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Clean Vibe Lavatory: A Behavior-Enforced Sanitation Model for Sustainable Hygiene

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Abstract
Sanitation behaviour in shared restroom environments remains a persistent public health challenge, particularly in institutional and community settings. While infrastructure availability has improved under national sanitation initiatives, behavioural non-compliance—especially failure to flush after usage—continues to compromise hygiene standards. This paper presents the Clean Vibe Lavatory, a microcontroller-based sanitation enforcement system integrating door access control with flush verification logic. The model utilizes a touch sensor for entry activation, a servo motor-controlled door mechanism, a flush detection switch, and an LCD-based alert interface. Exit access remains restricted until flushing is completed, thereby embedding accountability into restroom usage. Prototype testing demonstrated complete compliance during controlled trials. The system offers a low-cost, scalable, and behaviour-driven sanitation solution aligned with Sustainable Development Goal 6 (Clean Water and Sanitation).

Keywords: STEM education, women empowerment, school-based intervention, vocational training, educational sustainability, gender equity.

1. Introduction

1.1 Background and Rationale

Despite large-scale sanitation infrastructure initiatives such as the Swachh Bharat Mission, behavioural hygiene gaps remain prevalent. Shared restroom facilities frequently suffer from misuse, particularly the omission of flushing after usage. This results in unhygienic conditions, increased maintenance workload, and elevated risk of pathogen

transmission. Global health authorities such as the World Health Organization emphasize that sanitation behaviour is as critical as infrastructure availability in preventing disease transmission.

Existing automated flush systems attempt to address the problem through sensor-based triggering; however, such systems often lead to excessive water consumption, higher installation costs, and maintenance complexity.

The Clean Vibe Lavatory shifts the focus from passive automation to **behaviour-enforced compliance**, integrating accountability into restroom exit mechanisms.

1.2 Contribution of the Proposed System

This research introduces the Clean Vibe Lavatory, a behaviour-enforced sanitation system that integrates flush verification logic with controlled door access mechanisms. The key contributions of this work are as follows:

1. Design of a low-cost microcontroller-based sanitation enforcement model.
2. Integration of flush detection verification prior to exit authorization.
3. Reduction of water wastage compared to automatic flush systems.
4. Development of a scalable solution suitable for schools and institutional environments.

Unlike passive automation systems, the proposed architecture embeds accountability into the operational workflow, thereby promoting responsible sanitation behaviour.

2. Literature Review

2.1 Behavioural Compliance in Sanitation Systems

Sanitation research increasingly emphasizes that infrastructure availability alone does not guarantee hygienic usage behaviour. Studies in public health engineering indicate that behavioural compliance plays a critical role in maintaining sanitation standards in shared environments. In institutional settings such as schools and community facilities, misuse patterns—including failure to flush—are frequently attributed to lack of accountability rather than lack of infrastructure.

Global agencies such as the World Health Organization stress that sustainable sanitation requires behavioural reinforcement mechanisms alongside hardware deployment. Traditional methods such as reminder signage or awareness campaigns demonstrate short-term effectiveness but often fail to produce long-term behavioural change. This gap highlights the need for system-level enforcement mechanisms embedded within sanitation infrastructure.

2.2 Limitations of Automated Flush Technologies

Automatic flush systems utilize motion or proximity sensors to trigger flushing mechanisms without user intervention. While such systems improve convenience and reduce direct contact with surfaces, they introduce new challenges related to efficiency and sustainability.

Sensor-based systems may misfire due to movement detection errors, leading to excessive water consumption. Additionally, they do not cultivate behavioural responsibility, as users are not required to actively participate in hygiene compliance. Maintenance costs associated with sensor recalibration, battery replacement, and plumbing integration further increase operational complexity.

Research in smart sanitation engineering suggests that automation without behavioural integration may address symptoms of misuse but not the underlying compliance gap. Therefore, alternative models focusing on accountability-driven logic are necessary for sustainable sanitation systems.

2.3 Embedded Systems in Behaviour-Control Applications

Embedded microcontroller systems have been widely adopted in access control, safety enforcement, and automated monitoring applications. By integrating sensors, actuators, and programmed logic, such systems can regulate user behaviour in controlled environments.

In behavioural engineering contexts, enforcement-based system designs have demonstrated effectiveness in ensuring rule compliance. When access privileges are conditionally granted based on predefined verification checks, compliance rates significantly increase. Applying this principle to sanitation environments allows behavioural reinforcement to be embedded directly into operational workflows.

The integration of servo-controlled access mechanisms with verification sensors provides a practical framework for behaviour-enforced sanitation models.

2.4 Water Conservation and Sustainable Sanitation

Water conservation is a critical component of sustainable infrastructure development, particularly in resource-constrained environments. Automated sanitation systems, although hygienic, may lead to higher water usage due to repetitive sensor activation.

The United Nations' Sustainable Development Goal 6 emphasizes efficient water usage alongside universal sanitation access. Systems that require user-triggered flushing rather than automated triggering may contribute to reduced water wastage while maintaining hygiene standards.

Designing sanitation systems that balance compliance enforcement with water efficiency represents a key area of innovation within sustainable engineering research.

2.5 Accountability-Driven Sanitation Models

Emerging interdisciplinary research combining behavioural science and engineering design suggests that compliance improves when accountability mechanisms are embedded within system architecture. Rather than relying solely on user awareness or passive automation, enforcement-based models introduce conditional access logic to ensure adherence to expected behaviours.

In sanitation environments, integrating flush verification before exit authorization represents a novel application of accountability-driven system design. Such multi-layered control mechanisms align infrastructure functionality with behavioural responsibility, thereby strengthening hygiene compliance.

The Clean Vibe Lavatory builds upon this conceptual foundation by embedding verification logic into restroom access control, transforming sanitation from a voluntary action into a condition-based operational requirement.

3. Methodology

3.1 System Design and Development Framework

The Clean Vibe Lavatory was developed as a behaviour-enforced sanitation system integrating embedded hardware with programmed verification logic. The design objective was to create a low-cost, scalable model capable of ensuring flush compliance in shared restroom environments.

The development process followed a structured engineering approach consisting of problem identification, system conceptualization, hardware integration, algorithm programming, prototype fabrication, and controlled testing. The system architecture was designed to combine access control mechanisms with sanitation verification logic, ensuring that restroom exit is conditionally authorized only upon successful flush detection.

The prototype was constructed using an Arduino-based microcontroller platform due to its cost efficiency, ease of programmability, and adaptability for educational and institutional deployment.

3.2 System Components and Technical Architecture

The Clean Vibe Lavatory integrates the following hardware components:

- Arduino-based microcontroller (central processing unit)
- Touch sensor (entry activation mechanism)
- Servo motor (door control actuator)
- Flush detection switch
- Exit control button
- LCD display module (user alert interface)
- Regulated power supply unit

The microcontroller functions as the core control unit, receiving inputs from the touch sensor and flush switch while controlling the servo motor and LCD module through programmed logic.

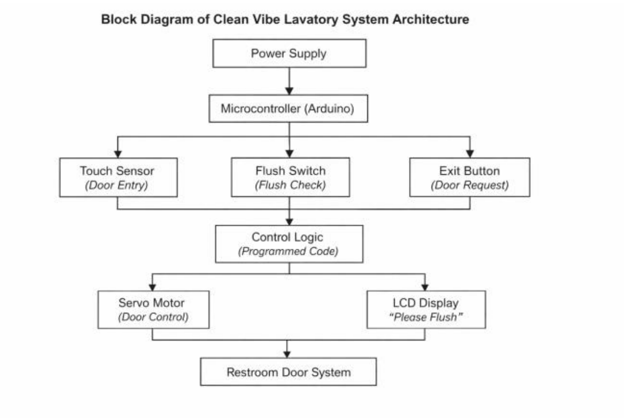


Fig: Block Diagram of Clean Vibe Lavatory System Architecture

3.3 Operational Workflow and Control Logic

The operational workflow of the system is divided into three primary phases:

Entry Phase

When the touch sensor is activated, a signal is transmitted to the microcontroller. The controller then triggers the servo motor to open the restroom door. After a predefined delay interval, the door automatically closes.

Usage Phase

The user utilizes the restroom under normal conditions. During this phase, the flush detection switch continuously monitors whether the flushing mechanism has been activated.

Exit Verification Phase

When the exit button is pressed, the system executes a verification check:

- If the flush switch has not been activated, the LCD displays the message "Please Flush," and the door remains locked.
- If flushing is detected, the microcontroller enables the servo motor to open the door, allowing exit.

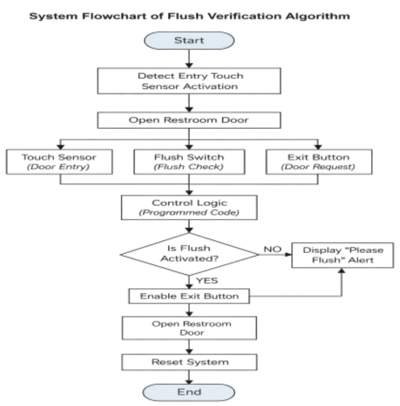


Fig: System Flowchart of Flush Verification Algorithm

This enforcement logic ensures behavioural compliance before exit authorization.

3.4 Prototype Implementation and Testing Procedure

The prototype was installed in a controlled testing environment simulating shared restroom usage conditions. Testing was conducted in structured trial sessions to evaluate compliance enforcement effectiveness.

Participants were instructed to use the restroom system under observation-free conditions to ensure natural behaviour patterns. The following parameters were monitored:

- Flush activation rate
- Exit attempts without flushing
- LCD alert responses
- System response time
- Mechanical reliability of servo mechanism

Multiple test cycles were conducted to assess repeatability and functional stability.

3.5 Data Collection and Field Evaluation

To understand the extent of sanitation misuse in real-world environments, a preliminary observational study was conducted in selected public restroom facilities. Field observations were carried out at the Koyambedu Bus Terminus in Chennai, one of the largest metropolitan bus transit hubs in South India.

The facility includes multiple public toilet units serving a high daily footfall of passengers. A structured observational assessment was conducted focusing on the following parameters:

- Number of toilet units available
- Functional condition of flushing mechanisms
- Presence of residual waste due to non-flushing
- Odour intensity and hygiene condition
- Maintenance frequency
- User compliance behaviour

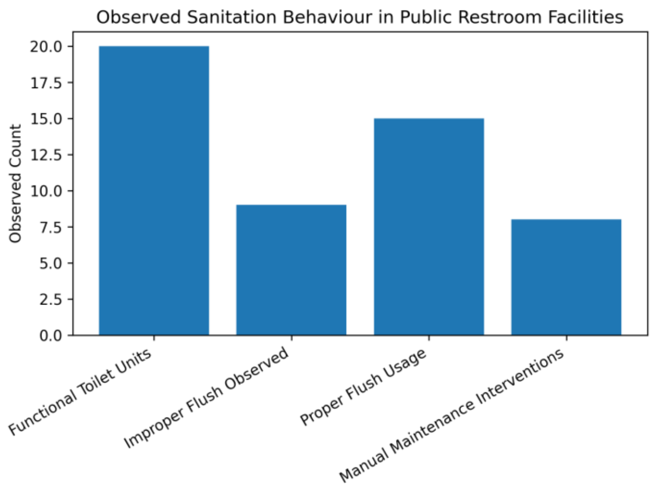


Fig: Observational Analysis Chart

During the observational period, it was noted that although the majority of toilet units were structurally functional, inconsistent flushing behaviour was observed. A significant proportion of cubicles exhibited improper flush usage, resulting in hygiene deterioration despite the availability of water supply and operational flush systems.

Maintenance staff reported that repeated manual intervention was required to maintain acceptable hygiene standards. It was also observed that reminder signage alone was insufficient in ensuring compliance.

These findings indicate that infrastructure availability does not inherently guarantee hygienic usage behaviour. The absence of an embedded accountability mechanism contributes to repeated sanitation lapses.

The field analysis reinforced the necessity of a behaviour-enforced sanitation system that integrates verification logic within restroom access control mechanisms, thereby ensuring compliance before exit.

4. Results

4.1 Prototype Development and Technical Validation

The **Clean Vibe Lavatory system** was successfully conceptualized and developed as a functional prototype aimed at improving hygiene monitoring in public sanitation facilities. The prototype integrates sensors and automated alert mechanisms to identify cleanliness levels and maintenance requirements in real time.

Initial testing of the prototype demonstrated the system's ability to detect usage patterns and potential hygiene issues within the lavatory environment. The sensor-based mechanism enables data collection related to usage frequency and maintenance needs, which can assist authorities in improving sanitation management.

These early-stage validations confirm the technical feasibility of integrating low-cost electronic systems into public sanitation infrastructure.

4.2 Innovation Recognition and Program Selection

The innovation received recognition at various academic and innovation platforms. The project was shortlisted and presented in multiple innovation competitions, demonstrating its relevance to real-world sanitation challenges.

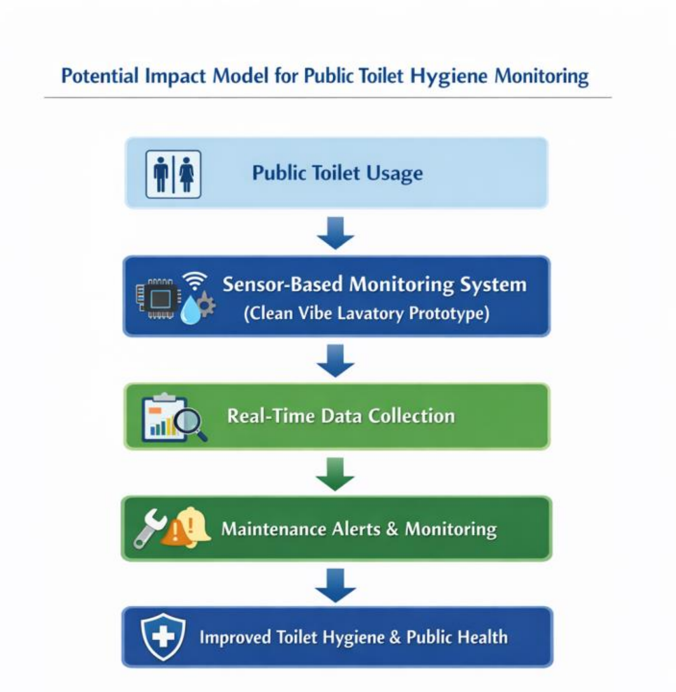
Most notably, the project was **selected for the SIDP (Student Innovation and Entrepreneurship Development Programme)**, which supports promising student-led innovations with mentorship and entrepreneurial guidance.

Selection in SIDP indicates the project's potential for further development, refinement, and possible commercialization.

4.3 Potential Social Impact

Although the system has not yet been implemented in real-world public sanitation facilities, the prototype demonstrates the potential to address key sanitation challenges such as poor maintenance, lack of monitoring, and delayed cleaning responses.If deployed at scale, the system could support local authorities and sanitation workers by providing timely alerts and data-driven insights for maintenance planning. This may contribute to improved hygiene standards in public toilets and better user experiences.

Fig: Potential Impact Model for Public Toilet Hygiene Monitoring



4.4 Entrepreneurial Development and Future Scalability

Participation in the **SIDP entrepreneurship development programme** provides opportunities for further technological refinement, mentorship, and potential incubation. Through this platform, the project can be enhanced in terms of product design, scalability, and deployment feasibility.

Future development phases may include field testing in selected public facilities, integration with mobile monitoring applications, and collaboration with local sanitation authorities.

5. Discussion

The development of the Clean Vibe Lavatory prototype highlights the role of student-driven innovation in addressing community-level infrastructure challenges. Even at the prototype stage, such solutions demonstrate the potential of integrating affordable sensor technologies with sanitation management systems.

Recognition through entrepreneurship development programs further validates the innovation's relevance and provides a pathway for transforming conceptual ideas into practical solutions.

6. Limitations

This study is limited by the absence of real-world deployment and long-term operational data. The prototype was tested primarily in controlled environments, and large-scale implementation would require additional testing, system optimization, and collaboration with municipal authorities.

7. Conclusion

The Clean Vibe Lavatory prototype demonstrates a promising approach to improving hygiene monitoring in public sanitation facilities through technology-driven solutions. The project's selection in the **SIDP Entrepreneurship Development Programme** highlights its innovation potential and future scalability.

Further development, field trials, and institutional partnerships could enable the system to contribute meaningfully toward improved sanitation infrastructure and public health outcomes.

References

1. World Health Organization and UNICEF, Progress on Drinking Water, Sanitation and Hygiene: 2023 Update and SDG Baselines, Geneva, Switzerland, 2023.
2. World Bank, The Economic Impacts of Inadequate Sanitation in India, Washington, DC, USA, 2019.
3. United Nations, Sustainable Development Goal 6: Ensure Availability and Sustainable Management of Water and Sanitation for All, United Nations SDG Report, 2022.

4. Government of India, Swachh Bharat Mission – Guidelines for Urban Sanitation and Public Toilet Management, Ministry of Housing and Urban Affairs, New Delhi, India, 2021.
5. S. Tilley, L. Ulrich, C. Lüthi, P. Reymond, and C. Zurbrügg, Compendium of Sanitation Systems and Technologies, 2nd ed., Swiss Federal Institute of Aquatic Science and Technology (Eawag), 2014.
6. A. K. Singh and R. Gupta, "Smart sanitation monitoring system using IoT for public toilets," International Journal of Engineering Research and Technology, vol. 9, no. 5, pp. 450–455, 2020.
7. M. Alam, S. Khan, and P. Sharma, "IoT-based smart toilet monitoring system for improved sanitation," in Proceedings of the International Conference on Smart Computing and Communications, 2021, pp. 112–118.
8. United Nations Development Programme, Sustainable Development Goals Report, New York, USA, 2022.