Placing Aside a Strategy That Makes Use of Dijkstra's Algorithm to Determine the Most Cost-Effective and Efficient Route for Managing Trash Properly While Reducing Pollution

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Abstract— **This research proposes an innovative approach to model and optimize a waste disposal management system using Dijkstra's algorithm. The goal is to find the shortest routes for proper waste disposal in order to reduce pollution and costs. The intention is to minimize expenses and pollution by discovering the most efficient routes for disposing of garbage. The trash disposal pathways were modeled and optimized using Dijkstra's algorithm. This allows the waste management board to find the most efficient routes, minimizing distance, time and costs. The results show Dijkstra's algorithm can be effectively applied to improve the waste disposal process in Ebonyi state. Optimized waste disposal routing in Abakaliki, Ebonyi State. Modeled an equation to calculate the shortest paths between dumpsites. Applied Dijkstra's algorithm to design the optimization model. The system is a scalable and adaptable model, it advances the integration of technology in municipal services, promoting the use of Geographic Information Service (GIS) and real-time data for dynamic route optimization. The paper recommends further research on integrating a user-friendly interface and alerts for the system. It also discusses the broader applications of this Dijkstra-based route optimization approach beyond just waste management, such as in traffic management, urban planning, and other logistics/transportation domains. The work presents a practical application of Dijkstra's algorithm to enhance the efficiency and sustainability of waste disposal systems, with potential for wider impact across different sectors.**

Index Terms—**Unplanned Waste, Dijkstra's Algorithm, Disposal, Recycling, Waste Management, Geographic information system (GIS).**

1. Introduction

For decades, agriculture has been the cornerstone of Kenya's economy, with the sector contributing approximately 30 per cent to the Gross Domestic Product (GDP) and employing 80 per cent of the national workforce, predominantly in rural areas (PwC, 2022). Farming in Kenya is heavily reliant on rainfall patterns, which are becoming more unpredictable due to changing weather patterns. Traditionally, efforts to enhance food security have focused on means to upscale agricultural production such as animal husbandry, irrigation, pesticides, and inorganic fertilizers. However, the results have been detrimental to the environment without substantially increasing food supply. In addition to deforestation, pollution, and soil erosion, agricultural activities in Africa, particularly livestock rearing, have emitted large amounts of methane and carbon dioxide into the atmosphere (Van Huis, 2015).

By 2050, over 50 per cent of the world's population is projected will face water shortages (World Bank, 2017). With agriculture contributing nearly 70 per cent of freshwater withdrawals, FAO has urged countries to reform their agrifood systems to make them more sustainable. Such a warning if left unheeded spells doom for Kenya, where over 80 per cent of the land mass is arid, and agriculture is resource-intensive. Insect farming could provide a more reliable, sustainable and cost-effective solution in overcoming food insecurity challenges.

At present, edible insects form the diets of about 2 billion people globally. In Africa, there are nearly 2,300 documented species of edible insects, with the more common ones being crickets, grasshoppers, locusts, termites, mopane worms, and black soldier flies (Matandirotya et al., 2022). Consumer acceptance on eating insects in Kenya varies from one community to another. Some like the Luhya, Giriama, and Luo consider insects as a supplemental staple in their diets (Kagezi et al., 2010).

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Meanwhile, communities in the frontline of periodic bouts of droughts and floods such as the Pokot and Turkana utilize insects as an emergency source of food for both humans and their livestock herds.

Municipal waste-related environmental contamination poses serious threats to Nigeria's environment, causing harm to residential and business zones. With 36 states and a federal capital territory, Nigeria has 37 capital cities and other metropolitan and semi-urban districts. The daily production of enormous volumes of garbage without proper disposal is a significant issue. Municipal waste management includes collection, transportation, processing, resource recovery, recycling, and disposal. (Khan, et al., 2022).

The collection, transportation, processing, resource recovery, recycling, and disposal of trash are all included in municipal waste management (Juárez-Hernández, 2021). Despite the widespread regulation in Nigeria, perfection in waste management and disposal has not been achieved. Families make modest efforts to clean up their surroundings, but most states have regulations for general clean-ups and create offenses for non-compliance. Waste disposal and management are still indiscriminate, with waste dumped on roadside, drainage channels, and erosion sites (Opio, 2021).

Several waste management organizations operate in the states under legislation, providing them with the authority to handle waste and recycle it. Private businesses and waste-pickers have significantly improved waste management in Nigeria, and trash recycling also involves private businesses and waste collectors (Morais et al., 2022). However, open dumping, open burning, incineration, unregulated landfills, composting, and dumping into drain channels, streams, and rivers are still the most common methods of disposing of municipal trash (Husain, 2023).

According to Alabi and Wohlmuth (2019), many of Nigeria's member states have had to deal with waste, leading to mountains of trash in many places, deteriorating the environment and lowering the standard of living in certain areas. This puts other hidden components of the environment, such as groundwater supplies, at risk. Businesses and households rely heavily on private waste management companies to efficiently dispose of waste (Cheng et al., 2022).

The acute failure of Nigeria's waste management system is evident in the excess of garbage, health risks for hygiene and sanitation, and the challenge of maintaining a clean city during exceptional times like holidays (Steffi, Mishel, Selvakumar, Manivel, & Muthusamy, 2023).

The link between waste generators and the waste management system is crucial for efficient waste collection and transportation. Municipal solid waste disposal is a global issue that needs to be addressed, regardless of a municipality's size, socioeconomic makeup, or complexity of waste management programs. Many municipalities have been forced to evaluate their solid waste management programs and assess their cost-effectiveness in terms of collection, transportation, processing, and disposal due to increasing population concentration in cities and various cost, health, and environmental concerns (Nikiema, & Asiedu, 2022).

Besides, the focus of this research will be on route optimization and vehicle need optimization (Dhanare, Nagwanshi, & Varma, 2022). Conventional waste management systems collect waste daily, while smarter systems collect waste when there is an overflow of bins, which is ineffective.

This study aims to address these challenges by optimizing waste collection based on factors such as bin condition, distance, road congestion, truck capacity, and other factors.

However, costs are a complex topic due to various variables influencing them, such as location, volume and composition of solid waste, technology used, collection and transportation, travel lengths, and labor/landfill costs. Estimates suggest that between 60 and 80 percent of the money spent on solid waste collection, transportation, and disposal is spent at the initial stage. Even a minor improvement in the collecting process can result in a significant reduction in overall cost.

Dijkstra's algorithm, a popular computer science algorithm, was used to optimize an efficient route for proper waste disposal management (Kavitha, & Sumathi, 2022). The link-cost of routes was calculated based on bin status, distance, and road congestion, with the garbage truck following the shortest path for waste collection.

2. Aim and Objectives

A. Aim

This study aims to apply Dijkstra's algorithm to optimize an efficient route for proper waste disposal management, reducing pollution and minimizing costs.

B. Objectives

- To develop a route optimizer system that utilizes Dijkstra algorithm for waste disposal management.
- To optimize waste collection routes by minimizing travel distances and maximizing resource utilization.
- To incorporate additional constraints such as vehicle capacity and time windows into the route optimization process.
- To evaluate the performance of the developed route optimizer using real or simulated data.

3. Mathematical Model

The mathematical model for designing a new and efficient route optimizer for waste disposal management using Dijkstra's algorithm:

Let's define the following variables:

N = Set of nodes (dump sites)
E = Set of edges (roads/paths) connecting the nodes
$w(i,j)$ = Weight/Cost of the edge $(i,j) \in E$
s = Source node (starting dumpsite)
t = Destination node (ending dumpsite)

The objective is to find the shortest path from the source node s to the destination node t, minimizing the total weight/cost.

The mathematical model can be formulated as:
Minimize $\sum_{(i,j) \in E} w(i,j) * x(i,j)$
Subject to:
$\sum_{j:(i,j) \in E} x(i,j) - \sum_{j:(j,i) \in E} x(j,i) =$
{
1, if i = s
-1, if i = t
0, otherwise
}

$x(i,j) \in \{0, 1\} \ \forall \ (i,j) \in E$
Where:
x(i,j) = 1 if edge (i,j) is part of the shortest path, 0 otherwise.

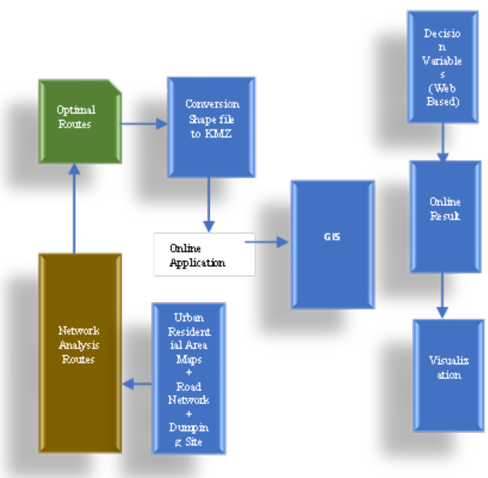

Fig.1. Dijkstra-based model

This Dijkstra-based model can be implemented using appropriate data structures and programming languages to create the route optimizer for waste disposal management. The optimized routes can then be used to improve the efficiency of the waste collection and disposal process, reducing costs, travel times, and environmental impact.

4. Results And Discussion

The Dijkstra algorithm and mathematical model have been used to design a new route optimizer for waste disposal management. The model optimizes waste disposal routes by finding the shortest path between the source and destination, leading to significant cost savings in fuel consumption, vehicle maintenance, and labor costs. This improves efficiency, resulting in faster collection and transportation times, better resource utilization, and increased productivity. The optimized routes also reduce the carbon footprint and environmental impact of waste disposal operations, with shorter travel distances and reduced fuel consumption contributing to lower greenhouse gas emissions and a smaller ecological footprint. The model is scalable and adaptable, accommodating larger networks of dump sites and roads, and considering factors like real-time traffic conditions, vehicle capacity constraints, and renewable energy sources for waste collection vehicles. The route optimizer provides valuable insights to waste management authorities, enabling them to make more informed decisions regarding resource allocation, fleet management, and strategic planning for waste disposal infrastructure.

5. Conclusion

In conclusion, the implementation of a Dijkstra-based route optimizer can lead to significant improvements in cost-effectiveness, operational efficiency, and environmental sustainability.

A. Contribution To Knowledge

The new and effective waste disposal management route optimizer makes a significant contribution to a number of fields of study and real-world applications. For example, traffic management agencies can use the data generated from the system's implementation to identify congested areas and take preventive or corrective action to decongest those areas, improving traffic flow and lowering the risk of delays and accidents. minimizing travel times and distances, particularly for heavy-duty vehicles, reducing emissions and the carbon footprint, all of which support more environmentally friendly waste management techniques. By providing information on garbage generation trends, it can also be utilized in urban planning to assist create more effective waste management policies and infrastructure.

Having developed a scalable and adaptable model, it enhances the integration of technology into municipal services by encouraging the use of Geographic Information Service (GIS) and real-time data for dynamic route optimization. It also provides insight to other researchers into how Dijkstra's algorithm can be scaled or adapted for other logistics and transportation problems. Finally, it shows how effective Dijkstra's algorithm is at solving shortest path problems outside of theoretical contexts, which could have a positive impact on a variety of industries, including emergency response, delivery services, and public transportation.

The creation and application of a Dijkstra-based route optimizer in trash management, taken as a whole, emphasizes the usefulness of algorithmic efficiency in improving urban living conditions, sustainability, and service delivery.

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