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MS-MD-Shortest route pathfinder for multiple sources to multiple destinations of directed graph models

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Abstract
This paper presents a computer package that was developed to obtain the shortest route from the Multiple Sources to Multiple Destinations of Directed Graph Models of the Nigeria refineries to their deports located outside the refineries towns and the Nigeria roads network of motorable road b from multiple sources to multiple destinations directly without decomposing like in the case of the existing computer packages. The existing ones cannot solve the network problem of multiple sources to multiple destination (MSMD) directly but by first splitting the network into single sources to single destination networks and these networks are solved individually before superimposing into a single network manually. Also in the existing computer packages, Network data are not inputted directly before solving the problem, rather only the numerical part of the data is extracted from the network and inputted for solving the network problem and also the solution of the network is not presented in the network-like form rather, they are presented in tables which destroys the beauty of the network. Secondly, some of these computer packages, like Microsoft Excel, need to be reprogrammed before performing these tasks; these make solving such problems very hectic. Hence the need for simpler Graphic User Interface (MSMD-Shortest Route finder) that network models are inputted directly without tempering with the network, splitting the network nor reprogramming and also the solution are presented in a network tree with the summary, which is the objective of this research. The distances of the various roads in the Nigeria roads network were obtained using google map from google GPS and Nigeria Atlas map. The Optimal routes of the Nigeria refineries to their deports by road and Nigeria roads network of motorable road from multiple sources (coastal towns: Lagos, Port-Harcourt, Asaba/warri and Calabar) to multiple destinations (border towns: Katsina, Sokoto and Maiduguri) were obtained using MSMD-Shortest Route finder. The shortest routes obtained by using the MSMD-Shortest Route finder compares favorably with the existing ones and was found to be the best.

Keywords: Shortest route, multiple sources to multiple destinations network, petroleum, road network, network model, pipeline products, MSMD-shortest path finder

Introduction
Shortest Path problems are one of the base operations of the network problems. The problem is to reach a target location(s) from a beginning location(s). There are generally numerous available paths to achieve this goal. The objective of the Shortest Path problem is to achieve this goal with the minimum distance traveled and there are two ways to achieve this: using algorithms manually or designing and developing a computer package.

There are quite a number of existing computer packages developed using different algorithms for solving network model problems particularly for single-source-to-single destination. The Spreadsheet WEB template uses dynamic programming techniques to solve up to 16-node shortest path problem. It carries the dynamic programming onto the web and solves the problem online (Pagos, 2017) [9]. Taha (2007) [11], Hevey (2018) [5], Dordal (2020) [4] and Adeleke *et al*., (2011) [2] used network models to find the most efficient way to link a number of locations directly or indirectly, the shortest route between two cities, the maximum-cost flow in a pipeline network, the minimum-cost flow in a network that satisfies supply and demands requirements at different locations, medical services, computer network and scheduling the activities of a project. Taha (2007) [11] used computer package, TORA's interactive module to solve: Linear equations, Linear programming, Transportation model, Integer programming, Network models, Project planning, Queuing analysis, Zero-sum game and others.

The author further used Microsoft Excel solver (MS-Excel is the most powerful spreadsheet package brought by Microsoft, the three main components of this package are: Electronic spreadsheet, Database management and Generation of Charts) and AMPL model for large-scale problems, in solving different algorithms.

According to Weiss (2011) [12] and Stojanovic and Regodic (2016) [10], POM-QM for Windows (also known as POM for Windows or QM for Windows) is the most user-friendly software package available in the fields of production and operations management, quantitative methods, management science, or operations research. POM-QM for Windows has been designed to help better learning and understanding of these fields. The software can be used either to solve problems or to check answers that have been derived by hand. POM-QM for Windows contains a large number of models, and most of the problems in operations research can be solved or approached using it.

Most popular existing computer packages like Microsoft Excel, QM for Windows, Tora and others cannot solve the network problem of Multiple Sources to Multiple Destination (MSMD) directly but first split the network into either: single source to single destination networks or single source to multiple destinations networks and these networks are solved individually before superimposed into a single network manually. Secondly, some of these computer packages like Microsoft Excel need to be reprogrammed before performing these tasks, these make solving such problems very hectic. Hence need for simpler package that network models can be inputted directly without tempering with the network model, splitting the network nor reprogramming. Thirdly, all these computer packages do not input the network models directly before solving the problem, rather, only the numerical part of the data is extracted from the network and inputted for solving the network problem and also the solution of the network is not presented in the network-like form rather, in tables which destroys the beauty of the network. Hence the need for our GUI where network models can be inputted directly with the solution also in a network tree and the summary represented, which is the objectives of our research (Mensah *et al*., 2020) [7].

The computer package was developed using the C# programming language. C# is a language built specifically to program the Microsoft. NET Framework. Programming languages have strength in different areas, some languages are powerful but can be bug-prone and difficult to work with, while others are simpler but can be limiting in terms of functionality or performance. C# is a new language designed to provide an optimum blend of simplicity, expressiveness and performance. Many features of C# were designed in response to the strengths and weaknesses of other languages, particularly Java and C++. The C# language specification was written by Anders Hejlsberg and Scott Wiltamuth (Albahari *et al.*, 2001) [3].

The Pipeline and Product Marketing Company (PPMC) receives crude oil from the Nigeria National Petroleum Corporation (NNPC) unit called the National Petroleum Investments Management Services (NAPIMS). The PPMC then supply the crude oil to the NNPC local refineries. However, petroleum products are sometimes imported to supplement local production when the local refineries are unable to process enough for the country's needs. Petroleum products either imported or refined locally are received by the PPMC through import jetties and pipelines and distributed through pipelines to deport strategically located all over the country from where petroleum tankers lift the products to designated retail outlets. There is also a provision for using the rail system to move from some of the PPMC deport to designated retail outlets. Over the past years, the cost of transporting these products through the pipeline network annually has amounted to billions of dollars. The production and distribution of petroleum products in Nigeria downstream sector is an important factor in her domestic economy. From 1970 to date, the nation has invested substantially in refineries, storage deports and pipelines. The total pipeline network is about 4500km (PPMC, 1994a). Unfortunately, within the past few years, the supply of these petroleum blends to storage deports and then to consumers has not been enough to meet the increasing demand, which include: Domestic sector, Industrial sector, Transport and Agricultural sectors (PPMC, 1994b). The influence underlying the consumption of major petroleum products both for transport and domestic activities have received a great deal of attention since the first oil crisis in the early 1970s (Espey, 1996). In addition to determine the key influences on the consumption of petrol and other products like House Hold Kerosene (HHK) and Automatic Gas Oil (AGO), many studies examining PMS (Premium motor spirit) commonly known as fuel demand have been undertaken to predict future demand (Banaszak *et al*., 1999 and Ediger and Akar, 2007), proper scheduling of the distribution through pipeline networks can facilitate the economic integration of refinery locations and storage depots for easy shipments of the products from refineries to depot locations and then to consumers at minimum delivery cost (Eke and Enibe, 2007).

The Nigerian refineries with their locations are as follows

- Port-Harcourt Refinery Company limited (PHRC) situated in Port-Harcourt, Rivers State.
- Warri Refinery and Petrochemical Company Limited (WRPC) situated in Warri, Delta State.
- Kaduna Refinery and Petrochemical Company Limited (KRPC) situated in Kaduna, Kaduna State.
- Apapa, Atlas core jetty, Lagos where imported refined petroleum products are stored.

The storage depots are located in Aba, Enugu, Makurdi, Yola, Benin, Ore, Mosimi, Atlas-cove and Satellite both in Lagos, Ibadan, Ilorin, Suleja, Minna, Kaduna, Jos, Gombo, Maiduguri, Kano, Port Harcourt, Warri, Calabar and Gusau. As shown in Figure 1: below:

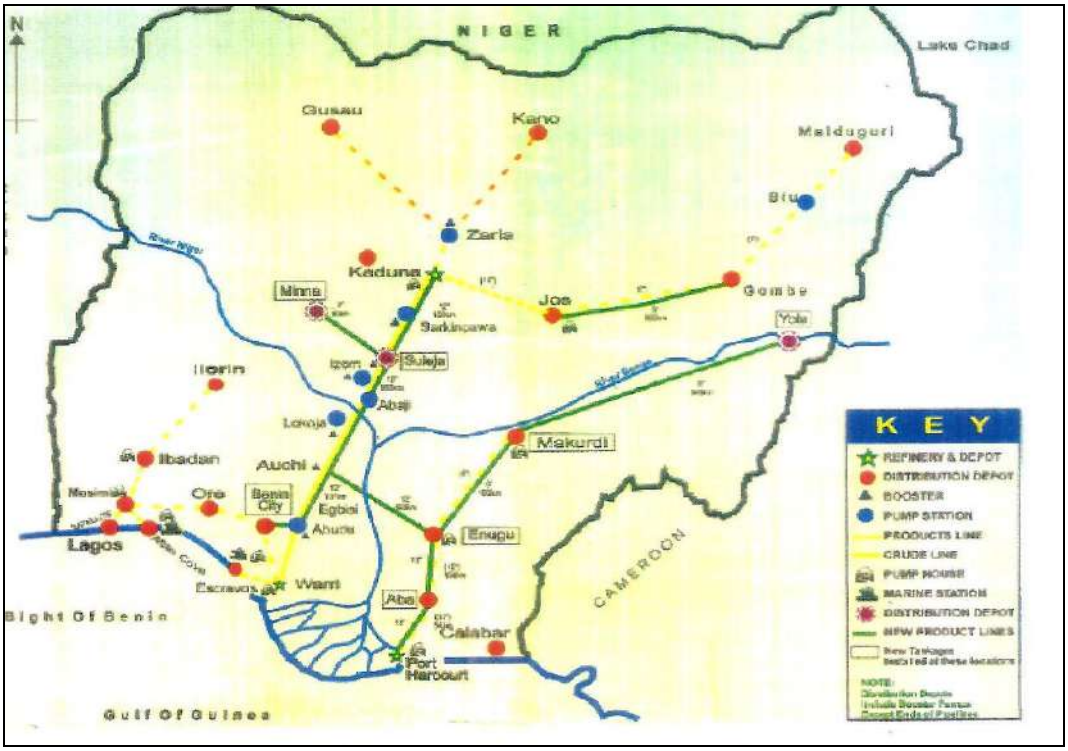

Fig 1: NNPC-PPMC crude oil and products pipeline network

To enhance the distribution of crude oil products from the oil rich of the Niger Delta to other parts of the country, a grid of oil pipeline was constructed to link some of the states at strategic locations. The network consists of multi products pipeline and crude oil pipeline that criss-cross the country and from a grid that links 23 petroleum storage deport to the four refineries at port Harcourt (I and II), Kaduna and warri, the off-short terminal Bonny and Escravos and the jetties at Atlas cove, Calabar, Okirika and Warri. However, the vandalization of oil pipeline installations has assumed worrisome dimensions and a variety of forms in Nigeria. Various terms, such as oil bunkering, oil theft, pipeline vandalization, fuel scooping, and oil terrorism, have been used to describe the various forms of theft of crude oil and its refined products in Nigeria which both lead to the severe shortages of the products which, in turn, lead to loss of billions of naira and loss of innocent lives by fire incidents caused by pipeline vandalization. This act of pipeline vandalization leaves NNPC with almost one option of distributing refined products to the 23 storage deports. This option is nothing but trucking (i.e. transporting by road). Hence in this research work, we examine road network in Nigeria with the possibility of obtaining the shortest routes from each of the four sources to the 16 deports outside the refinery town and also the Nigeria road network of multiple sources to multiple destinations, in order to optimize the cost of transporting such product and related products within Nigeria using the computer package designed in this research work.

The Step by Step Procedure on how to Solve Shortest Route Problem Using Microsoft Excel

According to Oh and Hildreth (2016) [8] and Abdullah and Hua (2017) [1] the following are Step by Step Procedure on how to Solve Shortest Route Problem Using Microsoft Excel:

Step 1: model the problem, it is important to name each column for easy identification when inputting the formulas. Using the demand/supply column, the source node and the destination node are assigned the values 1 and -1 respectively and every other node zero meaning they are neither sources nor destinations

Step 2: input the first formula as "=sumif(from,cellname,on-route)-sumif(to,cellname,on-route)" under the Net Flow column.

Step 3: depress the enter key and then copy the formula in step 2 to every cell under the Net Flow column, stop when the destination node is reached located at the nodes column. Zeros will appear in every cell under the column if the formula is inputted correctly.

Step 4: input the second formula as "=sumproduct(on-route, distance)" in an empty cell under the distance column.

Step 5: depress the enter key, zero will appear in the cell where the formula in step 4 has been entered because there is no any value in the on-route column at this stage.

Step 6: click on "DATA" at the top of your screen, then, solver pop up menu will appear at the top right hand side of the screen, click on solver, solver parameter box will open.

Step 7: set objective as the total distance cell i.e. select the cell that has zero value under the distance column, select Min, then select the entire on-route column as the variable cell you want to change.

Step 8: click on "add" to add the constraint Net Flow =Supply/Demand by selecting the entire Net Flow column, equal to and then the entire Supply/Demand.

Step 9: click on "ok", the solver parameter box will display accordingly all the cell you selected in step 7 and 8.

Step 10: select unconstraint variable make it Non-Negative, select simplex LP as the solving method, click solve, the Excel solver will display the result. Under the Net Flow column, change from zeros to 1 and -1 respectively and every other cell in that column remain zero satisfying the constraint Net Flow = Supply/Demand. Also, the on-route

column contains zeros and ones. Where 1 means a path is on the shortest route and zero means a path is NOT on the shortest route. Moreover, the cell in step 4 changed from zero to the total optimal value. Select keep solver solution and close the window to save your solution.

Features of the MS-MD Shortest Route Finder (Proposed Computer Package)

Starting the computer package:

- Double click on Microsoft Visual Studio Express 2012 for Windows Desktop icon to create a platform where the newly developed package can be lunched.
- Click on "File", then "Open Project" (Ctrl+Shift+O)
- Double click on "MinDistance Folder", then click on "MinDistance", MinDistance
- Lastly click on "Start", Start to lunch the programme.

The Workflow of the Developed Computer Application Package is shown in Fig 2. "Input screen" of the computer package is shown in Fig 3 below. To input data into the application package, click at any point on the screen (canvas) where you want to start a node and the following pop-up menu will display (see Fig 4), then enter the node's name. After all nodes are entered as shown in Fig 5 below, click on any of the two nodes to enter the appropriate edge weight as shown in Fig 6, Fig 7, Fig 8, Fig 9, and Fig 10.

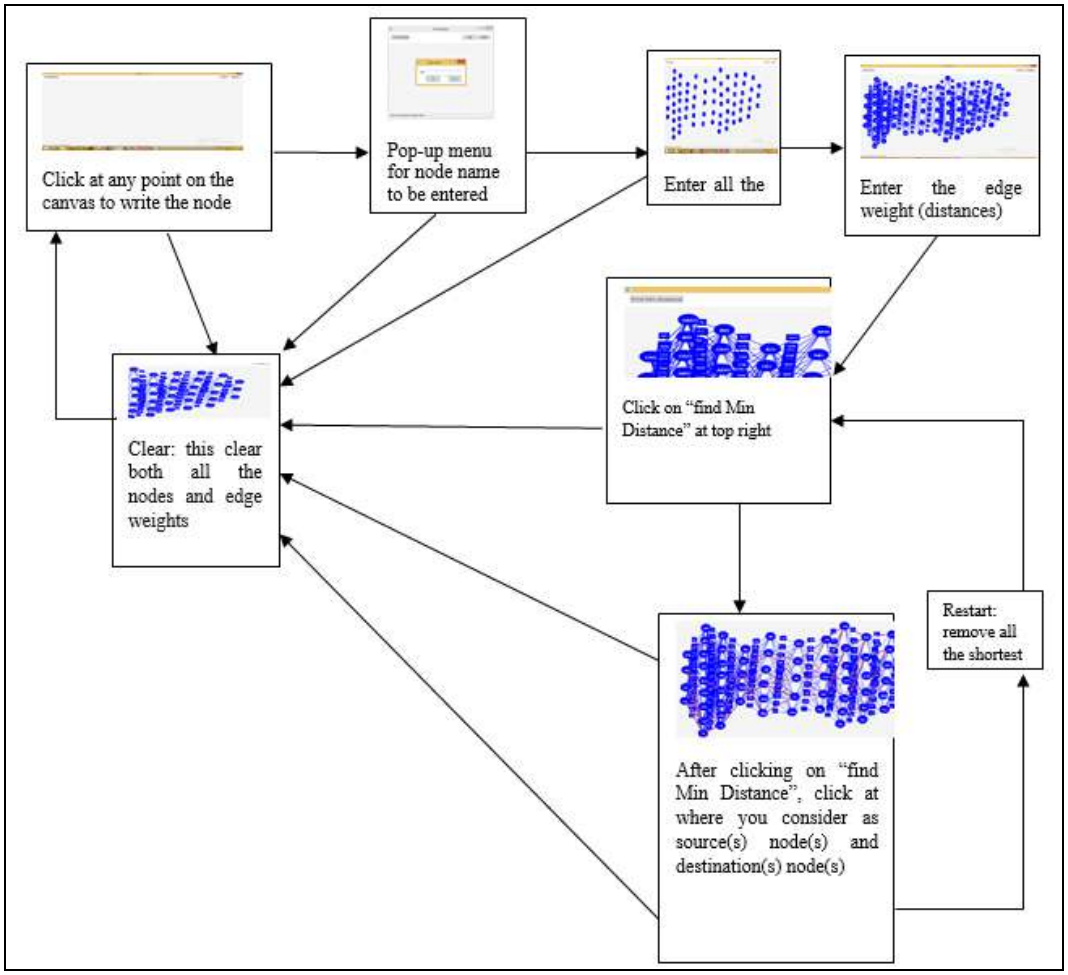

Fig 2: Workflow of the Developed Computer Application Package

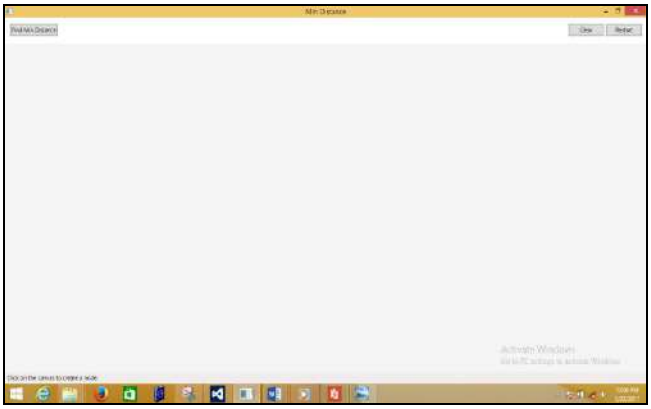

Fig 3: The input screen of the computer package

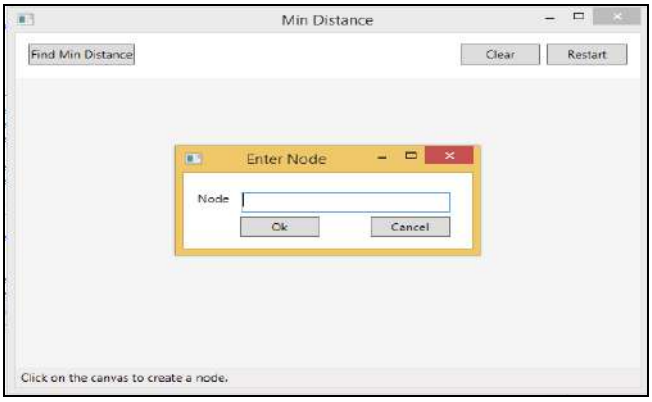

Fig 4: Enter Node menu

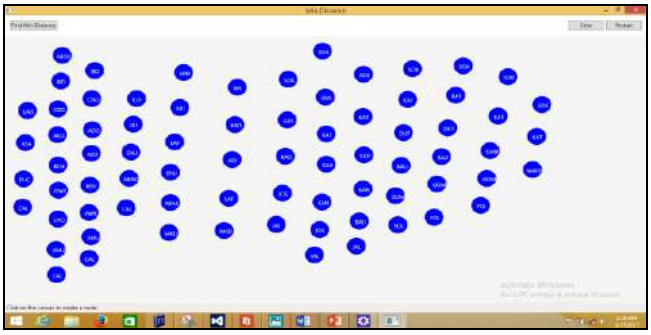

Fig 5: Canvas with the entered nodes

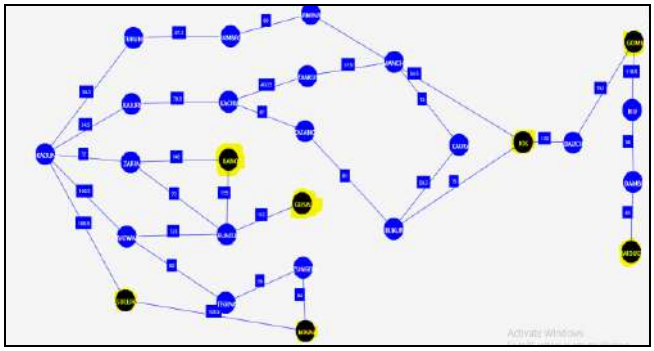

Fig 6: The Road Network from KRPC to the Deports

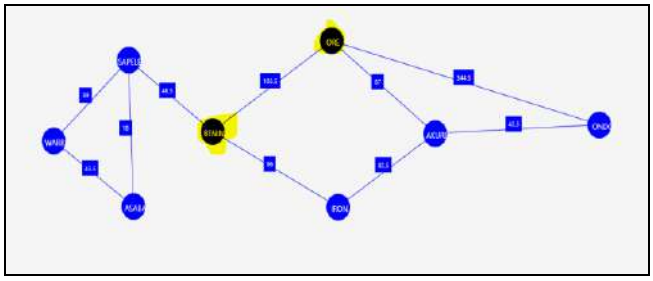

Fig 7: The Road Network from WRPC to the Deports

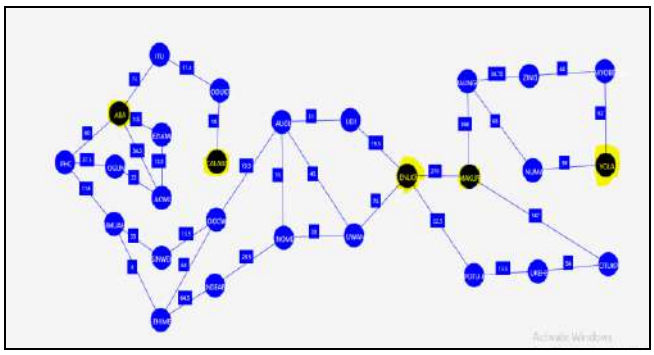

Fig 8: The Road Network from PHRC to the Deports

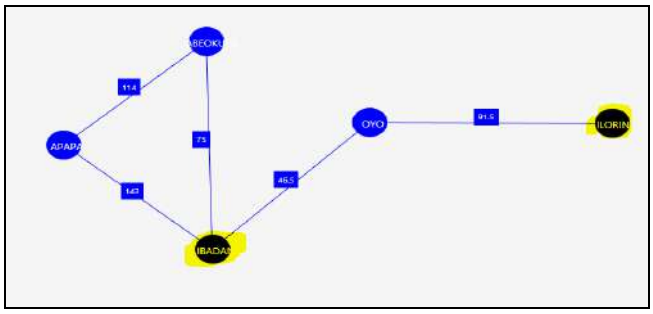

Fig 9: The Road Network from Apapa Atlas cove Jetty to the Deports

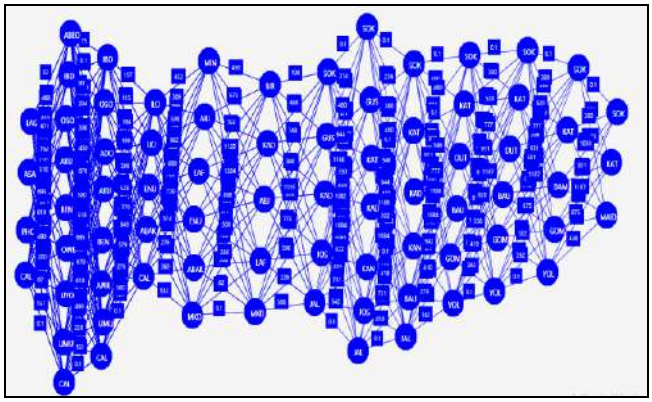

Fig 10: Nigeria road network of motorable road from multiple sources (coastal towns: Lagos, Port-Harcourt, Asaba/warri and Calabar) to multiple destinations (border towns: Katsina, Sokoto and Maiduguri) with distance measurement (km) using the newly developed computer package

Results

To obtain the shortest path, click on "Find Min Distance" on top left, then choose your source nodes and destination nodes, these results of Fig 6, Fig 7, Fig 8, Fig 9 and Fig 10 are shown in Fig 11, Fig 12, Fig 13, Fig 14 and Fig 15.

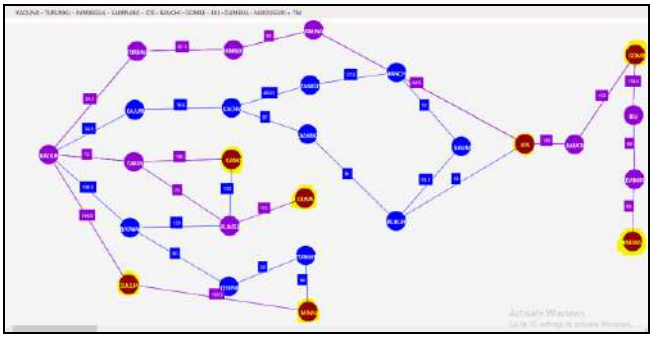

Fig 11: The Shortest Path of KRPC to the Destinations Deports

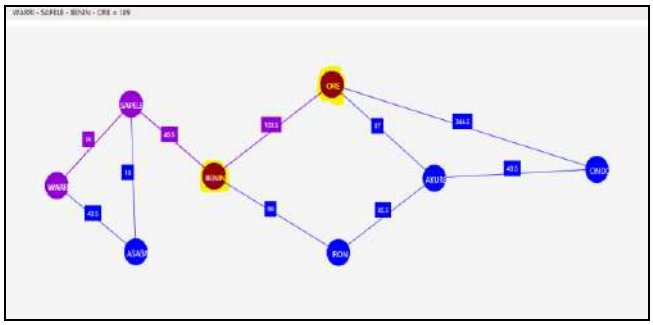

Fig 12: The Shortest Path of WRPC to the Destinations Depots

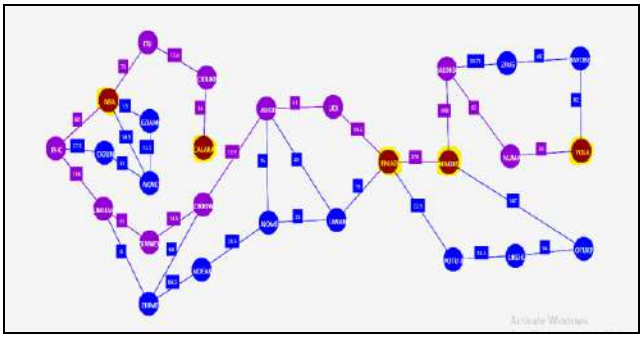

Fig 13: The Shortest Path of PHRC to the Destinations Depots

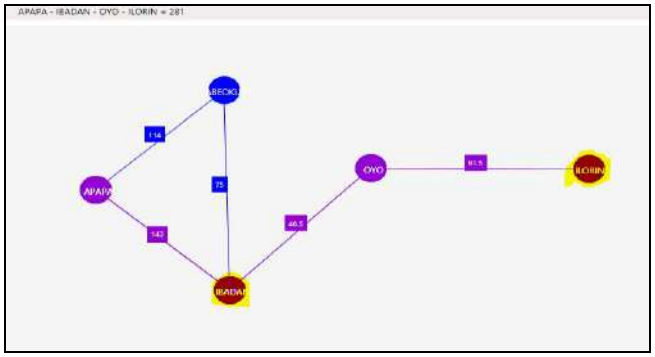

Fig 14: The Shortest Path of Apapa Atlas cove Jetty road network to the Destinations Depots

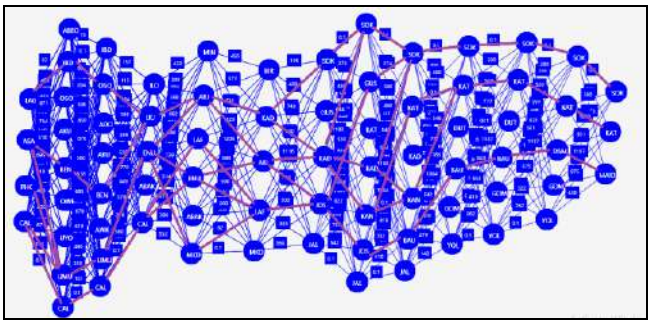

Fig 15: The result of shortest paths from multiple sources to multiple destinations (from Lagos, Asaba, Port Harcourt and Calabar to Sokoto, Katsina and Maiduguri) using the computer package.

Discussion

From Fig 11: the shortest routes of the result of the computer package from Port Harcourt to the depots through intermediary nodes are:

1. Kaduna to Kano = Kaduna→Zaria→Kano. = 217km
2. Kaduna to Suleja = Kaduna →Suleja. = 166.5km
3. Kaduna to Gusau = Kaduna →Zaria →Funtua→ Gusua =260km
4. Kaduna to Minna =Kaduna →Suleja→ Minna =270km
5. Kaduna to Jos = Kaduna →Turunku→pambegua →Saminaka→Jos Bauchi→ Gombe =502.5km
6. Kaduna to Maiduguni = Kaduna →Turunku →Pambegua→Samiralca→Jos →Bauchi→ Gombe→Biu→DamBua→Maiduguri= 764km

From Figure 12: the shortest routes are

1. Warri to Benin→ Warri→ Sapele→Benin = 85.5km
2. Warri to Ore → Warri→ Sapele → Benin → Ore = 189km

From Fig 13: the shortest routes of the result of the computer package from Port Harcourt to the depots through intermediary nodes are:

1. Port Harcourt to Aba = Port Harcourt → 60km
2. Port Harcourt to Calabar = PHC → Aba → Itu →Oduka→ Calabar = 164.4km
3. Port Harcourt to Enugu = PHC→Umuahi→Sinweke→Okigwe→Augu→Udi→ Enugu= 244.5km
4. Port Harcourt to Makurdi = PHC → Umuahia → Sinweke → Okigwe → Augu → Udi → Enugu →Makurdi= 514.5km
5. Port Harcourt to Maiduguri = PHC →Umuahia → Sinweke →Okigwe → Augu → Udi → Enugu → Makurdi→Jalnigo→Numan→Yola= 1014.5km

From figure 14. The sheet routes are

1. Apapa to Ibadan = Apapa→Ibadan = 143km
2. Apapa to Ilonin = Apapa→Ibadan→Oyo→Ilonin = 281km

Lastly from Fig 15, the results obtained compared favourably to that in Ikpotokin and Tamber (2017) as:

1. a. Lagos to Sokoto: Lagos-Ibadan-Oshogbo-Lokoja Abuja-Kaduna-Sokoto = 1375km
   b. Lagos to Katsina: Lagos- Ibadan-Oshogbo-Lokoja-Abuja-Kaduna-Kano-Katsina =1298km
   c. Lagos to Maiduguri: Lagos- Ibadan-Oshogbo-Lokoja-Abuja-Jos-Bauchi-Damaturu-Maiduguri =1589km
2. a. Asaba to Sokoto: Asaba-Benin-Lokoja-Abuja-Kaduna-Sokoto =1279km
   b. Asaba to Katsina: Asaba-Benin-Lokoja-Abuja-Kaduna-Kano-Katsina =1191
   c. Asaba to Maiduguri: Asaba-Umuahia-Enugu-Lafia-Jos- Bauchi-Damaturu-Maiduguri =1404km
3. a. Port Harcourt to Sokoto: PHC-Umuahia-Enugu-Abuja-Kaduna-Sokoto =1291km
   b. Port Harcourt to Katsina: PHC-Umuahia-Enugu-Abuja-Kaduna-Kano-Katsina =1203km
   c. Port Harcourt to Maiduguri: PHC-Umuahia-Enugu- Lafia-Jos- Bauchi-Damaturu-Maiduguri =1352km
4. a. Calabar to Sokoto: Calabar-Lafia-Jos-Gusau-Sokoto = 1314km
   b. Calabar to Katsina: Calabar-Enugu- Abuja-Kaduna-Kano-Katsina =1240km
   c. Calabar to Maiduguri: Calabar-Lafia-Jos- Bauchi-Damaturu-Maiduguri =1282km.

Research Findings

In this research work we find out that

- A computer application programme was developed using C# programming language due to its response to the strengths and weakness of the other languages.
- The computer package developed solves the network models of MS-MD directly without decomposing them into SS-SD, SS-MD or MS-SD (in the reversed order) like the case of the existing computer packages
- The computer package developed also solves the network models of SS-SD, SS-MD or MS-SD (in the reversed order).
- The computer package developed also finds the shortest path of any two nodes within the network.
- Unlike the google map and other GPS (Global Positioning System) devices that show only one path at a time, the computer package developed displays more than one path if selected.
- The computer package developed enhanced the speed and accuracy of solving the shortest path of complex networks of multiple sources multiple destinations at once without splitting the network like the already existing ones.
- The computer package developed also handles the other types of directed graph (with non-negative edge weight) of: single source – single destination, single source – multiple destinations and multiple sources – single destination.
- The computer package developed offers convenience tool for user, researcher, intended researcher,

transporters, transporting and logistic companies, project managers, business analyst, telecommunication companies, electricity wiring/distribution, military operations, automobile companies, pipeline/pneumatic tube network, construction companies, etc.
- The computer package developed is also very suitable and be implemented on the stand alone PC for solving complex network of shortest path problems and critical path analysis.

Contributed to Knowledge

This research work contributed to knowledge as follows:
- Successfully Modeled the Nigeria refineries networks and the Nigeria roads network of multiple sources – multiple destinations.
- Successfully designed and developed a computer package using the C# programming language which solve the models developed and obtain the shortest path.
- The computer package developed was used to solve the models that were developed.
- The computer package developed was used to obtain the shortest path of the model developed without splitting it into individual network as in the case of the existing computer packages respectively.
- The validation test was carried out to shows that computer package developed do not lack validity.
- The computer package developed offers convenience tool for user, researcher, intended researcher, transporters, transporting and logistic companies, project managers and business analyst, telecommunication companies, electrification/distribution, military operations, automobile companies, pipeline/pneumatic tube network, construction companies, etc if adopted.|

Conclusion

Objectively, this study has applied to all the laid-down procedure to collect, analysis and interpret roads network data of the stage coach problem. The outcome of the analysis has produced five (5) results of the network using the MSMD-pathfinder (proposed computer package). Conclusively, the MSMD-pathfinder should be used for determination of the optimal path (shortest route) involving many sources (multiple sources) and multiple destinations, multiple sources and single destinations, single sources and single destination and single source of multiple destinations.

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