Optimal Routes for Distributing Refined Products for Kaduna Refining and Petrochemical Company (KRPC), Kaduna, Kaduna State, Northwest, Nigeria.

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Abstract **-** *In this research work, the dynamic programming approach was used to determine the shortest route from Kaduna Refinery and Petrochemical Company (KRPC) located at Kaduna, Kaduna State, Nigeria to the seven (7) depots located outside the refinery towns. The optimal routes from the refinery to the seven depots by roads were obtained. The distance of the various roads in the Nigeria road network was obtained using map reading from the Nigerian atlas map. Also, the data of Nigerian roads was collected from Kaduna State Transport Authority (KSTA), Kaduna, Kaduna State, Nigeria. The shortest routes so obtained compares favorably with the actual ones and were found to be the best. In addition, Microsoft excel was used to solve the network problem*.

Keywords **-** *Node, Arc, Shortest Route, Microsoft Excel, Optimal Route*.

I. INTRODUCTION

The movement of people, goods and services is an important aspect of economic development of towns and cities all over the world. Land values tend to increase in areas with expanding transportation networks and increase less rapidly in areas without such improvement. Rapid and continue rise in housing and land prices are expected in cities with transportation improvement and rapid economic and population growth as in [3].

Reference [2] noted that transportation in Nigeria started as far back as the pre-colonial era. The first form of transportation was shanks pony (i.e. human foot). During that period, transportation facilities such as roads, railways, and air transport systems were really not in existence. The emphasis then was on bush path. However, [6] states that, people eventually, learn to use animals such as donkeys, horses, camels, among others, for transportation. As years went by, different modes of transportation were invented, Cargo movement by trucks, trains, planes and boats are the most essential part of a business. Therefore, for businesses to be able to sell their products locally, nationally or internationally to make profit and grow larger, they must also be able to receive shipment of raw products which they need to make their items. The other side of transportation is moving people. People need to go places and getting there on horses back is not the best option. Plane, trains, buses, boats, cars, e.t.c, all need to be made, maintained and some are staffed.

Just like in any part of the world, transportation play a significant role in the economic growth and development of Nigeria both directly and indirectly, Reference [6] estimated that losses in the Nigerian economy arising from the poor state of roads is about N450 billion yearly.

Even though all these modes of transportation play a significant role in the economic growth and development of Nigeria, this study will seek to address road transportation system in Nigeria by finding the shortest route of transporting refined products from Kaduna Refinery and Petrochemical Company Limited (KRPC) situated in Kaduna, Kaduna state, Nigeria to the 7 storage depots outside the refinery town situated at Jos, Gusau, Kano, Suleija, Minna, Gombe and Maiduguri all in Nigeria.

Even though there are pipe lines from the refinery to all the 7 depots, the vandalization of oil pipelines 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 has leads to the severe

shortages of the product which in turn lead to loss of billions of Naira and loss of innocent lives by fire incidents cause by pipeline vandalization.This act of pipeline vandalization leaves KRPC with almost one option of distributing refined products to the 7 storage depots. This option is nothing but trucking (i.e. road transport). Hence in this work, we examine road network of the company with the possibility of predicting the shortest routes from each of the source to the 7 depots outside the refinery town, in order to minimize the cost of transporting such products within Nigeria. With the assumption that all the possible routes from the refinery to the 7 depots are the same and good.

According to reference [1], "it is difficult to trace back the history of the shortest path problem. One can imagine that even in very primitive (even animal) societies, finding short paths (for instance, to food) is essential.Compared with other combinatorial optimization problems, like shortest spanning tree, assignment and transportation, the mathematical research in the shortest path problem started relatively late.Compared with other combinatorial optimization problems, like shortest spanning tree, assignment and transportation, the mathematical research in the shortest path problem started relatively late.

Reference [1] again stated that, path Problems were also studied at the beginning of the 1950s context of "alternate routing", that is, finding a second shortest route if the shortest route is blocked. The author further stated that, there are two well- known methods of shortest-length paths: the Bellman-Ford method and Dijkstra's method.Reference [4] used dynamic programming to find the optimal route from the sea port sources (Lagos, Warri, Port Harcourt and Calabar) to Maiduguri, Nigeria. Reference [5] used Floyd Warshal's Algorithm to find the shortest routes for 21 major cities in Nigeria considering Calabar, Cross River state as the origin and Kaduna, Kaduna state as the sink node.

All these authors considered only the major roads connecting the states capitals and used the Nigerian distance matrix as their source of data. Moreover, the authors both used dynamic programming method (classical and/or TORA software) to find the optimal routes from a source to a destination. In this study, for greater reliability we will use the idea of map reading to obtain the distances of all the possible routes from the source to the 7 destinations outside the refinery town. And then code the dynamic programming algorithm in Microsoft Excel to find the optimal routes (shortest paths) from Kaduna refinery and petro chemical Company (KRPC) situated at Kaduna, Nigeria to 7 storage depots outside the refinery town.

II. METHODOLOGY

For greater reliability, the idea of map reading was used to find the distances (in kilometers) between the nodes from the Nigerian atlas map that shows all the 36 states, 774 Local Government Areas and all the roads linking the entire Local Government Areas. Also, interview was used to collect data of all the possible routes from the refinery to the 7 depots outside the refinery town.

In this study, from the Nigerian roads selected which link the source and the 7 destinations, the modeled networks consist of twenty-six (26) nodes with thirty-two (32) arcs.

A. Procedure of the Shortest Route Problem Using Micro-Soft Excel

Consider the network infigure 1 where node A is the source node and node F is the destination node.This network can be modeled in Microsoft Excel as shown below in figure 2 below.

Step1: Model the problem in Excel as shown in figure 2 below. It is important to name each column, for easy identification when imputing the formulas. Under the Demand/Supply column, the source node and the destination node are assign the values 1 and -1 respectively and every other node zero meaning they are neither sources nor destinations.

Step 2: Impute the first formula as =sumif(from,h3,on-route)-sumif(to,h3,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 in the Nodes' column is reached. Zeros will appear in every cell under the column if the formula is imputed correctly.

Step 4: Impute the second formula as =sumproduct(on-route,distance) in cell F19

Step 5: Depress the enter key, zero will appear in cell F19 because there is no any value in the on-route column at this stage.

Step 6: Click on DATA at the top of your computer screen, solver box 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 cell, i.e, select the cell that has zero value under the distance column, select minimize, 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 column.

Step 9: Click ok, the solver parameter box will display accordingly all the cells you selected in steps 7 and 8.

Step 10: Select make Unconstraint variable Non-Negative, select simplex LP as the solving method, click solve. The Excel solver will display the result. Under the net flow column, cells I13 and I18 will change from zeros to 1 and -1 respectively and every other cell in that column will remain zero satisfying the constraint net flow = supply/demand. Also, the on-route column contains zeros and ones. 1 on a path means the path is on the shortest route and zero on a path means the path is NOT on the shortest route. Moreover, the cell in step 4 will change from zero to the total optimal distance. Select keep solver solution and close the window to save your solution.

III. IMPLIMENTATION

The KRPC road network with the distances in kilometers is shown below in figure 3 where the red node is the source node (refinery town), the blue nodes are the destinations (depot towns). And the broken line means a dummy route. After implementation of the above procedure, the result is obtained and shown in figures 4 to 10.

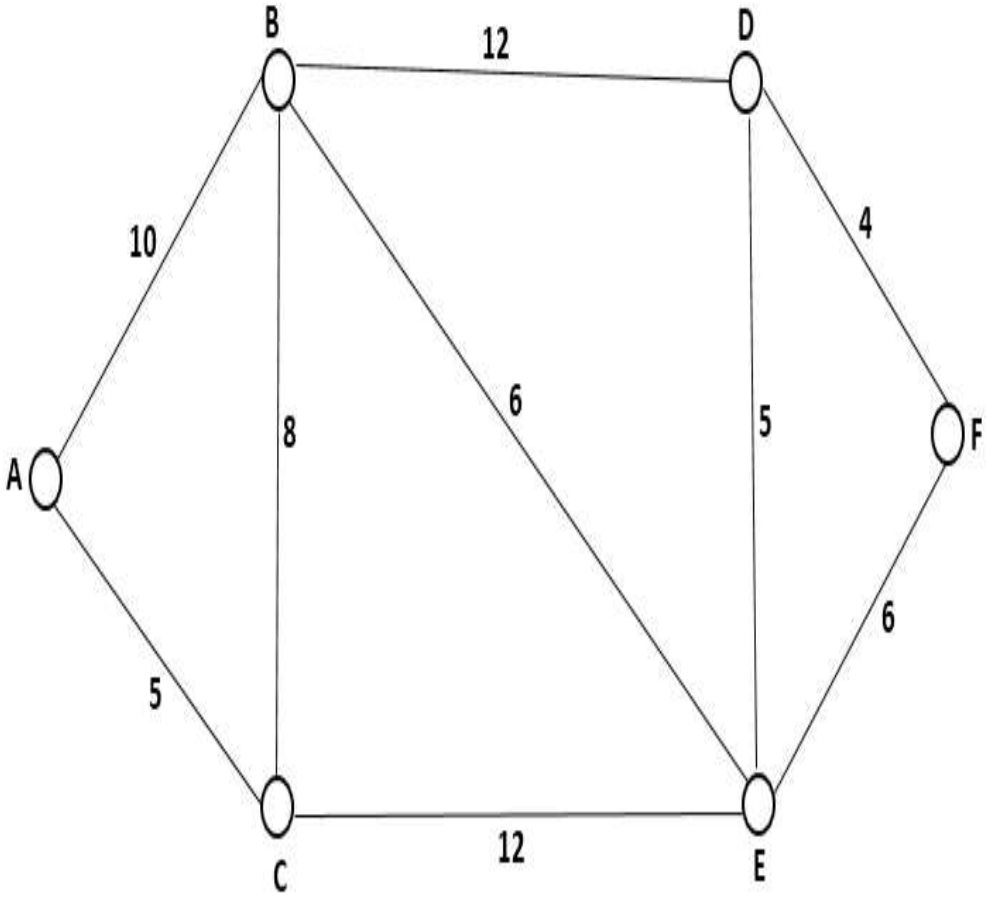
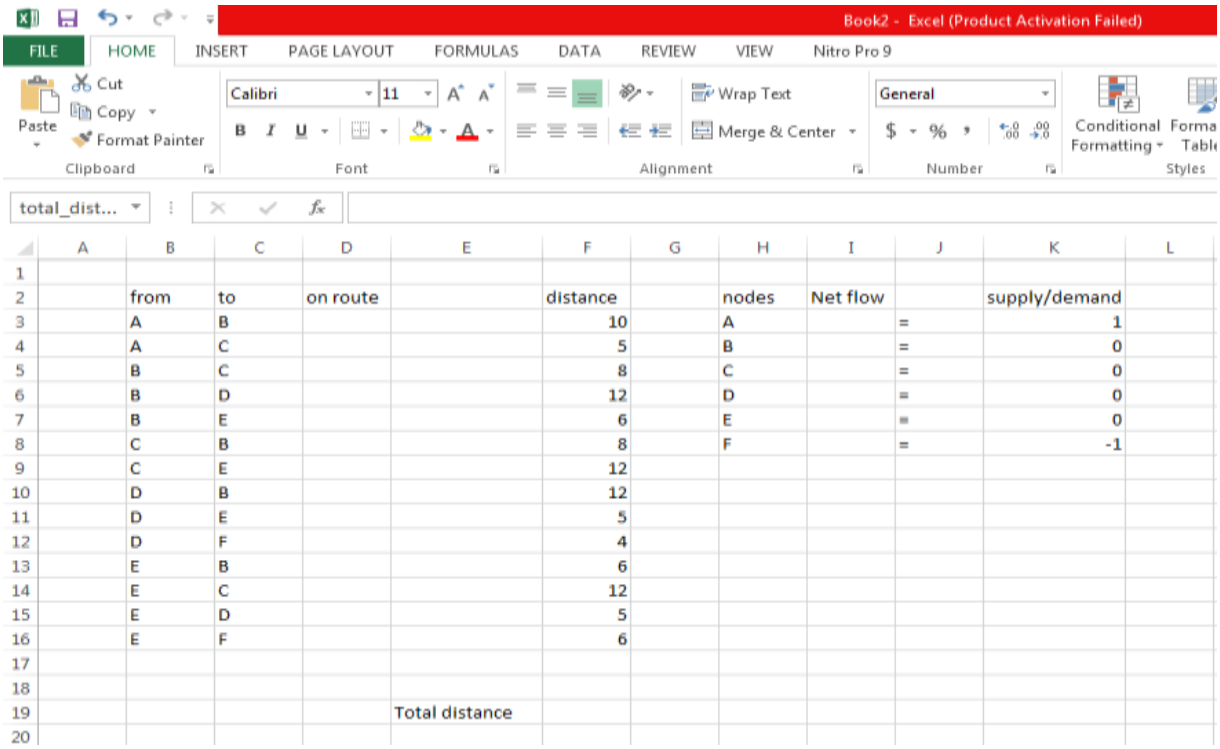


Fig. 1: An arbitrary network.



	A	B	C	D	E	F	G	H	I	J	K	L
1												
2		from	to	on route		distance		nodes	Net flow		supply/demand	
3		A	B			10		A		=	1	
4		A	C			5		B		=	0	
5		B	C			8		C		=	0	
6		B	D			12		D		=	0	
7		B	E			6		E		=	0	
8		C	B			8		F		=	-1	
9		C	E			12						
10		D	B			12						
11		D	E			5						
12		D	F			4						
13		E	B			6						
14		E	C			12						
15		E	D			5						
16		E	F			6						
17												
18												
19					Total distance							
20												

Fig. 2: Model of the network of figure 1 in Microsoft Excel.

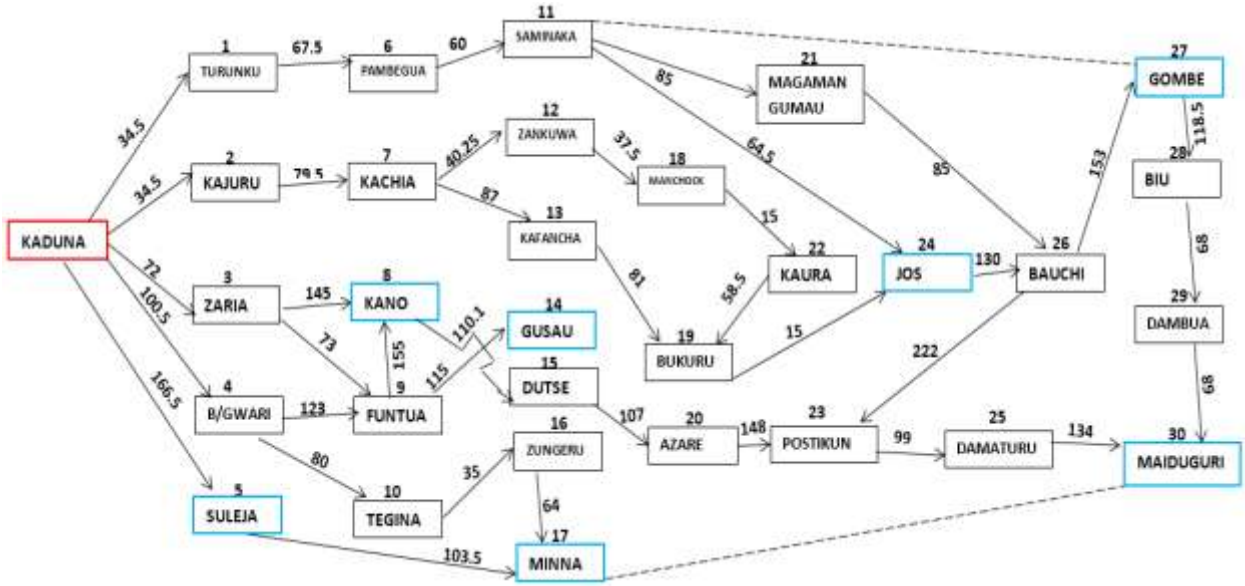
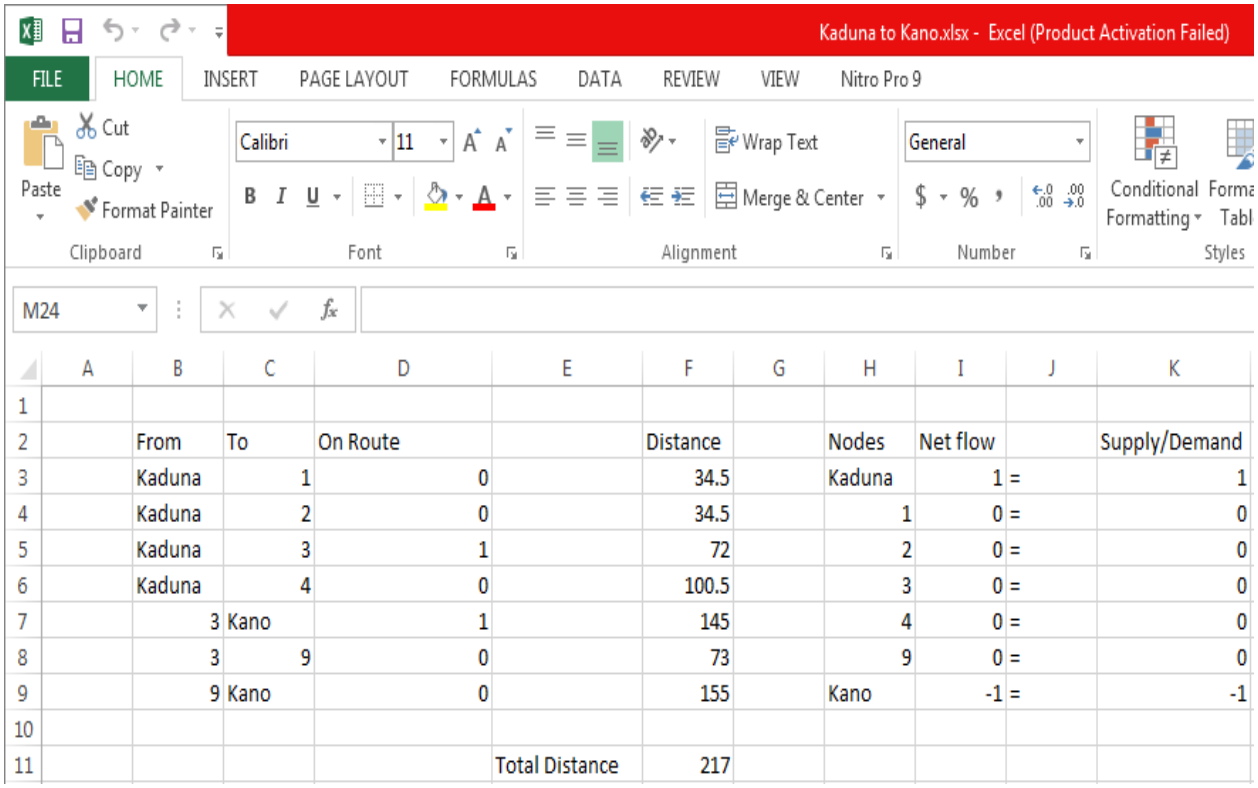
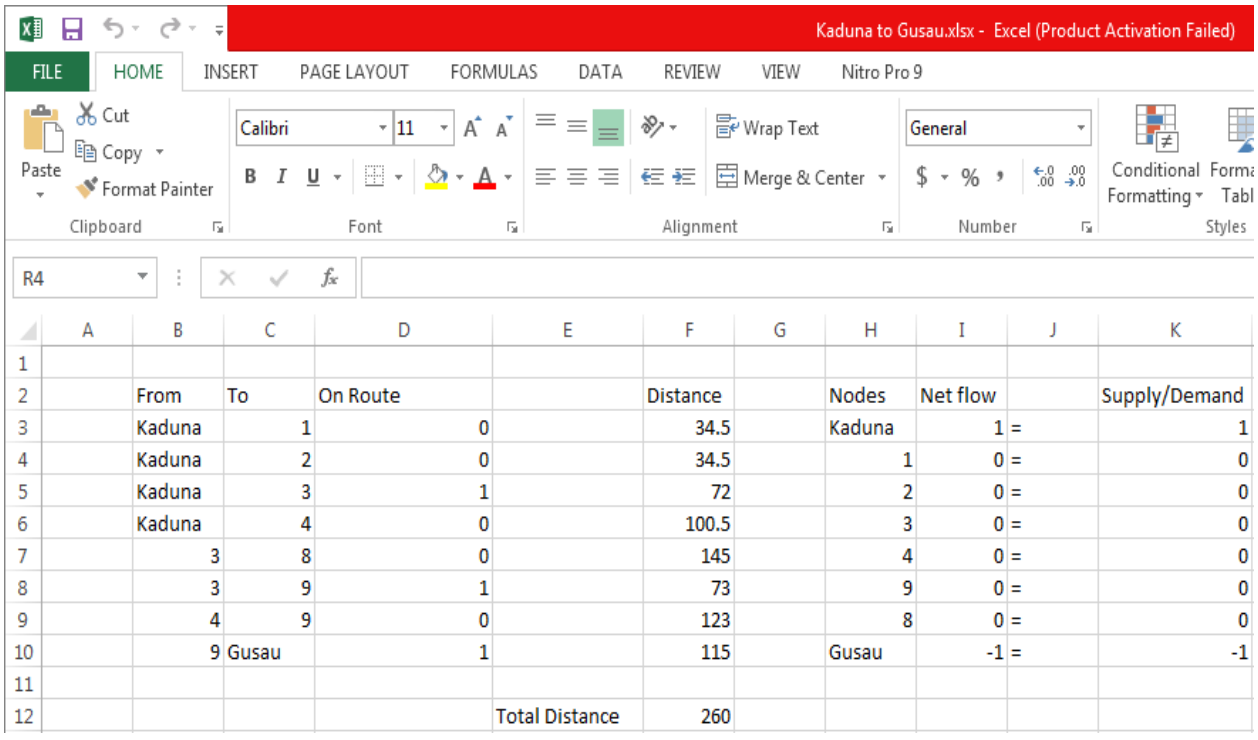


Fig. 3: KRPC Road Network.



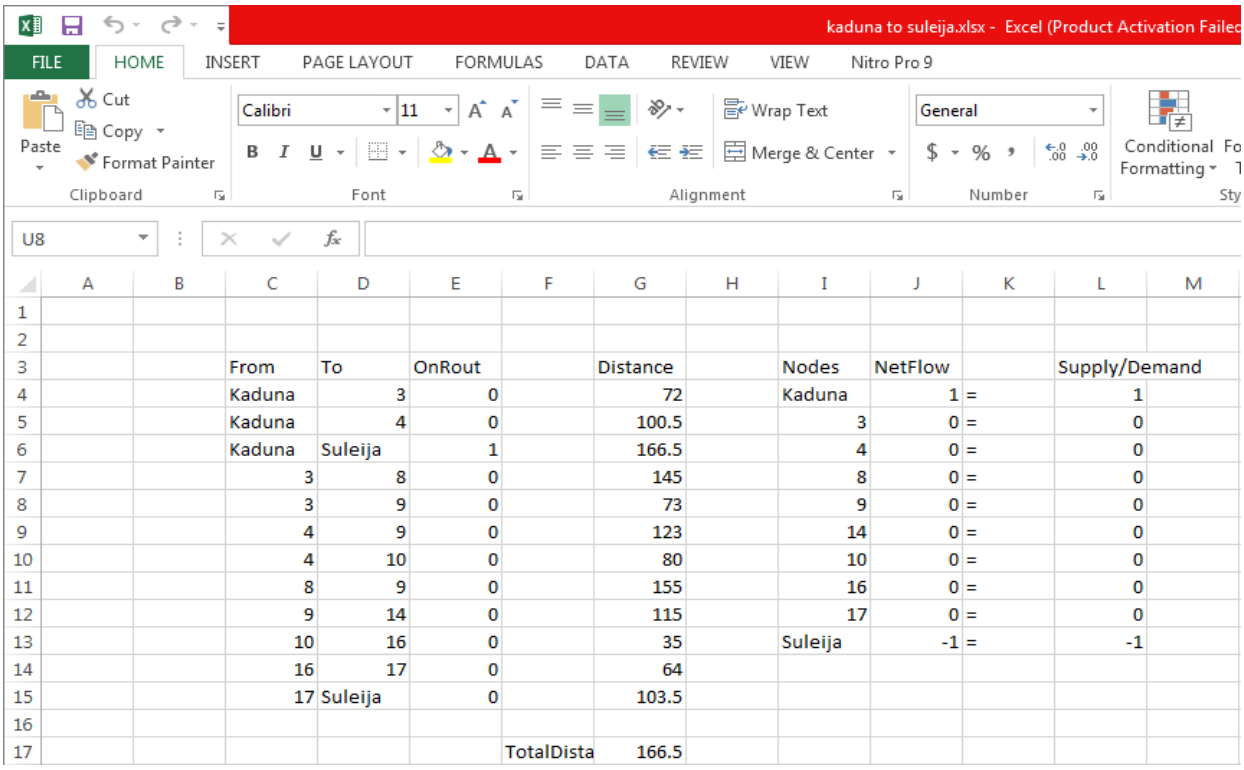
	A	B	C	D	E	F	G	H	I	J	K
1											
2		From	To	On Route		Distance		Nodes	Net flow		Supply/Demand
3		Kaduna	1	0		34.5		Kaduna	1	=	1
4		Kaduna	2	0		34.5		1	0	=	0
5		Kaduna	3	1		72		2	0	=	0
6		Kaduna	4	0		100.5		3	0	=	0
7		3	Kano	1		145		4	0	=	0
8		3	9	0		73		9	0	=	0
9		9	Kano	0		155		Kano	-1	=	-1
10											
11					Total Distance	217					

Fig. 4: Shortest Route from Kaduna to Kano.



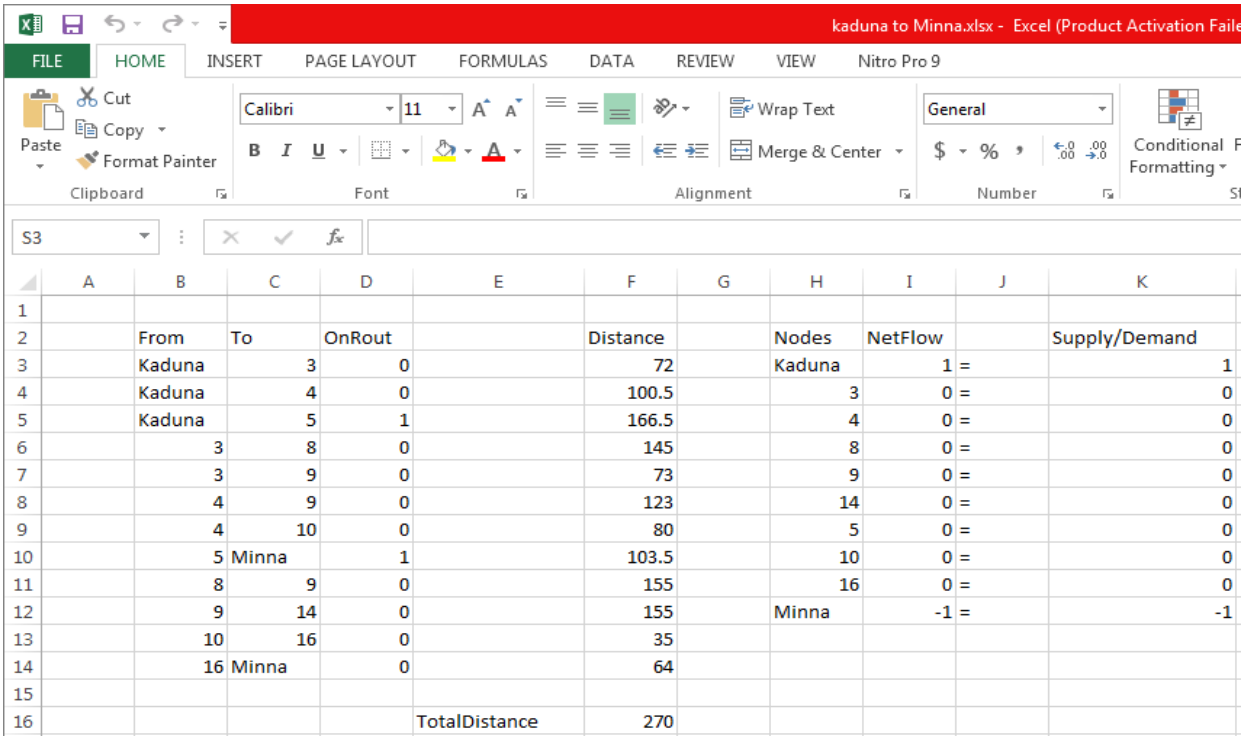
	A	B	C	D	E	F	G	H	I	J	K
1											
2		From	To	On Route		Distance		Nodes	Net flow		Supply/Demand
3		Kaduna	1	0		34.5		Kaduna	1	=	1
4		Kaduna	2	0		34.5		1	0	=	0
5		Kaduna	3	1		72		2	0	=	0
6		Kaduna	4	0		100.5		3	0	=	0
7		3	8	0		145		4	0	=	0
8		3	9	1		73		9	0	=	0
9		4	9	0		123		8	0	=	0
10		9	Gusau	1		115		Gusau	-1	=	-1
11											
12					Total Distance	260					

5: Shortest Route from Kaduna to Gusau.



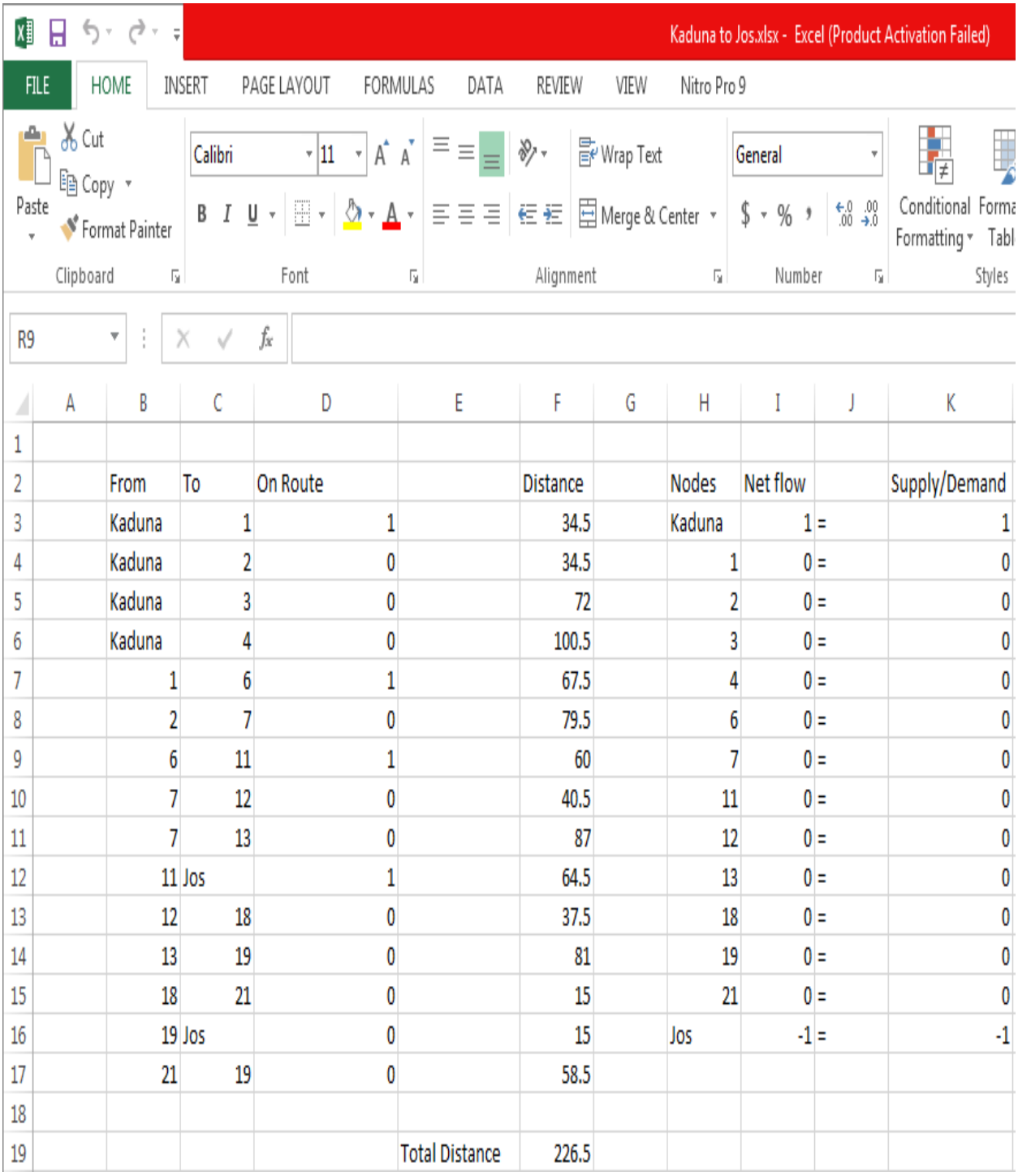
	A	B	C	D	E	F	G	H	I	J	K	L	M
1													
2													
3			From	To	OnRout		Distance		Nodes	NetFlow		Supply/Demand	
4			Kaduna	3	0		72		Kaduna	1	=	1	
5			Kaduna	4	0		100.5		3	0	=	0	
6			Kaduna	Suleija	1		166.5		4	0	=	0	
7			3	8	0		145		8	0	=	0	
8			3	9	0		73		9	0	=	0	
9			4	9	0		123		14	0	=	0	
10			4	10	0		80		10	0	=	0	
11			8	9	0		155		16	0	=	0	
12			9	14	0		115		17	0	=	0	
13			10	16	0		35		Suleija	-1	=	-1	
14			16	17	0		64						
15			17	Suleija	0		103.5						
16													
17						TotalDista	166.5						

Fig. 6: Shortest Route from Kaduna to Suleija.



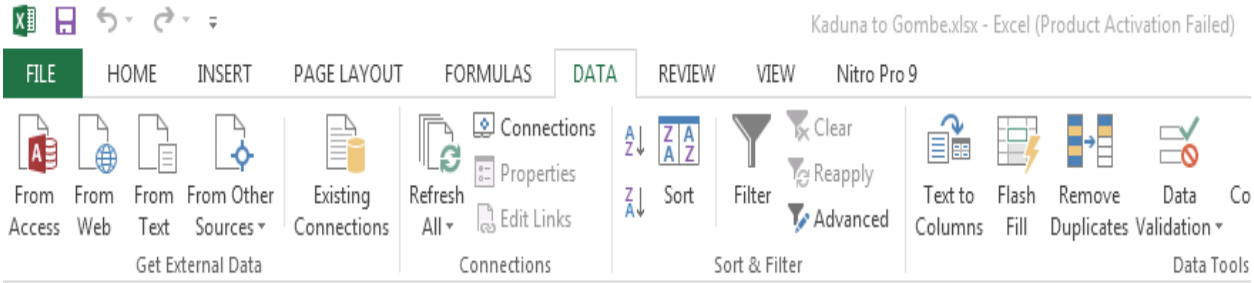
	A	B	C	D	E	F	G	H	I	J	K
1											
2		From	To	OnRout		Distance		Nodes	NetFlow		Supply/Demand
3		Kaduna	3	0		72		Kaduna	1	=	1
4		Kaduna	4	0		100.5		3	0	=	0
5		Kaduna	5	1		166.5		4	0	=	0
6		3	8	0		145		8	0	=	0
7		3	9	0		73		9	0	=	0
8		4	9	0		123		14	0	=	0
9		4	10	0		80		5	0	=	0
10		5	Minna	1		103.5		10	0	=	0
11		8	9	0		155		16	0	=	0
12		9	14	0		155		Minna	-1	=	-1
13		10	16	0		35					
14		16	Minna	0		64					
15											
16					TotalDistance	270					

Fig. 7: Shortest Route from Kaduna to Minna.



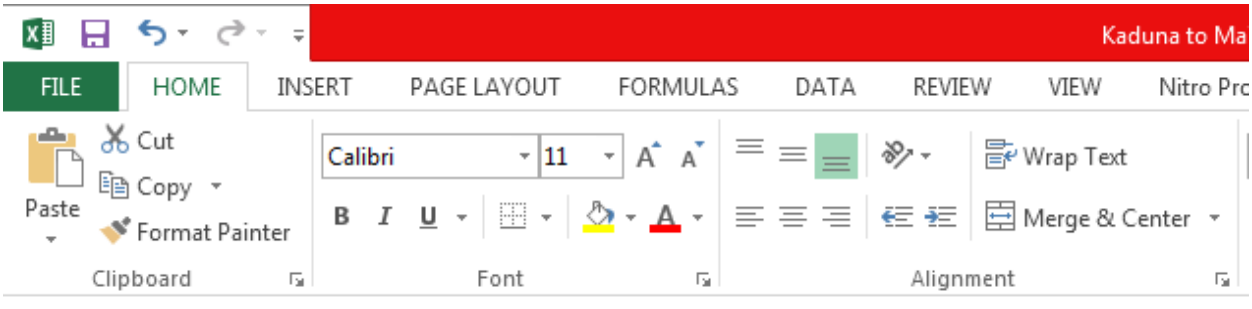
	A	B	C	D	E	F	G	H	I	J	K
1											
2		From	To	On Route		Distance		Nodes	Net flow		Supply/Demand
3		Kaduna	1	1		34.5		Kaduna	1	=	1
4		Kaduna	2	0		34.5		1	0	=	0
5		Kaduna	3	0		72		2	0	=	0
6		Kaduna	4	0		100.5		3	0	=	0
7		1	6	1		67.5		4	0	=	0
8		2	7	0		79.5		6	0	=	0
9		6	11	1		60		7	0	=	0
10		7	12	0		40.5		11	0	=	0
11		7	13	0		87		12	0	=	0
12		11	Jos	1		64.5		13	0	=	0
13		12	18	0		37.5		18	0	=	0
14		13	19	0		81		19	0	=	0
15		18	21	0		15		21	0	=	0
16		19	Jos	0		15		Jos	-1	=	-1
17		21	19	0		58.5					
18											
19					Total Distance	226.5					

Fig.8: Shortest Route from Kaduna to Jos.



	A	B	C	D	E	F	G	H	I	J	K
2		From	To	On Route		Distance		Nodes	Net flow		Supply/Demand
3		Kaduna	1	1		34.5		Kaduna	1	=	1
4		Kaduna	2	0		34.5		1	0	=	0
5		Kaduna	3	0		72		2	0	=	0
6		Kaduna	4	0		100.5		3	0	=	0
7		1	6	1		67.5		4	0	=	0
8		2	7	0		79.5		6	0	=	0
9		6	11	1		60		7	0	=	0
10		7	12	0		40.5		11	0	=	0
11		7	13	0		87		12	0	=	0
12		11	23	1		85		13	0	=	0
13		11	24	0		64.5		18	0	=	0
14		12	18	0		37.5		19	0	=	0
15		13	19	0		81		21	0	=	0
16		18	21	0		15		22	0	=	0
17		19	24	0		15		23	0	=	0
18		21	19	0		58.5		24	0	=	0
19		23	26	1		85		25	0	=	0
20		24	26	0		130		26	0	=	0
21		26	22	0		222		28	0	=	0
22		26	Gombe	1		153		29	0	=	0
23		22	25	0		99		Gombe	-1	=	-1
24		25	30	0		134					
25		30	29	0		68					
26		29	28	0		68					
27		28	Gombe	0		118.5					
28											
29					Total distance	485					

Fig. 9: shortest route from Kaduna to Gombe.



	A	B	C	D	E	F	G	H	I	J	K
1											
2		From	To	On Route		Distance		Nodes	Net flow		Supply/Demand
3		Kaduna	1	1		34.5		Kaduna	1	=	1
4		Kaduna	2	0		34.5		1	0	=	0
5		Kaduna	3	0		72		2	0	=	0
6		Kaduna	4	0		100.5		3	0	=	0
7		Kaduna	5	0		166.6		4	0	=	0
8		1	6	1		67.5		5	0	=	0
9		2	7	0		79.5		6	0	=	0
10		3	8	0		145		7	0	=	0
11		3	9	0		73		8	0	=	0
12		4	9	0		123		9	0	=	0
13		4	10	0		80		10	0	=	0
14		5	17	0		103.5		11	0	=	0
15		6	11	1		60		12	0	=	0
16		7	12	0		40.25		13	0	=	0
17		7	13	0		87		14	0	=	0
18		8	15	0		110.1		15	0	=	0
19		9	14	0		155		16	0	=	0
20		10	16	0		35		17	0	=	0
21		11	23	1		85		18	0	=	0
22		11	24	0		64.5		19	0	=	0
23		12	18	0		37.5		20	0	=	0
24		13	19	0		81		21	0	=	0
25		15	20	0		107		22	0	=	0
26		16	17	0		64		23	0	=	0
27		18	21	0		15		24	0	=	0
28		19	24	0		15		25	0	=	0
29		20	22	0		258		26	0	=	0
30		21	19	0		58.5		27	0	=	0
31		22	25	0		99		28	0	=	0
32		23	26	1		85		29	0	=	0
33		24	26	0		130		Maiduguri	-1	=	-1
34		25	Maiduguri	0		134					
35		26	27	1		153					
36		27	28	1		118.5					
37		28	29	1		68					
38		29	Maiduguri	1		68					
39											
40					Total Distance	739.5					

Fig. 10: Shortest route from Kaduna to Maiduguri.

IV. INTERPRETATION

From figure 4, shortest route from Kaduna to Kano is: Kaduna → 3 → Kano, where in figure 3, 3 represents Zaria, hence the shortest route from Kaduna refinery to Kano depot is: Kaduna refinery → Zaria → Kano depot with the total distance of 217km, Which coincide with the data of Nigerian roads collected from Kaduna State Transport Authority (KSTA), that is, the route is the shortest and safest. Hence the route is optimal.

From figure 5, shortest route from Kaduna to Gusau is: Kaduna → 3 → 9 → Gusau,where from figure 3, 3 represents Zaria, 9 represents Futua.Hence, the shortest route from Kaduna refinery to Gusau depot is:Kaduna refinery → Zaria → Funtua →Gusau depot with the total distance of 260km.Which also coincide with the data of Nigerian roads collected from Kaduna StateTransport Authority (KSTA) that the route is shortest and safest. Hence, optimal.

From figure 6, shortest route from Kaduna refinery to Suleija depot is:Kaduna refinery → Suleija depot with the total distance of 166.5km.And the result similarly coincide with the data of Nigerian roads collected from Kaduna State Transport Authority (KSTA),that the route is the shortest and safest. Hence, optimal.

From figure 7, shortest route from Kaduna to Minna is: Kaduna → 5 → Minna, where from figure 3 above, 5 represents Suleija. Hence, the shortest route from Kaduna refinery to Minna depot is: Kaduna refinery → Suleija → Minna depot with the total distance of 270km. Which also coincide with the data collected from Kaduna State Transport Authority (KSTA), that is the route is the shortest and safest. Hence, optimal.

From figure 8, shortest route from Kaduna to Jos is: Kaduna → 1 → 6 → 11 →Jos, where from figure 3, 1 represents Turunku, 6 represents Pambeguwa, 11 represents Saminaka. Hence, the shortest route from Kaduna refinery to Jos depot is: Kaduna refinery → Turunku → Pambeguwa → Saminaka → Jos depot with the total distance of 226.5km. But from data of Nigerian roads collected from Kaduna State Transport Authority (KSTA), this route is not the finest, the finest routes are: (1) Kaduna refinery → Turunku → Kachia → Kafanchan → Bukuru → Jos depot = 297km. (2) Kaduna refinery → Turunku → Kachia → Zankuwa → Manchock → Kaura → Bukuru → Jos depot = 280.25km. However, these routes have the history of some hoodlums blocking the roads at any time and kill people. Hence the route Kaduna refinery → Turunku → Pambeguwa → Saminaka → Jos depot with the total distance of 226.5km is optimal.

From figure 9, shortest route from Kaduna to Gombe is: Kaduna → 1 → 6→ 11→ 23 → 26 → Gombe, wherefrom figure 3, 1 represents Turunku, 6 represents Pambeguwa, 11 represents Saminaka, 23 represents Magaman Gumau and 26 represents Bauchi. Hence, the shortest route from Kaduna refinery to Gombe depot is: Kaduna refinery → Turunku → Pambeguwa → Saminaka → Magaman Gumau → Bauchi → Gombe depot with the total distance of 485km. And from the data of Nigerian roads collected from Kaduna State Transport Authority (KSTA), the route is the shortest and safest. Hence, optimal.

From figure 10, shortest route from Kaduna to Maiduguri is: Kaduna → 1 → 6 → 11 → 23 → 26 → 27 → 28 → 29 → Maiduguri, where from figure 3, 1 represents Turunku, 6 represents Pambeguwa, 11 represents Saminaka, 23 represents Magaman Gumau, 26 represents Bauchi, 27 represents Gombe, 28 represents Biu, 29 represents Dambua. Hence, the shortest route from Kaduna refinery to Maiduguri depot is: Kaduna refinery → Turunku → Pambeguwa → Saminaka → Magaman gumau → Bauchi → Gombe → Biu → Dambua → Maiduguri depot with the total distance of 739.5km. However from data of Nigerian roads collected from Kaduna State Transport Authority (KSTA), this route is not the finest and safest as well because the road between Kaduna to Magaman gumau is bad and the road between Gombe to Maiduguri is not safe due to the Boko Haram activities. Thus, forcing travelers to take the route: Kaduna → Zaria → Kano → Dutse → Azare → Potiskun → Damaturu → Maiduguri. Hence the optimal route (shortest, safest and finest) from Kaduna refinery to Maiduri depot is: Kaduna refinery → Zaria → Kano → Dutse → Azare → Potiskun → Damaturu → Maiduguri depot = 829km.

V. CONCLUSION

We have successfully developed and analyzed the road network for transporting refined products from the source (Kaduna) to the 7 destinations outside the refinery town.

In addition, an Excel solver was used to speedily analyze the network and the solution confirm to the real life situation. Figure 11 below is the network

showing the critical paths where red node is a refinery town and blue nodes are the depot towns.

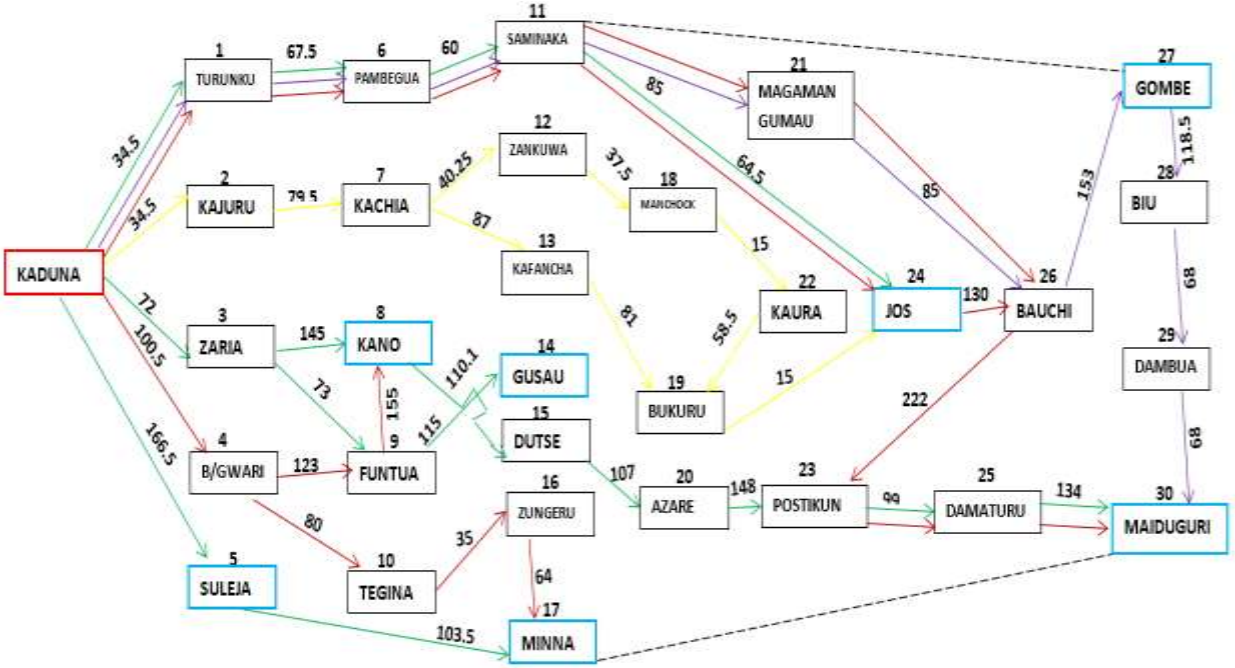


Fig 11: KRPC Road Network Showing the Critical Paths.

Key:

_____Optimal route (shortest, safest and finest).

_____ Good routes but longer and not safe.

_____ Good routes but longer.

_____ Shortest but bad routes and not safe.

---------- Dummy routes

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