Route Optimizer: Best Tool for Waste Disposal Management

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ABSTRACT

Efficient waste disposal management is a critical challenge for modern urban systems, requiring solutions that minimize operational costs, reduce environmental impact, and adapt to dynamic traffic conditions. This study proposes a **Route Optimizer framework** using a **machine learning–enhanced reinforcement learning (RL) routing model** integrated with classical graph algorithms such as **Dijkstra** and **A***. The methodology involves constructing a weighted graph of urban road networks, real-time data from IoT bin sensors, preprocessing geospatial such as GIS mapping, and traffic-aware routing which enables dynamic scheduling and on-demand pickups, reducing unnecessary stops, fuel consumption and then having an RL agent that will undergo training on learning optimal routing policies through iterative prototyping and simulation. The optimization algorithm combines **real-time traffic predictions** (via supervised ML models) with **RL-based decision-making**, in order to adapt to congestion, vehicle capacity, and time-window constraints.

Keywords: Route optimizer, Waste disposal management, Municipal solid waste, Waste collection routing, IoT bin sensors

INTRODUCTION

The everyday activities of people living in urban areas generate large quantities of waste. Presently, the yearly production of solid waste in the world amounts to about 1.6 billion metric tons and a notable amount of money is used in taking care of huge amount of solid waste. Hoornweg & Thomas (2019) said that, in the 2015, Asian countries alone spent about US$25 billion on solid waste management per annum and it is expected to rise to US$50 billion by 2025. Hoornweg & Thomas (2019) also added that in general, the production or generation of waste is directly proportional to the economic growth, increase in population and the changes in lifestyle of the people". Ackerman (2017) opined that, as the world is developing and progressing, waste generation products are also increasing and it has become a major concern at a global scale. The effect of waste on public health and environment, such as emissions to air, water and the soil contamination, land degradation and habitat deterioration, has inspired engineers and scientists to carry out more research on waste management solutions with more favorable environmental footprints. Dipanjan et al. (2017) was of the opinion that domestic, industrial and other wastes are also the reasons for environmental pollution. For that reason, municipal solid waste management systems (MSWMS) are needed for the sustainable development of developing countries. Howard and Irwin (2015) stated that, a perfect or model waste disposal site is one, which is located reasonably close to the source of the waste, is not situated in a floodplain, has a proper road network and is underlain by geologically strong, stable and competent rock material. Heywood et al. (2018) added that, it is therefore imperative that many factors must be incorporated into landfill siting and therefore, Geographic Information System (GIS) is an ideal tool for this type of study or research, keeping in view its ability to manage large volumes of spatial data from a wide range of sources". According to Sumathi et al. (2018), Rahman and Hoque (2016), being a computer based system said that the rationale behind using GIS is that it is one of the most exciting technologies available to geographers today and it provides support for making decisions using spatial data. This rationale simply can be attained by organizing, visualizing, combining, querying, or analyzing data. GIS has progressed to essential tools of urban planning and administration,

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detection of zone, business planning, management of natural resource, and optimization of solid waste management from collection to dumping of solid waste. The method of using GIS techniques in environmental assessment gives a low cost and digital data.

Problem Statement

Municipals lack an integrated, data-driven routing solution that can match collection resources to actual demand while reducing operational cost and environmental impact. Various methods initially used fail to optimize routes for vehicle capacity, traffic conditions, bin fill levels, and service constraints at the same time, thereby producing suboptimal schedules and unnecessary trips.

Theoretical Review

Route Optimizer

Route optimizer as a system, analyses data in order to determine the most efficient paths for waste collection vehicles. Some factors such as distance, traffic, vehicle capacity and service schedules are used to create optimized routes. Qureshi, (2013) was of the opinion that optimization is discovering an option with the largely cost efficient or premier realizable performance based on certain restraints, by capitalizing on required factors and reducing unwanted ones". The idea of optimization in solving routing problems is referred to as route optimization. Route optimization is about finding the best route among several others with the most cost or time effective under the given constraints. There is obvious that route optimization, whether scientific or mere reasoning of an individual, has been sought after in present era, and earlier than now. The spurring factor necessitating this, prior before now was security. Qureshi, (2013) also added that "the financial (economic) factor is concerned with reducing cost of travelling while ecological (environmental) factor is concerned with protecting the environment from vehicles' emission of smokes". As travel cost further arise, route optimization also get further important. Several researchers or scientists have proposed different techniques to find the shortest path between two points, which is known to be optimal route.

Waste Disposal Management

According to Adewole (2019), waste management is the collection, keeping, treatment and disposal of wastes in such a way as to render it harmless to human and animal life, the ecology and the environment generally. The essence of waste management is to protect human lives in particular and the environment in general. United Nation's (UN) (2018) defines sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own need. The principle of sustainable development looks forward to achieving societal and environmental equity while in pursuit of economic gain. From the point of view of sustainable development, waste is interpreted broadly or narrowly. In broadly interpreting what waste is, it explains various forms of pollution, ranging from discharges of toxins into the commons, or of emissions into the atmosphere. On the other hand, a narrow interpretation of waste is made up of those byproducts of production and consumption that are the subject of specific waste control programs. Adewole (2019), continued to say that, sustainable development is an implied development without destruction; it is the judicious use of non-renewable resources for the present and future generations, which are non-renewable resources, which must be used at a judicious rate, neither too fast nor too slow and to ensure that the natural wealth that they represent is converted into long-term wealth as they are used. In Nigeria, waste is clearly explained as a sustainable development without endangering future development. This means that in our efforts to explore and exploit the natural resources to serve us, there is an obvious paradox evident in the need to ensure economic development, while protecting the environment. It is necessary to know that there must be a balance between levels of development and the stock of natural resources, which means that development must be at a level that sustained without prejudice to the natural environment or to future generations. A quick look at the meanings of waste in media and printed documents reveals that waste is considered as an unwanted good that is no longer useful or needed. In the German Waste Act of August (1993) opined that, waste is defined as a portable object that has been abandoned by the owner and also as an orderly disposal garbage. Uchegbu (2018) said that, waste is defined as those materials which are generated as a result of normal operations over which we have control in terms of their production, disposal or discharge.

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Figure 2. Waste Disposal Management

Municipal Solid Waste

Josephine, (2016) said that the environment of man lies at the mercy of both natural disaster and negligence on the part of man in the course of controlling the gifts of nature. The later, takes the form of dumping solid/industrial waste in the wrong place, desert encroachment, erosion, depletion of ozone layer, depletion of natural resources, pollution of land, rivers, seas, the air and generally the environment. In early times (pre-colonial days up until 1970s), the disposal of refuse and other wastes did not pose any significant problem. The population was small and enough land was available for assimilation of wastes. Solid waste problem started with urban growth that resulted partly from national increase in population and more importantly from immigration. No towns in Nigeria especially the urban and semi-urban centers of high population density can boast of having found a lasting solution to the problem of filth and huge piles of solid waste, rather the problem continues to assume monstrous dimensions to urban and city dwellers. Public hygiene starts and ends in their immediate surroundings, and it believed that the city would take care of itself. The situation has so deteriorated that today the problem of solid waste has become one of the nation's most serious environmental problems. Josephine, (2016) added that, despite environmental agencies set up by the various states in Nigeria, the deterioration of the urban environment remains a challenge to the communities especially the local government that are constitutionally responsible for managing the waste.

Waste Collection

Waste collection plays an important role in waste management processes. It is also a wide and complex subject. Josephine (2016) noted that waste collection involves diverse elements such as collection systems, special equipment, personnel requirements and the layout of collection routes as well as loading and unloading activities. It starts now where filled waste containers or garbage bags are loaded in waste trucks. Josephine (2016) also postulated that waste collection represents almost 50% of the total cost of waste disposal. Management arrangements include municipal services to franchised private companies and informal groups in developing countries. There are several methods that are used for waste collection. Among them, the most common are:

(1) Simple emptying method where standardized containers mechanically are emptied into a collection vehicle and then returned at the starting point.
(2) Exchange method where others replace containers. This technique is often used in handling high volume of waste such as construction debris and waste in industrial areas.

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IoT Bin Sensors

Marques et al. (2019), pointed out on the importance of IoT and its capability of updating outdated systems. This IoT plays a significant role in solid waste management by its capability of improving the efficiency of waste collection, controlling the overflow of waste, and promoting sustainable waste disposal practices. IoT bins sensors help in monitoring when waste bins are full and then alert the waste management team for waste collection.

Waste Treatment And Disposal System

Abdul (2010); Freduah George (2016); Foday et al. (2013) opined that generally, "waste treatment is as vital as its collection". Hence, a suitable method is required in order to maximize the treatment process. Some of the methods for waste treatment include the following: biological treatments, detoxification with neutral ash, incineration, open burning.

Open Burning

According to Lekan (2017), "open burning is regarded as an ancient method of waste disposal system". It is all about burning of unwanted material in an open space without control from weather element like air or wind. In this type of method, smoke is released into the environment in an uncontrolled manner. Foday et al. (2013) and Lekan (2017) were of the opinion that, "it has been widely accepted that open burning method has tendency to create environmental pollution. Sometimes refuse could be confined to barrel or incinerator, once the burning device does not contain emission control device or lid it is agreed to be open burning". Furthermore, smoke is often released into the air, which may cause fog, acidulated precipitations, acid rain, and depletion of Ozone layer because of the release of aerosol to the atmosphere.

Figure 3: Open burning by Lekan, (2017)

Dumps and Landfills

Abdul (2010) said that, "dumps are location designated for stacking of refuse and waste materials". Buffer location is always selected where there is a low water table or areas where water that filters through the dumps or landfills would not leak into the ground. The landfills or dumps are designed in such a way that the sides and bottom are lined and covered with impenetrable materials that would not give room for a leaching process

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to take place. The percolate is collected at the bottom of the dumps or landfill pumped out for biological and chemical treatment before disposing. Rodents and pest often kept off by polythene covering or shadow shed. Furthermore, underground watercourse pollution to surrounding land mass is possible; this overcome through creating of weeping boreholes which water subjected to hydrological test for possible watercourse contamination. Freduah (2016) opined that in advanced European countries, dumps and landfills are equipped with gas sensors as illustrated in Figure 2.1 that has capacity of detecting release of methane gas and morphine or Chloro fluoro hydrocarbon emission".

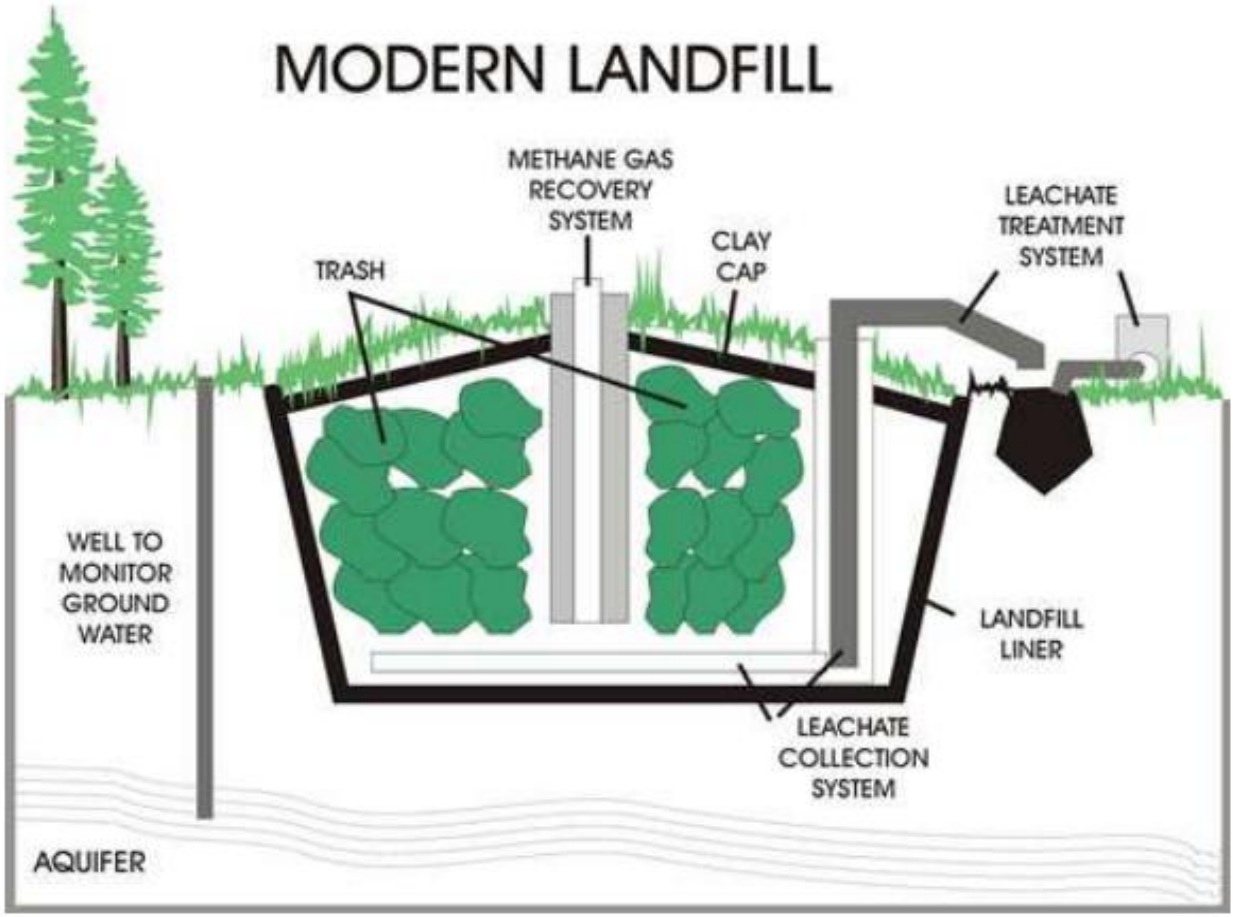

Figure 4: Main Features of a Modern Landfill (Freduah, 2016)

REVIEW OF RELATED LITERATURE

Pratima (2017) published a paper titled "Design and Implementation of Smart Waste Management System using FOG computing". This system uses ultrasonic sensor for sensing the level of waste and using Arduino node MCU it will send the data to the server and from which it will analyze the filled level and according to which the collector truck will go for collection as per the optimized route generated. In this paper, he developed an efficient system using Arduino IDE. The Arduino integrated development environment (IDE) and ifogSim tool for modelling IoT and Fog environments.

Kadafa (2017) examined the current Status of Municipal Solid Waste Management Practice in FCT Abuja. The study aims at identifying the current challenges and areas requiring improvement in FCT Abuja. The data collection was in stages, using an integrative approach via semi- structured interview and field observations. The qualitative data analyzed descriptively, while the quantitative data was analyzed using basic statistics. Based on the findings, it concluded that municipal solid waste management is a serious issue due to its human health and environmental sustainability implications that properly addressed within the FCT Abuja.

Jan (2020) conducts a study that focused on "Industrial Waste Management Models". His objective was to determine the commonly known business economic models, tools, methods and organizational theories as well

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as the Pollute-Pay-Principle applied in waste management. System theory adopted in order to get a clear picture of the model societal context; the economic model methods studied and modified from a waste management point of view. It concluded that theoretical findings point at the fruitful possibility to modify commonly used cost- revenue methods including the Pollute-Pay-Principle in an industry.

Adewole (2019) carried out research on "Waste management towards sustainable development in Nigeria with emphasis on Lagos State". The researcher did a conceptual work that pinpointed major effects of waste management on quality of life and he outlined perceived causes of intractable waste problems. He recommended that expanding recycling program could help minimize solid waste pollution but the key to solving severe solid waste problems lies in reducing the amount of waste generated.

Techniques Used

Hard Computing techniques

These are analytical approaches that make use of deterministic reasoning, crisp classification and binary logic in order to take care of precision, certainty and rigor. Some approaches include;

Dijkstra's Algorithm

Bale et al. (2016) said that "the foundation of shortest-path algorithm is the Dijkstra's Algorithm. Dijkstra computes the shortest paths from a particular node, which is the source of every other available node in the graph by preserving provisional distances for every node". Geisberger, (2011) stated that "the nodes visited in sequence following the shortest-path from the origin by the algorithm". This terminates the sequence after all goal nodes are visited. Dijkstra's algorithm solves problem in single-source shortest path and it is unsuitable for graphs with negative edge weights.

A* search Algorithm

Bale et al. (2016) said that A* search algorithm is an algorithm which is generally useful in graph traversal and path discovery. This is the way of plotting capable passable path with multiple nodes. Geisberger, (2011) opined that A* uses heuristics to accomplish improved time performance. In order to achieve its target, lower bounds are used on target distance to straight the search of Dijkstra's algorithm to the goal. The node is resolved according to their provisional distance between the origin and goal plus the lower bound. The effectiveness of this approach mainly lies on the lower bounds. Wilkie et al. (2012) pointed out that, the nodes geographic coordinates determine the simplest lower bound, in road networks and this result to poor performance. A* algorithm and graph were used in the improvement of a novel algorithm for self-aware route planning. The algorithm was able to forecast traffic and planned route for each car.

ALT (A* search Landmarks and Triangle inequality)

ALT is Dijkstra's algorithm speed-up technique that is pre-processing-based, which permits fastness in calculations of shortest paths in large road networks. There are some degrees of freedom in pre-processing of the ALT algorithm that is, in the graph, it must choose a subset of nodes, called landmarks, which perform a particular role. Landmark selection is NP-hard, thus, there is existence of effectual and no precise answer or algorithm. ALT stands for A* search Landmarks and Triangle inequality, which are the main constituent of the algorithm. ALT algorithm is a simplification of Dijkstra's algorithm that makes use of a function (the potential function π) to assess distances from one node to another in the graph. A high-quality potential function π used to decrease the explored space of the shortest path queries successfully. According to Goldberg, (2015), "the use of landmarks is a way to describe a potential function". Fuchs, (2010) said that "the distances from and to every other node, computed through the pre-processing phase, and the triangle inequality used in approximation of distances within the graph". The triangle inequality is known for any three nodes i; j; k in the graph, d(i; j) + d(i; k) + d(k; j), where d(i ; j) is the distance between i and j, i.e. shortest path between the two nodes length.

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Artificial Neural Network (ANN)

According to Bale, et al. (2016), Artificial Neural Network (ANN) also known as "Neural Network is responsible for information processing and it is stirred by the way biological nervous systems (brain) carry out information processing". Bale et al. (2016) also stated that "ANN is made up of a large number of extremely unified processing elements (neurones) functioning in harmony to resolve definite problems". Learning by example is one key feature of ANN just as humans. In biological systems, learning means fine-tuning to the synaptic relations that exist among the neurons, this also apply to ANN. Nerve cells must not be the only system that can carry out neural computation but an artificial system that can also imitate basic translation of a neural computational system, this is done by ANN which is an instance of an artificial neural system. Moussa, (2013) said that, "ANN is also known in different literatures as Parallel Distributed Processing, Connection Science, Connectionism and Neural Computing". ANN is a computational organization for the purpose of imitating biological neural networks. The ANN constituent computational units known as neurons, that linked through weighted interconnections. The weight, which is a number of that interconnection, determines the strength of the related interconnection. The adjustment of the weights of the interconnections based on various practical learning algorithms produce the learning process in ANN. A crucial attribute of this technology is that it advances its performance on a specific task by steadily learning a mapping linking the inputs and output. Salehinejad and Talebi (2010) applied ANN in combination with fuzzy logic and ant colony in multi parameter route selection system for route optimization. The hybrid system used to forecast the traffic situation and management road utilization, which further aided free movement.

METHODS USED

Requirement gathering

In this case, product requirements are gathered. The developer and customer come together todiscuss overall objectives of the software, as well as identify those requirements, which known. They establish some objectives like what the prototype will be used for, and features the final system the prototype would reflect.

Quick design

Quick design system is created when requirements are known. It includes only aspects of the system that are vital to the construction of the prototype such as input and output format of software, which are visible to the user rather than detailed design plan. It helps to construct a prototype.

Prototype building

Information got during quick design is used to enhance the software requirements, to achieve customer satisfaction. It is necessary to ensure low development cost for the prototype, as well as speedy development. This achieved by disregarding the requirements that are not of interest to the customer.

User Evaluation

The prototype evaluated in order to identify features to be add or removed. User gives comments and suggestions, which in turn provided, to the developer.

Refining prototype

If the user is not satisfied with the present prototype, then it is improved according to the requirement and a new prototype is developed. The new prototype is evaluated like previous prototype, and the process continues until all necessary requirements are met.

Engineer product

When all the requirements met, the user accepts the end prototype, and evaluates the end system with its regular maintenance for preventing its failures.

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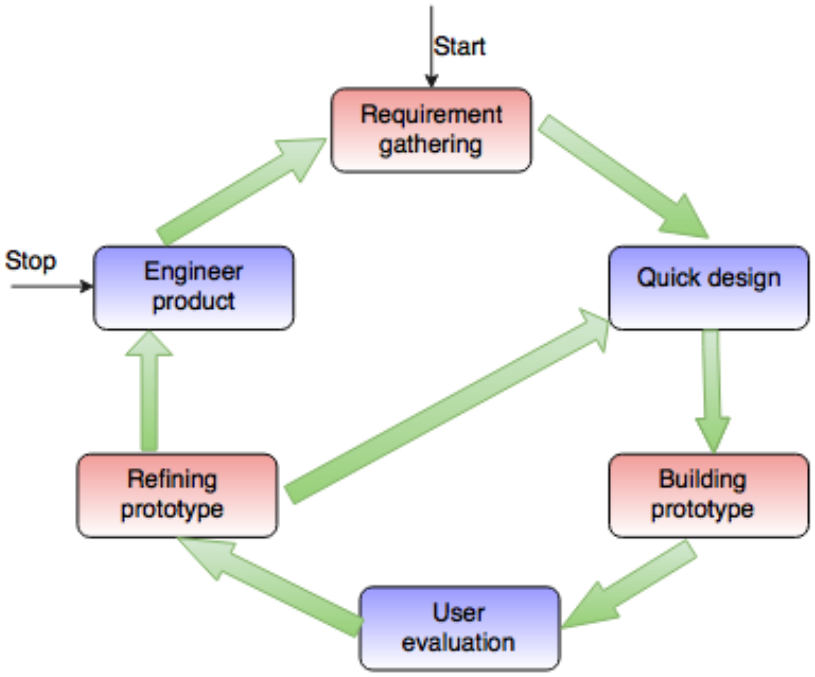

Figure 5: Prototyping methodology

Analysis Of The System

Route optimization is the way of determining the best path between a set of locations with a fixed order in a road network using some algorithms. It aims at improving routes for better efficiency and cost-effectiveness. When we use the term route optimization, we mean solving vehicle routing problems (VRP) and travelling sales representative problems (TSP). It is used in solving different vehicle routing problems such as the capacitated VRP with time windows or the VRP with multiple depots.

The criterion used in determining the best path can be different. This criterion could be distance or travel time. Anything is possible as long as it identified by allocating some quantity, a *cost,* to each road segment, and looking for the *least-cost path.* Optimal routes mean the drivers spend less time driving, which reduces fuel costs and can increase the number of stops a driver can make in a day, which can help improve service delivery. The flowchart diagram in Figure 3.2 below illustrates this process.

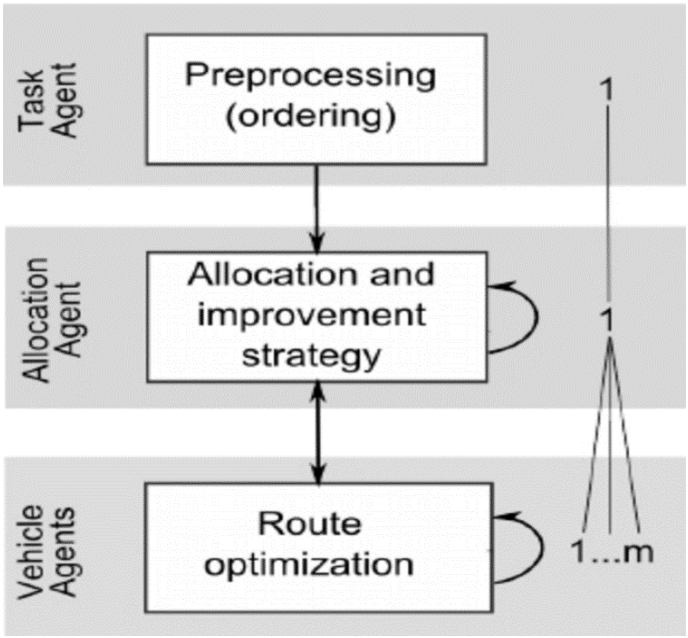

Figure 3.2: Architecture of existing Route Optimizer (Vokřínek et al., 2019)

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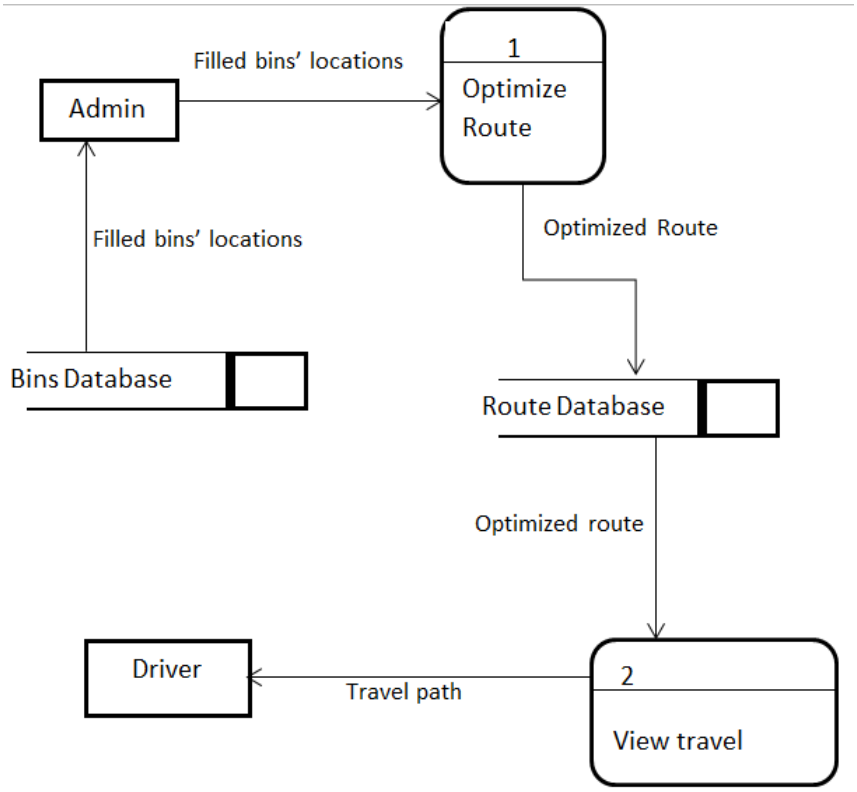
Data Flow Diagram (DFD) of the Existing System



CONCLUSION

The least-cost path analysis is a useful approach in determining the optimal route (route optimizer) for waste disposal management, because it provides a fast and vital application in finding all kinds of linear features for the planning of waste disposal. It is a high geographical information system (GIS) tool to integrate user information and replace the conventional methods of road planning. It can minimize the cost and time of waste disposal routing. In urban areas, many environmental constraints are involved e.g. dump of refuse in many locations. It needs a careful sustainable approach for finding route planning to evacuate all the waste. The method based on route optimization using Dijkstra algorithm to find the shortest path to all other vertices in a graph is applied in considering environmental and economic aspects with integration of the GIS and the multi-criteria decision analysis approach. The new efficient route optimizer is a cost effective GIS-based intelligent approach in route planning which leads to a sustainable, faster and cheaper planning method in waste disposal management.

REFERENCES

1. Adebayo, P. I., Emmanuel, R. A., Olapeju, A. E., & Tosin, C. O. (2020). Development of A Web based GIS Waste Disposal Management System for Nigeria. International journal Information Engineering and Electronic Business, 4(3), 40-48
2. Akshaya, B., and Selvakumar, K. (2019). Innovative Waste Management Technique via Garbage. International Journal of Recent Technology and Engineering (IJRTE), 8(2), 23-40
3. Adewole, A.T. (2019).Waste management towards sustainable development in Nigeria. International NGO Journal, 4(4), 173-179.
4. Abdul, S. (2010). Journal of Sustainable Development in Africa Environmental and Health Impact of Solid Waste Disposal at Mangwaneni Dumpsite in Manzini: Swaziland. Volume 12, No.7.
5. Amusan, L. M., Joshua, O., Oloke, O. (2013). Performance of Build- Operate-Transfer Projects: Risks' Cost Implications from Professionals and Concessionaires Perspective. European International Journal of Science and Technology 2 (3), 239-250
6. Agunwamba, T (2018). Solid waste management in Nigeria problems and issues. Environmental Management, 22(6): 849 – 856.

7. Beatrice, A. and Jussi, K. (2017).Municipal Solid Waste Management Problems in Nigeria: Evolving Knowledge Management Solution. International Journal of Environmental, Ecotoqicat, Geological and Mining Engineering 7(6).
8. Bale, D. L. T., Ugwu, C., Nwachukwu, E. O (2016). Route Optimization Techniques: An Overview. International Journal of Scientific& Engineering Research, 7(11), 40-50.
9. Baum, M. (2011). On Preprocessing the Arc-Flags Algorithm. KIT – University of the State of Baden-Wuerttemberg and National Laboratory of the Helmholtz Association.
10. Bell, J. E. and McMullen, P. R. (2014). Ant colony optimization techniques for the vehicle routing problem. Elsevier Ltd Advanced Engineering Informatics, 18(3), 41–48
11. Bellifemine, F., Caire, G., Trucco, T. and Rimassa, G. (2013). Jade Programmer's Guide. JADE 4.3", 2013. http://jade.tilab.com/doc/programmersguide.pdf.
12. Chang, N.B.; Wei, Y.L. (2012). Comparative study between heuristics algorithm and optimization technique for vehicle routing and scheduling in the solid waste management system. Civil Engineering and Environmental System, 19, (1), 41-65
13. Caric, T. and Gold, H. (2008). Vehicle Routing Problem, In-Teh Croatian branch, I-Tech Education and Publishing KG, Vienna, Austria.
14. Dian, H. S., Sasongko, S. B. (2019). Review Modeling of Solid Waste Transportation Routes Using Geographical Information System (GIS). E3S Web of Conferences 125, 0 (2019) http:dio.org10.1051/e3sconf/20191250 ICENIS 2019 7006 7006
15. Darquennes, D. (2005). Implementation and Applications of Ant Colony Algorithms, 2005.http://www.swarmbots.org/~mdorigo/HomePageDorigo/thesis/master/Darque nnesMASTER.pdf
16. Enugu State Government (2017). Statutory Responsibility of ESWAMA," Official Gazette, Edict No. 8, 2017.
17. Freduah, G. (2016). Problems of Solid Waste Management in Nima, Accra. Undergraduate Research Journal for the Human Sciences. University of Ghana, Legon. 2(3).12-22.
18. Foday, P. S., Xiangbin, Y., Quangyen, T. (2013). Environmental and Health Impact of Solid Waste Disposal in Developing Cities(2013) A Case Study of Granville Brook Dumpsite, Freetown, Sierra Leone,4 (7), 30-50.
19. Fuchs, F. (2010). On Preprocessing the ALT-Algorithm, KIT – University of the State of Baden-Wuerttemberg and National Laboratory of the Helmholtz Association, 2010.
20. Geisberger, R. (2011). Advanced Route Planning in Transportation Networks," des Karlsruher Instituts für Technologies, 2011.
21. Goldberg, A.V. and Harrelson, C. (2015). Computing the Shortest Path: A* Search meets Graph Theory," Proceedings of the 16th Annual ACM–SIAM Symposium on Discrete Algorithms (SODA'05), 2015, pp. 156–165
22. Ghiani, G., Laganà, D., Manni, E., Musmanno, R., & Vigo, D. (2014). Operations research in solid waste management: A survey of strategic and tactical issues. Computers & Operations Research, 44(4), 22-32.
23. Geisberger, R., Sanders, P., Schultes, D. and Delling, D. (2011). Contraction Hierarchies: Faster and Simpler Hierarchical Routing in Road Networks," 2011. http://algo2.iti.kit.edu/schultes/hwy/contract.pdf.
24. Idowu, P. (2020). Development of A Web based GIS Waste Disposal Management System for Nigeria. International Journal of Parallel Programming. 4(2), 40-48. 10.5815/ijieeb.2020.03.06
25. Jan, S. (2020). Industrial Waste Management Models. A Theoretical Approach. Lund Institute of Technology Lund University Sweden.
26. Josephine, I. O. and Anulika, V. O. (2016). Solid Waste Management in Nigeria: Contributions to Sustainable Development: A Study of Eswama, Enugu State Of Nigeria. Humanities and Social Sciences Review, CD-ROM. ISSN: 2165-6258: 06(01):169–182 (2016)
27. Jennings, N. R. (2010) On Agent-Based Software Engineering. Artificial Intelligence, 2010, 117 pp. 277–296
28. Karskens, J. (2015). Mail Delivery Problem Route Optimization with Capacity Constraints" http://www.few.vu.nl/en/Images/researchpaperkarskens_tcm39-363659.pdf, Retrieved July, 2015

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

29. Kammoun, H. M., Kallel, I., Casillas, J. and Alimi, A. M. (2008). A Road Traffic MultiAgent Simulation using TurtleKit under MadKit, 2008. kammoun.regim.org/wpcontent/uploads/2012/01/2008_ICAISC_HIJA.pdf.
30. Kulkarni, A.J., Tai, K., Abraham, A.(2015). Probability collectives: a distributed multi-agent system approach for optimization. In: Intelligent Systems Reference Library, vol. 86. Springer, Berlin (2015) (doi: 10.1007/978-3-319-16000-9, ISBN: 978-3-319-15999-7)
31. Kahraman, C. (2017) "Fuzzy decision-making application," Int. J. Approx. Reason, 2017, 44: pp. 91-92
32. Kuppuchamy, N.K. and Manimegalai, R. (2013). Manet Routing: Optimization by Genetic and Fuzzy Logic Approach," Journal of Theoretical and Applied Information Technology
33. Kisimi, K. (2018) A Web-based Solid Waste Management System for Sierra Leone. A thesis presented to the Faculty of Mathematics and Natural Science at University of Bergen Norway
34. KadafaAdatiAyuba, L., Abdullah, H. S. and Sulaiman, W. N. (2017). Status of Municipal Solid. Waste Management Practice in FCT Abuja.
35. Lekan, M. A., Charles, A. (2017) Multi-Parameter Optimization of Cost Entropy for Reinforced Concrete Office Building Projects Using Ant Colony Optimization. Journal of Engineering and Applied Sciences.12 (9). 2260-2275.
36. Mohammed, S. N. (2015). Policy Guidelines on Solid Waste Management, retrieved on 23rd April, 2016
37. Murat, Y. and Uludag,N. (2018). Route choice modelling in urban transportation networks using fuzzy logic and logistic regression methods," Journal of Scientific & Industrial Research, 6(7), 19-27
38. Moussa, S. M. (2013). The implementation of intelligent QoS networking by the development and utilization of novel cross-disciplinary Soft computing theories and techniques. http://etd.lib.fsu.edu/theses/available/etd-11252003-192138/unrestricted/dissertation4.pdf
39. Modebe, Onyeonoro, U. U. (2018) and I. Household Solid Waste Management in Awka, Anambra State. West African journal of Medicine 27 (I), 56
40. Mohd Aizat, S. B. (2019). Development of GIS Database and Facility Management System: Asset and Space in ukm. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-4/W16, 2019 6th International Conference on Geomatics and Geospatial Technology (GGT 2019), 1–3 October 2019, Kuala Lumpur, Malaysia
41. Nallusamy, R., Duraiswamy, K., Dhanalaksmi, R. and Parthiban,P. (2019). Optimization of multiple Vehicle Routing Problems using Approximation Alg
42. orithms," International Journal of Engineering Science and Technology, 2019 vol 1 (3)
43. Nazif, H. and Lee, L.S. (2010). Optimized Crossover Genetic Algorithm for Vehicle Routing Problem with Time Windows" American Journal of Applied Sciences, 2010, 7(1) pp. 95-101.
44. Ofomata, G.E. and Phil-Eze, P.O. (2017. A survey of Igbo National, Warri: Africana First Publishers Ltd.
45. Ogwueleka, T.C. (2013). Analysis of urban solid waste in Nsukka, Nigeria, Journal of Solid Waste Technology and Management, 29, (4), 234-245
46. Oxford Dictionary, Retrieved July 10, 2015 http://www.oxforddictionaries.com/definition/english/route
47. Olaniyan O.M., Ogude, U. C.and Olabode I. O (2020). Implementation of web based waste disposal management system with integrated payment. Department of Computer Engineering, Federal University Oye-Ekiti, Nigeria
48. Otti, K. (2018). A model for solid waste management in Anambra State. i~cJournai of Soil Science and Environmental Management 2(2),.39-42.Available online at http//www.academicjournals.org/JSSEM.
49. Pratima, P. W. (2017). A Conceptual Use of ICT to Approach Municipal Waste Problem International Journal for Informaytion (IJI), 10(3), 34-44.
50. Qureshi, M. F., Ali Shah,S. M. and Al-Matroushi, G.I.G. (2013). A Comparative Analysis of Multi-Criteria Road Network," European Centre for Research Training and Development UK.
51. Ramesh, K. R., Ramakrishna, C. (2015). GIS Based Optimal Route Analysis for the Transportation of Solid Waste - A Case Study from Hyderabad City. International Journal of Advanced Research in Science and Technology, 4(3), 56-60.

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52. Salehinejad, H. and Talebi, S. (2010). Dynamic Fuzzy Logic Ant Colony System-Based Route Selection System," Applied Computational Intelligence and Soft Computing, Hindawi Publishing Corporation.
53. Sadiq, S. (2012). The travelling Salesman Problem: Optimizing Delivery Routes using Genetic Algorithms," Operations Research SAS Global, USA.
54. Uchegbu, S.N. (2018). Environmental Management and Protection, Enugu: Joe Best Publisher Ltd.
55. Vergara, S. E., & Tchobanoglous, G. (2012). Municipal Solid Waste and the Environment: A Global Perspective. Environment and Resources, 37(37), 277-309.
56. Marques, P.; Manfroi, D.; Deitos, E.; Cegoni, J.; Castilhos, R.; Rochol, J.; Pignaton, E.; Kunst, R. An IoT-based smart cities infrastructure architecture applied to a waste management scenario. *Ad Hoc Netw.* **2019**, *87*, 200–208. [**Google Scholar**] [**CrossRef**]