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RESEARCH ARTICLE

OPTIMAL TRANSPORTATION NETWORK USING CHALLENGES AS CATALYTIC FACTORS ON INSURGENT-ACTIVITIES-CHARACTERIZED ROUTES TO MAIDUGURI

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ABSTRACT

Transportation problems in the country Nigeria are very hectic, especially with so many challenges on the highway, such as: obstacles, armed robbery attacks, insurgency and terrorism, which hinder the free flow of traffic of goods and services. This study is designed to address these challenges by using Dynamic Programming on transportation networks using traditional technique, traditional technique with incorporated task of obstacles and traditional technique with incorporated infrastructural advantages. The data used for analysis were from government agencies. The results obtained from these redesigned three networks were superimposed to obtain the final optimal route from the seaport sources: Lagos, Warri, Port Harcourt and Calabar to Maiduguri are 2998km, 2671km, 2636km and 2491km respectively. The result shows superiority of the new critical path to the normal critical path.

INTRODUCTION

The history of transportation in Nigeria dates back to the pre-colonial era. Within this period, transportation facilities such as roads, railways, air transport facilities were really non-existent with emphasis then on the bush paths. According to Ighodaro (2009) the history of road transport in Nigerian back to 1904 when Lord Luggard attempt the construction of a mule road linking Zaria and Zungeru both in the northern states of Nigeria. The road was later extended from Zaria to Sokoto, Katsina and Maidugri, however, the road linking Ibadan and Oyo constructed in 1906 is recorded to be the first motorable road ever constructed in Nigeria. At the independence in 1960, the Nigerian landscape was dotted with a skeletal network of trunk roads as well as secondary and feeders roads that exhibited the characteristic which reflected the purpose of their construction. They were narrow and winding, being simply meant to facilitate the evacuation of agricultural produce from the interior to the ports for exports in addition to serving as links between scattered human settlements thus permitting ease of administration. The author added that in 1925, the central government of Nigeria set up a Road Board, by 1926, H. E. Walker proposed a skeleton trunk road system to link the major administrative centers in the country. These roads were designed as a frame upon which the network of secondary roads could be built thus enabling the general road system to be considered as a co-coordinated whole rather than a jigsaw of small disjointed sections. The Nigerian road system is classified into four broad categories, these are:

i. Federal trunk “A” roads: these are roads under federal government ownership and they are developed and maintained by the federal government.
ii. Federal trunk “F” road: these roads were formerly under state government ownership but are taken over by the federal government with a view to upgrading them to federal high way standards.
iii. Trunks “B” roads are under the ownership and management of the states government.
iv. Trunk “C” road are under the local government ownership and management.

Each tier of government has the responsibility for planning, construction and management of the network of roads under its jurisdiction. Since these roads were constructed, road transportation problems in the country Nigeria keeps increasing. The transportation problems in the country are very hectic, especially with so many challenges on the highways such as: obstacles, armed robbery attacks, Boko Haram insurgencies and kidnappings, which hinder the free flow of traffic of goods and services. This study is designed to address those challenges in order to order to obtain the optional route from the seaport sources: Lagos, Warri, Port Harcourt and Calabar through the hinterland to Maidugri. The rest of the

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paper is structured as follows: section two (2) provides literature review and theoretical framework for the study while section three (3) is on the methodology, section four (4) focuses on the result and discussion and the last section concludes the paper.

Statement of the Problem

The study is designed to address the road transportation problems in the country Nigeria which is very hectic especially with so many challenges on the highway such as obstacle, armed robbery attacks, insurgency and kidnappings, which hinder the free flow of traffic of goods and service. This study will address these challenges by using dynamic programming method on the Nigeria roads networks, using traditional technique with incorporated task of obstacles and traditional technique with incorporated task of infrastructural advantages. The result obtained from those redesigned three network are superimposed and the final optional route from seaport sources: Lagos, Warri, Port Harcout, Calabar to Maiduguri are obtained

Aim

The aim of this work is to obtain the optional network on Nigerian road transportation system from seaport source: Lagos, Warri, Port Harcourt and Calabar through the hinterland to Maidugri, the insurgent activities gateway, commercial city and a gateway to two countries (Chad and Cameroon).

Objectives

In order to achieve the above aim, the following specifies objectives will be pursued:

1. To develop a model of Nigerian road network system of motorable road from coastal towns through hinterland to border town (i.e. Lagos, Warri, Port Harcourt and Calabar to Maiduguri).
2. To obtain the optimal route of Nigerian roads as specified in "1" above under normal circumstance using traditional dynamic programming method and a computer package named TORA.
3. To obtain the optimal route based on obstacles that are been faced as challenges on Nigerian roads network system of motorable roads from coastal towns through hinterland to border town (from Lagos, Warri, Port Harcourt and Calabar to Maiduguri) such as:

a. Untarred roads
b. Bad bridges
c. Other hazards such as frequency of armed robbery attacks, Boko Haram insurgency and kidnappings.

Using traditional dynamic programming method and a computer package named TORA.

4. To obtain the optimal route based on infrastructural development been used as challenges on
Nigerian roads network system of motorable roads from coastal towns through hinterland to boarder town (from Lagos, Warri, Port Harcourt and Calabar to Maiduguri) using traditional dynamic programming method and a computer package named TORA.
5. The three redesigned networks (2,3and 4) above will be superimposed to obtain the optimal route from coastal towns through hinterland to boarder town (from Lagos, Warri, Port Hacourt and Calabar to Maiduguri) using dynamic programming.

Significance of the Study

According to Onakomaiya (undated) " of all commodity movements to and from the seaports, at least two –third are now handled by road transport while up to 90% of all other internal movement of goods and persons take place by roads". The essence of this work is to maximize advantage and minimize or reduce disadvantage of network and also to make a contribution to the growing literature on the network analysis, dynamic programming and identifying for the transporters and intending travelers the optimal route.

Definition

1. LAG - LAGOS
2. WAR/ASA- WARRI/ASABA
3. PHC - PORT HARCOURT
4. CAL - CALABAR
5. ABEO - ABEOKUTA
6. IBD - IBADAN
7. OSO - OSHOGBO
8. AKU - AKURE
9. BEN - BENI CITY
10. OW - OWERRI
11. UYO - UYO
12. UMU - UMAUHIA
13. CAL - CALABAR
14. IBD - IBADAN
15. OSO - OSHOGBO
16. ADO - ADO- EKITI
17. AKU - ANKA
18. BEN - BENNI CITY
19. AWKA - ANKA
20. UMU - UMAUHIA
21. CAL - CALABAR
22. ENU - ENUGU
23. LKJ - LOKOJA
24. ENU – ENUGU
25. ABAK – ABAKELIKE
26. CAL – CALAB AR
27. MIN - MINNA
28. ABJ – ABUJA
29. LAF – LAFIA
30. ENU – ENUGU
31. ABAK – ABAKELIKE
32. MKD – MAKURDI
33. BIR - BIRNI-KEBI
34. KAD - KADUNA
35. ABJ – ABUJA
36. LAF – LAFIA
37. MKD – MAKUDI
38. SOK - SOKOLTO
39. GUS – GUSAU
40. KAD - KADUNA
41. JOS – JOS
42. JAL – JALINGO

43. GUS - GUSAU
44. KAT – KATSINA
45. KAD - KADUNA
46. KANO – KANO
47. JOS - JOS
48. JAL - JALINGO
49. KAT - KATSINA
50. KANO - KANO
51. BAU – BAUCHI
52. JAL - JALINGO
53. DUT - DUTES
54. BAU - BAUCHI
55. GOM - GOMBE
56. YOL - YOLA
57. DUT - DUTSE
58. BAU - BAUCHI
59. GOM – GOMBE
60. YOL - YOLA
61. DAM - DAMATURU
62. GOM – GOMBE
63. YOLA - YOLA
64. MAID – MADUGURI.

Assumptions of the Study

The study assumes the following according to Okafor (2008). It is assumed that:

1. the primary and secondary sources of data are accurate
2. the study is worth conducting for problem solving and decision making within operations research
3. the software and the hardware used in this study and research are the appropriate technology
4. the prototype as case study are accurate and gives appropriate fit
5. the decision values are not change over the planning horizon
6. the driver moves at a constant average speed.
7. the movement will always be a forward movement, from one node to another.
8. the nodes are not geographically proportionate.
9. all arc lengths are nonnegative

Literature review

The history of transportation in Nigeria dates back to the pre-colonial era, within this period, transportation facilities such as roads, railways, air transport craft etc. were non-existing with emphasis then on the bush path. At present, the modes of transportation in Nigeria include roads, railways, inland waterways, coastal waters, the deep sea, and the pipeline as stated by Anyanwu *et al*. (1997). According to Onakomaiya (undated), "of all commodity movements to and from the seaports, at least two –third are now handled by road transport while up to 90% of all other internal movement of goods and persons take place by roads. The author also stated that, the current network of roads in Nigeria is shared among the three tiers of government as: Federal roads, State roads and local roads. Tim (2003), estimated that losses in the Nigerian economy arising from the poor state of roads is about N450 billion yearly. According to Taha (2007), there are multitudes of situations in practice that can be modeled and solved as networks (nodes connected by branches). Some recent survey reports show that as much as 70% of the real-world mathematical problems can be represented by network related models. The author also stated that, network optimization models are widely used for problem in such diverse areas as production schedule, electricity distribution, project planning, facilities location, resources management and financial planning, to name just but few examples. The author further stated that, a network representation provides such a powerful visual and conceptual aid for portraying the relationships between the components of systems that is used in virtually every fields of scientific, social and economic endeavour. He also stated that many network optimization models are special types of linear programming problem (LPP), however, there are five important kinds of network problems (possible applications) and each has specific structure that arise frequently in applications ,they include:

i. Shortest-route problem
ii. The minimum cost flow schedule problem, which provide a unified approach to many other application because of it far more general structure
iii. The minimum spanning tree problem
iv. The critical path method (CPM) of time-cost tradeoffs.
v. The maximal flow problem.
   The solution of these situations and others like it, is accomplished through variety of network optimization algorithms.

According to Hillier and Lieberman (2005), the algorithms for the shortest-route problem is given as follows:

i. Objectives of *nth* iteration: n-1 Find the nth nearest node to the origin (to be repeated for n=1,2,3…) until the nth nearest node is the destination.
ii. Input for nth iteration: n-1 nearest nodes to the origin (solved for the previous iterations), including their shortest path and distances from the origin (these nodes, plus the origins will be called solved nodes, the others are unsolved nodes).
iii. Candidates for nth nearest nodes: Each solved node that is directly connected by a link to one or more unsolved nodes provides one candidate-the unsolved node with the shortest connecting link. (Ties provide additional candidates).
iv. Calculation of nth nearest node: For each solved node and its candidates, add the distances between them and the distance of the shortest path from the origin to this solved node, the candidate with the smallest total distance is the nth nearest node, and its shortest path is the one generating this distance.

Hillier and Lieberman (2005, pp 351-356) state that, the shortest route problem can be formulated using linear programming. The model is general in the sense that it can be used to find the shortest route between any two nodes in the network. Suppose that the shortest-route network includes n node and we desire to determine the shortest-route between any two nodes s and t in the network, the LP assumes that one unit of flow enter the network at nodes and leaves at node t.

Let

X_{ij} = amount of flow in arc (ij)

$= \begin{cases} 1, if\ arc\ (ij) is\ on\ the\ shortest - route \\ 0,\ otherwise \end{cases}$

C_{ij} = length of arc (ij)

Thus, the objective function of the linear program becomes

Minimize, $Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} X_{ij}$

The constraints represent the conservation of flow equation at each node:

Total input flow = total output flow
Mathematically, this translates for node j to.

$$\begin{bmatrix} External\ input \\ into\ node\ j \end{bmatrix} + \sum X_{ij}$$

$$= \begin{bmatrix} External\ output \\ from\ node\ j \end{bmatrix} + \sum X_{jk}$$

And $X_{ij} \geq 0, for\ all\ i\ and\ j.$

According to Dreyfus (2002), dynamic programming was developed by Richard Bellman in 1950 and is used heavily to solve problems of inventory, shortest route, resources allocation, equipment replacement, work-force size investment etc, since the invention of the method; there have been various improvements on the method. Now computer packages such as LINGO/LINDO, TORA, Excel add-solvers etc are available for solving many complex dynamic programming problems.
Hillier and Lieberman (2001, pp553- 568), Wayne (2003), Taha (2007, pp. 235-295, 405-425), Bertsekas and Dimitri (1976), Gupta and Hira (2012, p 639) and Sharma (2011), all attested that, dynamic programming method has wide variety of applications such as solving problems of inventory, shortest route, resources allocation, equipment replacement, work-force size etc. According to Hillier and Lieberman (2001, pp 538-541), the stage coach problem (shortest route) is a literal prototype of dynamic programming problems, therefore, one way to recognize a situation that can be formulated as a dynamic programming problem is to notice that its basic structure is analogous to the stagecoach problem. They also stated the basic features that characterize dynamic programming problems as:

1. The problem can be divided into stages, with a policy decision required at each stage.
2. Each stage has a number of states associated with the beginning of that stage.
3. The effort of the policy decision at each stage is to transform the current state to state associated with the beginning of the next stage (possibly according to a probability distribution)
4. The solution procedure is design to find an optional policy for the overall problem, i.e a prescription of the optimal policy decision at each stage for each of the possible states.
5. Given the current state, an optimal policy for the remaining stages is independent of the policy decision adopted in previous stages.
6. The solution procedure begins by finding the optimal policy for the last stage.
7. A recursive relationship
8. When we use this recursive relationship, the solution procedure starts at the end and moves backward stages by stage.

According to Wiener (1873), Tarry (1895) and Biggs *et al* (1976) path finding, in particular searching in a maze, belongs to the classical graph problems. They form basis for depth first search techniques. According to Leyzorek *et al* (1957) and Dijstra (1959), Dijkstras methods prescribes how to choose an arch with smallest length (then each arc is chosen at most once, if length are non-negative). Ferllet *et al* (2004), Chabrier (2002) and Roussean *et al* (2003) worked on ESPPRC (Elementary shortest path problems with resources constraint) pricing problems in the context of the vehicle routing problem with time windows (VRPTW)

MATERIALS AND METHODS

This involves development of a model of the Nigerian roads network system of motorable roads from coastal towns through hinterland to extreme town and time taken for any delay on a particular route were converted to distance and were added to the original distance thereafter, the traditional dynamic programming technique and a computer package (TORA) were used to analyze the data. Also for the sake of this study, all the affected routes are represented with the following colours for easy identification:

1. Black –all routes on the initial network
2. Brown –route untarred
3. Yellow – route with bad bridge
4. Red - route with terrorist activities
5. Orange – route with advantages
   a. New road –Green
   b. Old but still good –purple
   c. Old road with narrow bridge – blue
   d. Old dilapidated road– yellow
   e. Untarred road– tan
   f. Marshy terrain roads– pink
   g. Unpassable road-dark red
6. Blue -optimal route
7. Green -superimposed optimal route

Types of Data Collected

The data used were secondary: the data were collected from the records of government agencies, modeled and tabulated.

Method of Derivation of Solution and Analysis

Tabulated data were analyzed using the traditional dynamic programming technique and were also fed into the computer package software TORA and run several times then, the two results were compared, which the two results were the same.

Analysis

2. The penalty attached to the untarred roads:

i. Fairly Motorable, $p_{11}=1/4km$ is added to every kilometer $=> P_{11}=X_i+ ¼ X_i$
ii. Maneuver with great difficulty, P_{12} = ½ KM is added to every Kilometer $P_{12}= X_i + ½ X_i$ are roads or routes since all

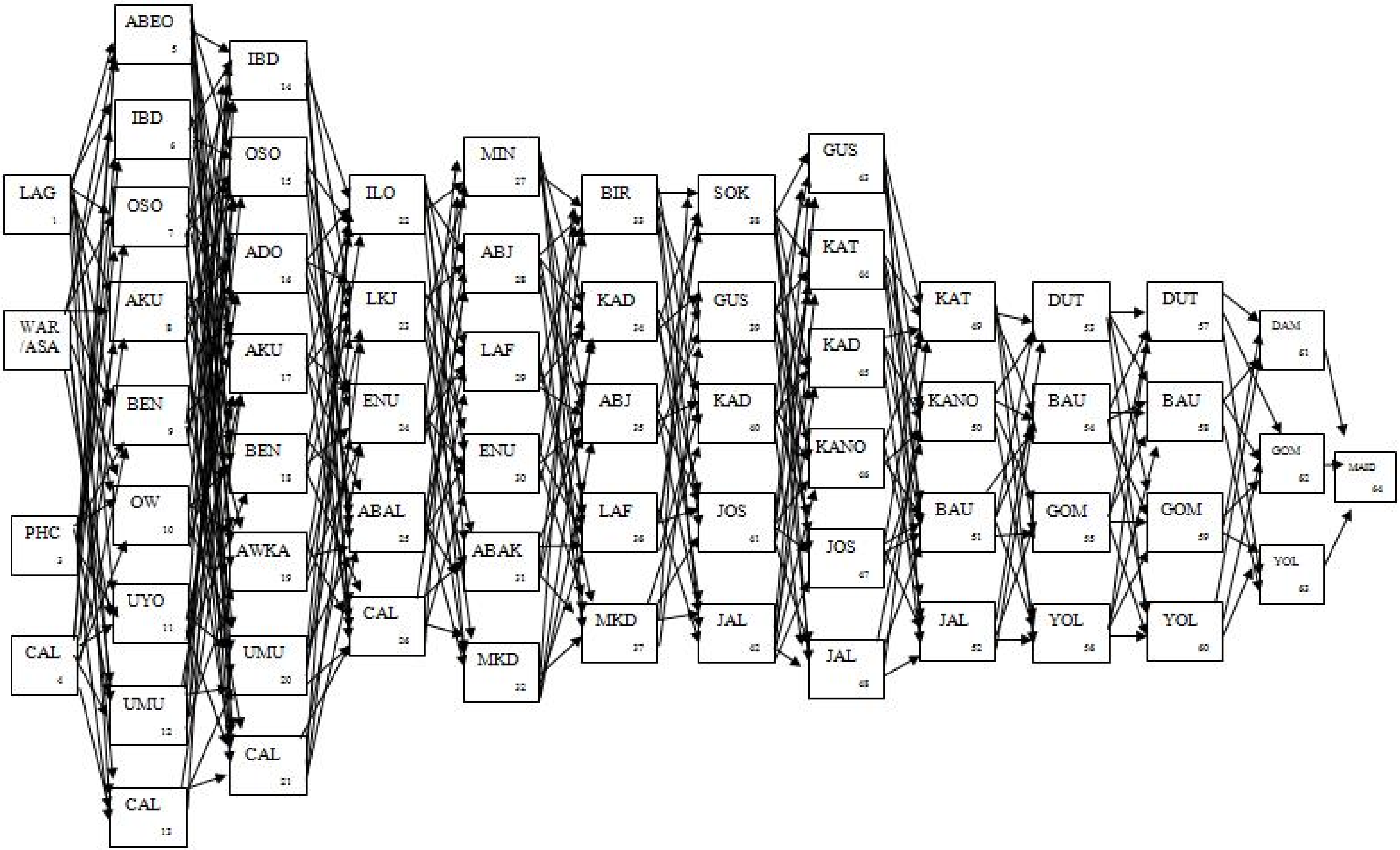

Fig. 1. Nigerian Roads Network (model) from Coastal Cities through hinterland to extreme town (Lagos, Warri, Port Harcourt Calabar to Maiduguri)

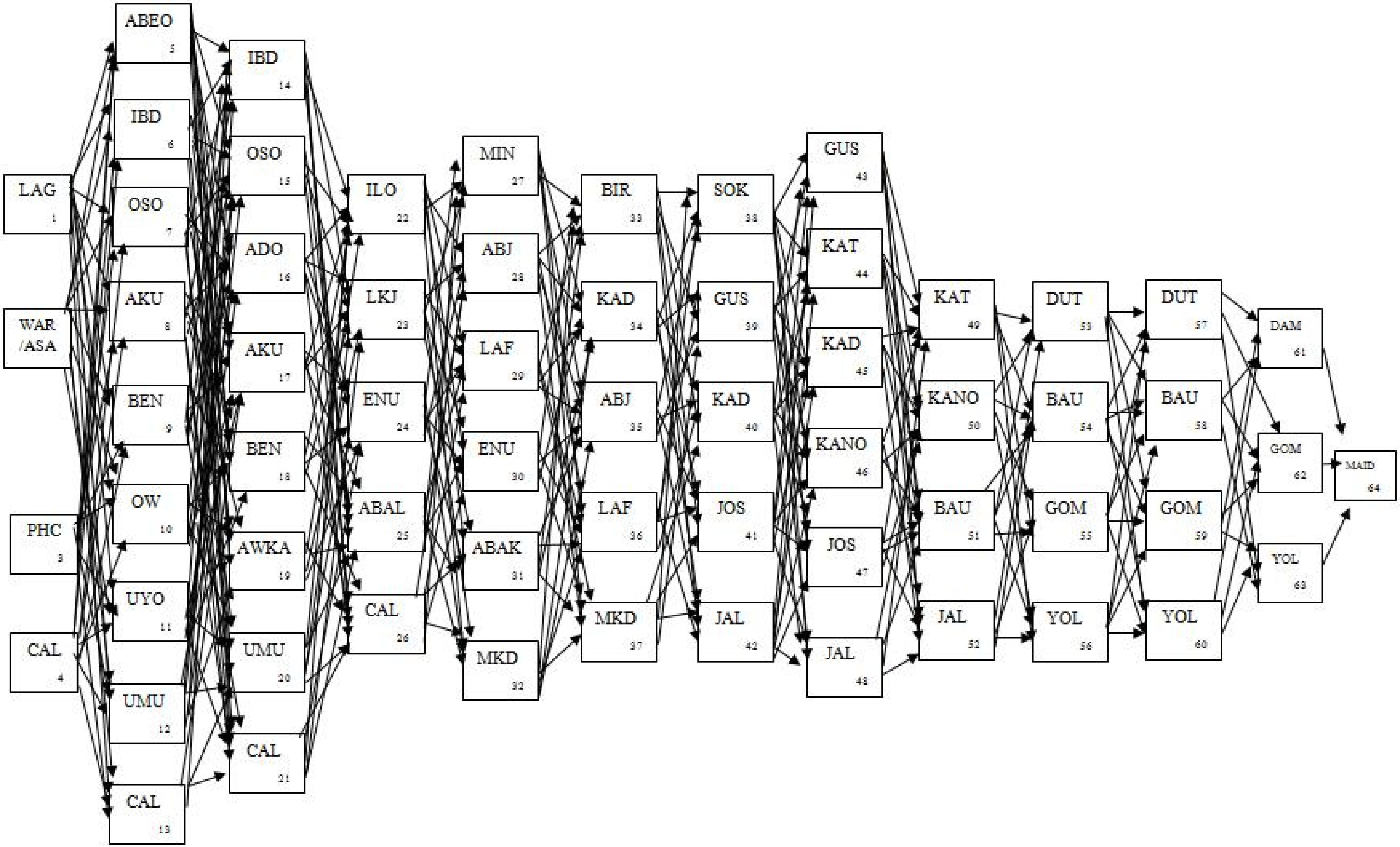

Fig. 2. Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, warri, Port Harcourt Calabar to Maiduguri) under normal circumstances

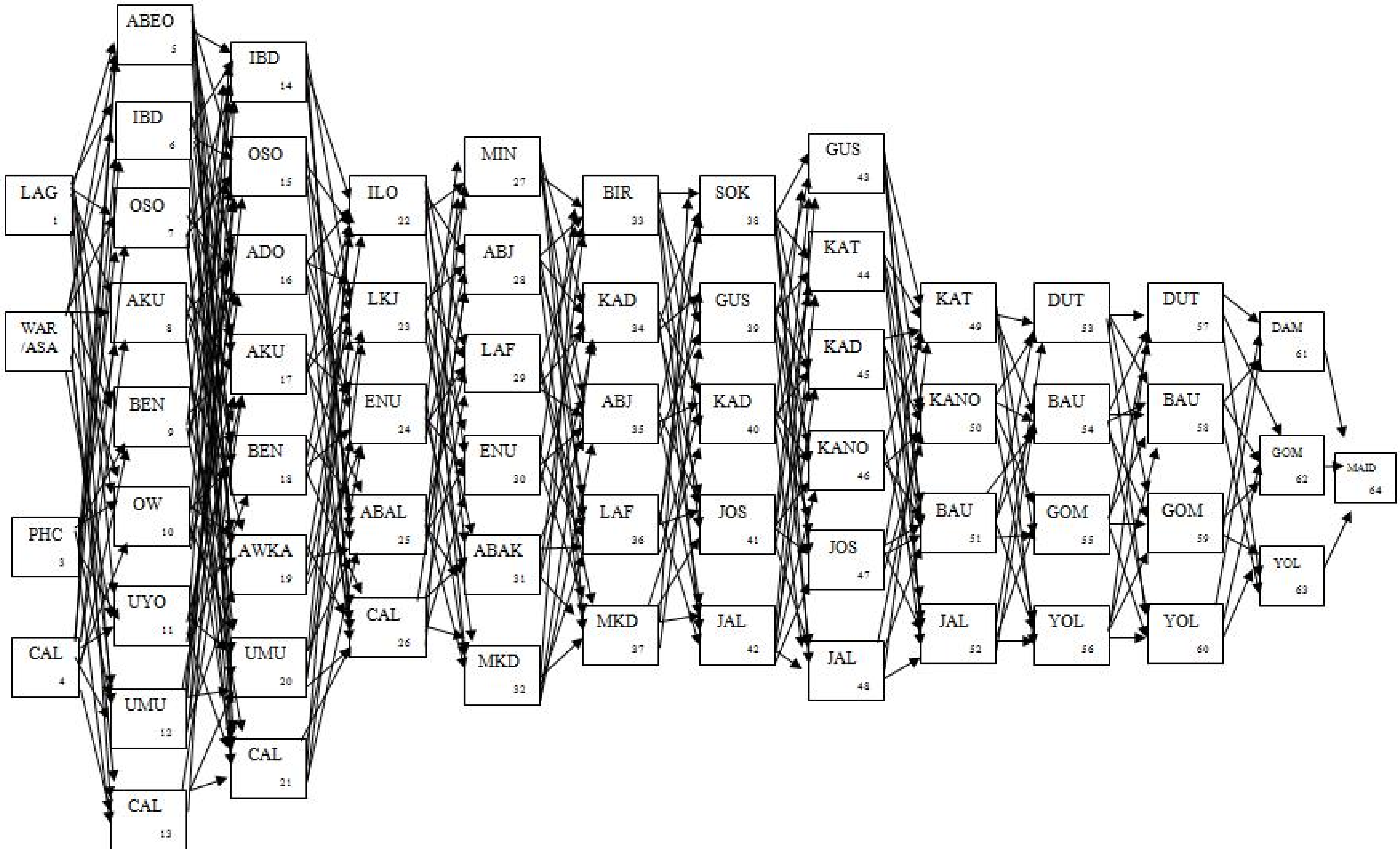

Fig. 3. Nigerian Roads Network from Coastal Cities through hinterland to extreme town (lagos, warri, Port Harcourt Calabar to Maiduguri) with Untared Roads

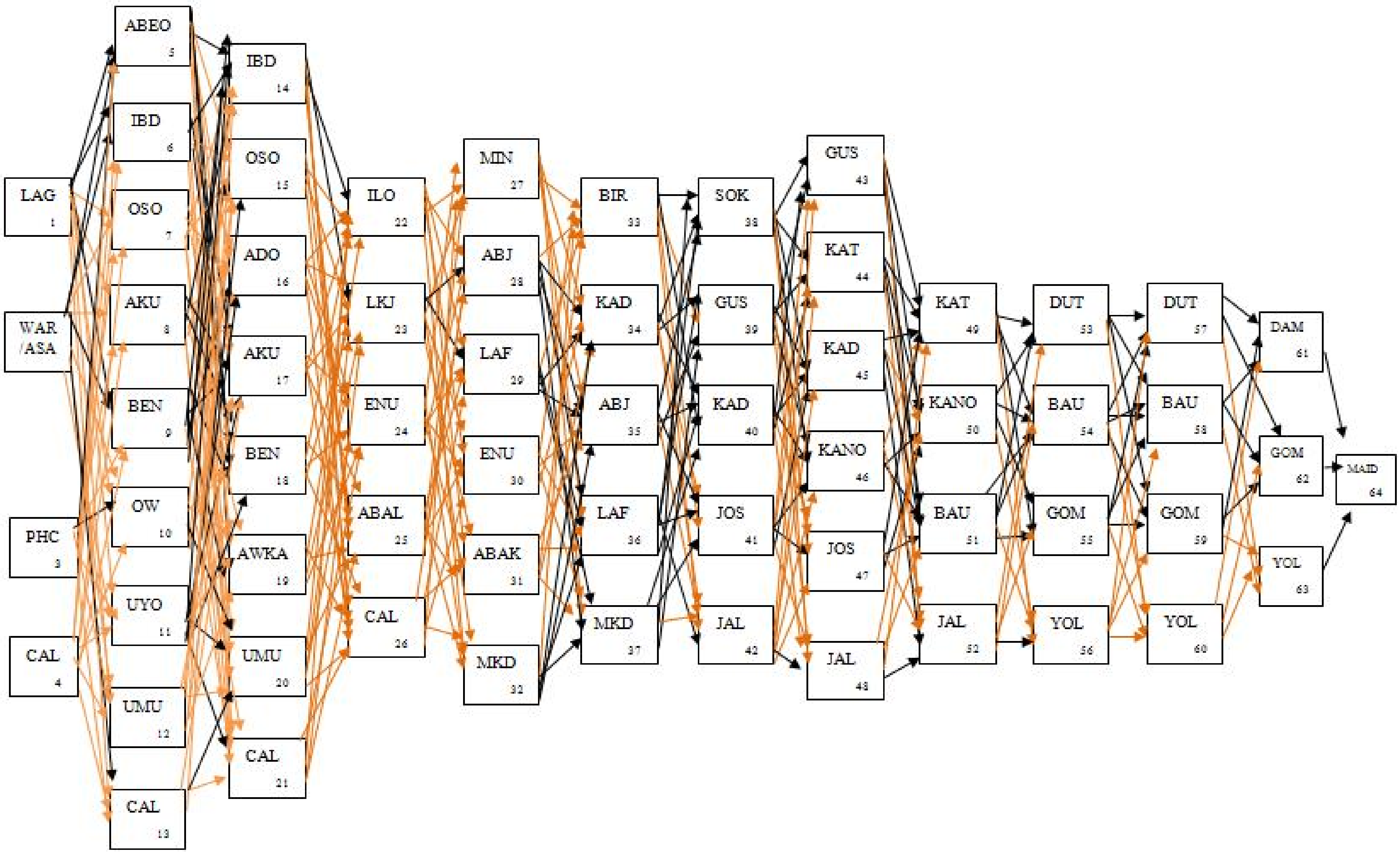

Fig.4. Nigerian Roads Network from Coastal Cities through hinterland to extreme town (lagos, warri, Port Harcourt Calabar to Maiduguri) with Bad Bridges

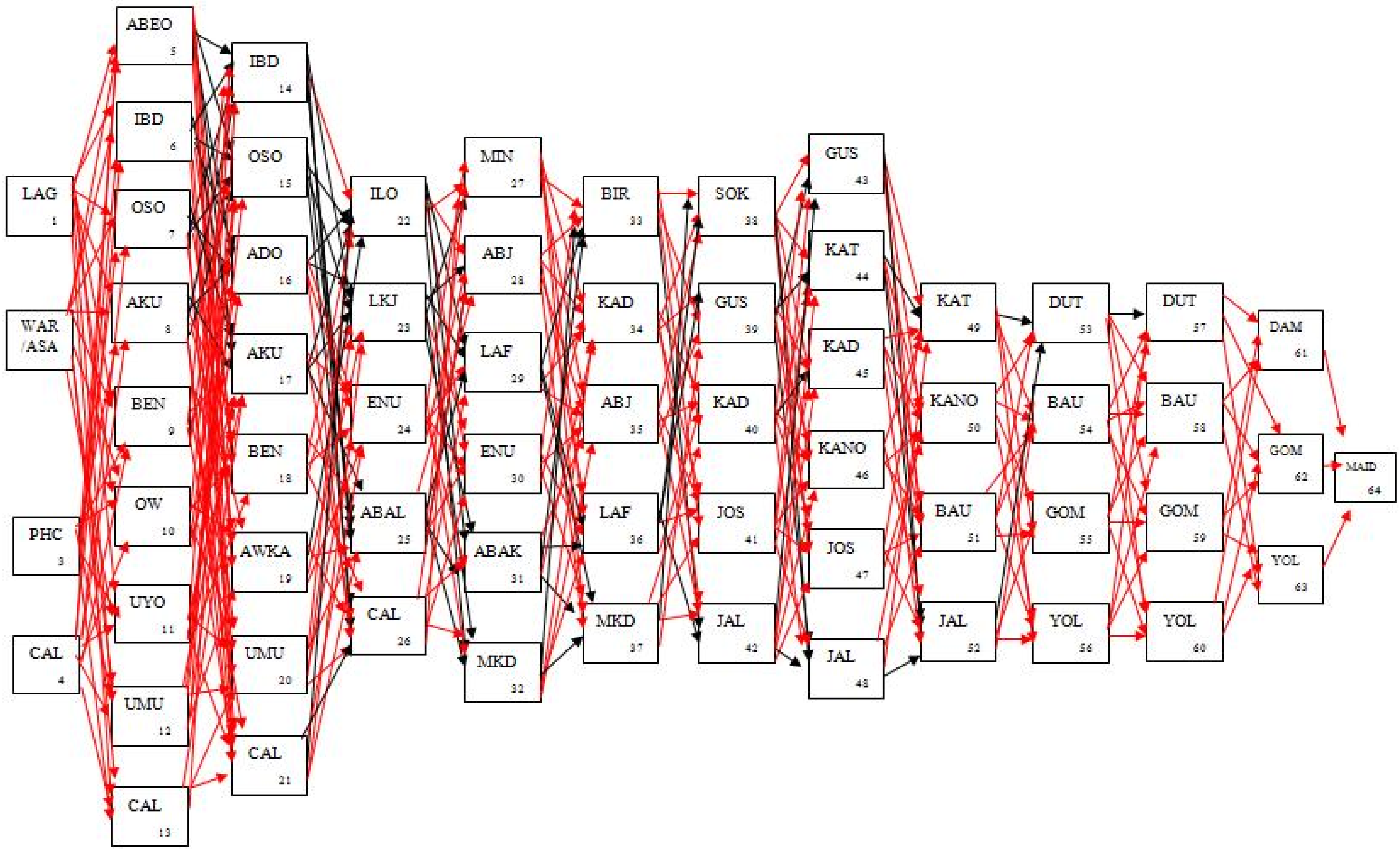

Fig. 5. Nigerian Roads Network from Coastal Cities through hinterland to extreme town (lagos, warri, Port Harcourt Calabar to Maiduguri) with frequent armed robbery attacks, Boko Haram Insurgences and Kidnappings

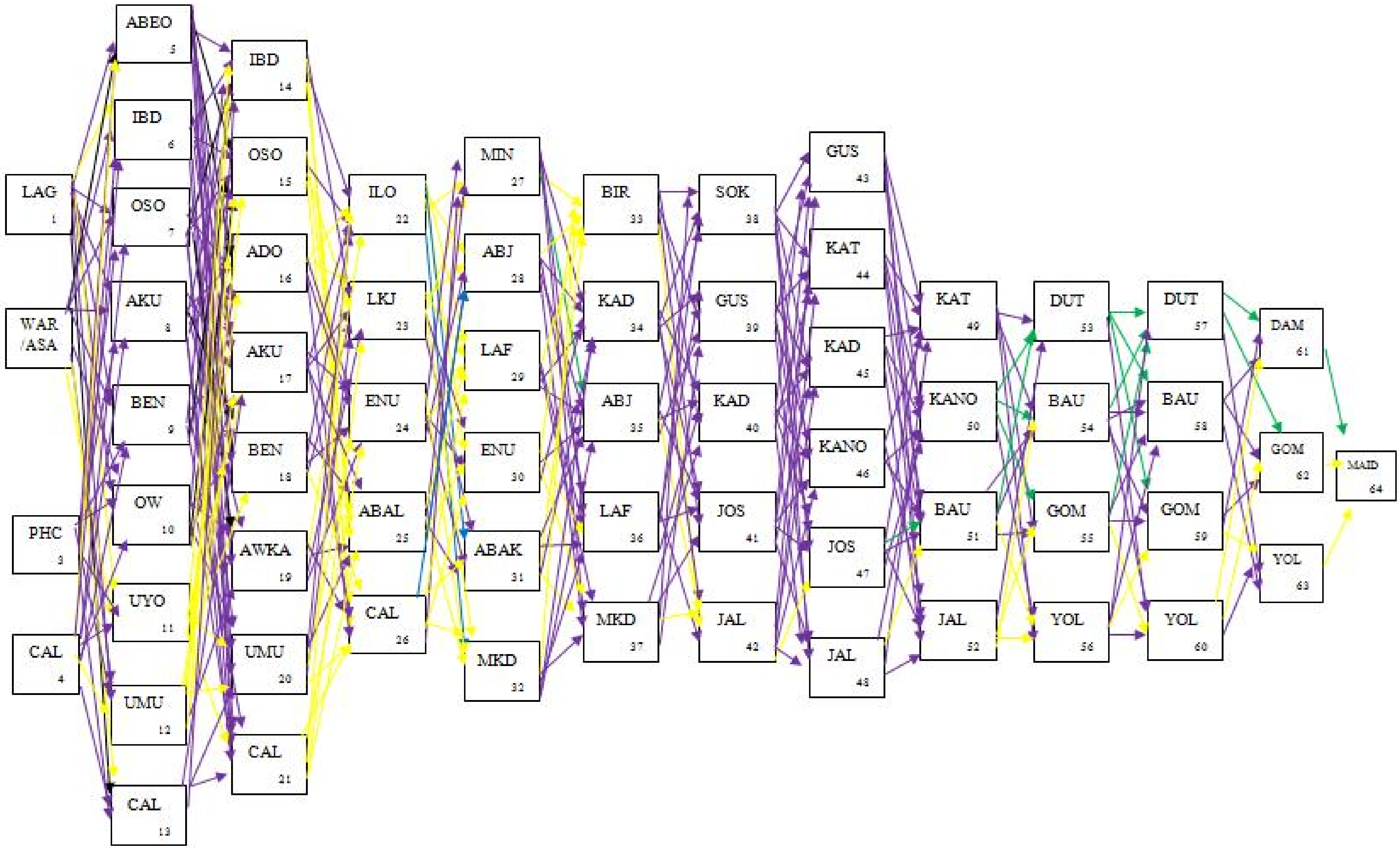

Fig. 6. Nigerian Roads Network from Coastal Cities through hinterland to extreme town (lagos, warri, Port Harcourt Calabar to Maiduguri) based on Advantages of cost/damage on the route

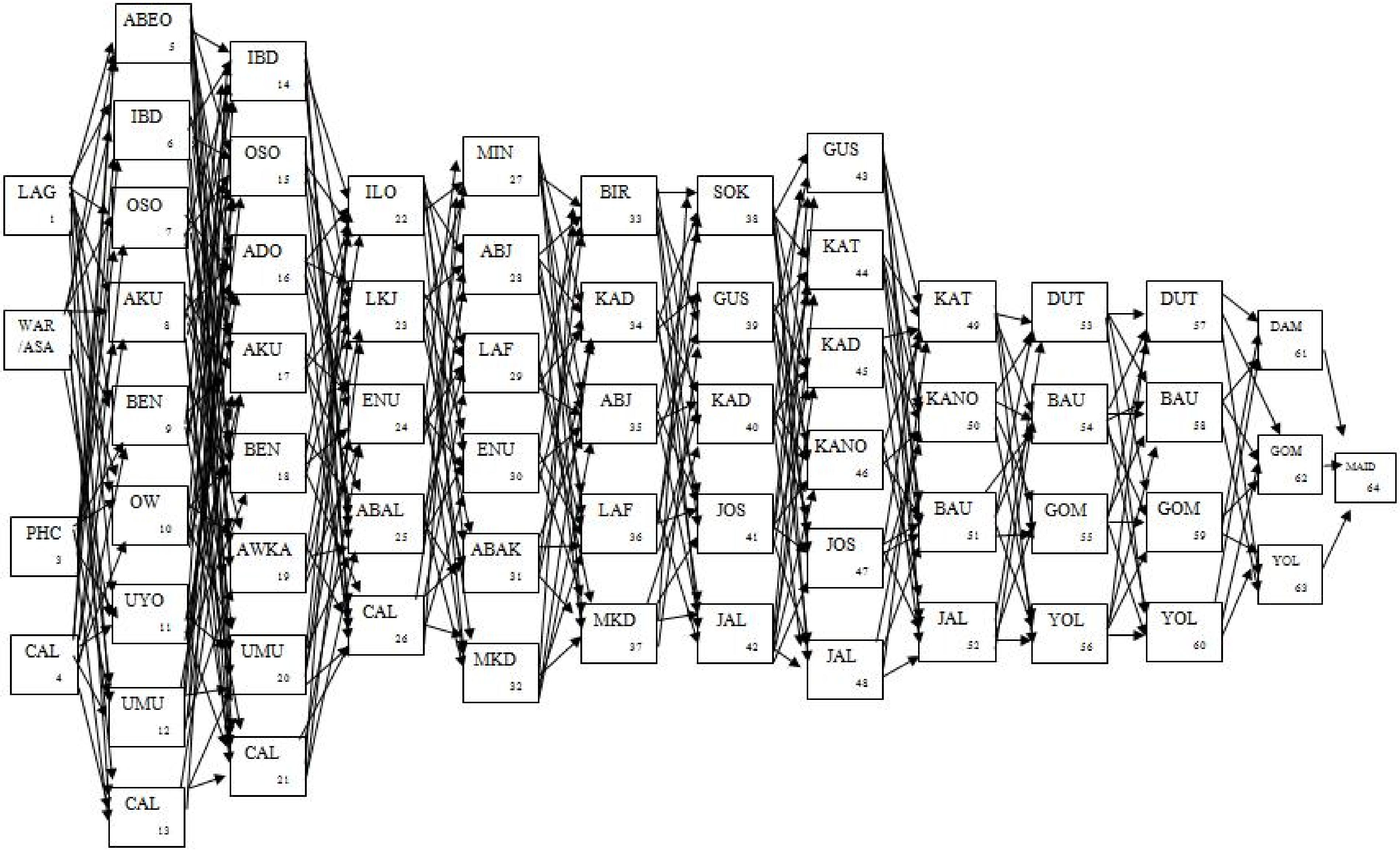

Fig.7. Nigerian Roads Network from Coastal Cities through hinterland to extreme town (lagos, warri, Port Harcourt Calabar to Maiduguri) with Figs. 2, 3 and 4 above superimposed

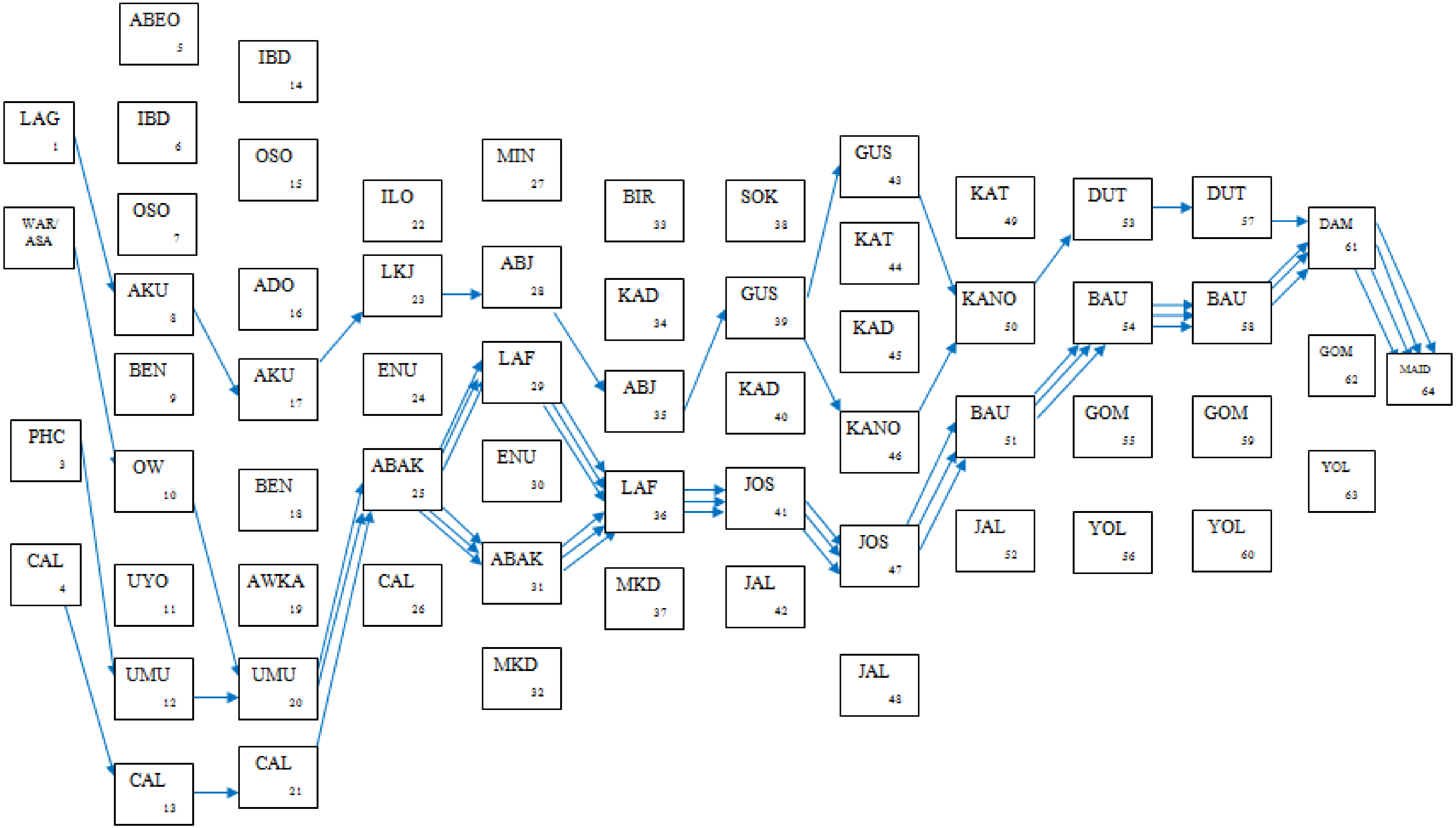

Fig. 6. shortest-route of Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, Warri, Port Harcourt Calabar to Maiduguri) under normal circumstances

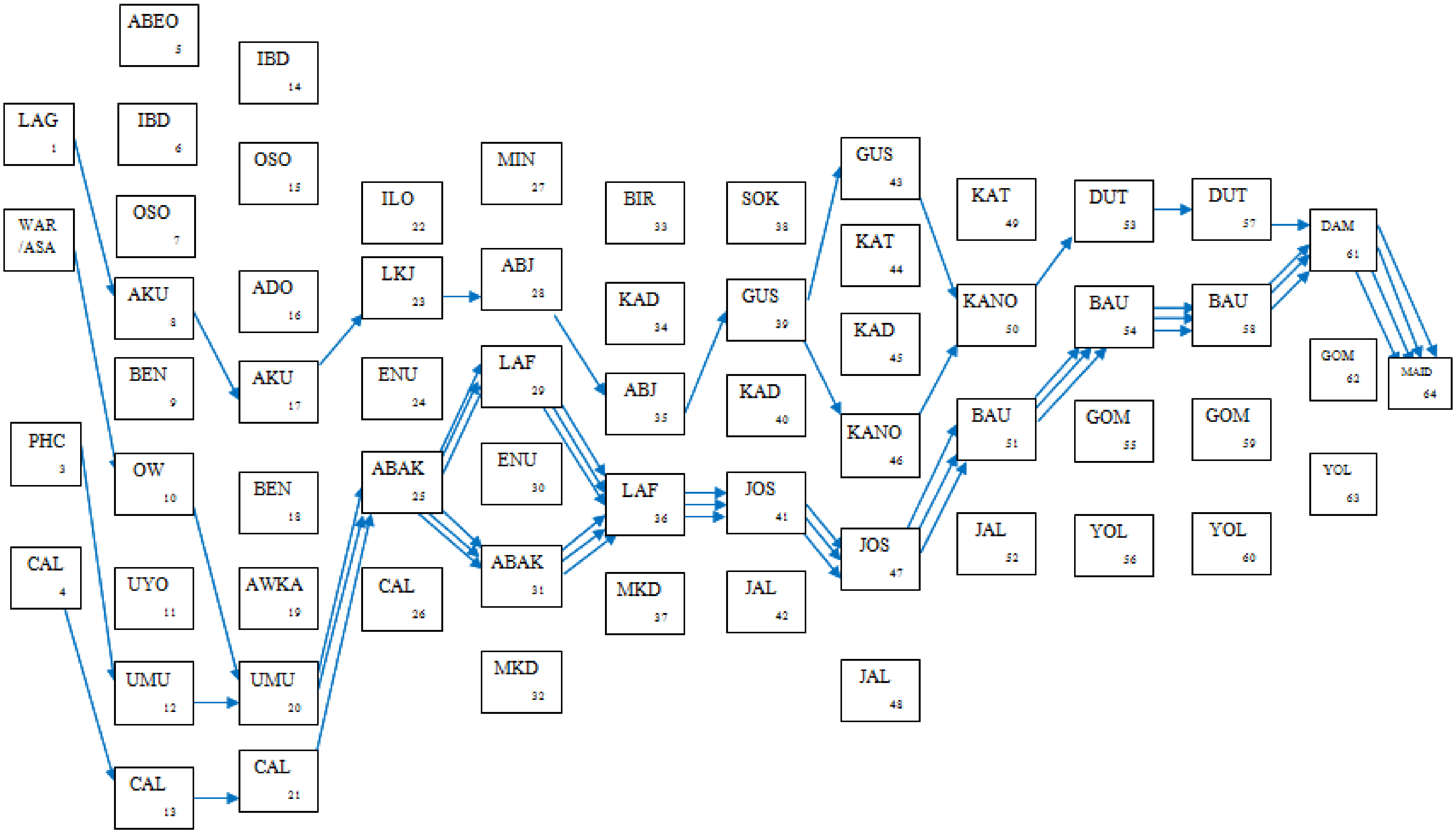

Fig. 7. Shortest-route of Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, Warri, Port Harcourt Calabar to Maiduguri) with Untared Roads

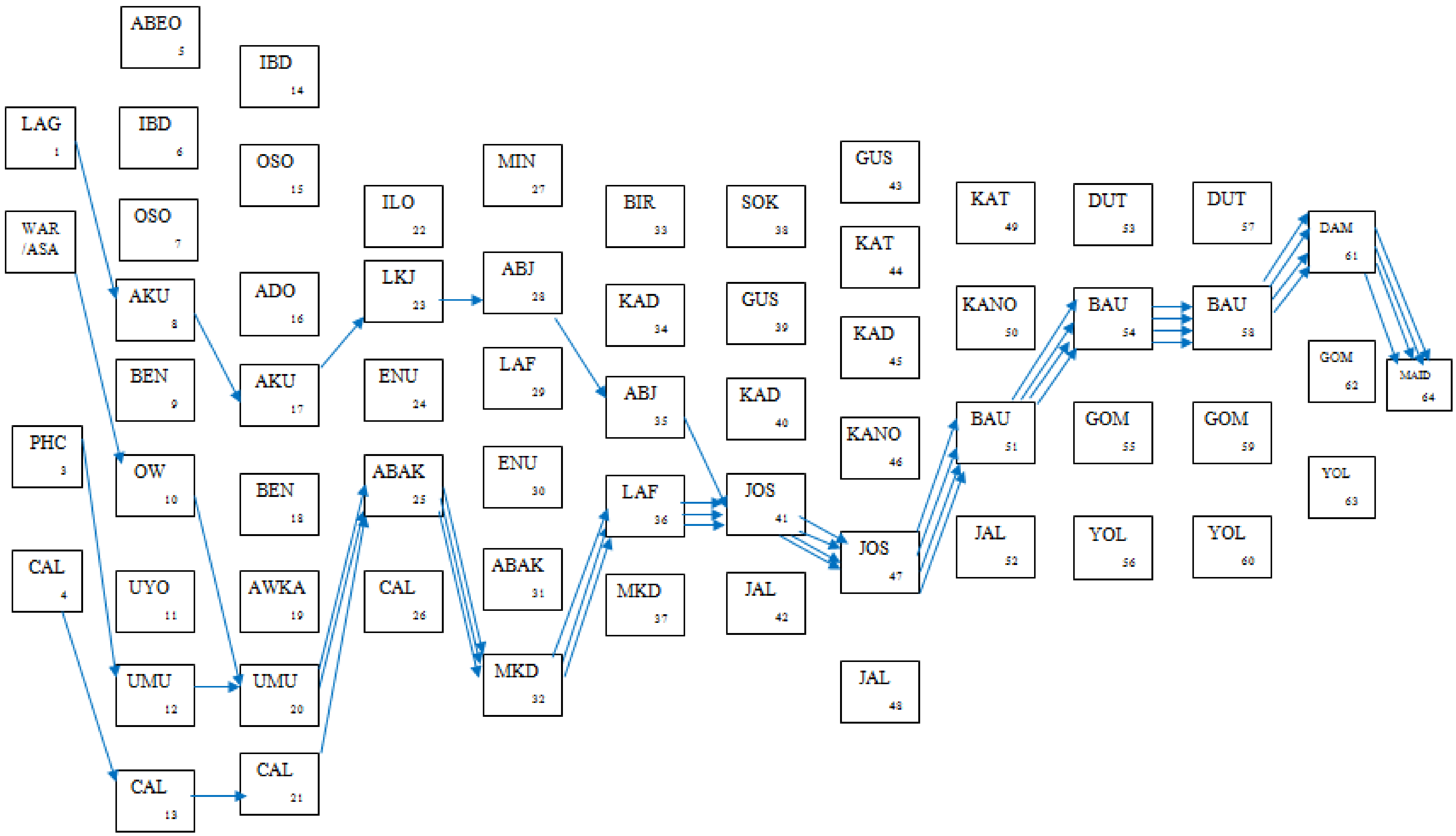

Fig. 8. Shortest-route of Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, Warri, Port Harcourt Calabar to Maiduguri) with Bad Bridges

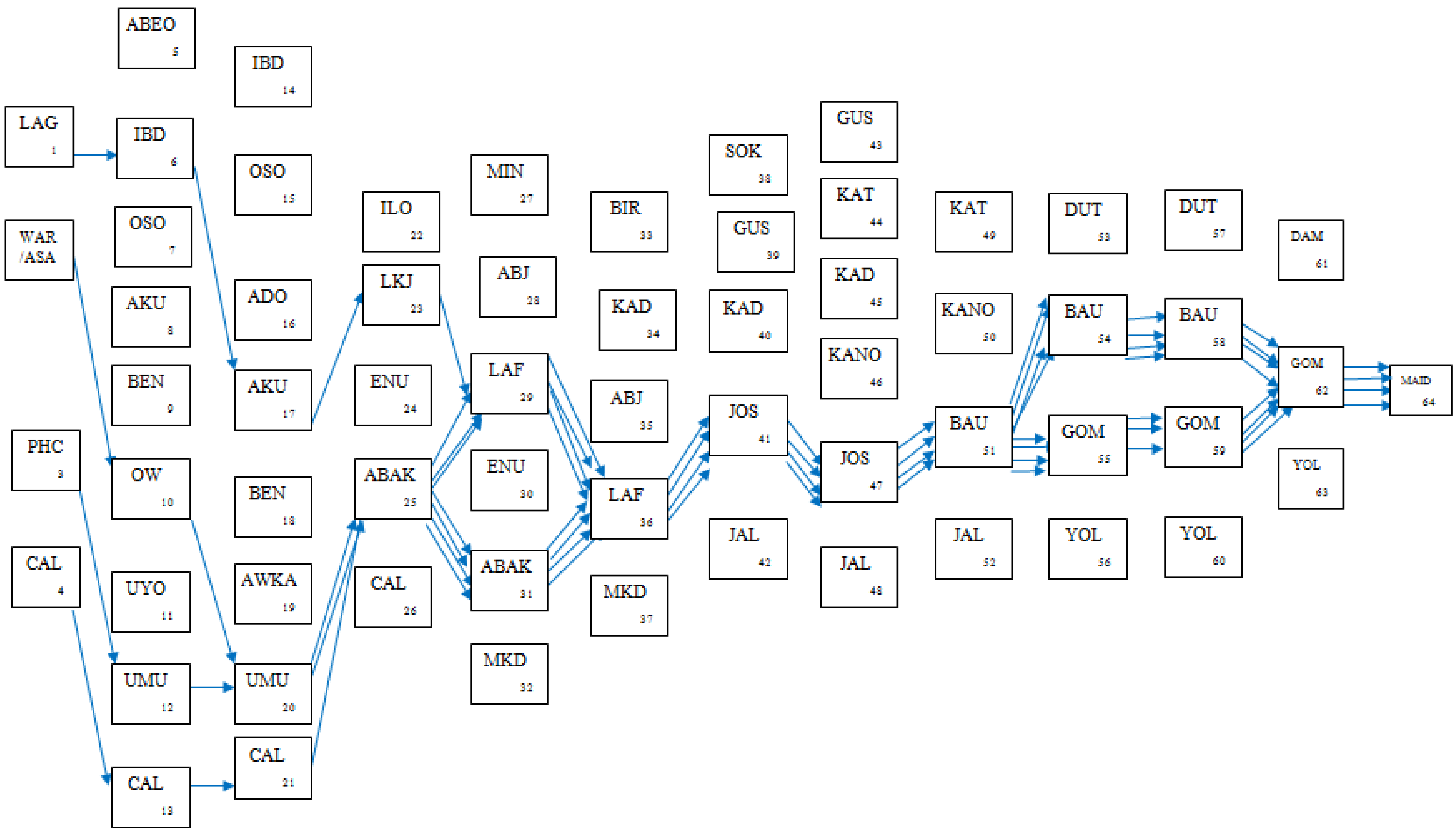

Fig. 10. Shortest-route of Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, Warri, Port Harcourt Calabar to Maiduguri) with frequent armed robbery attacks, Boko Haram Insurgences and Kidnappings

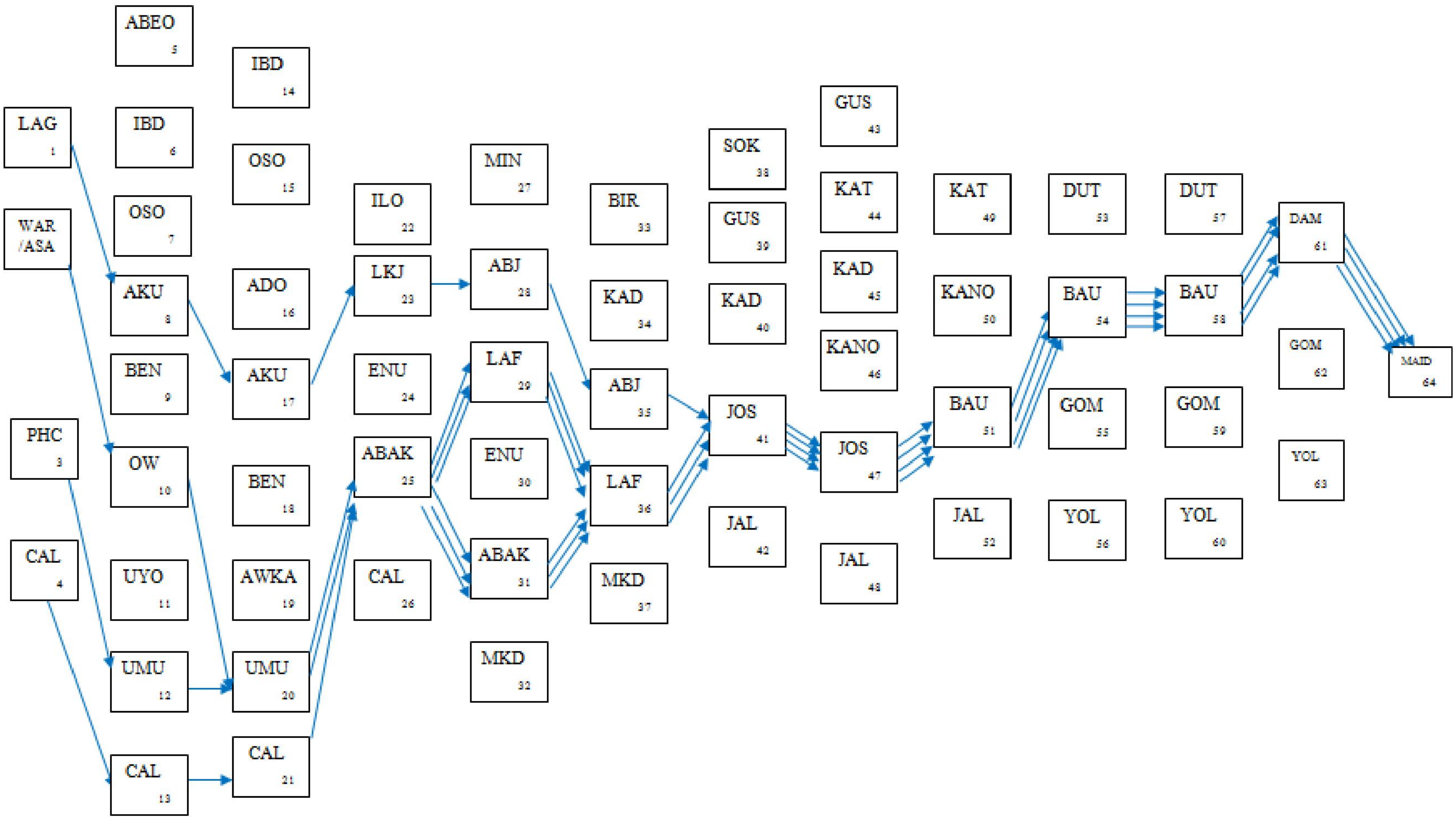

Fig. 11. Shortest-route of Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, Warri, Port Harcourt Calabar to Maiduguri) based on Advantages of cost/damage on the route

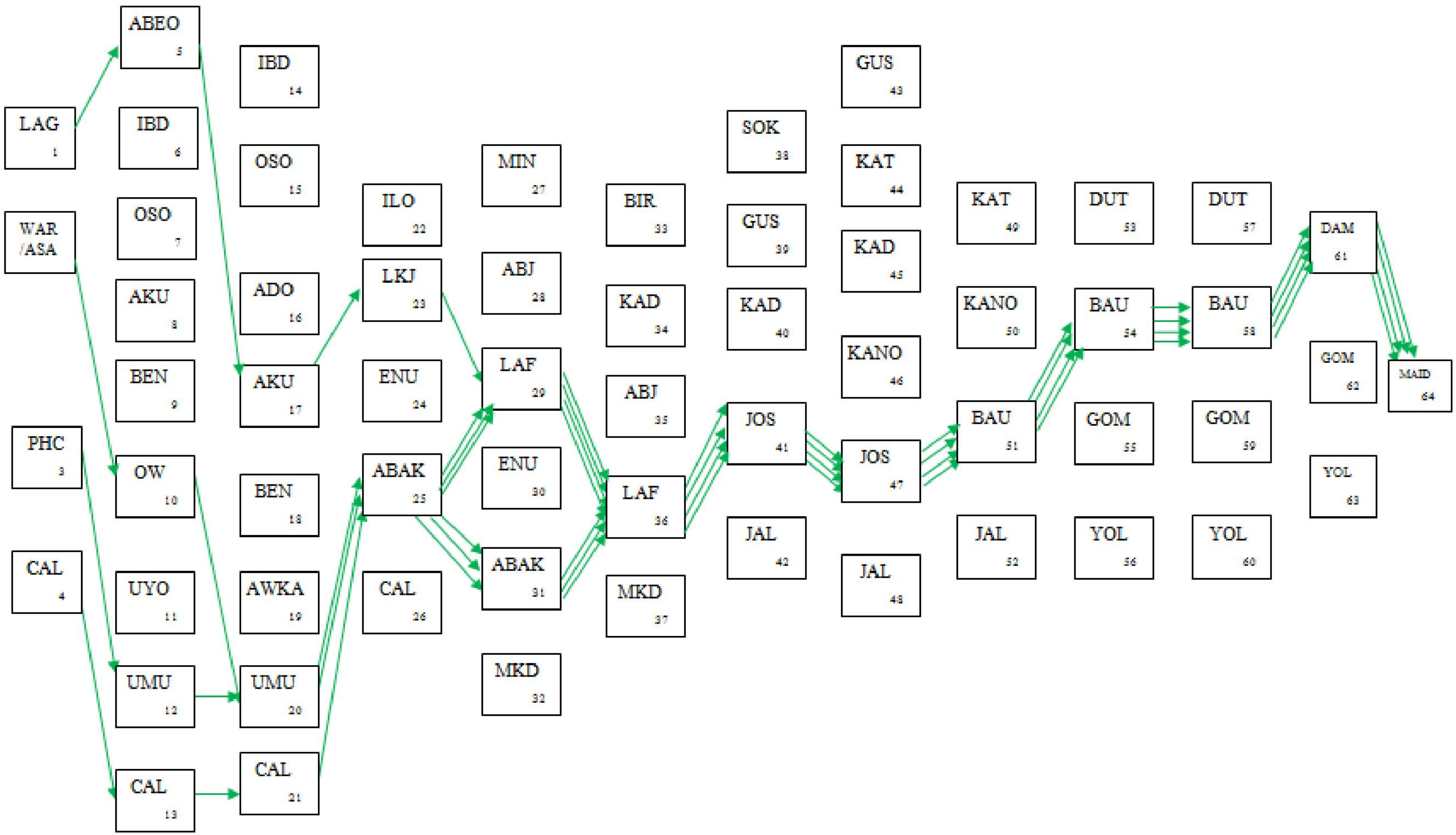

Fig. 12. The optimal route (superimposed results) of Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, Warri, Port Harcourt Calabar to Maiduguri)

Tables of Nigerian Roads Distances from Coastal Cities through hinterland to extreme town (Lagos, warri, Port Harcourt Calabar to Maiduguri) under normal circumstances are obtained from Fig. 2 source from Nigeria traveler's maps

Table 1. stage1

	5	6	7	8	9	10	11	12	13
1	101	141	284	270	320	574	709	611	782
2	472	430	386	300	130	77	230	140	280
3	671	656	551	465	295	112	120	114	205
4	764	518	691	580	490	200	67	151	0

Table 1. stage2

	14	15	16	17	18	19	20	21
5	77	183	283	262	314	507	595	764
6	0	106	176	185	300	465	582	518
7	106	0	100	86	907	421	526	691
8	155	86	50	0	220	335	490	630
9	300	907	220	120	0	165	279	490
10	555	463	427	377	240	90	60	200
11	676	599	578	528	375	195	88	67
12	582	526	490	440	279	105	0	151
13	518	691	630	580	490	260	51	0

Table 1. stage3

	22	23	24	25	26
14	162	584	558	640	518
15	115	313	486	568	691
16	145	213	480	532	630
17	195	202	400	482	580
18	399	287	254	312	490
19	530	326	65	147	260
20	770	405	118	136	151
21	849	579	276	174	0

Table 1. stage4

	27	28	29	30	31	32
22	334	482	643	653	667	563
23	307	193	346	310	392	311
24	598	393	365	0	52	266
25	646	490	315	82	0	216
26	860	729	490	276	174	532

Table 1. stage5

	33	34	35	36	37
27	509	292	156	331	440
28	665	186	0	175	280
29	540	358	175	0	99
30	1128	772	393	365	266
31	1155	673	490	315	216
32	939	500	280	99	0

Table 1. stage6

	38	39	40	41	42
33	139	480	748	844	1143
34	335	267	453	625	408
35	519	0	186	358	697
36	821	302	297	206	495
37	1290	677	625	450	0

Table 1. stage7

	43	44	45	46	47	48
38	219	380	480	546	644	1143
39	0	207	267	292	429	408
40	267	225	0	260	302	697
41	429	592	302	291	0	495
42	924	958	692	786	495	0

Table 1. stage8

	49	50	51	52
43	207	292	592	408
44	0	172	518	958
45	428	260	410	697
46	172	0	301	786
47	592	291	130	495
48	958	786	408	0

Table 1. stage9

	53	54	55	56
49	302	518	675	875
50	130	301	457	711
51	170	0	155	416
52	541	408	253	153

Table 1. stage10

	57	58	59	60
53	0	109	288	550
54	109	0	155	416
55	288	115	0	262
56	550	416	262	0

Table 1. stage11

	61	62	63
57	303	288	550
58	321	155	416
59	266	0	262
60	528	262	0

Table 1. stage12

	64
61	133
62	318
63	436

the roads (routes) considered in this research are tarred the result is the same with that of all condition been equal (that is under normal circumstance) as is in "1" above

Tables of Nigerian Roads Distances from Coastal Cities through hinterland to extreme town (Lagos, Warri, Port Harcourt Calabar to Maiduguri) with Untared Roads are obtained from Fig. 3 source from Nigeria traveler's maps

Table 2. stage1

	5	6	7	8	9	10	11	12	13
1	101	141	284	270	320	574	709	611	782
2	472	430	386	300	130	77	230	140	280
3	671	656	551	465	295	112	120	114	205
4	764	518	691	580	490	200	67	151	0

Table 2. stage2

	14	15	16	17	18	19	20	21
5	77	183	283	262	314	507	595	764
6	0	106	176	185	300	465	582	518
7	106	0	100	86	907	421	526	691
8	155	86	50	0	220	335	490	630
9	300	907	220	120	0	165	279	490
10	555	463	427	377	240	90	60	200
11	676	599	578	528	375	195	88	67
12	582	526	490	440	279	105	0	151
13	518	691	630	580	490	260	51	0

Table 2. stage3

	22	23	24	25	26
14	162	584	558	640	518
15	115	313	486	568	691
16	145	213	480	532	630
17	195	202	400	482	580
18	399	287	254	312	490
19	530	326	65	147	260
20	770	405	118	136	151
21	849	579	276	174	0

Table 2. stage4

	27	28	29	30	31	32
22	334	482	643	653	667	563
23	307	193	346	310	392	311
24	598	393	365	0	52	266
25	646	490	315	82	0	216
26	860	729	490	276	174	532

Table 2. stage5

	33	34	35	36	37
27	509	292	156	331	440
28	665	186	0	175	280
29	540	358	175	0	99
30	1128	772	393	365	266
31	1155	673	490	315	216
32	939	500	280	99	0

Table 2. stage6

	38	39	40	41	42
33	139	480	748	844	1143
34	335	267	453	625	408
35	519	0	186	358	697
36	821	302	297	206	495
37	1290	677	625	450	0

Table 2. stage7

	43	44	45	46	47	48
38	219	380	480	546	644	1143
39	0	207	267	292	429	408
40	267	225	0	260	302	697
41	429	592	302	291	0	495
42	924	958	692	786	495	0

Table 2. stage8

	49	50	51	52
43	207	292	592	408
44	0	172	518	958
45	428	260	410	697
46	172	0	301	786
47	592	291	130	495
48	958	786	408	0

Table 2. stage9

	53	54	55	56
49	302	518	675	875
50	130	301	457	711
51	170	0	155	416
52	541	408	253	153

Table 2. stage10

	57	58	59	60
53	0	109	288	550
54	109	0	155	416
55	288	115	0	262
56	550	416	262	0

Table 2. stage11

	61	62	63
57	303	288	550
58	321	155	416
59	266	0	262
60	528	262	0

Table 2. stage12

	64
61	133
62	318
63	436

3 Bad Bridges:

i. Fairly Motorable, P_{13}=*1/4KM* is added to every Kilometer of fairly Motorable bad bridges => $X_i + 1/4X_i = P13$
ii. Maneuver with great difficulty, P_{14} = *60%* is added to every kilometer with bad bridges that can be maneuvered with great difficulty

$P_{14} = X_i + 60\%\ of\ X_i$

Tables of Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, warri, Port Harcourt Calabar to Maiduguri) with Bad Bridges are obtained from Fig. 4 source from Nigeria traveler's maps

Table 3. stage1

	5	6	7	8	9	10	11	12	13
1	101	141	355	338	400	713	886	764	978
2	472	430	483	375	163	96	288	175	350
3	839	820	689	581	369	112	150	143	256
4	955	648	864	725	613	250	84	189	0

Table 3. stage2

	14	15	16	17	18	19	20	21
5	77	229	354	328	314	634	774	995
6	0	133	220	231	375	581	728	648
7	133	0	125	108	1134	526	658	864
8	185	108	63	0	220	385	490	630
9	375	1134	275	213	0	206	349	613
10	694	579	534	471	300	113	60	250
11	676	599	578	528	375	195	88	67
12	728	658	618	550	349	131	0	189
13	648	864	788	725	613	325	189	0

Table 3. stage3

	22	23	24	25	26
14	162	730	698	800	648
15	143	391	608	710	864
16	181	266	600	665	788
17	499	359	318	390	613
18	663	506	148	170	189
19	963	506	148	170	189
20	1061	424	345	218	0

Table 3. stage4

	27	28	29	30	31	32
21	418	603	804	816	834	1079
22	386	193	346	388	490	389
23	748	491	459	0	103	333
24	808	618	394	103	0	270
25	1075	911	613	345	218	665

Table 3. stage5

	33	34	35	36	37
26	636	371	195	414	550
27	831	186	0	175	280
28	1050	358	175	0	99
29	1410	965	491	456	333
30	1444	841	613	394	270
31	1173	500	280	99	0

Table 3. stage6

	38	39	40	41	42
32	139	419	519	1016	1613
33	480	267	0	378	871
34	748	453	186	297	781
35	544	625	358	206	450
36	1123	724	500	336	519

Table 3. stage7

	43	44	45	46	47	48
37	219	380	480	546	805	1429
38	0	207	267	292	536	510
39	267	428	0	260	378	865
40	536	740	378	291	0	619
41	1155	1198	865	983	619	0

Table 3. stage8

	49	50	51	52
42	207	292	592	510
43	0	215	518	1198
44	428	260	513	697
45	215	0	301	983
46	740	291	163	169
47	1198	983	570	0

Table 3. stage9

	53	54	55	56
48	302	518	675	1094
49	130	301	457	889
50	190	0	155	570
51	676	510	316	153

Table 3. stage10

	57	58	59	60
52	0	109	288	688
53	109	0	155	520
54	288	115	0	328
55	688	520	328	0

Table 3. stage11

	61	62	63
56	303	288	688
57	321	155	520
58	266	0	328
59	660	328	0

Table 3. stage12

	64
60	133
61	318
62	436

4 Roads or routes with high frequency of other hazards armed robbery attacks, Boko haram insurgency and kidnapping), P_{15}=85% is added to every routes affected by other hazards.

=> $P_{15}=X_i + 85\%$ of X_i

Tables of Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, warri, Port Harcourt Calabar to Maiduguri) with frequent armed robbery attacks, Boko Haram Insurgences and Kidnappings are obtained from Fig. 5 source from Nigeria traveler's maps

Table 4. stage1

	5	6	7	8	9	10	11	12	13
1	187	261	525	500	592	1062	1312	1130	1447
2	873	796	786	555	241	142	426	259	518
3	1241	1214	1019	860	546	207	222	211	379
4	1413	958	1278	1073	907	370	124	151	0

Table 4. stage2

	14	15	16	17	18	19	20	21
5	77	183	283	262	581	938	1101	1413
6	0	106	176	185	555	860	1077	958
7	106	0	100	86	1678	779	973	1278
8	185	86	50	0	407	712	907	1166
9	555	1678	407	315	0	305	516	907
10	1027	857	790	697	444	167	111	370
11	1251	1108	1069	977	694	361	163	124
12	1077	973	907	814	516	194	0	279
13	958	1278	1166	1073	907	481	279	0

Table 4. stage3

	22	23	24	25	26
14	300	584	1032	640	958
15	115	313	899	568	1278
16	145	213	888	532	1166
17	195	202	740	482	1073
18	738	531	470	577	907
19	981	603	120	272	481
20	1425	749	218	252	279
21	1571	1071	511	322	0

Table 4. stage4

	27	28	29	30	31	32
22	618	892	643	1190	1234	1597
23	572	357	346	574	392	311
24	1106	727	675	0	152	492
25	1195	907	315	152	0	216
26	1591	1349	907	511	322	984

Table 4. stage5

	33	34	35	36	37
27	942	549	289	612	814
27	1230	344	0	324	518
28	1554	662	324	0	183
29	2087	1428	727	675	492
30	2137	1245	907	583	400
31	1737	925	518	183	0

Table 4. stage6

	38	39	40	41	42
32	257	335	960	1519	863
33	888	494	0	1034	1289
34	1384	838	344	549	1156
35	1561	1156	662	381	833
36	2078	1339	925	622	768

Table 4. stage7

	43	44	45	46	47	48
37	405	703	888	1010	1191	2115
38	0	383	494	540	794	755
39	494	792	0	481	559	1289
40	794	1095	559	538	0	916
41	1709	1772	1280	1454	916	0

Table 4. stage8

	49	50	51	52
42	383	540	1095	755
43	0	318	958	1772
44	792	481	759	1289
45	318	0	557	1454
46	1095	538	241	916
47	1772	1454	755	0

Table 4. stage9

	53	54	55	56
48	302	518	675	1619
49	130	301	457	1315
50	190	0	155	770
51	541	408	253	283

Table 4. stage10

	57	58	59	60
52	0	109	288	1018
53	109	0	155	770
54	288	115	0	485
55	1018	770	485	0

Table 4. stage11

	61	62	63
56	561	288	1018
57	594	155	770
58	492	0	485
59	977	485	0

Table 4. stage12

	64
60	246
61	318
62	808

5. Advantages based on cost/damage on the route for every affected route:

a. New road with no obstacles $P_{21} = X_i + 0\%\ of\ X_i$

$=> X_i + 0\%$

$0\% => 100\% - 100\%$ of goodness = 0% of badness.

b. old but good roads with minor obstacles P_{22}

$P_{22} = X_i + (100\% - 80\%)\ of\ X_i$

$=> X_i + 20\%\ of\ X_i$

c. Good road but narrow bridges $P_{23} = X_i + 40\%\ of\ X_i$

d. Old dilapidated road, $P_{24} = X_i + 50\%\ of\ X_i$

e. Untarred road $P_{25} = X_i + 70\%\ of\ X_i$

f. Truncated roads $P_{26} = X_i + 80\%\ of\ X_i$

g. Mashy terrain roads $P_{27} = X_i + 90\%\ of\ X_i$

h. Unpassable $P_{28} = X_i + 100\%\ of\ X_i$

Tables of Nigerian roads distances based on Advantages (cost/damage) on the route are obtained from Fig. 6 source from Nigeria traveler's maps

Table 5. stage1

	5	6	7	8	9	10	11	12	13
1	121	212		324	384	689	851	733	1173
2	566	516		360	156	92	322	168	392
3	805	787		558	354	134	144	137	246
4	1070	622		870	588	240	80	181	0

Table 5. stage2

	14	15	16	17	18	19	20	21
5	92	220	340	314	372	608	714	917
6	0	127	211	222	360	558	698	622
7	127	0	120	103	1088	505	631	829
8	222	102	60	0	264	462	588	756
9	360	1088	330	204	0	198	355	588
10	666	556	512	452	288	108	72	240
11	946	839	809	739	525	273	123	94
12	698	631	588	616	391	147	0	211
13	725	829	756	696	588	312	227	0

Table 5. stage3

	22	23	24	25	26
14	194	701	837	960	777
15	138	470	583	682	1037
16	218	320	576	638	756
17	234	242	480	578	696
18	479	344	305	374	686
19	795	391	78	176	312
20	924	486	142	163	181
21	1189	811	386	244	0

Table 5. stage4

	27	28	29	30	31	32
22	501	723	965	914	934	1295
23	464	290	519	370	470	467
24	718	472	548	0	98	399
25	775	588	473	98	0	324
26	1032	875	735	414	244	798

Table 5. stage5

	33	34	35	36	37
27	764	356	156	397	528
28	998	223	0	210	336
29	1260	430	210	0	119
30	1692	926	472	548	399
31	1733	808	588	378	324
32	1409	600	336	119	0

Table 5. stage6

	38	39	40	41	42
33	167	402	623	985	1935
34	576	320	0	362	836
35	897	544	223	356	750
36	1013	750	430	247	540
37	1348	869	600	403	498

Table 5. stage7

	43	44	45	46	47	48
38	263	456	576	350	773	1372
39	0	248	320	655	515	490
40	320	514	0	312	367	836
41	515	710	362	349	0	743
42	1109	1150	830	943	743	0

Table 5. stage8

	49	50	51	52
43	248	350	710	490
44	0	206	622	1150
45	514	312	492	836
46	206	0	361	943
47	710	349	130	594
48	1150	943	612	0

Table 5. stage9

	53	54	55	56
49	362	622	810	1050
50	130	301	457	853
51	190	0	186	499
52	812	612	380	230

Table 5. stage10

	57	58	59	60
53	0	109	288	660
54	109	0	186	499
55	288	173	0	393
56	660	499	393	0

Table 5. stage11

	61	62	63
57	303	288	660
58	385	186	499
59	319	0	393
60	792	393	0

Table 5. stage12

	64
61	133
62	477
63	654

6. The superimposed equation for the affected routes:

$X_i + [(\frac{1}{4}X_i \text{ or } \frac{1}{2}X_i) + (\frac{1}{4}X_i \text{ or } 60\% X_i \text{ or } 85\% X_i) + (0\% X_i \text{ or } 20\% X_i \text{ or } 40\% X_i \text{ or } 50\% X_i \text{ or } 70\% X_i \text{ or } 80\% X_i \text{ or } 90\% X_i \text{ or } 100\% X_i)]$

Table of Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, Warri, Port Harcourt Calabar to Maiduguri) with Figs. 2, 3 and 4 above superimposed:

Table 6. stage1

	5	6	7	8	9	10	11	12	13
1	207	331	653	621	656	1320	1631	1405	2033
2	968	882	888	690	267	179	575	322	700
3	1543	1509	1267	1070	679	258	276	267	472
4	1910	1192	1589	1508	1127	410	154	340	0

Table 6. stage2

	14	15	16	17	18	19	20	21
5	92	265	410	380	455	735	863	1108
6	0	127	255	268	435	1070	1339	1108
7	137	0	129	111	1940	900	1125	1478
8	238	111	64	0	470	823	1048	1347
9	642	1940	470	364	0	353	597	1048
10	1277	1065	982	867	552	207	123	460
11	1690	1348	1301	1188	844	439	198	151
12	1339	1125	1048	1100	698	263	0	347
13	1295	1589	1449	1334	1127	598	393	0

Table 6. stage3

	22	23	24	25	26
14	235	847	977	1120	907
15	167	548	705	824	1209
16	254	373	664	771	914
17	283	293	580	699	841
18	918	660	584	718	1127
19	1378	750	150	338	598
20	1771	932	307	313	347
21	2123	1448	690	435	0

Table 6. stage4

	27	28	29	30	31	32
22	868	1253	1125	1633	1101	1510
23	803	454	519	713	568	544
24	1375	904	1132	0	189	825
25	1486	1127	457	189	0	378
26	1978	1677	1274	718	435	1383

Table 6. stage5

	33	34	35	36	37
27	1323	683	328	761	1012
28	1729	381	0	359	574
29	1470	734	359	0	119
30	2933	1776	904	1132	825
31	3003	1548	1127	457	378
32	2441	1150	644	119	0

Table 6. stage6

	38	39	40	41	42
33	285	486	960	1888	3354
34	984	547	0	695	957
35	1720	1042	381	609	1438
36	1730	1281	734	422	540
37	2302	1484	1025	689	955

Table 6. stage7

	43	44	45	46	47	48
38	449	779	984	1119	1481	2629
39	0	242	547	599	987	1061
40	547	877	0	533	695	957
41	987	1362	695	597	0	1139
42	2125	2203	957	1808	1139	0

Table 6. stage8

	49	50	51	52
43	424	599	938	1061
44	0	396	1062	1343
45	877	533	943	957
46	396	0	557	1286
47	1362	597	273	1139
48	2203	1808	1061	0

Table 6. stage9

	53	54	55	56
49	362	1062	1384	2013
50	241	557	845	1635
51	352	0	318	957
52	812	1061	658	360

Table 6. stage10

	57	58	59	60
53	0	202	533	1265
54	202	0	318	957
55	533	270	0	681
56	1265	957	681	0

Table 6. stage11

	61	62	63
57	561	533	1265
58	658	318	957
59	545	0	681
60	1373	681	0

Table 6. stage12

	64
61	246
62	652
63	894

RESULTS

According to Sharma (2011, P.765), the general recursion relationship for the problem of shortest route is given as:

$$f_i^*(X_i) = Min\{d(X_{i-1}, X_i) + f_{i-1}^*(X_{i-1})\} \quad i = 1, 2, 3, \ldots$$

Where:

$f_i^*(X_i)$ is the shortest distance to node X_i at stage i

$d(X_{i-1}, X_i)$ is the distance from node X_{i-1} *to node* X_i

Table 10A. Analysis of the Results of the Routes from Lagos to Maiduguri

Stage No:	Lagos (normal)	Lagos (untarred)	Lagos (bad bridges)	Lagos (terrorism)	Lagos (advantage)	Lagos (superimposed)
1	270	270	338	187	324	207
2	0	0	0	185	0	380
3	202	202	253	202	242	293
4	193	193	491	346	290	519
5	0	0	0	0	0	0
6	297	297	297	622	356	422
7	0	0	0	0	0	0
8	130	130	163	755	130	273
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	321	321	321	253	385	658
12	133	133	133	808	133	241
Total	1546	1546	1996	3358	1860	2993
Mean	114.8333	114.8333	126.5	271.5	141.25	222.5833

Table 10B. ANOVA Result

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	1436823.833	11	130620.3485	9.684546368	1.9875E-09	1.967547
Columns	260849	5		3.868010252	0.004483913	2.382823
Error	741812.6667	55	13487.50303			
Total	2439485.5	71				

From Table10B above, the hypothesis above, that is F-test, shows that $F_{cal} = 3.8680 > F_{tab} = 2.3828$, hence we reject H_0 otherwise accept H_1: at least two means are not equal => new critical path is superior to normal critical path.

Table 11A. Analysis of the Result of the Routes from Warri/Asaba to Maiduguri

Stage No:	Warri (normal)	Warri (untarred)	Warri (bad bridges)	Warri (terrorism)	Warri (advantage)	Warri (superimposed)
1	77	77	96	142	92	179
2	60	60	60	111	72	123
3	136	136	170	252	163	313
4	315	315	270	315	473	457
5	0	0	99	0	0	0
6	206	206	206	622	247	422
7	0	0	0	0	0	0
8	130	130	163	755	130	273
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	321	321	321	253	385	658
12	133	133	133	808	133	246
TOTAL	1378	1378	1518	3258	1695	2671
Mean	112.9167	112.9167	125.4167	268	139	219.6667

Table 11B. ANOVA Result

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	1436824	11	130620.3	9.684546	1.99E-09	1.967547
Columns	260849	5	52169.8	3.86801	0.004484	2.382823
Error	741812.7	55	13487.5			
Total	2439486	71				

From Table11B above, the hypothesis above, that is F-test, shows that $F_{cal} = 3.8680 > F_{tab} = 2.3828$, hence we reject H_0 otherwise accept H_1: at least two means are not equal=> new critical path is superior to normal critical path.

Table 12A. Analysis of the result of the Routes from Port Harcourt to Maiduguri

Stage no	PHC (normal)	PHC (untarred)	PHC (bad bridges)	PHC (terrorism)	PHC (advantage)	PHC (superimposed)
1	114	114	143	211	137	267
2	0	0	0	0	0	0
3	136	136	170	252	163	313
4	315	315	270	315	473	457
5	0	0	99	0	0	0
6	206	206	206	622	247	422
7	0	0	0	0	0	0
8	130	130	163	755	130	273
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	321	321	321	253	385	658
12	133	133	133	808	133	246
Total	1355	1355	1505	3216	1668	2636
Mean	112.9167	112.9167	125.4167	268	139	219.6667

Table 12B. ANOVA Result

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	1539731.486	11	139975.5896	10.20766018	8.18038E-10	1.967546647
Columns	254895.5694	5	50979.11389	3.71763014	0.005706047	2.382823301
Error	754203.9306	55	13712.79874			
Total	2548830.986	71				

From Table12B above, the hypothesis above, that is F-test, shows that $F_{cal} = 3.7176 > F_{tab} = 2.3828$, hence we reject H_0 otherwise accept H_1: at least two means are not equal => new critical path is superior to normal critical path.

Table 13A. Analysis of the Result of the Routes from Calabar to Maiduguri

Stage no	Calabar (normal)	Calabar (untarred)	Calabar (bad bridges)	Calabar (terrorism)	Calabar (advantage)	Calabar (superimposed)
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	174	174	218	322	244	435
4	315	315	270	315	473	457
5	0	0	99	0	0	0
6	206	206	206	622	247	422
7	0	0	0	0	0	0
8	130	130	163	755	130	273
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	321	321	321	253	385	658
12	133	133	133	808	133	246
Total	1279	1279	1410	3075	1612	2491
Mean	106.5833333	106.58333	117.5	256.25	134.3333	207.5833

Table 13B. ANOVA Result

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	1745976.278	11	158725.1162	11.17575894	1.69498E-10	1.967546647
Columns	234456.6111	5	46891.32222	3.301595401	0.011172577	2.382823301
Error	781144.3889	55	14202.62525			
Total	2761577.278	71				

From Table13B above, the hypothesis above, that is F-test, shows that $F_{cal} = 3.3016 > F_{tab} = 2.3828$, hence we reject H_0 otherwise accept H_1: at least two means are not equal => new critical path is superior to normal critical path.

f_i is computation from f_{i-1} using starting at $i = o$, the recursive set $f_0(x_0) = 0$.

$f^*_{i-1}(X_{i-1})$ is the optimal distanced for the previous stages.

Using the traditional dynamic programming and computer Package TORA (in Operation Research an Introduction 8th Edition by Hamdy A. Taha) after feeding necessary data, the following results were obtained.

Analysis of Superiority of New Critical Path to the Normal Critical Path

These analyses are based on the following assumptions:

1. Critical Path is the longest path and containing zero slacks
2. Data are from same normal population
3. Variances are not known.
4. α level = 5% or 0.05 level

Research Hypotheses

With regard to the Superiority of New Critical Path to the Normal Critical Path from Lagos, Warri/Asaba, Port Harcourt and Calabar to Maiduguri, ANOVA test was carried out.

F-statistics (ANOVA) test: two hypotheses were considered:

Null hypothesis: H_0: $\mu_1 = \mu_2 = \mu_3 = \cdots = \mu_k$

Alternative hypothesis: H_1: at least two means are not equal, if $F_{cal} > F_{tab}$, we accept H_1 that new critical path is superior to the Normal Critical Path otherwise reject H_0.

This hypothesis is applied to Tables 10A to 13B, which are tables of stages of the position of the towns in the same category as shown in the tables below:

DISCUSSION

From the above analysis of the Nigerian roads network models, it is established and evidently clear that the models developed for the determination of the shortest route from coastal town through the hinterland, to extreme town (Lagos, Warri, Port Harcourt and Calabar to Maiduguri) with respect to distance have a good result showing the intermediate cities along the shortest route. The research work has achieved its main aim among others five (5) roads network models were objectively built. Which were empirically developed and solved to obtained the optional route from coastal cities through the hinterland to extreme town (Lagos, Warri, Port Harcourt and Calabar to Maiduguri). On a general research note, other relevant issues were isolated to give a broad spectrum of understanding of the research objectives and how they were fully achieved. These relevant research issues were set to choose a more robust model for determining the optimal and a safest route that enhance transporters, travelers, intending travelers among others from coastal towns through hinterland, to extreme town of Nigeria. In order to achieve the research objectives, some relevant and related literature were duly consulted and cited herein.

The researcher of the work done so far and how he could plan for the study in order to achieve his research objectives with ease In the nutshell, the works of, Anyanwu *et al* (1997), Tim (2013) dreyfus (2002), Hillier and lieberman (2001) Wayne (2003), Taha (2007) Gupta and Hira (2012), Sharma (2011) Tarry (1895), Biggs *et al* (1976), Dijstra (1959), Feillet *et al* (2004), Chabrier (2002), Roussear *et al* (2003) among others, were reviewed and mainstreamed into the study. Furthermore, the details methodology for the study was clearly outlined. Data were collected through documentary method a sample of 36 states and federal Capital Territory in Abuja (FCT) the relevant data were collected and objectively analyzed using dynamic programming method. The data collected and used for the study were initially graphed and displayed on a table for easy access and to facilitate analysis. The data analysis was conducted objectively and in factual manner using the graphs (Nigerian roads network models) and tables with the recursion equation:

$f_i(x_i)=Min\{d(x_{i-1},x_i)+f_{i-1}(x_{i-1})\}$, $i=1,2,3,\ldots1$,

which gave the following results:

Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, Warri, Port Harcourt Calabar to Maiduguri) under normal circumstances

Lagos to Maiduguri as: Lagos→Abeokuta→Akure→Lokoja→Abuja→Gusau→Kano →Dutse→Maiduguri = 2998km

Warri to Maiduguri as: Warri→Owerri→Umuahia→Abakelike→Lafia→Jos→Bauchi →Damaturu→Maiduguri = 2671km

Port Harcourt to Maiduguri as: PortHarcourt→Umuahia→Abakelike→Lafia→Jos→Bauchi→ Damaturu→Maiduguri = 2636km

Calabar to Maiduguri as: Calabar→Abakelike →Lafia→Jos→Bauchi→Damaturu→Maiduguri = 2491km.

5.2 Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, Warri, Port Harcourt Calabar to Maiduguri) with untarred routes:

Lagos to Maiduguri as: Lagos→Abeokuta→Akure→Lokoja→Abuja→Gusau→Kano →Dutse→Maiduguri = 2998km

Warri to Maiduguri as: Warri→Owerri→Umuahia→Abakelike→Lafia→Jos→Bauchi →Damaturu→Maiduguri = 2671km

Port Harcourt to Maiduguri as: PortHarcourt→Umuahia→Abakelike→Lafia→Jos→Bauchi→ Damaturu→Maiduguri = 2636km

Calabar to Maiduguri as: Calabar→Abakelike →Lafia→Jos→Bauchi→Damaturu→Maiduguri = 2491km. These results are same as (1) above because all the routes considered are tarred.

Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, Warri, Port Harcourt Calabar to Maiduguri) with bad bridges

Lagos to Maiduguri as: Lagos→Akure→Lokoja→Abuja→Jos→Bauchi→Damaturu →Maiduguri = 2998km

Warri to Maiduguri as: Warri→Owerri→Umuahia→Abakelike→Makurdi→Lafia→Jos→Bauchi→Damaturu→ Maiduguri = 2671km

Port Harcourt to Maiduguri as: PortHarcourt→Umuahia→Abakelike→Makurdi→Lafia→Jos →Bauchi→Damaturu→Maiduguri = 2636km

Calabar to Maiduguri as:

Calabar→Abakelike → Makurdi→Lafia→Jos→Bauchi→Damaturu→Maiduguri = 2491km.

Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, Warri, Port Harcourt Calabar to Maiduguri) with frequent armed robbery attacks, Boko Haram Insurgences and Kidnappings

Lagos to Maiduguri as: Lagos→Ibadan→Akure→Lokoja→Lafia→Jos→Bauchi→Go mbe→Maiduguri = 2998km

Warri to Maiduguri as:

Warri→Owerri→Umuahia→Abakelike→Lafia→Jos→Bauchi → Gombe →Maiduguri = 2671km

Port Harcourt to Maiduguri as:

PortHarcourt→Umuahia→Abakelike→Lafia→Jos→Bauchi→ Gombe →Maiduguri = 2636km

Calabar to Maiduguri as:
Calabar→Abakelike →Lafia→Jos→Bauchi→ Gombe →Maiduguri = 2491km.

Nigerian Roads Network from Coastal Cities through hinterland to extreme town (Lagos, Warri, Port Harcourt Calabar to Maiduguri) based on advantages of cost/damage on the route

Lagos to Maiduguri as: Lagos→ Akure→Lokoja→Abuja→Jos→Bauchi→Damaturu→Maiduguri = 2998km

Warri to Maiduguri as:
Warri→Owerri→Umuahia→Abakelike→Lafia→Jos→Bauchi →Damaturu→Maiduguri = 2671km

Port Harcourt to Maiduguri as:
PortHarcourt→Umuahia→Abakelike→Lafia→Jos→Bauchi→ Damaturu→Maiduguri = 2636km

Calabar to Maiduguri as: Calabar→Abakelike →Lafia→Jos→Bauchi→Damaturu→Maiduguri = 2491km.

Global optimal route (when result 1, 2 and 3 above are superimposed)

Lagos to Maiduguri as:
Lagos→Abeokuta→Akure→Lokoja→Lafia→Jos→Bauchi→ Damaturu→Maiduguri = 2998km

Warri to Maiduguri as:
Warri→Owerri→Umuahia→Abakelike→Lafia→Jos→Bauchi →Damaturu→Maiduguri = 2671km

Port Harcourt to Maiduguri as:
PortHarcourt→Umuahia→Abakelike→Lafia→Jos→Bauchi→ Damaturu→Maiduguri = 2636km

Calabar to Maiduguri as: Calabar→Abakelike →Lafia→Jos→Bauchi→Damaturu→Maiduguri = 2491km.

Conclusion

Objectively, this study has applied to all the laid down procedure to collect, analysis and interpret roads network data of the stagecoach problem which is a prototype of dynamic programming. The outcome of the analysis has produced four (4) separate mathematical models: under normal circumstances, based on obstacle, based on infrastructural development and the three (3) superimposed models which are incorporated into dynamic programming model (recursive equation) with respect to distance. Conclusively, new critical path is superior to normal critical path and the dynamic programming model should be used for determination of the optimal route (shortest route) involving many sources and single destination and also safest route of many sources with a single destination.

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