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Optimizing Urban Waste Management through Smart Technology

Laboratory 4 - Mini Project Documentation Report

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Introduction

As urbanization accelerates globally, the volume of municipal solid waste (MSW) is increasing at an alarming rate. According to the World Bank, global waste generation is expected to grow to 3.40 billion tonnes by 2050, more than double the population growth over the same period (Kaza et al., 2018). Traditional waste management systems, which rely on fixed collection schedules and manual monitoring, are struggling to keep up with this growth. This inefficiency leads to overflowing bins, environmental pollution, and wasted resources in terms of fuel and labor. By integrating Internet of Things (IoT) technology into waste management infrastructure, cities can transition from reactive to proactive collection methods. This report explores the implementation of smart waste management systems to create cleaner, more sustainable urban environments.

Problem Description

The current waste management framework in many urban areas faces significant logistical and environmental challenges. The primary issue is the inefficiency of "static routing" garbage trucks follow a fixed path and schedule regardless of whether bins are full or empty.

This creates a twofold problem. First, resources are wasted when trucks stop to collect from empty or near-empty bins, unnecessarily consuming fuel and increasing carbon emissions. Research indicates that traditional collection trucks often travel unnecessary distances, contributing significantly to urban air pollution and operational costs (Anagnostopoulos et al., 2017). Second, in high-density areas, bins often reach capacity before the scheduled collection time. Overflowing waste attracts pests, creates foul odors, and poses severe sanitary risks to the community, including the spread of vector-borne diseases (Alam & Ahmade, 2013). Furthermore, the lack of real-time data means that city administrators cannot accurately predict waste generation spikes caused by events or holidays. Without a technological intervention, these inefficiencies will continue to strain municipal budgets and degrade public health.

Proposed Solution

To address the inefficiencies of static waste collection, the proposed solution is the development of a "Smart Waste Collection System" (SWCS) utilizing IoT sensors and data analytics.

The core of this solution involves installing ultrasonic fill-level sensors inside public waste bins. These sensors transmit real-time data regarding the fill percentage of each bin to a centralized cloud dashboard. Using this data, a dynamic routing algorithm generates optimized collection routes, directing drivers only to bins that are near capacity. This shift ensures that collection

services are demand-driven rather than schedule-driven. Studies have shown that such dynamic routing models can reduce transportation distances and associated costs by over 30% compared to static methods (Medvedev et al., 2015). Additionally, integrating mobile applications for citizen reporting fosters community engagement. This solution is expected to significantly lower the operational costs of waste management companies while eliminating the sanitary risks of overflowing bins.

Conclusion

The mismanagement of solid waste is a critical issue that affects both the environment and public health. Traditional collection methods are no longer sufficient to handle the demands of a growing urban population. The implementation of a Smart Waste Collection System offers a data-driven alternative that optimizes resources and ensures timely collection. By shifting from fixed schedules to dynamic, sensor-based routing, municipalities can reduce their carbon footprint and improve the cleanliness of city streets. Embracing this technological advancement balances urban development with environmental sustainability, ensuring a healthier ecosystem for future generations.

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