Developing and Evaluating a Dynamic Route Optimization Model for Smart Waste Collection in Urban Area Utilizing Real-Time Data Integration and Adaptive Algorithms

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Introduction
Nigeria's megacities are contending with the problem of waste management due to the increasing volume of waste. Traditional waste collection methods are usually not effective and timely. This research attempts to answer this issue by using a mathematical model to propose a dynamic route optimization model for a smart waste collection system. the model is proposed on real time data from IoT enabled waste bins and GPS enabled collection trucks. This model provides the best route possible for the truck movement by using dynamic data, creating and updating efficient collection routes with adaptive algorithms, such as Dijkstra or A* algorithm. The objective is to minimize the total travel distance D: $D=\sum i=1nd(i,j)xij$, and minimizing fuel consumption and travel time: $Cost=\alpha D+\beta T$. It is intended that this study explores the viability of this dynamic approach in order to minimize the total travel distance, reduce fuel consumption and optimization in resource allocation and generally increasing the efficiency and responsiveness of waste collection services within the complex urban environments. The findings will be useful in practice for application and benefits of intelligent route optimization for waste management sustainability in a major Nigeria city.

System Design & Methodology
The mathematical model used two interrelated models: a route optimization model for plot plan optimization and collection path planning and a real-time decision model to trigger and adjust collections to meet immediate needs. Three core components, which works in seamless coordination, are structured around the proposed smart waste management system. First, IoT sensors like ultrasonic or weight sensors, placed in strategical place on smart waste bins across the city. The second key component is geolocation enabled collection trucks. And the third is a cloud-based system which is incorporated with a good user interface web and mobile application.

Result and discussion
The primary objective is to minimize the total travel distance for waste collection trucks while ensuring that waste bins are emptied efficiently. The problem can be formulated as a Vehicle Routing Problem (VRP), which determines the most efficient routes for trucks collecting waste from multiple locations.

Conclusion
Ultimately, the successful adoption of a dynamic route optimization model within a broader smart waste management framework can contribute to a cleaner, healthier, and more sustainable environment for its residents. By embracing the power of data-driven decision-making and adaptive technologies, the city can move towards a future where waste is managed efficiently and effectively, minimizing its environmental impact and enhancing the quality of urban life. The integration of IoT sensors, GPS tracking, and intelligent algorithms empowers waste management authorities with unprecedented levels of situational awareness and decision-making capabilities.

Keywords: Adaptive Algorithm, Dijkstra's Algorithm, Geolocation technologies, Smart waste management and Optimization.