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SMART GRID INTERACTIVE GEO-LOCATION AND/OR GRAPH IN INSTALLATION OF ELECTRIC TOWER TRANSMISSION LINES

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ABSTRACT

The paper interactive geo-location and/or graph in installation of national electric towers grid transmission lines with AND/OR graph is a novel approach aimed at minimizing the cost of installation of electricity grid lines from one location to another by calculating the paths leading to the nodes. This system leverages the power of graph theory and logical operations to provide a comprehensive framework for managing spatial data. The AND/OR graph component serves as a flexible and powerful data structure for representing complex relationships between spatial entities and decomposing the problems into various parts to achieve different goals. The implementation of the AND/OR graph was done using a visual C-sharp as a programming language. The interactive geo-location (Google location map) captures the interconnectedness of geographic locations of the areas and their distances. This system yielded positive results in choosing the best paths for the installation of national electricity grid lines by computing the cost of each of the arcs emerging from CURRENT state to the goal state (end point) of the paths. The AND/OR graph implementation in the installation of grid lines focused on two routes as case studies, the Uturu to Umuahia and Aba to Ukwa. Employing this system it was found that the shortest paths in the installation of electric towers grid lines from Uturu to Umuahia is through Uturu, Ezinachi, Ofeme, Ogi, Arondiizuogu and Umuadiawa while from Aba to Ukwa is through the paths Ohanku, Egbelu, Akanu, Alaorji, Aba-Owerri, Ovom and Nnentu.

Keywords: AND OR GRAPH, grid lines, geo-information system

INTRODUCTION

The study of Geo-locational grid using And/Or graph involves the use of geographic information system and graph theory to represent and analyze national grid systems for geographical location purposes. Geo-location refers to the process of determining the geographical location of an object or event, [9]. National grid systems refers to the final stage of the electrical grid which distributes electricity to homes, industries, and other users from the generating stations. The national grid network is made of high voltage power lines, gas pipelines interconnectors and storage facilities

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that together enable the distribution of electricity. In current Nigeria national grid system, electricity flows in one direction that is from the producer which is the Nigeria electricity supply industry (NESI) to the transmission company of Nigeria (DISCOS) then to the final consumers. The electricity situation in Nigeria can be best described as epileptic with no sign in view of improvement. This epileptic situation affects virtually every sector of the economy such as the manufacturing services, and residential sectors of the economy, which in turn affects the country's economic growth. Even with the recent reforms in the power sector more than half of the country's population still lacks access to electricity as a result of poor planning and bottlenecks. The epileptic condition of the power sector can be attributed to the inadequate power- plants, poor transmission and distribution facilities. The Nigeria national grid experiences an average of thirty-five (35) system breakdown every ten years. The study of the geo-location National grid using And/or graph provides a framework for understanding the relationships and optimizing the use of national grid systems in geo-location applications in order to have effective transmission and power distribution strategies [10]. It combines the power of geographic information system and graph theory to facilitate the analysis of the national grid system. The planning stage in the installation of national electric grid is paramount to effective maximization of scarce resources which could be deployed to other sectors of any economy.

2. LITERATURE REVIEW

And/or graph is a form of graph or tree which is applied in problem solving and problem decomposition by finding the best paths to the node. The nodes of the graph represent states or goals and their successors are labeled using alphabets or numbers. Graph is a veritable tool that keeps track of all the nodes and all the edges connected to them [11]. Graph was applied in real life application in designing street lighting systems which offers optimization in pole distance, height of the poles, boom angle and length and angle of the luminaire [3]. Graph cut for image segmentation is a newly developing graph based image segmentation technique. It is effective but takes huge computational burden. [7] opined that a modern electrical power system is typically a large and complex engineering system whose healthy existence is crucial to industrial and socio-economic development of the nations. [9] Opined that advocates for an advanced and secured approach for improving communication in a social Network with the use of geo-location technique is paramount in enhancing area points.

2.1 National Grid Lines

National grid lines are the electric towers with copper wires that carry electricity and transmit from one location to another from the generating stations. Nigeria has so many generating plants such as Kainji Dam, Egbim power station, Afam power stations and many more others. [1] Opined that Nigeria's power sector suffered almost 222 fractional or aggregate grid collapses in the 12 year period from January 2010 to September 2022, according to recent reports, the country Nigeria and so many other African countries have struggled with erratic poor power generation and distribution for years, often emanated from disruptions to current infrastructures such as heavy rains, vandals

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and heavy winds. It is pertinent to note that Nigeria and some other African countries supply of energy catastrophes remains one of the precarious factors that has hindered its anticipated economic growth. [2] opined that Nigeria's national electricity grid lines has shrunken more than over 200 times in the past nine years, frequently resulting in prevalent shutdowns. As obtainable in every other system, when a constituent of the electric power is flawed, the entire formation is vitiated [6] [4].

2.2. **Problems Associated with National Grid Installation**

Many contributing factors are responsible with installation of National grid in Nigeria as a country. Some of these problems are

1. Improper planning
2. Amateur engineers used at the sites
3. Bureaucratic attitudes of the government and contractors
4. Non-standard materials purchased to cut cost
5. Under funding of the projects [8]

3 MATERIALS AND METHODS

This section discusses the processes and procedures of AND/OR graph to create efficient paths for the installation of national grid lines by calculating the cost function of each path using geo-location. The existing national grid lines were taking into consideration, where the path functions were calculated and compared with the new system. The figure 1 shows the architecture of and/or graph in decomposing the problems of grid locations to efficiently install national grid lines.

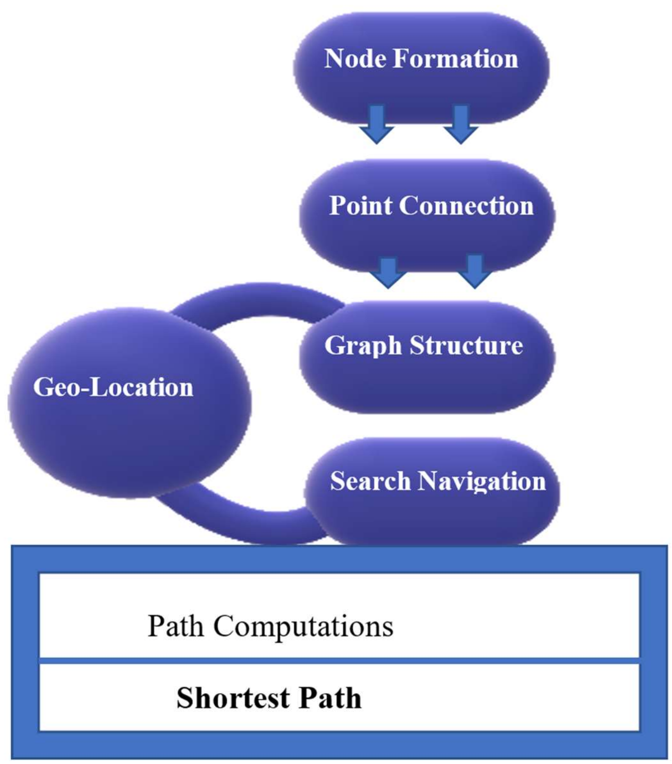

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Fig. 1: Architecture of Geo-location AND/OR Graph

1. **Nodes**:
    b. Grid cells: each grid cell represents a specific area on the national grid, defined by its coordinates or address.
    c. Points of interest: these nodes represent important locations such as landmarks or geographical features.
2. **Point Connection (Edges)**:
    a. Adjacency relationships: Edges connect neighboring grid cells to establish the spatial relationship between them.
    b. Connection to point of interest: Edges connect grid cells to point of interest that falls within their boundaries.
3. **Graph structure**: The AND/OR graph comprises two levels:
    a. Grid level: this level represents the national grid, with grid cells as nodes and adjacency relationships as edges.
    b. Point of interest level: this level represents the points of interest within each grid cell, with the grid cells as nodes and connections to point of interest as edges.
4. **Search and navigation** (Shortest Path): To utilize the system for geo-location, the following actions should be performed:
    a. Grid cell Lookup: given a set of coordinates or an address, the system can identify the corresponding grid cell(s).
    b. Point of interest Lookup: within a specific grid cell, the system can provide a list of points of interest along with their respective details.
    c. Navigation: by leveraging the adjacency relationships between grid cells, the system can offer navigation guidance for moving from one grid cell to another.
    d. Distance and routing: the system can calculate distances between grid cells and suggest the most efficient routes based on the adjacency relationships
5. Integration with Geo-location technologies: the AND/OR graph system can be integrated with various geo-location technologies and data sources to enhance its functionality. This include satellite imagery, GPS data, geo-coding services, and real-time traffic information.

3.1 Algorithm of AND/OR Graph

a) Select an unexpected node from the most promising path from INIT (call it NODE)
b) Generate successors of NODE = FUTILITY (i.e NODE is unsolvable); otherwise for each SUCCESSOR that not an ancestor of NODE do the following;
i. Add SUCCESSOR to G
ii. If SUCCESSOR is a terminal, label it SOLVED and set H (SUCCESSOR) = 0
iii. If SUCCESSOR is not a terminal node. Compute its h
c) Propagate the newly discovered information up the graph by doing the following;
Let S be set of SOLVED nodes or nodes whose h values have been changed and need to have values propagated back to their parents. Initialize S to Node, until S is empty repeat the followings:

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i. Remove a node from S and call it CURRENT
ii. Compute the cost of each of the arcs emerging from CURRENT. Assign minimum cost of its successor at its h
iii. Mark the best path out of CURRENT by marking the arc that had the minimum cost in step ii
iv. Mark CURRENT as SOLVED if all of the nodes connected to it through new labelled arc have been labelled SOLVED,
v. If CURRENT has been labelled SOLVED or its cost was just changed, propagate its new cost backup through the graph, so that add all of the ancestor of CURRENT to S.

The update parent node function is given in equation 1

3.2 The Path Function Calculation

To calculate the heuristic evaluation function estimating the problems at point A, evaluating the different paths using the geo-location, we employed equations 1 and 2

$H(n) = x_c - x_y + y_c - y_g$ (1)

Where x_c and y_c are the nodes.

G(n) = cost value. To find the minimum solution for each path, equation 2 is employed.

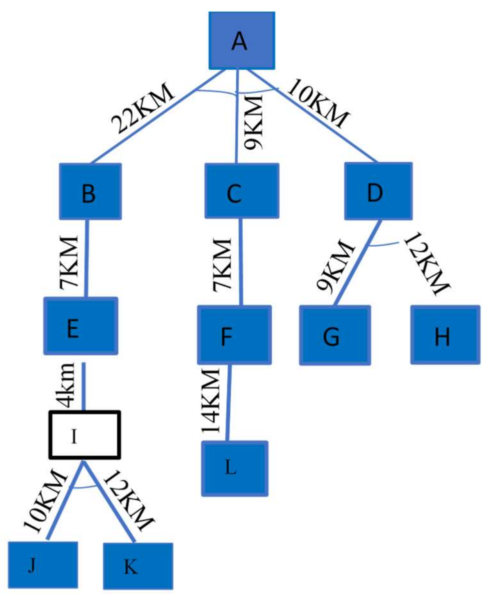
$F(n) = h(n) + g(n)$ (2)

Where the cost value function $g(n) = +1$

3.3 Node Formation

This paper employed two National Grid locations to form the AND/OR graph as shown in figures 2 and 3 respectively.

i. From Uturu in Abia State spanning to Umuahia the state capital
ii. From Aba, the commercial nerve center of Abia State to Ukwa in Abia State



1.

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Fig. 2: AND/OR Graph from Uturu to Umuahia

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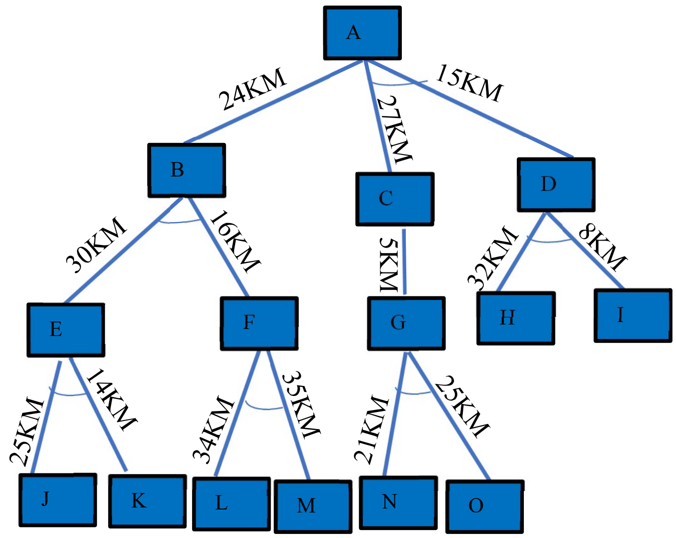
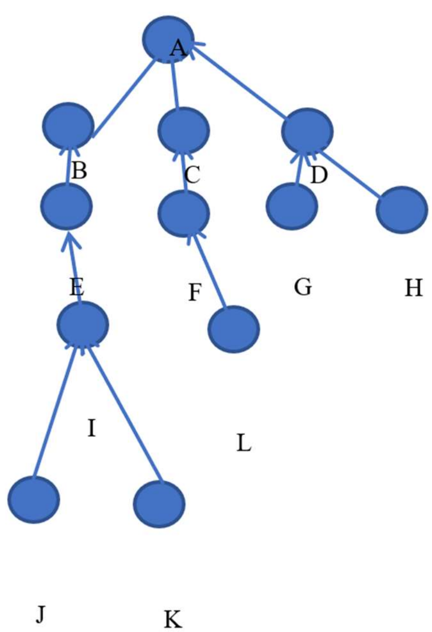


Fig. 3: AND/OR Graph from Aba to Ukwa

3.4 **Graph Formation**

Figures 4 and 5 depict the formation of the graphs from the AND/OR graph depicted in figures 2 and 3. The graph formed is a directed graph as it imminently points to the locations of the parent node at A. This clearly shows that the paths leading to the parent node emanated from nodes J, K, L, G and H in figure 4 and J, K, L, M, N and O in the figure 5.



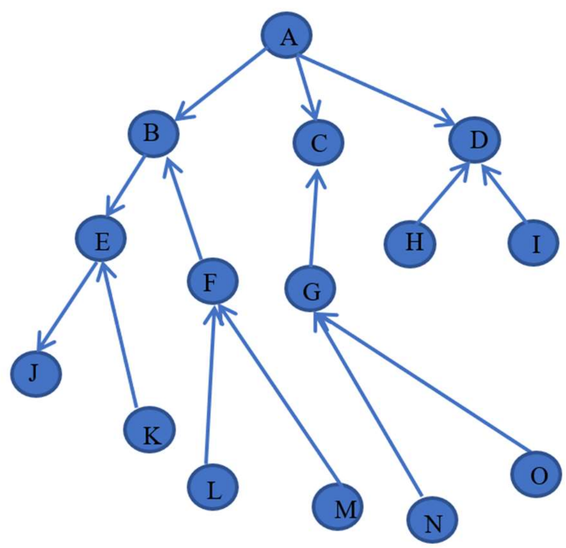


Fig.4: Graph of Uturu to Umuahia

fig. 5: Graph of Aba to Ukwa

Table 1: Node in Uturu-Umuahia Paths

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Node	Points
A	Umuahia
B	Uzuakoli
C	Ofeme
D	Umuadiawa
E	Akara
F	Ezinachi
G	Ogi
H	Arondizuogu
I	Isiukwuato
J	Okigwe
K	Ihube
L	Uturu

Table 2: Node in Aba-Ukwa Paths

Node	Points
A	Aba
B	Asa Umunka
C	Alaorji
D	Ovom
E	Ogwe
F	Obehie
G	Akanu
H	Nnentu
I	Aba-Owerri
J	Egbelu
K	Ngwaiyiekwe
L	Amaorji
M	Abala
N	Ohanku
O	Egbelu

4 RESULTS AND DISCUSSION

The figure 6 shows the AND/OR graph applications developed in the decomposition of the nodes and the computations to achieve the expected results. The nodes that ranges from 1 to 12 as depicted in figure 6 is where the spatial data are inputted based on the distances calculated from the geo-location (Google Map) and computed using the compute button.

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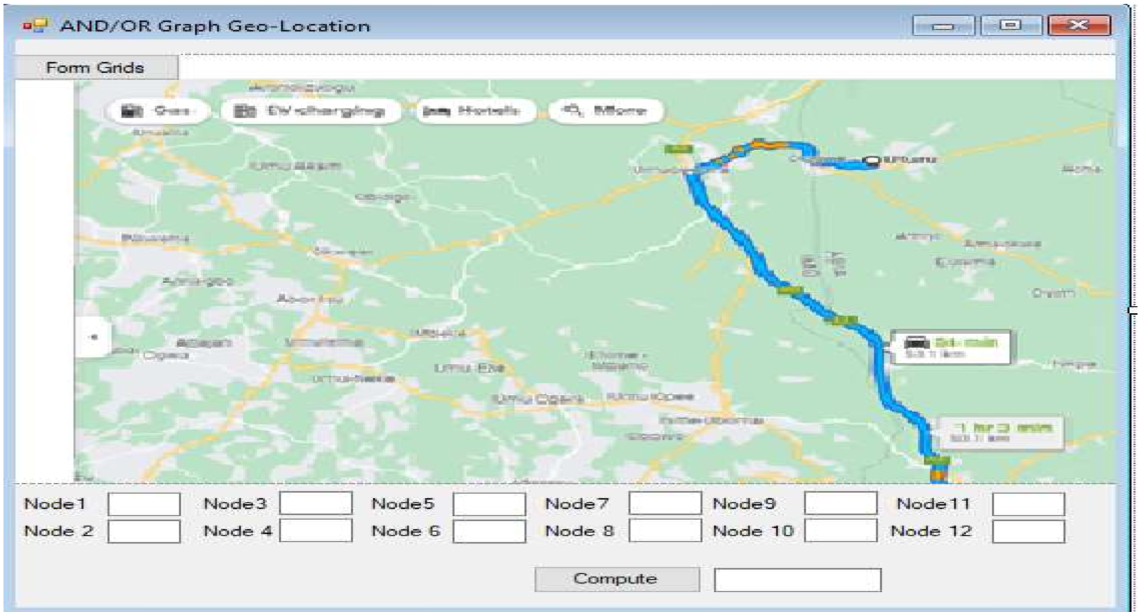

Fig. 6: AND/OR Graph Geo-location Application

4.1 Calculated Results

Tables 3 and 4 show the calculated results from figure 6. It depicts precisely how the calculations on all the paths are made.

Table 3: Calculated Node Results on the Paths of Uturu-Umuahia

Path 1	**Path 2**	**Path 3**
H(n) → J = 10 + 1 = 11	H(n) → C = 9 + 1 = 10	H(n) → D = 10 + 1 = 11
H(n) → K = 12 + 1 = 13	H(n) → F = 7 + 1 = 8	H(n) → G = 9 + 1 = 10
H(n) → I = 4 + 1 = 5	H(n) → L = 14 + 1 = 15	H(n) → H = 12 + 1 = 13
H(n) → B = 22 + 1 = 23		
H(n) → E = 7 + 1 = 8		
Total = 60	**Total** = 33	**Total** = 34

NOTE: With the AND/OR graph algorithm, we took the successive paths from the CURRENT state which is J and K in path 1, L in path 2 and G and H in path going up to A the goal state as illustrated in table 3 depicted in figures 2 and 4 . In the first arc, marking the first path, we calculated all the paths J, K, E and B = 11 + 13+ 5 + 8 + 23 = 60. In the second path, we have the calculated values as follows; C + F + L = 10 + 13 + 11 = 34. Consequently in the third path, the calculations made are as follows; D + H + G = 10 + 13 + 11 = 34

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NOTE: The cost values of + 1 were added to the paths. The first path is joined with second path with an arc in A, it implies the composition of the two paths will be added, given the cumulative of 60 + 33 = 93.

Also, since the second path is joined with the third arc to A the goal state, we do the computation of the two, having the cumulative of 33 + 34 = 67.

Table 4: Calculated Node Results on the Paths of Ukwa-Aba

Path 1	**Path 2**	**Path 3**
H(n) → J = 25 + 1 = 26	H(n) → C = 27 + 1 = 28	H(n) → D = 15 + 1 = 16
H(n) → K = 14 + 1 = 15	H(n) → O = 25 + 1 = 26	H(n) → H = 32 + 1 = 33
H(n) → F = 16 + 1 = 17	H(n) → N = 21 + 1 = 22	H(n) → I = 8 + 1 = 9
H(n) → B = 24 + 1 = 25	H(n) → G = 5 + 1 = 6	
H(n) → E = 30 + 1 = 31		
Total = 185	**Total** = 82	**Total** = 58

In table 4, by taking successive steps to get the goal state, the three parts leading to the goal state were calculated starting from the initials state to the CURRENT states. Employing the equations 1 and 2, the various paths indicated in figures 3 and 5 were decomposed into three parts with successive paths. The first path did not have any arc joining it with another path to A, therefore the calculations made yielded J + K + I + B + E = 26 + 15 + 35 + 36 + 17 + 31 + 25 = 185. Consequently, the second path is the cumulative calculations of N, O, G and C which is 82. Also, the cumulative of third path gave H + I + D = 58. The paths, second and third are joined by the arc at A as shown in figure 3, therefore the cumulative of the two paths yielded 140.

4.2 Implementation of AND/OR Graph

A lot of money have been wasted in installation of national transmission electricity grid lines as a result of non-inclusion and availability of enhanced geo-location system that can compute shortest path, cost effective and efficient paths in the installation of grid lines. By employing AND /OR graph in the figure 2, it could be deduced that by taking the second path as shown in table 5, we can minimize the cost of installation.

Table 5: Cost of Wire Comparison in the Paths from Uturu to Umuahia

No. of Lines	**Cost of Path 1 (₦)**	**Cost of Path 2(₦)**	**Cost of Path 3 (₦)**
1	60km x 3,000,000 = ₦180,000,000	33km x 3,000,000 = ₦ 99,000,000	34 x 3,000,000 = ₦ 102,000,000

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6	6 x 180,000,000 = ₦ 1,080,000,000	6 x 99,000,000 = ₦ 594,000,000	6 x 102,000,000 = ₦ 612,000,000

From table 5, a total of **₦468,000,000** (Four hundred and sixty eight million naira only) or $561,600,000,000 would be saved on the procurement of copper wires for the transmission of electricity.

Note: Cost of 500m of 150mm thickness bare copper wire in Nigerian Market is N1,500,000 (one million and five hundred thousand naira) which when converted to kilometer gives 0.5km. Then, the cost of double of 500m wire of 150mm thickness copper wire will be 1000m which is N3,000,000 (three million naira) per 1 km. (Source: EEDC, Umuahia Branch).

Note: $1 = N1,200 currently in Nigeria as at 2023 in the parallel market.

Table 6: Cost of Wire Comparison on the Paths from Aba to Ukwa

No. of Lines	**Cost of Path 1 (₦)**	**Cost of Path 2(₦)**	**Cost of Path 3 (₦)**
1	185km x 3,000,000 = ₦555,000,000	82km x 3,000,000 = ₦246,000,000	58 x 3,000,000 = ₦174,000,000
6	6 x 555,000,000 = ₦3,330,000,000	6 x 99,000,000 = ₦1,467,000,000	6 x 174,000,000 = ₦1,044,000,000

As shown in table 6, the implementation of the AND/OR graph by taking the successive paths and calculating the arcs from the current state, the best solution appeared to be path 3 with a cost effective function of the installation wires costing N1,044,000,000. Path 3 is the best shortest path to take in terms of cost of 150mm thickness bare copper wire in the installation of national electricity grid lines from Aba to Ukwa. Furthermore, in table 6, after critical analysis, a total of **N819,000,000** (Eight hundred and nineteen million naira only) or $982,800,000,000 could be saved from the procurement of bare copper wires that could span from Aba to Ukwa.

Table 7: Cost of Electric Tower and Insulators on the Paths from Uturu to Umuahia

	No of Towers in Path 1	**No of Towers in Cost of Path 2**	**No of Towers in Cost of Path 3**
	60km/0.4 = 150	33/0.4 = 82	34/0.4 = 85
Cost in ₦	3,200,000 x 150= 480,000,000	3,200,000 x 82 = 262,400,000	3,200,000 x 85 = 272,000,000

Note: The spacing standard from one Electric Tower to the other is between the range of 300m to 500m and we took the middle bound of 400m which is converted to kilometers as 0.4Km. The cost of one tower electric pole for national grid is N3,000,000, while the insulators are N200,000. (Source: EEDC, Umuahia Branch). In table 7, the path with the best solution to minimize cost is

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path 2. In table 7, it could clearly be deduced that by taking paths 2 and 3 to the parent node, a total of **₦208,000,000** (Two hundred and eight million naira only) or $249,600,000,000 would be saved on building electric towers and insulators and other accessories.

Table 8: Cost of Electric Tower and Insulators on the Paths from Aba to Ukwa

	Path 1	**Path 2**	**Path 3**
No. of Towers	185km/0.4 = 462	82/0.4 = 205	58/0.4 = 145
Cost in ₦	3,200,000 x 462= 1,478,000,000	3,200,000 x 205 = 656,000,000	3,200,000 x 145 = 464,000,000

From table 8, it could be ascertained that in terms of cost of electrical towers and insulators/conductors that path 3 yields most favourable best path. This geo-location database refers to the precise geo-graphic location of the points of interest. It typically involves identifying the path function, latitude and longitude coordinates of high tension power lines from Uturu-Umuahia.

Google maps does not specifically use a national grid database, it does incorporate various geographic datasets and algorithms to deliver accurate user-friendly mapping experiences. These datasets includes landmarks, geographic boundaries, and points of interest. In table 8, the analysis showed that by taking the paths 2 and 3, a total of **₦358,000,000** (Three hundred and fifty eight million naira only) or $429,600,000,000 would be saved.

5 CONCLUSION

The Nigeria national grid is interconnected network of power generation, transmission and distribution infrastructure that supplies electricity across the country. However, Nigeria national grid faces several challenges, including inadequate infrastructure, high cost of materials, bureaucratic attitudes on the part of the government and contractors, insufficient power generation capacity, frequent power outages and transmission losses and most importantly lack of technical-know-how in taking spatial locations during installations. The concept of a smart grid involves integrating advanced technologies and geo-locational systems into the traditional electricity grid infrastructure. The use of smart grid interactive geo-location AND/OR Graph system is a veritable tool in the installation of electric towers as it saves cost.

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