# Remote Health Service Delivery Mechanism Using Vehicle Routing And Dijkstra Algorithm In Akure Metropolis

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**Abstract**

Health services in Nigeria are one of the major factors why the majority of the populace are going abroad. Developing a service delivery mechanisms in health care management limit the challenges of travelling abroad for medical checkup. In the rural community in Nigeria, most people find it difficult to visit the hospital when they are ill. They prefer to use the local medication than visiting the health centres for proper medication diagnostic due to lack of money. This study attempted bringing the medical expert to the people's homes using the mobile health van or ambulance in case of an emergency. The vehicle routing algorithm and Dijkstra's algorithm served as a mechanism to calculate the shortest route or path to get to the patient location with an optimal distance and minimal cost. Hyper Pre-processor (PHP) was used to create an online-based registration form to get some information on the patient, consultant, and the nearest health facilities. Upon registration, the patient will go home with health wearable devices which will measure the body vital sign like blood pressure, electrical activities of the heart (ECG), body temperature and blood oxygen level. These wearable devices contain sensors attached to an Arduino Uno board with GSM/GPS 900. These will collect the measured readings and forward it to the server or cloud for the assigned medical consultant to render medical advice and for quick response in times of emergency. Google Earth Pro was used to get the Landsat and positions for the hospitals to create a database containing the addresses, longitude, and latitude. In conclusion, the design would allow patients to know the nearest hospital around them and calculate the shortest path to get to the hospital.

**Keyword:** *Delivery Mechanism; Health Service; Vehicle; Routing; Dijkstra Algorithm*

## 1. Introduction

According to [1] World Health Organization(WHO) defines health as a state of physical, mental and social well-being in which disease and infirmity are absent. Remote health service delivery is the system whereby health care resources and services delivered to the patient at any location. Home Health Care (HHC) covers a wide range of services at the homes of the patients. HHC mainly addresses the needs of the patients who are over-aged, who have disabilities and who have chronic diseases. HHC includes services such as nursing, medical visits, home life aids, psychological support, old people assistance, house cleaning, etc.

attention. The inability of a patient to find or get a health care centre to receive treatment when having health challenges like (heart failure, asthma) sometimes result in death.

Having observed the Hospital Management System in Ondo State, the condition is in bad shape. Currently, the location of the hospitals based on the different part of the community in the state, make it impossible to access by the patient because of distances. This study used the shortest path problem to finding the shortest path or route from a patient location to the nearest healthcare facility.

This aim of this reseatch is to design a remote health service delivery mechanism using vehicle routing and Dijkstra's algorithm in Akure metropolis. This study allows for quick access to health facilities remotely and to encourage prompt health care delivery. The cost of each route, the travel cost and travel time between each patient and the care centre must be known. A health service delivery system for health care centres can aid in the hospitals for reaching the patient in a golden hour, i.e. right on time. Also, it can be useful in the development of a database for hospitals in the study area. This study centred on health care centres only in Akure. It covers the entire hospitals in Akure using (Geographic Information System) GIS with the toposheet of Ondo State. The limitation of this study, it can only find the health care centres within the patient range or location.

## 2. Literature Review

The Vehicle Routing Problem or simply VRP is a well-known combinatorial

Presently, the percentages of Nigerians living up to the age of 52 and above have increased significantly, and the existing health care system had not given these people optimization problem and a generalization of the travelling salesman problem. This includes the optimal (minimal) routes for a fleet of vehicles starting from a single point (depot) to deliver the requested goods in all customers at different locations. Finding an optimal solution is an NP-hard problem, so heuristic strategies for the approximation of the optimal solution were used in this study.

Vehicle Routing Problem aids management of vehicle resources effectively and reliably like the reduction of fuel consumption, finding a faster route for travel. The design is required to handle these tasks ranging from a distance, map of the road, and fuel consumption to overcome the challenges. The Vehicle Routing Problem (VRP) in this study can best describe as the problem of designing optimal delivery or collection routes from one or several Hospital of geographically scattered patient in the cities, subject to side constraints.

### 2.1 Constraints Calculation for VRP Algorithm

The formulation of the TSP by [2] was to create the two index vehicle flow formulations for the VRP. Constraints **1** and **2** states that exactly one arc enters and exactly one leaves each vertex associated with a customer, respectively. Constraints **3** and **4** say that the number of vehicles leaving the depot is the same as the number entering. Constraints **5** are the capacity cut constraints, which impose that the routes must be connected and that the demand on each route must not exceed the vehicle capacity. Finally, constraints **6** are the integrality constraints.

$$\min \sum_{i \in V} \sum_{j \in V} c_{ij} x_{ij}$$

subject to

$$\sum_{i \in V} x_{ij} = 1 \quad \forall j \in V \setminus \{0\} \tag{1}$$

$$\sum_{j \in V} x_{ij} = 1 \quad \forall i \in V \setminus \{0\} \tag{2}$$

$$\sum_{i \in V} x_{i0} = K \tag{3}$$

$$\sum_{j \in V} x_{0j} = K \tag{4}$$

$$\sum_{i \notin S} \sum_{j \in S} x_{ij} \geq r(S), \ \forall S \subseteq V \setminus \{0\}, S \neq \emptyset \tag{5}$$

$$x_{ij} \in \{0,1\} \quad \forall i, j \in V \tag{6}$$

## 2.2 Constraints Calculation for Dijkstra's Algorithm

Dijkstra's algorithm is an algorithm for finding the shortest paths between nodes in a graph, which may represent, for example, road networks and was developed by computer scientist Edger W. in 1956.

For each visited node **v**, dist[**v**] considered the shortest distance from the source to **v**; and for each unvisited node **u**, dist[**u**] is assumed the shortest distance when travelling via visited nodes only, from source to **u**. This assumption is considered if a path exists; otherwise, the distance set to infinity. In which case, we choose an edge **vu** where u has the least dist[**u**] of any unvisited nodes, and the edge **vu** is such that dist[**u**] = dist[**v**] + length [**v, u**]. dist[**u**] is considered to be the shortest distance from the source to **u** because if there were a shorter path, and if **w** was the first unvisited node on that path then by the original hypothesis dist[**w**] > dist[**u**] which creates a contradiction.

```
function Dijkstra(Graph, source):

    create vertex set Q

    for each vertex v in Graph:
        dist[v] ← INFINITY
        prev[v] ← UNDEFINED
```

```
    dist[source] ← 0

    while Q is not empty:
        u ← vertex in Q with min dist[u]

        remove u from Q

        for each neighbour v of u:    // only v that is still in Q
            alt ← dist[u] + length(u, v)
            if alt < dist[v]:
                dist[v] ← alt
                prev[v] ← u

    return dist[], prev[]
```

## 2.2 Review of Related Works

The main objective of the Vehicle Routing Problem (VRP) is to design a set of minimum cost routed that serves several places, geographically dispersed, and fulfilling specific constraints of the problem. Since its first formulation in 1959, there have been many publications and has expanded its scope. In the last decade, there have been significant advances in terms of the technical solution to resolve large instances. Another aspect that has gained interest is the inclusion of technological innovations in the VRP. These include global positioning systems, radio frequency identification and use of high-capacity computer information processing [3]

Mohamad, AbdulRauf and AbdMalekMod [4] work on health care facility for Joharbahru city, Malaysia. A network dataset created from the feature source or sources that participate in the network. It incorporates an advanced connectivity model that can represent complex scenarios, such as multimodal transportation networks [4] Preparation of the network analyst such as the Shortest Route using Shortest Path tool: the closest facilities using the closest facility tool.

Tikani and Setak, [5] worked on Ambulance routing in a disaster response scenario considering different types of ambulances and semi-soft time windows using Heuristic Algorithms based on genetic algorithm and tabu search. They were able to find acceptable solutions for a problem in reasonable computational times, but due to the NP-hardness of the project, only small-sized instances solved. Tohidifard and Partovi [6] were able to calculate the shortest route using both genetic algorithm and particle swarm optimization, but only a small number of instances of it was solved.

Cordeau and Laporte [7] designed a Dial-a-Ride Problem (DARP): Variants, modelling issues and algorithms using dynamic programming, it can accommodate many users as much as possible but does not make use of the new technologies like vehicle positioning system. [8] implemented GIS and ArcGIS (network analyst) to design the ambulance management system, but it only works with Hyderabad (study area) road network. It finds the accident location on the road network and locates the nearest ambulance to the incident site. According to [9] the nearest location of the hospital can be calculated based on the user's location using Dijkstra's algorithm and Geographic Information System (GIS). Still, the system can only find hospitals in Aurangabad city. The development of Modeling to Solve the Multi-depot Vehicle Routing Problem with Time Window by Considering the Flexible End Depot in Each Route was solved using Genetic Algorithm (GA). The Clustering methods and the result compared between the K-means and FCM Clustering algorithms, but the vehicle capacity and time constraint were not determined [10].

Routing is the process of selecting a path for traffic in a network or between or across multiple systems. Several studies address issues of locating, dispatching, and the fleet of ambulances as emergency medical services (EMS). The main concern of EMS is immediate patient care before arriving at the hospital. By growing the demands for EMS, it becomes one of the active research areas in transportation and health care management [5].

Polimeni, [11] proposed the Vehicle Routing Problem with Time Windows for a particular case of the classical Vehicle Routing Problem. This work proposed a hybrid algorithm that combines the metaheuristic Iterated Local Search, the Variable Neighborhood Descent procedure and an exact Set Partitioning model. The algorithm is of high complexity.

(Contardo and Martinelli, [12] developed a Column generation and Exact algorithm for the multi-depot vehicle routing. The problem under capacity and route length constraints, it can produce the tightest lower bounds for two classes of problems, but they did not consider the future exact algorithms for the classes of problems. [13] designed an Application of Vehicle Routing Model to Mobile-Health Cloud Management in South Africa and adopted Cloud Computing, Bound Algorithm, and Lazy Branch as their methodology. The challenges with the study involve its applications in an environment where the numbers of cities or communities are enormous. It reduces the cost and also the waiting time of the patient.

Shankar, Mani, and Pandey [14] developed a GIS-Based Solution of Multi-Depot Capacitated Vehicle Routing Problem with Time Window Using Tabu Search Algorithm. It considered multiple parameters to get the relative paths, but the road network not efficiently handled because of its complexity.

Dabia, Ropke, Woensel, and De Kok [15] designed a branch and cut and price for the time-dependent Vehicle Routing Problem with time windows using column generation and Branch and Cut framework; it can calculate the best dispatch time from the depot. The only limitation is that it is time-dependent. According to [16] the vehicle routing problem in both public safety and health care can be solved using Heuristics Algorithms and Decomposition model (column generation) to develop a Vehicle Routing Models in Public Safety and Health Care. Still, continuity constraints cannot hold because of the absence of a backup nurse. [17] designed a Vehicle Routing Problem for Modeling Home Healthcare: a Case Study using robust optimization, it can handle the travel time uncertainty properly. It can be used in the sensitive application when time is crucial but based for patients with Peritoneal Dialysis (PD) only. [18] developed a Vehicle Routing Problem Solver using Google API, but the system is online-based, the complexity of the algorithm is low and more comfortable to implement.

## 3. Methodology

Four stages will be involved in the development of this system; Data Collection, Geo-referencing, Routing mechanism using VRP and Dijkstra's algorithms, and Data Analysis. This is to achieve an effective and efficient system with the desired result. An assumption was made in this study, that after patient registration, the patient will be provided with wearable devices to measure the body's vital sign like blood pressure, oxygen level, temperature and electrical activities of the heart, i.e. ECG Figure 3.1.

### 3.1 Design Requirement and Methology

The project designed implemented with a Google Earth Pro software used in getting the latitude and longitude of the hospitals in Akure metropolis to create a database. An ArcGIS software, Google API programming, Dijkstra's algorithm and VRP algorithm used in the design. The Hypertext Markup Language (HTML) and Hyper Pre-processor PHP programming languages for an online-based Login and Registration Portal. The design model of the systems shown in Figure 3.1 depicts the system design layout used in the methodology for carrying out the result of the projected objectives. The methods used in the methodology includes ;

i. Data Collection using online health delivery service system.
ii. Geo-referencing using Google Earth Pro.
iii. Routing mechanism using VRP and Dijkstra's algorithms

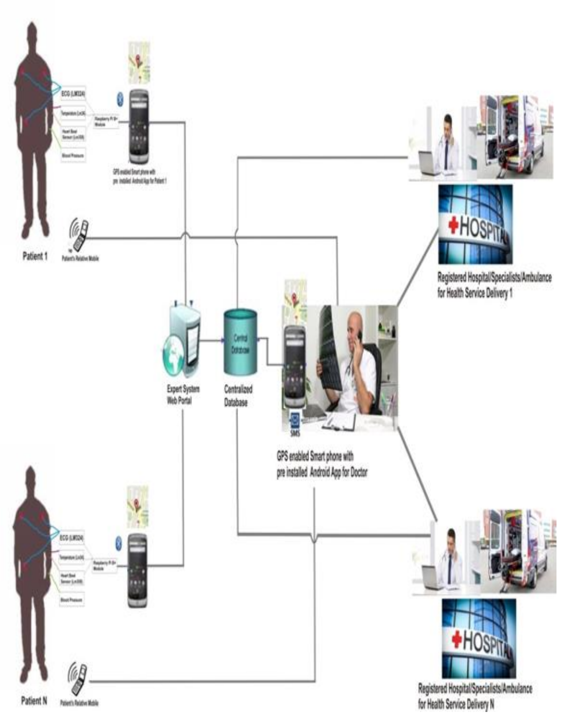



Figure 3.1: Pictorial Model of the design work

### 3.2 Data Collection (Case Study: Base Map)

Akure lies about 7°25’ north of the equator and 5°19’ east of the Meridian. It is about 700 km Southwest of Abuja and 311 km north of Lagos State. Residential districts are of varying density, some area such as Arakale, Ayedun Quarters, Ijoka, and Oja-Oba consists of over 200 persons per hectare. In contrast, areas such as Ijapo Estate, Alagbaka Estate, Avenue and Idofin have between 60-100 people per hectare. The town located in the tropical rainforest zone in Nigeria (Figure 3.2) shows the toposheet of Ondo State.

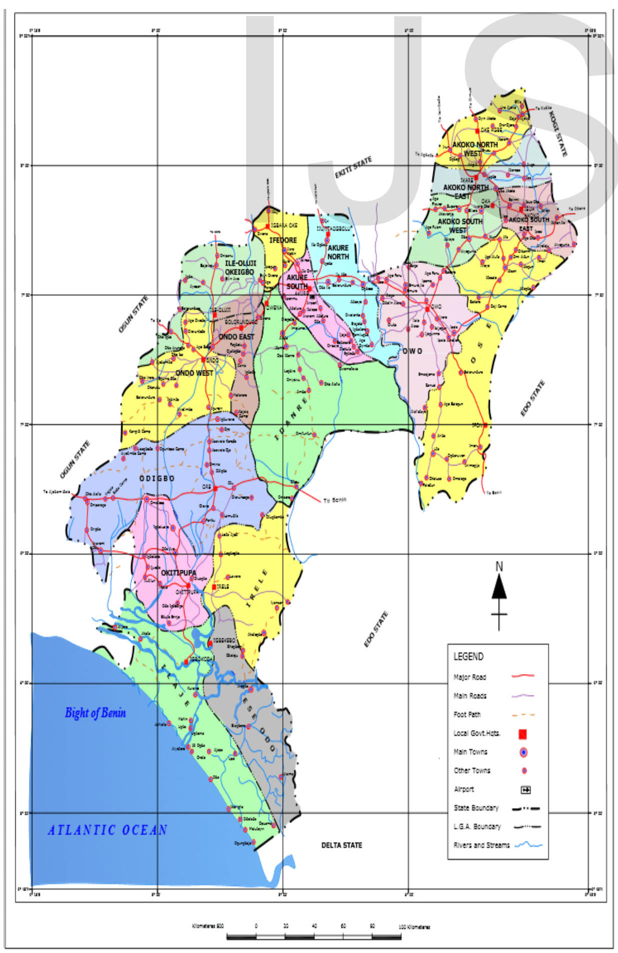



Figure 3.2: Toposheet of Ondo State (https://www.researchgate.net/figure/Map-of-Ondo-State showing-all-local-government-areas_fig2_289567037)

### 3.3 Hospital Location Database

The database created using MySQL and the details of the hospitals such as latitude and longitude (Figure 3.2), was extracted through Google Earth Pro. The coordinates of the health care were taken by using Google Earth Pro (Figure 3.3) and Global Positioning System (GPS). For the hospital's spatial data, connected to the internet services provided at each hospital. Attribute data that need to be stored in the database are the roads' name and lengths and names of the hospital and their facilities. Hyper Pre-processor (PHP) was used to fetch the latitude and longitude of the hospitals when calculating the shortest path to get to the patient (Table 1).

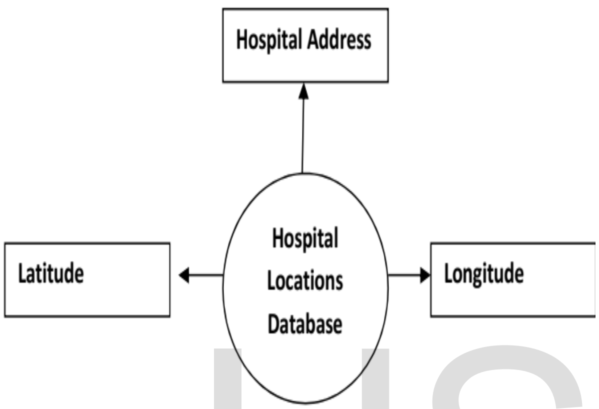



Figure 3.3: Hospital Database Flow Diagram

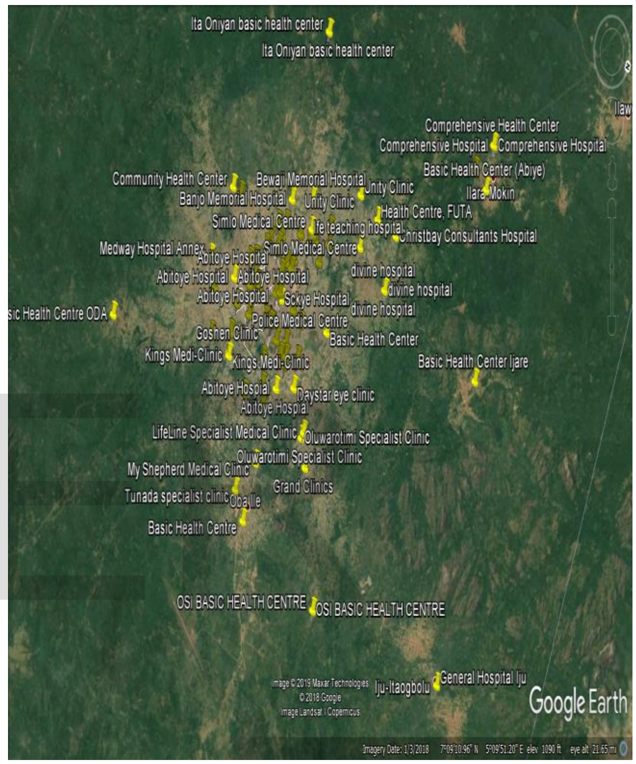



Figure 3.4: Landsat Image of Hospitals in Akure using Google Earth Pro

### 3.4 Development of an online health delivery services system

The web portal was developed with Hypertext Markup Language (HTML) with Hyper Pre-processor and Cascading Style (CSS) to style the pages like home page, patient page, doctor page and admin page.

The Home Page is where all users (patient, doctor and admin) login into the system figure4.1. All other pages linked to the home page. From the home page is the link to the patient web page designed to fetched patient details (data). Also, is the registration page which brings the data from the registration form to the database. There is also the patients' login page which developed to fetch the patient email and password from the database. The patient registration form consists of the following: Full Name, Address, Patient's Latitude& Longitude, City, Gender, Email and Password Figure 3.4. The doctor login page designed to check the validity of the doctors with their email and password. The admin of the system adds the doctors. If the Doctor Login details match what is in the database, then he/she is prompt to the Doctor dashboard.

Finally, the admin page designed for administrator login to the system to monitor the activities that go on in the developed web portal to check the authentication of the admin details in the database. The admin has access to add and also delete doctors. Figure 3.5 shows the data flow chart of the admin dashboard.

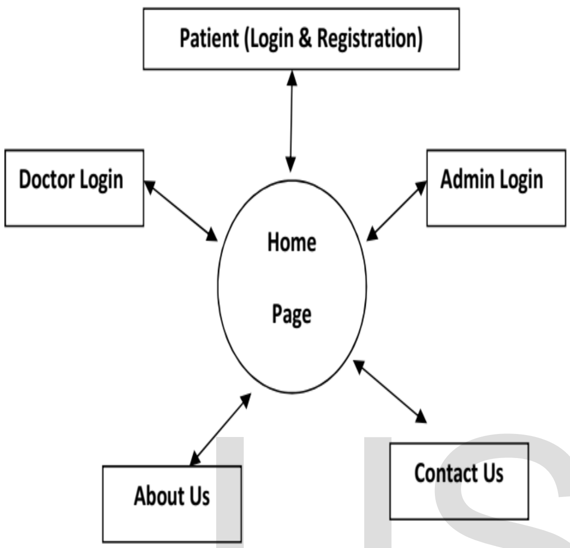



Figure 3.5: Data Flow Diagram of the Home Page


Figure 3.6 Home Page

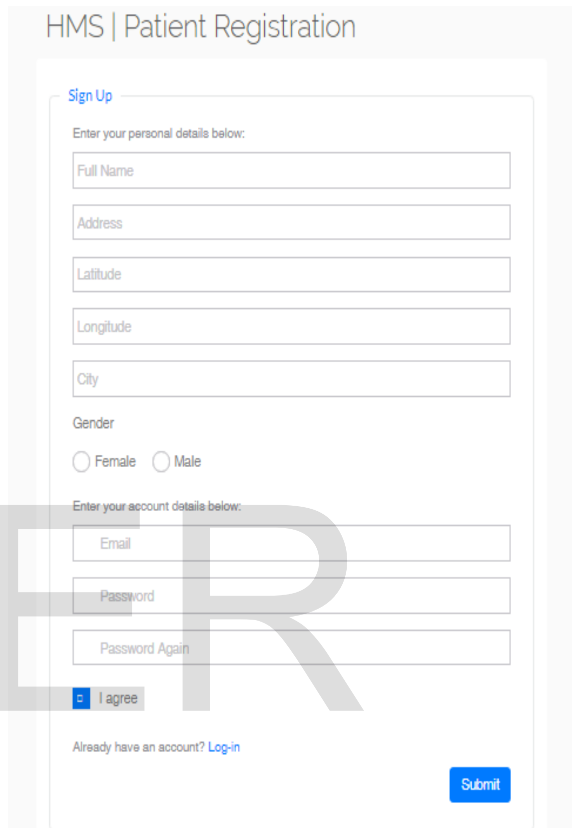



Figure 3.7: Patient Registration

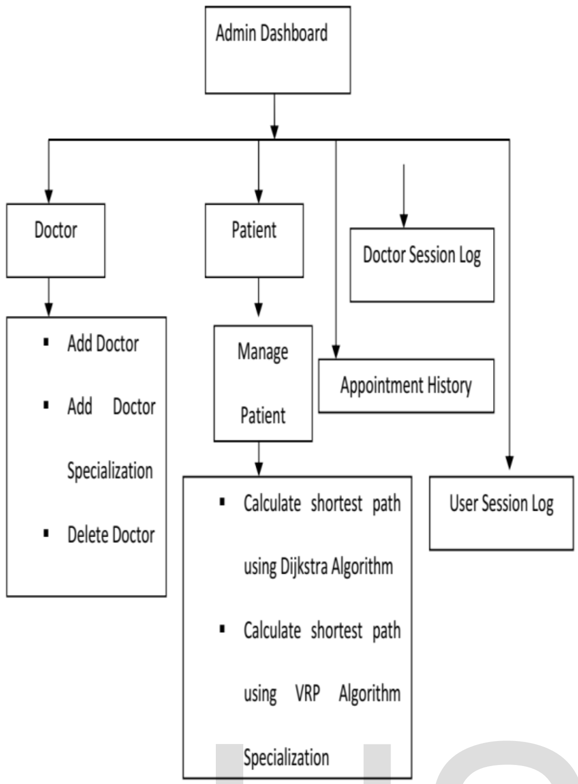



Figure 3.8: Data Flow Chart of the Admin Dashboard of the design work



### 3.5 Routing Mechanism using Dijkstra's and VRP Algorithm

The routing mechanism designed using Hyper Pre-processor (PHP). The arrangement implemented to calculate the shortest path or route from the patient to the hospital. VRP and Dijkstra's algorithms serve as the routing mechanism for the system. Figure 3.9 shows the data flow diagram of the routing mechanism. The VRP and Dijkstra's algorithms results were implemented on different windows or page to determine the shorter path or route for the patient.

The shorter path to reach to the patient location or the hospital determined by the formula below;

$$\int_{pat \to hosp}^{amb \to pat} dist\ (amb \to pat) + dist(pat \to hosp) + dist(amb \to hosp)$$

*Where, hosp – hospital,*
*amb – ambulance,*
*pat – patient,*
*dist – distance.*

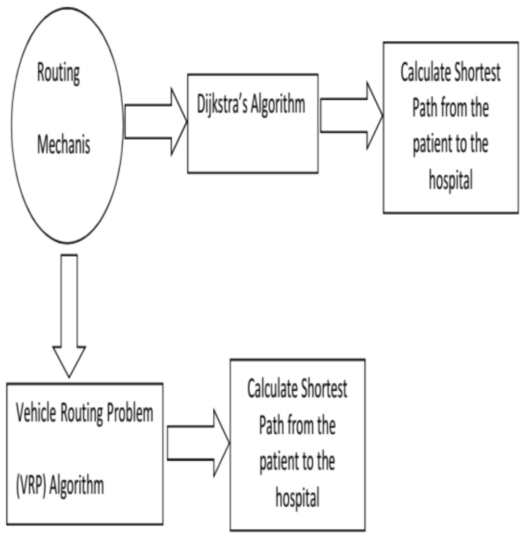



Figure 3.9: Data Flow diagram of the Routing Mechanism

## 4. Results and Discussion

The system tested on different platforms, and certain amendments made to ensure the system is performing the desired result. The entire performance test carried out on the system shows that the system is delivering the desired outcome and it justifies the aim and objectives of the study.

### 4.1 Results

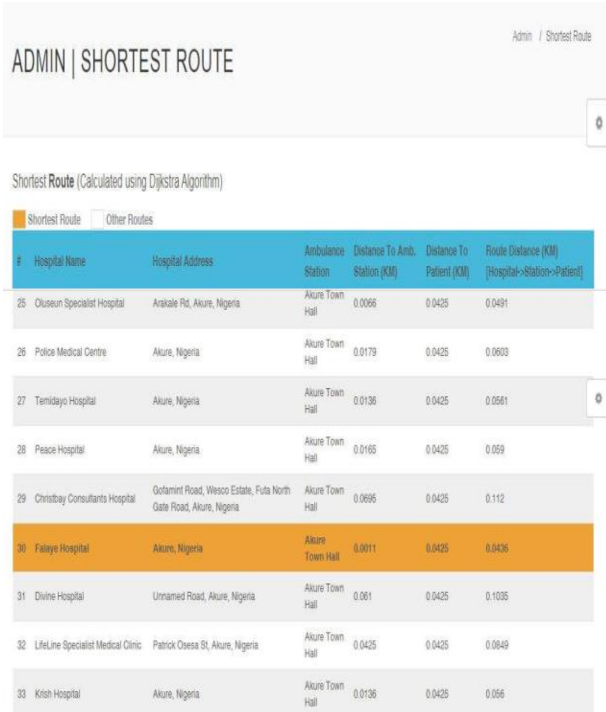
The software operated to first extract the details. This details includes the addresses ,distances between the patient and the nearest hospital. Then it calculates the shortest path by taking the savings and cost into consideration. The algorithms find the shortest path to the nearest hospital facility and calculate the optimal distance with cost incured. The shortest route from the ambulance(depot) to the patient using the VRP algorithm in Figure 4.10 and for Dijkstra's Algorithm is shown in Figure 4.11.

Shortest **Route** (Calculated using VRP Algorithm)

Shortest Route Other Routes

| # | Hospital Name | Hospital Address | Ambulance Station (Lat./Long.) | Hospital (Lat./Long.) | Patient (Lat./Long.) | Route Distance (KM) [Station-> Patient-> Hospital] |
|---|---|---|---|---|---|---|
| 28 | Peace Hospital | Akure, Nigeria | 7.25256014/5.19312000 | 7.23648882/5.18929720 | 7.28238869/5.22335291 | 6.54 |
| 29 | Christbay Consultants Hospital | Gofamint Road, Wesco Estate, Futa North Gate Road, Akure, Nigeria | 7.25256014/5.19312000 | 7.30668592/5.14947796 | 7.28238869/5.22335291 | 12.41 |
| 30 | Falaye Hospital | Akure, Nigeria | 7.25256014/5.19312000 | 7.25335836/5.19235849 | 7.28238869/5.22335291 | 4.83 |
| 31 | Divine Hospital | Unnamed Road, Akure, Nigeria | 7.25256014/5.19312000 | 7.30740023/5.16632223 | 7.28238869/5.22335291 | 11.48 |
| 32 | LifeLine Specialist Medical Clinic | Patrick Osesa St, Akure, Nigeria | 7.25256014/5.19312000 | 7.28238869/5.22335291 | 7.28238869/5.22335291 | 4.7 |
| 33 | Krish Hospital | Akure, Nigeria | 7.25256014/5.19312000 | 7.25691366/5.18026400 | 7.28238869/5.22335291 | 6.2 |
| 34 | Adedewe Hospital Agunloye | Iyalaje Street, Akure, Nigeria | 7.25256014/5.19312000 | 7.24828053/5.17258072 | 7.28238869/5.22335291 | 7.02 |
| 35 | Idera Clinics | Chief Afolabi Lane, Oshinle Quarters, Akure, Nigeria | 7.25256014/5.19312000 | 7.23384428/5.19106102 | 7.28238869/5.22335291 | 6.8 |
| 36 | Grand Clinics | Akure, Nigeria | 7.25256014/5.19312000 | 7.28745270/5.23211384 | 7.28238869/5.22335291 | 5.82 |
| 37 | Shekinah Hospital | Shittu Street, Alagbaka, Akure, Nigeria | 7.25256014/5.19312000 | 7.25535297/5.22071123 | 7.28238869/5.22335291 | 7.72 |
| 38 | Abitoye Hospial | Abiloye Street, Akure, Nigeria | 7.25256014/5.19312000 | 7.26288319/5.21846104 | 7.28238869/5.22335291 | 6.94 |

Figure 4.10: VRP Algorithm for the Shortest Path



ADMIN | SHORTEST ROUTE

Admin / Shortest Route

Shortest **Route** (Calculated using Dijkstra Algorithm)

Shortest Route Other Routes

| # | Hospital Name | Hospital Address | Ambulance Station | Distance To Amb. Station (KM) | Distance To Patient (KM) | Route Distance (KM) [Hospital->Station->Patient] |
|---|---|---|---|---|---|---|
| 25 | Oluseun Specialist Hospital | Arakale Rd, Akure, Nigeria | Akure Town Hall | 0.0066 | 0.0425 | 0.0491 |
| 26 | Police Medical Centre | Akure, Nigeria | Akure Town Hall | 0.0179 | 0.0425 | 0.0603 |
| 27 | Temidayo Hospital | Akure, Nigeria | Akure Town Hall | 0.0136 | 0.0425 | 0.0561 |
| 28 | Peace Hospital | Akure, Nigeria | Akure Town Hall | 0.0165 | 0.0425 | 0.059 |
| 29 | Christbay Consultants Hospital | Gofamint Road, Wesco Estate, Futa North Gate Road, Akure, Nigeria | Akure Town Hall | 0.0695 | 0.0425 | 0.112 |
| 30 | Falaye Hospital | Akure, Nigeria | Akure Town Hall | 0.0011 | 0.0425 | 0.0436 |
| 31 | Divine Hospital | Unnamed Road, Akure, Nigeria | Akure Town Hall | 0.061 | 0.0425 | 0.1035 |
| 32 | LifeLine Specialist Medical Clinic | Patrick Osesa St, Akure, Nigeria | Akure Town Hall | 0.0425 | 0.0425 | 0.0849 |
| 33 | Krish Hospital | Akure, Nigeria | Akure Town Hall | 0.0136 | 0.0425 | 0.056 |

Figure 4.11: Dijkstra's Algorithm for the Shortest Path

## 5. Conclusion

The system was able to calculate the shortest path to the nearest hospital which would help to reduce travel cost, reduce lateness and also improve in the improvement of the Hospital Management System (HMS) in the state. The new system expected to benefit patients, especially those that are not conversant with their locations since it uses a geographic information system. The new system will help to reduce the increase in death rate in Ondo State since an ambulance can get to the patient's location on time. The health care centres can adopt this system for the fastest access to their patients to reduce the death rate.it also conserve fuel consumption for the ambulance service delivery.

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