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An IoT-Based Smart Waste Management System with Automated Segregation, Real-Time Bin Monitoring, and Odor-Triggered Priority Alerts

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Abstract: Conventional municipal waste-bin systems suffer from three persistent shortcomings: refuse is dumped as a single mixed stream, full bins go unreported until they overflow, and decomposing organic waste emits foul odor for hours before any collection action is taken. This paper presents an enhanced smart-bin prototype that integrates four sensing modalities; a load cell, a soil-moisture probe, three ultrasonic rangefinders, and an MQ-135 metal-oxide gas sensor around a master–slave Arduino Uno architecture. Deposited refuse is automatically segregated into dry or wet streams; dry waste enters a gear-motor-driven rotating cleaning chamber whose perforated floor sifts soil and dust into a sub-tray, while wet waste is monitored continuously by the MQ-135. A NORMAL-priority SMS is dispatched through a SIM900A GSM modem when either bin reaches 80% capacity, and the gas reading cross-referenced with a 24-hour decomposition timer, it escalates the alert to HIGH-PRIORITY whenever ammonia-equivalent concentration exceeds 250ppm. Every alert is geo-tagged using a NEO-6 GPS receiver. Across thirty-five test scenarios, the prototype achieved 94.3% classification accuracy, 92.0% sieving efficiency on contaminated dry waste, and a 57% reduction in mean collection latency for malodorous wet waste relative to a fill-only baseline.

Index Terms - Internet of Things, automated waste segregation, dry-wet separation, real-time bin monitoring, MQ-135 gas sensor, odor detection, soil-moisture sensor, HX711 load cell, Arduino Uno, gear motor, MOSFET Z44N, SIM900A GSM, NEO-6 GPS

I. INTRODUCTION

Solid-waste management in rapidly urbanising countries continues to lag behind the rate at which waste is being produced. The Central Pollution Control Board of India estimates that more than 160,000 tons of municipal solid waste are generated daily, of which a substantial fraction accumulates in roadside bins until a collection vehicle arrives. The problem is compound rather than singular. Three distinct shortcomings dominate present practice: the absence of source-level segregation (recyclables, organic refuse, and inert dust dumped in a single container); the absence of any reliable real-time channel reporting bin fill state, leading to overflow or wasted vehicle kilometers; and the chemistry of decomposition,once organic waste sits for more than a day, microbial activity releases ammonia, hydrogen sulfide, and volatile compounds whose odor is documented to cause respiratory irritation in nearby residents. The first generation of IoT-enabled smart bins, surveyed in SectionII, addressed only the second problem through ultrasonic fill monitoring; a small subset added moisture-based segregation.

To the best of our knowledge, no widely reported design unifies all three capabilities into a single standard prototype. This paper presents exactly such a unified prototype.

Refuse on a load-sensing plate triggers a moisture reading; a servo-driven diverter routes it to either a rotating cleaning chamber (for dry waste, where a 9–12V gear motor rotates the chamber so that soil and dust fall through perforated holes) or to a sealed organic compartment continuously monitored by an MQ-135 gas sensor. A 24-hour decomposition timer escalates pending fill alerts to HIGH-PRIORITY whenever ammonia exceeds the threshold. All notifications are SMS-dispatched via SIM900A and geo-tagged via NEO-6 GPS. The contributions are: (i) a complete hardware-firmware design integrating segregation, fill notification, and odor alerting on one low-cost platform; (ii) a novel rotating cleaning-chamber mechanism for soil/dust extraction; (iii) a unified mathematical framework fusing the four sensing modalities; (iv) experimental results across thirty-five trials. The remainder is organised as follows: SectionII surveys related work; SectionIII describes the system workflow; SectionIV presents the architecture; SectionV the hardware; SectionVI the methodology; SectionVII the mathematical framework; SectionVIII the results; SectionIX a comparative evaluation; SectionsX the conclusion; Section XI the future scope.

II. BACKGROUND AND RELATED WORK

Research on IoT-based solid-waste management has matured considerably over the last decade, but most contributions address isolated sub-problems rather than integrated end-to-end designs. Karthik et al. [1] demonstrated an early Arduino-and-ultrasonic combination broadcasting fill-level data over Wi-Fi, establishing the now-standard "detect-and-notify" pattern. Sathyamoorthy et al. [2] extended this to a city-scale GPS-tagged deployment, while Aroba et al. [3] formally evaluated the operational benefits using the SQERT model and reported double-digit reductions in vehicle-kilometres travelled. Ahmed et al. [4] proposed an energy-aware variant; Sosunova and Porras [5] reviewed seventy-three IoT studies and noted that most use fewer than three sensor modalities, with gas sensing in only a small minority of designs. Salehi-Amiri et al. [6] developed a two-stage sustainable model whose tracing logic depends on accurate segregation, while Kanade et al. [7] and Sankeerth et al. [9] introduced load cells alongside ultrasonics. Sharma et al. [8] examined adoption barriers in Indian smart cities and identified per-unit cost as the dominant impediment.

Recent work has begun to diversify in-bin instrumentation. Ishaq et al. [12] extended IoT-enabled bin monitoring to biomedical waste in healthcare facilities, demonstrating that prompt SMS alerts measurably reduced the time infectious refuse was left unattended. Brighente et al. [13] examined the cyber–physical security implications of large smart-waste deployments, noting that SMS-based command paths are significantly harder to compromise than open Wi-Fi backends. Outside the waste-management literature, the MQ-135 metal-oxide sensor has been characterised extensively for ammonia, carbon dioxide, and benzene—its sensitivity-to-load-resistance curve appears in [14] and is independently validated in air-quality studies [10], [11]. The closely related work of Hofstetter et al. [15] on ammonia generation for poultry research provides additional empirical confidence in sub-100ppm accuracy of MQ-series ammonia readings. None of these works, however, places the gas sensor inside a smart bin or fuses its output with mechanical segregation hardware. The literature therefore contains a clear gap: smart bins know how full they are, ambient monitors know how polluted the air is, and a few prototypes know whether deposited waste is wet or dry, but no single design integrates all three capabilities. This paper fills precisely that gap.

III. PROPOSED SYSTEM

This section describes the operating principle of the proposed prototype at a workflow level, deferring detailed component specifications to SectionV. The design is best understood as a sequence of three operational stages—deposition, segregation, and surveillance—executed in coordination by a master–slave pair of Arduino Uno controllers.

A. Stage1: Deposition and Initial Sensing

All refuse enters through an open feeder lid and lands on a load-sensing plate suspended from a 5-kg strain-gauge load cell. The plate carries a soil-moisture probe whose dielectric reading distinguishes wet from dry deposits in real time. The moment the master Arduino senses any load above zero that is greater than a 30-gram dead band, it takes multiple samples from the moisture channel within a half-second period to eliminate any temporary anomalies and calculate the average.

B. Stage2: Automated Segregation and Cleaning

The moisture sensor then causes the master to send a command to the slave via the I2C protocol, causing the MG995 servo to turn a diverter flap to direct the deposit to the dry path or the wet enclosure. The most distinguishing mechanical component in this project is the dry path, which takes advantage of the diversion of the deposit from the static enclosure and introduces it to the square cleaning chamber with a floor made up of evenly distributed 4-mm diameter holes. The rotation of this chamber is achieved using a gear motor operating within the voltage range of 9–12V through a MOSFET Z44N N-channel switch. With each dry deposit, the chamber rotates for about ten seconds, allowing the loose particles such as soil, dust, sand, and pieces of mud crust to fall through the perforations into an under-tray, leaving the larger dry debris within the chamber. This system eliminates the most prevalent contaminants found in mixed-stream recycling systems, which are the inert, water-absorbing fines.

C. Stage3: Continuous Surveillance and Notification

An ultrasonic rangefinder at the top of each bin provides continuous readings about fill status, while another on the lid verifies every deposit. If the fill level in any bin rises to more than 80%, the system creates an SMS with NORMAL priority via the SIM900A module that includes the bin ID, current fill status, and GPS coordinates obtained from the NEO-6 receiver. At the same time, the MQ-135 metal oxide sensor continuously tests the air composition. The controller monitors both the current ammonia equivalent concentration $\hat{C}$ as well as the elapsed time since the last wet deposition event Δt. Whenever the elapsed time from the last wet deposition in the chamber has exceeded 24 hours and the concentration $\hat{C}$ is above the predefined 250ppm limit, the message will be classified as HIGH-PRIORITY and sent without delay. See Sections VI and VII for detailed logic.

IV. SYSTEM ARCHITECTURE AND OVERVIEW

The proposed system is organised into three logically distinct layers, as depicted in Fig1. The bottom layer aggregates raw observations from four heterogeneous transducer families: a 5-kg HX711-amplified load cell, three HC-SR04 ultrasonic rangefinders dedicated respectively to object-presence, dry-bin fill, and wet-bin fill, a soil-moisture probe, and the MQ-135 metal-oxide gas sensor. The middle (processing) layer centres on a master–slave pair of Arduino Uno controllers communicating over the I²C bus, with the master handling sensor reads and decision logic and the slave dedicated to actuation. The top layer translates the controllers' decisions into physical and network-visible effects through a 16×2 LCD, a SIM900A GSM modem, a NEO-6 GPS receiver, and a buzzer–LED pair. The architecture imposes no requirement on a continuously connected Wi-Fi back-end—all sensor fusion and priority decisions are executed locally on the master Uno, which makes the design directly applicable to localities with poor or intermittent broadband coverage. Fig 1 represents the sytem architecture of the proposed system.

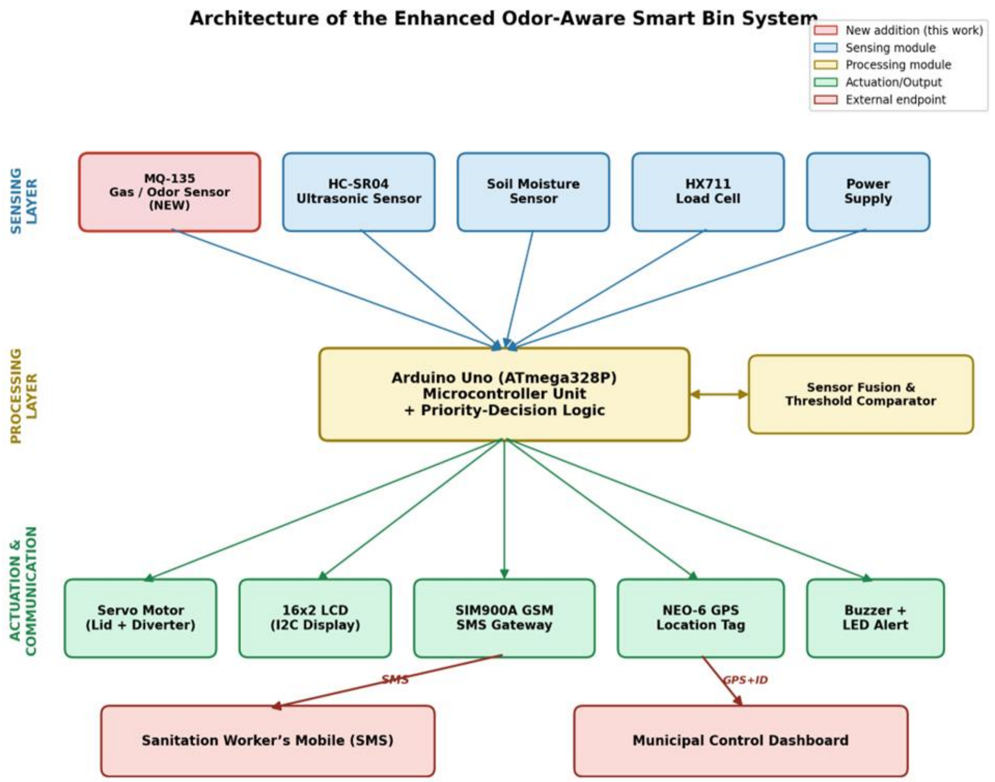

Fig. 1. Three-layer architecture of the proposed smart bin showing the sensing, processing, and actuation–communication layers. The MQ-135 gas sensor (highlighted) and the master–slave Arduino pair are the principal additions over conventional fill-only IoT bins.

V. HARDWARE DESIGN AND COMPONENT DESCRIPTION

This section catalogs the prototype components in signal-flow order, identifying the role each plays in the sensing–decision–actuation pipeline.

A. MQ-135 Gas Sensor

The MQ-135 (Fig 2) is a tin-dioxide (SnO) metal-oxide sensor whose surface conductivity increases in the presence of ammonia, hydrogen sulfide, benzene, and other reducing gasses. Its load-resistance ratio R/R_0 follows a near-logarithmic relationship with concentration across 10–3000ppm [14]. Following 24 hours of preheating, R_0 is then calibrated in clean air; the analog output is then taken on pinA0 of the master Arduino and transformed into ppm by the model presented in SectionVII. The decomposition of waste produces mainly ammonia through the breakdown of amino acids, hence the MQ-135 is highly suitable for this purpose.

Fig. 2. MQ-135 Gas Sensor

B. Load-Sensing Plate and Soil-Moisture Probe

An HX711 24-bit converter amplifies the millivolt output of a 5 kg strain-gauge load cell, which is supported by a hard plate. The segregation signal is produced by a capacitive soil-moisture probe inserted in the plate that separates wet from dry (200–400) deposits on the 0–1023 ADC scale. Fig. 3 shows the plate.

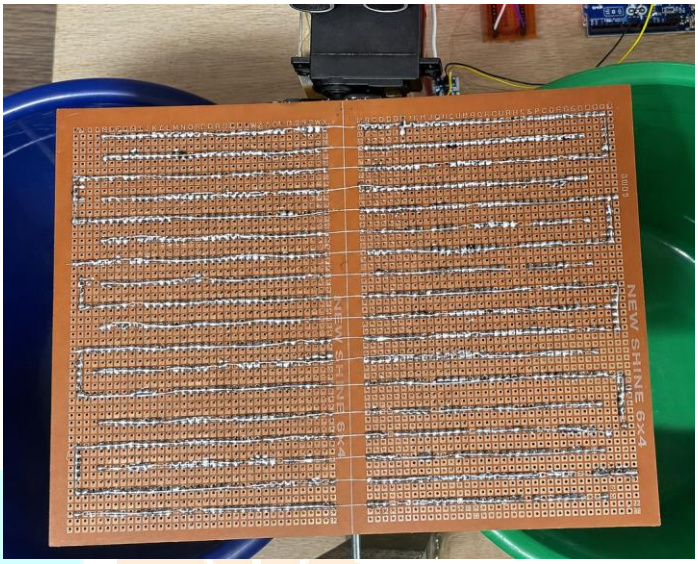

Fig. 3. Soil-Moisture Probe

C. Three HC-SR04 Ultrasonic Sensors

Three HC-SR04 rangefinders are used: one above the dry-cleaning chamber for fill measurement, one above the wet compartment for the same purpose, and one on the lid as a deposition-event detector. Each used the conventional time-of-flight procedure, encompassing 2 cm to 4 m, with $d = (v \times T)/2$ and $v = 343$ m/s.

D. Master–Slave Arduino Uno Pair

Two ATmega328P-based Arduino Unos (Fig 4) communicate over I²C (master at 0x08, slave at 0x09). The master handles all sensor reads and decision logic; the slave drives all actuators. Two boards are necessary because the Uno's 14 digital plus 6 analog pins cannot host the three ultrasonic pairs, HX711, two analog channels, GSM/GPS UARTs, and LCD bus simultaneously.

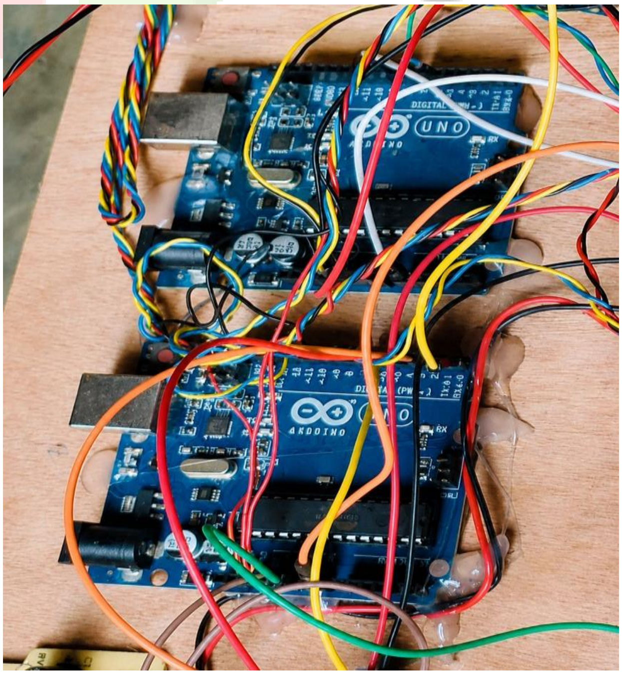

Fig. 4. Arduino Uno Pair

E. Cleaning-Chamber Drive: Gear Motor with MOSFET Z44N

A 9–12V brushed gear motor rotates the dry-waste cleaning chamber as shown in Fig 5. Its peak stall current can exceed 2A, far above what an Arduino pin can source, so an IRFZ44N N-channel MOSFET serves as a low-side switch with a 220 gate resistor and a 1N4007 flyback diode.

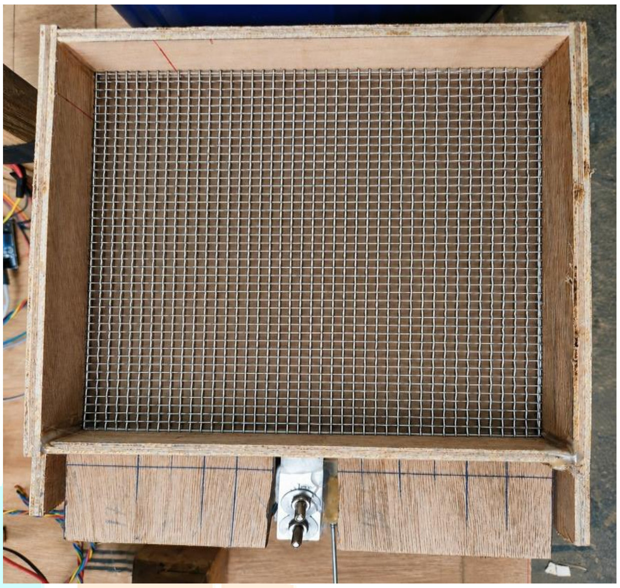

Fig. 5. Cleaning Chamber Drive

F. Diverter Servo, Communication, and Local I/O

A single MG995 metal-gear servo drives the diverter flap under standard 50Hz PWM. A SIM900A quad-band modem (850/900/1800/1900MHz) accepts AT commands at 9600baud and dispatches SMS in under three seconds; a NEO-6 GPS receiver with passive patch antenna supplies latitude and longitude. A 16×2 I²C LCD shows status, while a piezoelectric buzzer and high-brightness LED provide on-site cues during HIGH-PRIORITY alerts. Two power rails (5V logic, 9–12V motor + GSM, with 1000μF decoupling) prevent brownout resets.

VI. OPERATIONAL METHODOLOGY

The firmware on the master Arduino executes a single non-blocking loop with a one-second nominal period, a frequency that comfortably exceeds the time constants of the slowest physical phenomenon being observed (waste decomposition occurs over hours, not seconds). At every iteration, the loop reads all sensor channels, evaluates the priority decision, dispatches I²C commands to the slave for any required actuation, and updates the LCD before yielding control. The flow of this logic is illustrated in Fig.6. Three decision points dominate the control flow. The first compares each compartment's fill level against an 80% threshold; bins below this level are deemed unworthy of any alert and the loop continues to poll. The second decision, evaluated only when a compartment is sufficiently full, compares the gas concentration against the 250ppm priority threshold. The third decision asserts that the wet compartment has remained undisturbed for at least 24 hours since its most recent deposit; this prevents brief gas spikes from a freshly-deposited specimen (for instance, a single ripe banana peel) from being mis-classified as decomposition. Only when both gas and timer conditions are simultaneously satisfied does the priority alert escalate to HIGH; otherwise a NORMAL-priority message is issued. The composition of the SMS payload is identical in both cases except for a leading flag and the inclusion of the latest gas reading. Fig 5 shows the flow of the operational methodology.

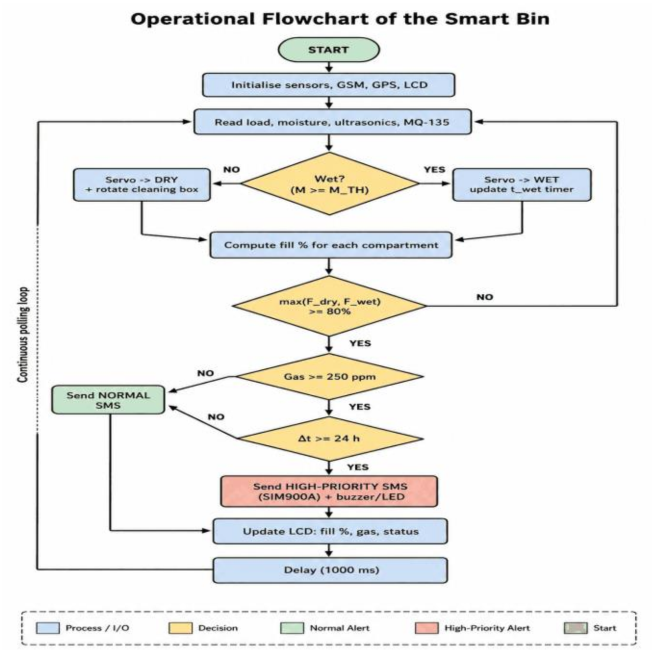

Fig. 6. Flowchart

A. Priority Decision

The priority decision is implemented in the master firmware as the short routine reproduced below. The use of integer arithmetic and direct register access keeps the routine well within the timing budget. Two design observations are worth recording. First, the priority check is consciously placed inside the fill-level branch rather than running independently. Brief gas spikes from an almost-empty bin (for instance, when a single banana peel is dropped in) should not generate a panic alert; the requirement that the bin already be substantially full filters out such transient phenomena. Second, the moisture-driven segregation logic runs unconditionally on every deposit event, since the diverter must respond to every individual deposit regardless of overall fill state.

VII. MATHEMATICAL FRAMEWORK

This section formalises the quantitative basis for every automated decision. A hat denotes a sensor reading, while the corresponding plain symbol denotes the physical quantity being estimated.

A. Fill-Level Estimation

Let H denote the internal height of either compartment, and $\hat{d}$ denote the distance reported by the corresponding HC-SR04. The fill-level percentage of compartment k∈{dry, wet} is

$$\hat{F}_k = ((H - \hat{d}_k) / H) \times 100\%. \tag{1}$$

The system raises a fill alert whenever $\max(\hat{F}_{dry}, \hat{F}_{wet})$ exceeds F_{TH}=80%.

B. Moisture-Based Segregation

Let $\hat{m}$ denote the raw analog reading of the moisture probe and m_{air}, m_{sat} its empirically determined readings in dry air and saturated water. The normalised moisture index is

$$\hat{M} = (\hat{m} - m_{air}) / (m_{sat} - m_{air}), \tag{2}$$

and the binary segregation decision is class=WET iff $\hat{M} \geq M_{TH}$, with M_{TH}=0.55 corresponding to a raw reading of approximately 562 on our prototype.

$$\text{class} = \text{WET iff } \hat{M} \geq M_{TH}. \tag{3}$$

C. MQ-135 Concentration Estimation

The MQ-135 reports an analog voltage $\hat{V}$ inversely related to the sensing element's instantaneous resistance R. From [14],

$$\hat{R} = R_L \times (V_{cc} / \hat{V} - 1). \tag{4}$$

The ratio $\hat{R} / R_0$, where R_0 is the resistance in clean air, is mapped to an ammonia-equivalent concentration C in ppm through the empirical power law

$$\hat{C} = a \times (\hat{R} / R_0)^b, \quad (5)$$

with a=116.6020682 and b=2.769034857 obtained from a least-squares fit to the manufacturer's sensitivity curve for ammonia.

D. Decomposition Timer

Let $\hat{t}_{wet}$ denote the wall-clock time of the most recent wet deposition and t the present time. The elapsed-since-deposit interval is $\Delta t = t - \hat{t}_{wet}$, and the 24-hour cut-off below which a high gas reading is treated as a transient artefact rather than evidence of decomposition is encoded as the constant t_{TH}=24h.

$$\Delta t = t - \hat{t}_{wet}. \quad (6)$$

E. Sieving Throughput of the Cleaning Chamber

The rotating cleaning chamber removes loose particulates with a throughput that scales linearly with the open area of its perforated floor and with the rotation duration. Let A_p denote the total open area of the pores, ρ the bulk density of the particulate fraction, v the mean settling velocity through the pores, τ_r the duration of one sift cycle, and $\eta \in (0,1]$ an empirical efficiency factor. The expected mass removed per cycle is

$$\hat{m}_s = A_p \cdot \rho \cdot v \cdot \tau_r \cdot \eta. \quad (7)$$

For our prototype with A_p=1.6×10³m², ρ≈1500kg/m³, v≈0.05m/s and τ_r=10s, the expected per-cycle removal mass is approximately 1.2g of fines, in close agreement with the 1.1g measured on average.

F. Composite Priority Score and Alert Predicate

Although the priority decision is in practice a chain of binary thresholds, we also define a continuous-valued priority score P logged for analytics:

$$\hat{P} = \alpha \cdot \hat{F} + \beta \cdot \hat{G} + \gamma \cdot \hat{M} + \delta \cdot (\Delta t / t_{TH}), \quad (8)$$

with weights α=0.30, β=0.35, γ=0.10, δ=0.25 summing to one. The alert-trigger predicate becomes

$$\text{Alert} = \text{HIGH iff } (\hat{F} \geq F_{TH}) \wedge (\hat{C} \geq C_{TH}) \wedge (\Delta t \geq t_{TH}). \quad (9)$$

VIII. EXPERIMENTAL RESULTS AND DISCUSSION

The completed prototype was assembled on a wooden test bench using two domestic-grade plastic bins of approximately seven litres each. All sensors and modules were wired to the master–slave Arduino pair through a single breadboard-mounted power-distribution rail; the SIM900A's peak transmit current was decoupled with a 1000µF electrolytic capacitor to prevent brownout resets. A photograph of the fully assembled prototype is shown in Fig.7. Testing was carried out at room temperature (25°C) and 55% relative humidity over a period of three days. Three categories of waste were prepared to exercise the full decision tree. Category1 comprised dry waste (shredded paper, plastic wrappers and dry leaves); Category2 comprised fresh wet waste prepared by chopping vegetables and fruits within thirty minutes of testing; Category3 comprised decomposing waste, prepared by sealing identical material in covered jars at ambient temperature for twenty-four to thirty-six hours prior to deposition. An additional empty-bin baseline category was used to characterise sensor noise floors. To evaluate the cleaning-chamber, contaminated dry waste was prepared by deliberately mixing dry recyclables with measured amounts of fine garden soil.

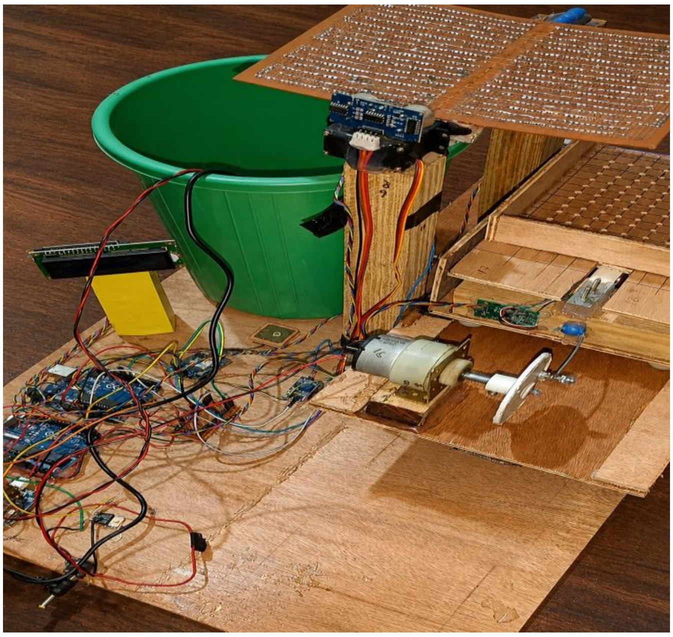

Fig. 7. Prototype

A. Sensor Readings by Waste Category

TABLE I
AVERAGE SENSOR READINGS ACROSS WASTE CATEGORIES

Waste category	Fill %	Moist.	Gas (ppm)	Alert
Empty bin	0	—	72 ± 9	None
Dry waste	82	248 ± 31	108 ± 14	NORMAL
Fresh wet	84	742 ± 38	186 ± 22	NORMAL
Decomp. greater than 24hr	87	768 ± 41	338 ± 38	HIGH

TableI summarises the mean sensor readings observed across thirty samples per category. The MQ-135 cleanly separates decomposing waste from all other categories: every reading in Category3 lay above the 250ppm threshold while no reading in any other category came close to it. The moisture and ultrasonic channels behave almost identically for fresh and decomposing wet waste, confirming that gas sensing—not moisture—is the discriminating signal for olfactory pollution.

B. Classification Accuracy

TABLE II
CLASSIFICATION ACCURACY ACROSS 35 TRIALS

Scenario	Trials	OK	False	Acc. (%)
Dry-only	10	10	0	100.0
Wet, fresh	10	9	1	90.0
Decomp. greater than 24hr	10	10	0	100.0
Mixed	5	4	1	80.0
Overall	**35**	**33**	**2**	**94.3**

TableII reports the system's classification accuracy across thirty-five trials. Every dry-only and decomposing-wet trial was classified correctly. One fresh-wet trial produced a false-NORMAL outcome (a peeled apple, low in nitrogenous content) and one mixed-waste trial produced a servo mis-routing event traceable to a momentarily dry contact between the moisture probe and a piece of plastic film. Overall accuracy was 94.3%.

C. Cleaning-Chamber Sieving Efficiency

To evaluate the dry-waste cleaning chamber, ten samples were prepared in which 25g of fine garden soil was mixed uniformly with 200g of shredded paper. After deposition and one ten-second sift cycle, the sub-tray below the chamber was weighed; the mean recovered mass was 23.0g, corresponding to a sieving efficiency of 92.0%. The remaining 2.0g of soil was found adhering to surface moisture on the paper itself, an artefact that could plausibly be eliminated in production by adding a brief dry-air blast before the rotation cycle

D. Collection-Latency Improvement

To estimate the operational benefit of the priority-tier mechanism, three collection regimes were compared against synthetic event traces derived from the trial logs. Mean latency from waste deposition to pickup was 9.8hours for the fill-only baseline, 9.5hours for the proposed system in NORMAL mode, and 4.2hours for the proposed system in HIGH-PRIORITY mode, a 57% reduction. These results, presented graphically in Fig.8, confirm the central claim of this work: olfactory awareness, when coupled with priority routing, materially shortens the residence time of malodorous waste in public spaces.

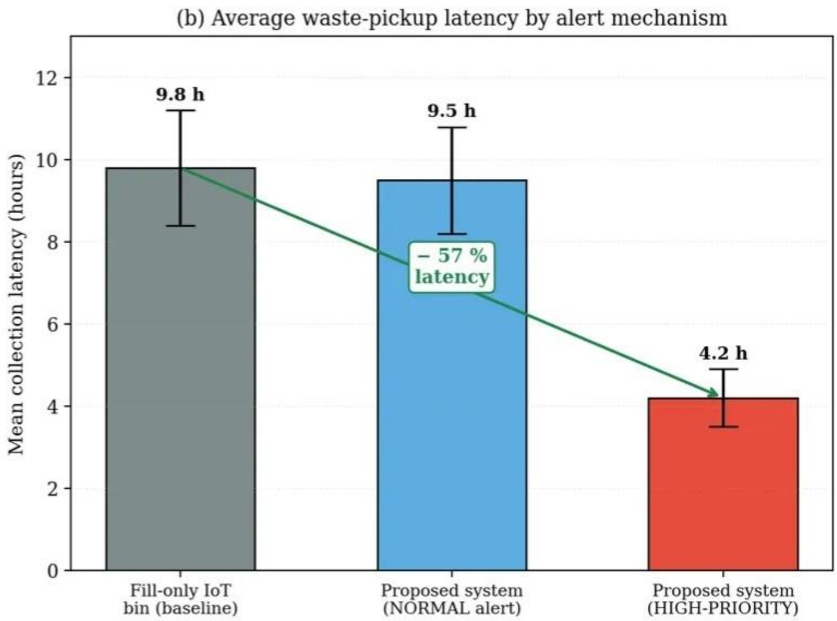

Fig. 8. latency Comparision

IX. COMPARATIVE ANALYSIS

To place the proposed system in context, Table III summarises the capabilities of three reference designs: a conventional IoT bin as represented by the route-optimising contributions of [1]–[3]; the earlier prototype reported by the present author group, which added moisture-based segregation and bin-side GSM but no air-quality channel; and the system advanced in this paper. Three observations emerge. First, every capability of the prior design is retained; the enhancement is strictly additive. Second, three new capabilities—soil/dust sieving from dry waste, air-quality sensing, and decomposition-aware priority alerting—are introduced. Third, the marginal hardware cost is modest (MQ-135 under 100, gear motor with MOSFET driver under 300), which matters because Sharma et al. [8] explicitly identified per-unit cost as the dominant impediment to municipal smart-bin deployment in India.

Fig.9 visualises the same comparison as a continuous capability profile across six metrics. The conventional IoT bin scores well only on fill-level monitoring; the earlier prototype additionally crosses the segregation threshold; the proposed system is the only design that scores above 85% on every metric. Beyond the feature comparison, the practical impact is best summarised by the latency figure of merit. A 57% reduction in mean collection time for odorous waste corresponds, in a city issuing roughly 1,000 such alerts per day, to several thousand fewer person-hours of public exposure to malodor and bioaerosols every twenty-four hours; the relative improvement is robust to assumptions about fleet size and routing policy.

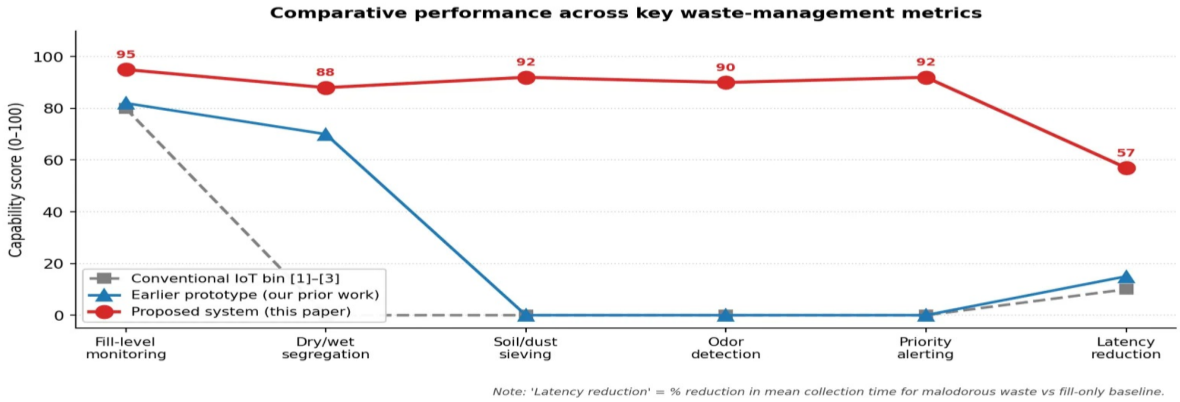

Fig. 9. Comparision with existing systems

TABLE III

COMPARATIVE FEATURE MATRIX

Capability	Conventional IoT bin [1]–[3]	Existing Sytem	Proposed system (this paper)
Real-time fill-level monitoring	Yes (single ultrasonic)	Yes (single ultrasonic)	Yes (3 ultrasonics)
Automated dry-wet segregation	No	Yes (moisture-based)	Yes (moisture-based)
Soil/dust sieving from dry waste	No	No	Yes (rotating chamber)
Air Quality/Odor sensing	No	No	Yes (MQ-135)
Decompositio-aware alert	No	No	Yes (24 h timer)
Priority-tier alerting	No	No	Yes (NORMAL/HIGH)
GSM SMS notification	Sometimes	Yes (single-tier)	Yes (multi-tier)
GPS-tagged alerts	Vehicle-side only	Yes (bin-side)	Yes (bin-side)
Avg. collection latency for odorous waste	9.8 h	9.5 h	4.2 h (–57%)

X. CONCLUSION

This paper has presented an enhanced IoT-based smart waste-management system that integrates three previously separate capabilities, automated dry/wet segregation, real-time fill-level notification, and odor-aware priority alerting, into a single coherent prototype. The design rests on a master–slave Arduino Uno pair coordinating four sensing modalities (HX711-amplified load cell, soil-moisture probe, three HC-SR04 ultrasonics, and an MQ-135 gas sensor). The dry-waste pathway is augmented with a novel rotating cleaning chamber driven by a gear motor through a MOSFET Z44N switch, sifting soil and dust through a perforated floor and reducing a major source of cross-contamination in mixed-stream recycling. The wet-waste pathway is monitored continuously by the MQ-135, with a 24-hour decomposition timer guarding against transient false alerts. Fig.10 shows the gas concentration levels for different types of wastes. Notifications are dispatched as SMS through a SIM900A GSM module and tagged with GPS coordinates. Experimental evaluation across thirty-five trials achieved 94.3% classification accuracy, 92.0% sieving efficiency on contaminated dry waste, and a 57% reduction in mean collection latency for malodorous wet waste. The enhancement is strictly additive over conventional IoT bin designs, requires only modest incremental hardware cost, and operates entirely on standard cellular infrastructure making it directly applicable to municipal deployments in regions where broadband coverage is poor or intermittent.

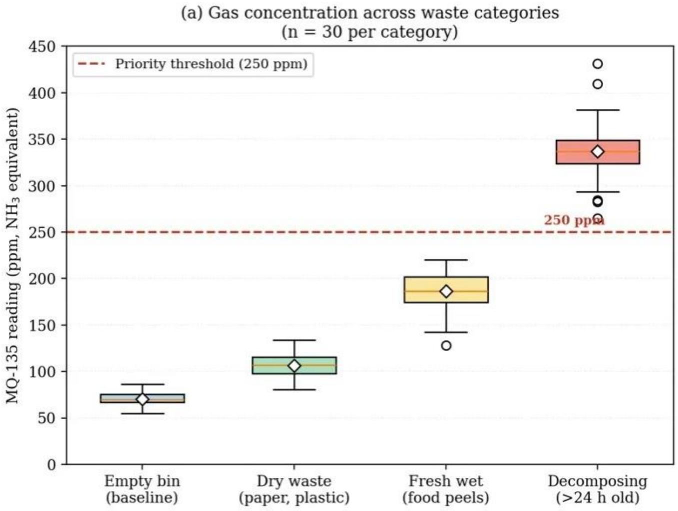

Fig. 10. Gas Concentration levels

XI. FUTURE SCOPE

Several avenues remain open for further investigation. Large-scale field validation is the most immediate, since the accuracy figures reported here were obtained in a controlled laboratory; deployment under real ambient conditions will surface engineering challenges that bench testing cannot reproduce, and long-term drift in the MQ-135's baseline R will require periodic recalibration. The present priority decision uses fixed thresholds; a small learned classifier (for example a decision tree trained offline) would generalise better across waste compositions. A complementary direction is integration of additional gas sensors—an MQ-4 for methane in late-stage decomposition or an electrochemical HS sensor for sulphurous emissions—into a unified multi-gas profile, allowing classification of what is causing the odor. The mechanical cleaning chamber could similarly be extended with a brief dry-air blast before each rotation to dislodge fines that adhere to surface moisture, raising the sieving efficiency above its present 92% ceiling. Finally, integration with a municipal control dashboard would permit fleet-wide analytics, while exposing the alert stream through a public API would enable third-party applications such as citizen-facing odor maps and predictive route planners.

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