

## SWACHHASURAKSHIT: A GOVERNANCE-INTEGRATED AI FRAMEWORK FOR URBAN WASTE MANAGEMENT IN TIER-2 CITIES

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### Abstract:

*The challenge of urban solid waste management is an enduring problem in many cities in the developing world because of the inefficiencies in the monitoring and collection processes and the administrative accountability of the municipalities. The present research aims at proposing a conceptual framework called SwachhSurakshit, which is an AI-based governance framework for the enhancement of the waste monitoring processes in the municipalities.*

*The framework would use multiple data sources such as CCTV surveillance, satellite imaging, and geo-tagging from the citizen community through deep learning-based object detection models.*

*The research assesses the conceptual feasibility of integrating AI in the governance of waste in urban cities. The results show the positive social, environmental, and operational implications of integrating AI in the governance of waste in urban cities, and the strong potential of the SwachhSurakshit framework in addressing the civic technology needs of tier-2 and tier-3 cities.*

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### Introduction:

Urban waste management is a vital issue that contributes to the overall cleanliness of a nation. Clean public spaces mark the effectiveness of a government's initiation to maintain its hygiene on a municipal level. India, a developing country, despite cleaning initiatives and multiple cleaning reforms, still gives rise to unanswered pleas by the public and unresolved issues in the cleanliness field.

This paper targets a specific city in Maharashtra, Kalyan. Kalyan, which is a city with 1.25 million inhabitants generates around 0.3-0.4 kgs of waste per capita per day. The Kalyan-Domivili Municipal Corporation claims to manage 100% of its solid waste. However, public data surrounding the cleanliness and hygiene fields suggest several gaps and inconsistencies in managing said solid waste. Multiple public surveys and news outlets report that the garbage does not get properly recycled or cleaned thoroughly. Sources cite a visible accumulation of garbage piling on the sides of the streets, giving rise to diseases and littering.

This paper proposes a solution to the ongoing issue of waste management in Kalyan-Dombivili. It entails an idea, "SwachhSurakshit" which augments the government's efforts with the help of a developing AI module.

## Literature Review:

### 1. Integrated Solid Waste Management and GIS-Based Systems

Integrated Solid Waste Management has been continuously renowned as a structural approach to address the environmental and operational challenges associated with the management of solid waste by municipal corporations in developing countries. ISWM integrates waste reduction, segregation, collection, transportation, treatment, recycling, and engineered landfilling into one planning framework.

Koushik Paul (2017) did a detailed study on the Indian Municipal systems, mainly on the Kolkata Municipal Corporation, wherein, he emphasised the importance of integrating Geographic Information Systems (GIS) with Management Information Systems (MIS) to improve waste management. The study represents how the integration of GIS and MIS systems help in pointing out the correct landfill sites, garbage bin allocations, optimal routes and the supervision of waste flows across several municipal jurisdictions.

The research emphasises on the fact that the waste collection and transportation contribute 70-80% of total municipal solid waste management expenditure. Though, spatial modelling and optimisation methods, significant reductions in transportation cost and operational anomalies were achieved. Also, the integration of recycling, engineered landfilling and composting within an ISWM model resulted in waste reduction, resource recovery and improved landfill lifespan.

Paul further highlights the role of these digital information systems (GIS and MIS), how they track bin status, vehicle movement and the amounts of waste in real-time. It points out how the current system that relied heavily on fragmented processes, now can adapt to a more integrally connected data-driven, co-ordinated system.

The GIS-MIS based ISWM models do provide strong planning and optimisation functionalities, but, the primary focus still remains on spatial analysis and cost reduction rather than real-time predictive monitoring with the help of artificial intelligence. This specific observation further suggests the potential scope for AI-integrated municipal waste management systems.

### 2. Deep Learning-Based Waste Detection Using UAV Systems

Verma et al. (2022) proposed the idea of using Unmanned Aerial Vehicles (UAVs) with Convolutional Neural Networks (CNNs) to automate waste detection with AI. The study addresses the limitations of manual waste detection and replaces the human factor in the equation with UAVs to capture images of clean and garbage-affected locations.

A collection of 2000 images were collected and then used with data augmentation techniques to improve the model's ability to accurately detect garbage. Two CNN architectures were trained and assessed using precision, recall, F1-score, and accuracy as performance metrics. Their best performing model acquired an accuracy of 94%, highlighting the effectiveness of this deep-learning AI module in detecting and identifying waste accumulation zones.

The study highlights the integration of surveillance cameras with AI detection modules and how it achieves almost an ideal percentage in detecting garbage effectively. However, the research prioritises on focusing on

open-areas with unmanned drones, rather than broader municipal waste management frameworks such as GIS-based routing, policy-level governance mechanisms or real-time administrative decision-making systems.

### 3. Identified Research Gap

In Paul's (2017) research, the GIS and MIS based Integrated Solid Waste Management systems do successfully optimise transportation routes and reduce operational costs. However, it only accounts for spatial and logistical efficiency without the incorporation of AI. With AI integration, it is an unexplored field with potential advantages.

Similarly, in Verma et al.'s(2022) research, the integration of deep learning models and Unmanned Aerial Vehicles (UAVs) provides precise results of the waste, as the CNN models put in a 94% accuracy. Despite its effectiveness, the model remains largely experimental and it does not extend into municipal governance frameworks, specifically in tier-2 and tier-3 cities.

At the administrative level, the public data provided by Kalyan-Dombivili Municipal Corporation does not indicate the use of AI-based tracking systems or transparency mechanisms combining CCTV or real-time waste detection technologies. This points to a disconnect between potential tech capability and the implementation of it on a governmental level.

Therefore, a gap exists in integrating AI-based garbage detection mechanisms with municipal transparency and valid governance frameworks within cities, especially Kalyan-Dombivili.

### Objectives:

The present study aims to:

1. Examine the shortcomings of the existing solid waste management system in tier-2 cities such as Kalyan-Dombivili.
2. Analyze the collaboration of AI-based detection model with local municipal government frameworks.
3. Design a multi-faceted structure that involves satellite imagery, CCTV feeds and citizen participation.
4. Enhance governmental accountability and transparency via a structured digital dashboard.
5. Evaluate the potential in the feasibility and scalability of AI-driven waste governance systems.

### Proposed Solution: SwachhaSurakshit Framework:

#### 1. System Architecture

The SwachhSurakshit framework relies on the augmentation of an AI-based garbage detection model with municipal governance. It is designed to be implemented in policies like Smart Cities

Mission or Swachh Maharashtra Abhiyan on a local level. The framework aids in improving responsiveness in garbage-affected areas through structural technological intervention.

The system functions primarily on visual data. Images are collected through existing CCTV networks, which consistently supervise public areas. These CCTV cameras are incorporated into the AI detection engine, which accurately identifies waste accumulation on public roads. With regards to ground-level monitoring, satellite images are periodically used to analyze dumping zones and landfill extension patterns.

Additionally, the framework includes citizen participation through geo-tagged photo submission mechanisms. Residents can upload a photo with geo-tagged information embedded on the image. These photos will help in identifying waste hotspots and aid in improving detection reliability. The culmination of CCTV feeds, citizen submissions and satellite data create a multi-source monitoring system.

All the accumulated visual inputs are processed through a centralized AI engine, which sends a structured concise report to the government. Based on the severity and location of the correctly detected waste, alerts are created to aid municipal authorities in catalyzing response measures.



## 2. AI Detection and Classification Mechanism

The SwachhSurakshit framework implements real-time object detection and classification models to point out and categorize waste accumulation across supervised areas. This system utilizes YOLO (You Only Look Once) object detection architecture due to its rapid processing speed and its compatibility with surveillance environments. YOLO aids instant identification of waste in images submitted through CCTV and citizen-submitted uploads.

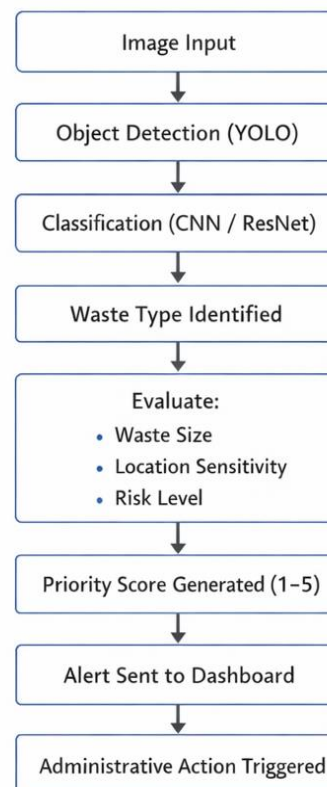
To avoid false detections, Convolutional Neural Network (CNN) architectures such as ResNet may be incorporated to consolidate classification accuracy. This layered detection mechanism ensures that the data is not singly sourced, but sourced through observations based on multiple trusted inputs.

The system differentiates the detected waste into plastic waste, organic waste, electronic waste, metal scrap, and abandoned vehicles. This informs us the fundamental state of the waste, further urging segregation compliance and enables the government to implement targeted collection strategies, rather than the usual functionality.

Additionally, the system incorporates a prioritization feature into the AI-detection engine, which enables the images to be re-ordered based on priority level. This priority level will range from 1-5, with one being the highest priority level. In which, areas which are more prone to garbage-related diseases, such as hospitals, schools, etc. will be assigned as the most urgent. And level 5 will include areas that are in need of an occasional sweep. Furthermore, waste size also influences prioritization.

Through this structured detection and identification cycle, SwachhSurakshit converts raw image inputs into actionable governance intelligence, comprising technical intelligence with administrative reliability.

Figure 2: AI Detection and Alert Mechanism



### 3. Governance Dashboard and Transparency Mechanism.

The SwachhSurakshit initiative collects all the detection outputs into a single digitalised dashboard for administration and transparency. It displays organized detection outputs, including waste type, clearance status and response updates and posts the results on the digitized dashboard. It is an operational interface between the municipal authorities and AI engine, displaying proper governance insights.

All the detected waste anomalies are shown through geo-tagged mapping, enabling authorities to visualize the areas with garbage hotspots across the city in real time. Each detection is marked with the types of waste accumulated, its size, the exact coordinates, time stamps and assigned priority level. This classification helps in identifying the recurring waste patterns and high-risk zones across different wards.

The dashboard is where the prioritization engine is fully utilized. It shows the priority level assigned to the waste detection hotspots on the city map. With the priority level and the size of waste accumulated in particular areas, the urgency is calculated and it gets administratively relayed to the municipal cleaning team. Waste cases occurring towards sensitive zones such as schools, hospitals and densely populated areas are automatically highlighted.

To improve transparency, the dashboard displays a before and after mechanism, wherein the pre and post images are shown with time stamps creating a digital audit trail of sanitation activities. It highlights the images taken during detection of waste in a specific area, and an adjacent after image taken post cleanup.

Through this systematic visualization system, SwachhSurakshit converts waste management from a complaint-driven model into a trackable, performance-oriented governance process. The dashboard does not represent municipal decision-making, rather, it supports decision-making by providing structured, real-time environmental intelligence.

### 4. Privacy and Ethical Safeguards

While the SwachhSurakshit framework captures images from CCTV feeds and citizen uploads, it is structured in a way that ensures ethical governance and safeguards privacy. The framework focuses exclusively on object detection rather than individual identification.

Automated face-blurring and censoring vehicle number plates are incorporated into the AI processing to mitigate personal data exposure. The framework does not store personal information of any individual. Access to the dashboard is restricted to authorised municipal personnel. Data retention policies are implemented to ensure that the visual records are archived only for defined authoritative durations.

Citizen-uploaded images go through strict protocols to decrease the risk of spam, misuse or false reporting. The AI detection system also integrates identification thresholds to prevent wrongful escalation of detections based on tampered or misleading visual inputs.

By enforcing these safeguards, SwachhSurakshit aims to balance technological monitoring while preserving privacy rights. The framework does not intend a mass-surveillance contraption, but rather an effective governance tool that enhances livelihood and recuperates waste flow in the society.

### Methodology:

This framework is a calculated result of systematic examination of the structural inefficiencies found in the current municipal waste management systems. The framework is an analytical review of the inefficiencies within the municipal waste management systems, such as public articles, municipal reports, research articles and public governance data.

The current framework is an integration of smart governance and an AI-based waste detection model. It involves the elements of GIS- and MIS-based mapping and deep-learning modules that identify waste with the help of models such as CNN architectures. This framework is conceptualised as a governance-oriented prototype to implement its effective uses structurally at a municipal level.

### Risk Assessment and Deployment Challenge:

The SwachhSurakshit framework suggests using AI to manage waste through a governance-integrated approach. However, putting this plan into action might face some administrative and operational challenges. Identifying these risks is important to assess how realistic real-world deployment is and to ensure a smooth adoption process.

#### 1. Technical Risks

AI-based object detection models like YOLO and CNN may not perform well in unreliable environmental conditions. Factors such as heavy rain, thick fog, motion blur, and poor CCTV placement can affect how accurately waste is detected. False positives, which occur when waste is detected where there is none, and false negatives, which happen when actual waste is missed, can undermine trust in automated alerts. Regular calibration of thresholds and retraining of models can help maintain reliable detection and steady performance.

#### 2. Infrastructure Constraints

Most public CCTVs were initially set up to monitor traffic and security. Issues like outdated hardware, poor quality, and limited bandwidth can hinder real-time image processing. Satellite images used for identifying landfill sites may not spot small waste in busy urban areas. Upgrading equipment strategically and integrating solutions in phases can help close these infrastructure gaps.

#### 3. Governance and Institutional Risks

The transparency of municipal operations in the SwachhCity framework could reveal existing inefficiencies, potentially causing resistance or hesitation within the administration. Additionally, changes in leadership might affect the framework's long-term continuity. Effective training, coordination between departments, and clear policies will be crucial for sustained implementation.

#### 4. Privacy and Ethical Considerations

Even with privacy protections built into the framework, constant public surveillance could raise concerns. Clear policies on data retention, controlled access to dashboards, and transparent planning will be vital for maintaining public trust and ethical standards.

## 5. Financial and Stability Risks

The initial rollout may require funding for cloud infrastructure and maintenance. Budget cycles and occasional funding sources could impact the timeline for implementation. Expanding SwachhSurakshit's coverage from specific wards to the entire city will necessitate coordinated workforce training and careful planning for gradual growth.

Despite these deployment challenges, they can be managed through gradual adjustments, regular maintenance, and structured governance. Understanding these risks enhances the practical feasibility of the SwachhCity framework without undermining its foundational ideas.

### Impact Assessment and Implementation Feasibility:

#### 1. Social Impact

The SwachhSurakshit framework aims to enhance public sanitation and citizen accountability through technological monitoring. With quick responses to garbage detections, SwachhSurakshit reduces prolonged exposure to unhygienic conditions in residential areas. This can indirectly support public areas which are prone to garbage-related diseases by minimizing waste accumulation. With the help of a digital public dashboard, geo-tagged photos and before-after image mechanism, the framework intends to enhance transparency leading to more civic trust of the public in local governance bodies.

#### 2. Environmental Impact

From an environmental standpoint, early detection and clearance of waste may reduce open dumping and overflows occurring in drainage systems and water bodies. The AI-based detection of the types of waste will help in establishing segregating plans especially with wastes like scrap metal, plastics and e-waste. Furthermore, hotspot mapping results in identifying recurring dumping zones in the city. That enables the optimization of collection routes, saving unnecessary fuel consumption and resulting in lesser carbon emissions. All these factors make the framework sustainable from an environmental perspective.

#### 3. Economic and Operational Impact

The municipal waste management system mainly allocates a significant portion of its funding to garbage collection and vehicle transport. With the AI-assisted model, SwachhSurakshit will aid in reducing recurring field inspections and optimize manpower allocation.

Automated validation systems can reduce the dispatch of cleaning teams to answer false claims, thereby improving resource utilization. In the long run, AI-assisted detection and classification will contribute to cost efficiency by helping in avoiding emergency cleanup expenditures, improving operational planning.

#### 4. Implementation Feasibility

The feasibility of the SwachhSurakshit framework heavily relies on existing digital infrastructure. Many Tier-2 cities have CCTVs preinstalled in public places. By using existing resources, integrating AI-modules in said CCTVs will help in minimizing capital expenditure.

The phased implementation of this framework in selected wards first, rather than complete city-wide deployment will help the municipality in slowly adapting to the framework adoption. This approach allows workforce training, technical calibration and governance alignment without overwhelming government capacity.

The SwachhSurakshit framework is structurally designed to be implemented in tier-2 and tier-3 cities with similar infrastructural features. Its scalability strengthens its technological relevance with the nation's broader smart governance ecosystem.

### Conclusion:

The urban waste management system continues to face structural inefficiencies despite many cleaning initiatives and public circulars. While GIS- and MIS-based systems and deep-learning modules promise technical capability, there is still a disconnect that separates municipal governance and technological integration.

This research proposed the SwachhSurakshit framework, which integrates the existing waste management system with an AI-based detection model for Tier-2 cities like Kalyan-Dombivili. It features multi-source data, waste type detection mechanism, geo-tagging and a public digital dashboard that enhances transparency of the government's work for the city. Unlike isolated detection, SwachhSurakshit emphasizes structured accountability, phased implementation, and policy alignment within existing municipal systems.

Although the deployment challenges may arise in infrastructure, funding, recurring maintenance and quality defects, yet, these factors do not diminish the conceptual strength of the framework. Instead, they highlight the importance of calibrated deployment and governance readiness.

Therefore, SwachhSurakshit does not represent a technological proposal, but a structured framework that analyzes waste and effectively alerts the government for its immediate clearance. Its adaptability and scalability positions it as a feasible civic-tech intervention within India's developing smart governance system.

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