different bathrooms with different acoustic properties. By making this dataset available to the public, author are giving researchers a great tool to improve privacy-preserving sound event detection in practical applications. This work has substantial real-world consequences. Without the need for cameras or wearable devices, the system can guarantee user privacy while supporting hygiene compliance monitoring, water usage analysis, and safety detection in settings like smart homes, hospitals, and eldercare facilities. In preparation for future work spanning a wide range of institutions, architectural styles, and use cases, author intend to augment the dataset. To further explore the limits of privacy-aware behavior monitoring, it may be helpful to investigate multi-modal extensions using non-visual sensors in order to decipher classes that sound similar.

[13] Winata Tegar Saputra et al. displayed who live in close proximity to the Citarum River have nothing but praise for the water monitoring system, which has the ability to enhance the water quality that is essential for farming, fishing, and domestic use. The method also helps get the word out about how important it is to keep rivers clean, since they are home to all sorts of life—human, animal, and plant. In order to meet community expectations and make the most of the system, it is essential to address privacy concerns and keep the water clean. The study does, however, have a number of caveats. The monitoring device can only tell you how clean the water is; it can't find the pollution sources or fix the water for you. Less is known about the monitored parameters as well. In addition, the Arduino-based solutions did not have their concerns about data protection and backend management resolved. As a result, author need more sophisticated methods of monitoring water quality and Internet of Things (IoT)-based solutions to clean up industrial or domestic waste. To enhance the system's range and dependability, these tools might incorporate extra metrics like dissolved oxygen and nitrate levels and make use of alternative communication technologies like LoRaWAN or NB-IoT. Protecting river ecosystems and its environs is a pressing environmental concern, and this work provides useful information and resources to that end. A number of rivers in Indonesia could benefit from the water monitoring system, which could help stop the pollution that is already there. The surveillance system can also be used to keep an eye on how the manufacturing facility handles its trash

disposal. By meeting all applicable regulations, this device may serve as a reliable water monitoring solution. Since there isn't already a web-based system in place to track the Citarum River's water levels in real-time, the West Java Provincial Government might implement this system. If any parameter indicators differ from the norms for unpolluted water, Citarum Harum authorities can react quickly with this method. Communities along the Citarum River can also keep enjoying the river's many uses without fear of harm.

[14] Leila Droprinichinski Martins et al. proposed that there are still gaps in continuous and real-time odor monitoring, even though there are promising opportunities to expand odor monitoring with low-cost sensors and IoT devices, particularly for environmental applications in regions with low and middle incomes. Based on their research, it is clear that there are still some issues with commercially available low-cost sensor models and IoT-enabled instruments. These include narrow quantification limits, inaccurate results in complex odor environments, high relative costs at destination markets, and a lack of widespread deployment by local authorities. Furthermore, environmental managers have not received or implemented many solutions, and many municipalities cannot afford or access professional monitoring systems. Before low-cost odor sensing technologies to relyably augment or substitute established odor monitoring frameworks, they require additional development, greater dissemination, and better integration.

3. METHODOLOGY

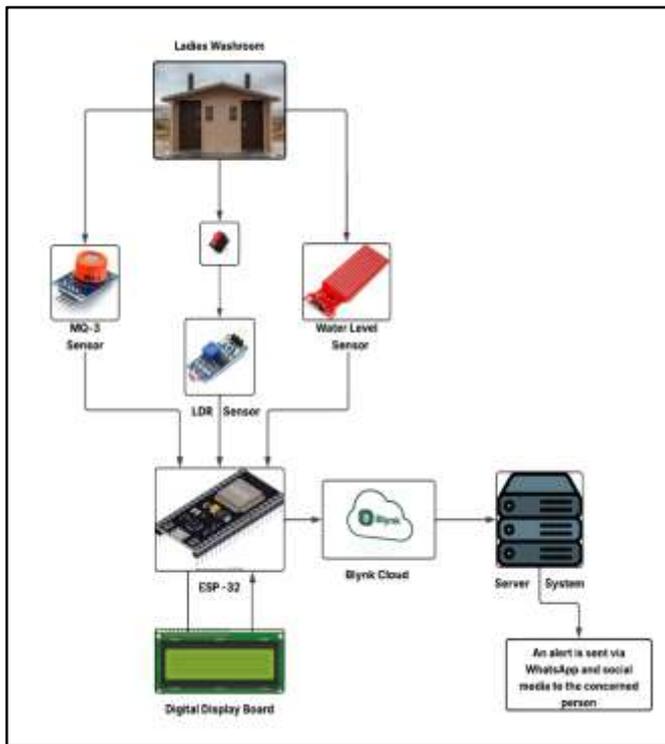


Fig 1: Overview Diagram

The proposed Ladies Washroom Maintenance System using Artificial Intelligence (AI) and Internet of Things (IoT) is designed to monitor hygiene and facility conditions inside a ladies' washroom in real time. The system integrates multiple sensors, a microcontroller, cloud communication, and an alert mechanism to ensure proper maintenance and safety. By continuously collecting environmental data and analyzing it through intelligent decision-making techniques, the system helps detect issues such as poor air quality, insufficient lighting, and low water availability. The overall workflow of the system is illustrated in the diagram, where sensor data is collected, processed, transmitted to the cloud, and analyzed to generate alerts for maintenance staff.

Step 1: Washroom Environment Monitoring using Sensors

In the first stage, several sensors are installed inside the washroom to continuously monitor the surrounding conditions. These sensors detect environmental parameters that directly affect hygiene and usability. The MQ-3 Gas Sensor is used to detect unpleasant odors or harmful gases that may indicate poor sanitation or lack of cleaning. The Light Dependent Resistor (LDR) measures the light intensity inside the washroom to ensure that sufficient lighting is available for users. In addition, a Water Level Sensor is placed in the water storage tank to monitor the availability of water

used for flushing and cleaning purposes. These sensors continuously collect environmental data and send the readings to the central processing unit for further analysis.

Step 2: Data Processing using Microcontroller

The collected sensor data is transmitted to the ESP32, which acts as the core controller of the system. The ESP32 receives signals from all connected sensors and processes them according to predefined threshold values. For example, if the gas sensor detects an abnormal increase in odor levels, if the LDR sensor detects low lighting conditions, or if the water level sensor detects insufficient water supply, the ESP32 identifies these conditions as maintenance issues. The microcontroller also controls the digital display board, which shows the current washroom status, including water level information and alert messages. This allows nearby staff members to quickly check the condition of the washroom without accessing the cloud platform.

Step 3: Cloud Communication and Data Storage

After processing the sensor readings, the ESP32 sends the data to the cloud using the Blynk IoT Platform. The cloud platform acts as a central monitoring system where all washroom data is stored and analyzed. Through internet connectivity, administrators can remotely access the system and monitor washroom conditions in real time. The cloud server also maintains historical records of sensor readings, which can be used to analyze washroom usage patterns and identify frequently occurring maintenance issues.

Step 4: AI-Based Decision Making and Alert Generation

Once the sensor data reaches the cloud server, the system performs intelligent analysis to determine whether the washroom requires maintenance. AI-based decision rules compare the incoming sensor values with predefined thresholds to identify abnormal situations such as excessive odor, insufficient lighting, or low water levels. When such conditions are detected, the system automatically generates maintenance alerts. These alerts are sent to the concerned maintenance personnel through communication platforms such as WhatsApp or other notification systems. This ensures that the responsible staff members are immediately informed and can take corrective actions quickly.

Step 5: Maintenance Response and System Feedback

After receiving the alert notification, the maintenance staff can take appropriate actions such as

cleaning the washroom, repairing lighting systems, or refilling the water tank. Once the maintenance task is completed, the sensor readings return to normal conditions, and the system updates the washroom status accordingly. This continuous monitoring and feedback mechanism ensures that the washroom remains hygienic, safe, and properly maintained at all times.

4.Results and Discussion

A hardware prototype was used to effectively develop and test the proposed Ladies Washroom Maintenance System that utilizes Artificial Intelligence (AI) and the Internet of Things (IoT). The air quality, light, and water availability of the restroom can be tracked by integrating several environmental sensors with an ESP32. A capability to continually monitor environmental parameters and provide maintenance alerts when abnormal circumstances are discovered is demonstrated by the experimental results.

The circuit diagram of the proposed system is shown below:

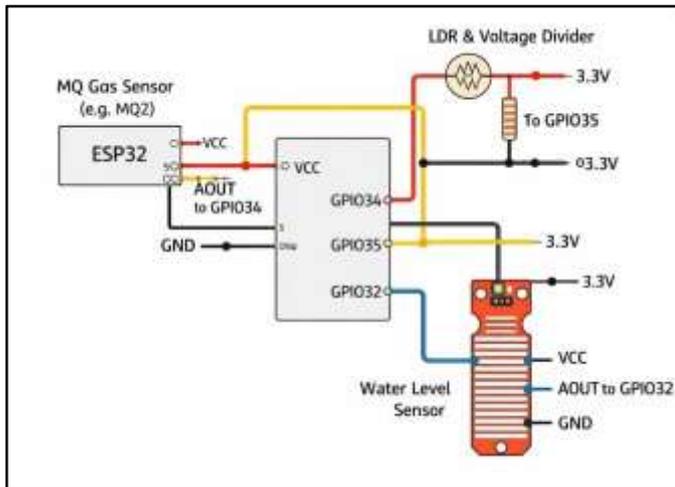


Fig 2: Circuit Diagram

The circuit diagram illustrates the connection between the sensors and the ESP32 microcontroller used for system control. The MQ Gas Sensor is connected to GPIO34 of the ESP32 to detect gas concentration and unpleasant odors in the washroom environment. The Light Dependent Resistor (LDR) is connected through a voltage divider circuit to GPIO35 to measure the lighting conditions inside the washroom. Similarly, the Water Level Sensor is connected to GPIO32 to detect the water level in the storage tank. All sensors are powered using the 3.3V supply from the ESP32 and share a common ground connection. The microcontroller collects the sensor readings and processes them to determine the status of the washroom environment.

The live working model of the proposed Ladies Washroom Maintenance System is shown below:



Fig 3.1: Live Working Model

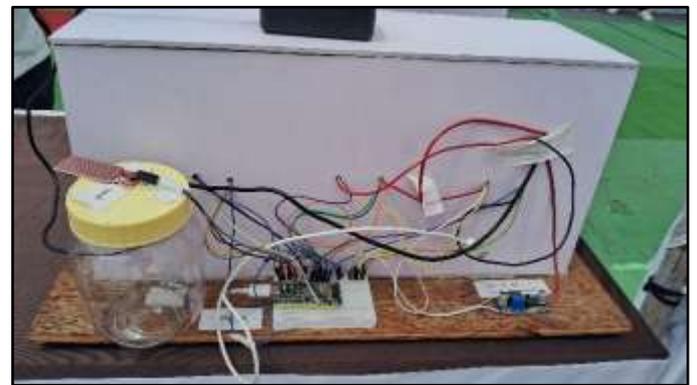


Fig 3.2: Live Working Model

The prototype model demonstrates the real-time implementation of the proposed system. The sensors are connected to the ESP32 through a breadboard setup, and a water container is used to simulate the water tank for monitoring water level. The system also includes a DC-to-DC converter for stable power supply to the circuit components. The front side of the model represents three washroom sections (Room 1, Room 2, and Room 3), which simulate multiple washroom units in a building. A digital display unit is installed on the front panel to show system status and monitoring information.

During the experiment, different conditions were simulated to test the functionality of the sensors. When the gas sensor detected an increase in odor levels, the system identified it as a sanitation issue. Similarly, the LDR sensor detected low lighting conditions when the light intensity decreased, and the water level sensor detected low water availability in the container. The ESP32 processed these sensor readings and transmitted the data for monitoring and alert generation.

5. CONCLUSIONS

By using automated maintenance and Internet of Things (IoT) sensor monitoring, this research proves that public restrooms may be far more hygienic and efficient. Timely maintenance actions are enabled by the system's constant monitoring of metrics such as utilization, cleanliness indications, and resource levels, which lowers the need on manual inspections. Hygiene management, health risk mitigation, user experience, and maintenance effort/cost optimization are all improved by the incorporation of IoT technologies. Addressing the increasing demand for clean and well-managed public facilities in today's urban setting, the suggested system provides a practical, scalable, and technology-driven solution for modern public washroom upkeep.

In the future, the proposed IoT-based public restroom maintenance system can be enhanced by integrating advanced AI and machine learning techniques to enable predictive maintenance using historical usage and sensor data. Real-time mobile applications can be developed for alert monitoring, remote control, and maintenance scheduling. The system can be extended with advanced air quality, odor detection, smart water management, and energy-efficient devices to improve sustainability. Furthermore, a centralized cloud-based dashboard can be implemented to monitor multiple public restrooms across cities, supporting large-scale smart city initiatives and improved public hygiene management.

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