An Evaluation and Sequencing of Highway for Rehabilitation in Northern Nigeria Using Dynamic Programming

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Abstract

This study sets out to evaluate and sequence highway rehabilitation in Northern Nigeria. The rehabilitation of highways is set against the background of the gradual decay of highways in the region. As a result dynamic programming was used in the evaluation and sequencing of highway rehabilitation. The Bellman equation model were used in the study. Result obtained showed that high priority roads include the Abuja-Kaduna-Zaria-Kano highways. The rehabilitation of roads were sequenced over ten year period (2011-2020). The rehabilitation of highly rated roads are for the year 2011, 2012 and 2013 while lowly rated roads were sequenced for rehabilitation of the years 2017, 2018, 2019 and 2020. A major conclusion reached is that a proper maintenance of roads could strengthen the development effort of the region.

Keywords: Dynamic Programming, Evaluation, Sequencing, Highway Rehabilitation, Northern Nigeria

Background of the Study

Highway rehabilitation is vital in order to prolong the lifespan of roads. A well maintained road reduces cost of operating vehicles by providing good moving surface. Proper maintenance keeps the roads open and ensures greater regularity, punctuality and safety of transport services. Effective highway rehabilitation is the most important prerequisite for safeguarding the investment and ensuring that the highways serve their purpose over the anticipated lifetime. It must be noted that highway should not be constructed if rehabilitation cannot be afforded and managed (CBN, 2002; Burningham and Stankerich 2005).

Highway development is a requirement of every nation, regardless of its industrial capacity, population size, or technological development. Movement of both people and goods enhances strong economic and political ties within and between regions (Nick, 2005).

Highway construction and rehabilitation are highly capital intensive projects that can deplete the financial resources of government. The federal government of Nigeria has over time invested huge amount of money on the construction of highways. Investment on highways have usually been thought of as a quick way of strengthening the economy as well as increasing political and administrative control of a region. (Hoyle 1973; Sammer 1981; Wong 2003; Tiendung et.al 2009). However, in recent times, the state of highway in the country had deterioted with most roads left to decay. Much of this could be traced to the fact that Nigerian highways, are heavily motorized with goods that ought to have passed through the railways and waterways. Further the poor usage of this roads by heavy duty trucks and trailers is frequently responsible for some of the fatal accidents. Indeed, trucks and trailers are known for overloading in contemptuous disregard for traffic laws. The excess weight of these trailers and trucks on the asphalt surfaced road is often responsible for the ubiquitous potholes. Because of the acute shortage in weighbridge provision, road weight capacity enforcement is flouted with impunity by the truck and trailer drivers in Nigeria. The federal road network carries 70% of freight in the country. It is therefore necessary to protect this asset and investment on a long term basis for future generations. The life spans of any federal road is 10-15 years, with best design and construction method. Adequate routine and periodic maintenance are necessary to attain the design life span and even beyond, (which make it eligible for either rehabilitation or reconstruction of a new one). But this was not the case with Nigeria roads as from the end of 80s to middle of 90s, little provisions were made to protect the huge investments on roads. (Ferma, 2007).

Another important problem is that in situation where roads are rehabilitated, they are often poorly done, It is a common thing for most roads to be washed away after heavy rainfall (Nwanko, 2002). Adoption of incompetent road rehabilitation procedures and use of incompetent road construction firms have further compounded the problem. For example the Umuachia express junction road was rehabilitated by merely scrapping off the road and then pouring light tar. The result is that in less than 3 weeks after resurfacing the road fell apart (Anyanwu, 1990). In the Northern sections of the country the situation has been much the same and the overall picture indicate a state of neglect. This is in spite of the introduction of organisations such as Federal Road Maintenance Agency (FERMA) which has as part of its objectives a restructuring and rehabilitation of roads. The situation has also been hampered by both insufficient funds by the government as well as the existence of a myriad of developmental problems which also need attention of the authorities.

The problems presented above therefore demand a structuring of priorities, as a result information as to which highways are to be reconstructed and the order in which such reconstruction is to be done become crucial.

Statement Of The Research Problem

A major need in highway development is to develop a structure that meets the needs of users and also takes into account the cost of highway construction. As a result, users as well as development needs should be balanced by consideration for cost of projects. The problem presented above therefore demands a structuring of priorities. As a result information as to which highways are to be done becomes crucial.

The linear programming model is particularly useful in solving network development problems. For example, Ridley (1968, 1969) introduced a network development model based on combinational programming the objectives being to determine links on which investments are to be made as well as the optimal flow on a given highway. The problem formulated by Ridley (1968) was basically a mixed zero- one programming in examining highway reconstruction in Columbia and Indonesia respectively. Also linear programming in combination with the branch and bound algorithm has been used by Boyce et.al (1973) in solving network development problem. In addition, several studies have been conducted on road transportation in Nigeria. Atubi and Onokala (2005) studied effective road transportation and communication network as a basis for rural development and transportation. The main objective of the study was to ascertain to what extent effective road transportation has aided rural development in Benin city, Nigeria. Results from the study revealed that the problem of road transportation in Benin city is not that of inadequate road network, rather it is deeply rooted in improper maintenance and rehabilitation of existing road. Aderamo and Omolaran (2006) examines the problem of accessibility and the incidence of poverty in Offa Local Government of Kwara state. The study revealed that rural transport is poorly developed in the area as most rural settlement are largely inaccessible and poor except settlements with important infrastructural facilities. Ibrahim (2007) studied the role of improved road development on agricultural produce marketing in greater Zaria, northern Nigeria. Results of the study showed that large quantities of agricultural commodities are transported to major periodic markets for sale. But this is determined by many factors, such as time, cost and road conditions. This has confirmed that good roads are incentive not only to production but also to marketing and distribution. Ibrahim (2009) in another study examined the role of road transportation in marketing and distribution of tomatoes in Nigeria. The results of the findings showed that road transport is a major connector factor in regional marketing and distribution of tomatoes in Nigeria. The correlation results revealed that there is a significant relationship between distribution and cost of transportation, road condition and delivery time.

The task of programming highway for rehabilitation has mainly been undertaken by mathematicians and engineers. Consequently, aspects of transportation studies involving highway-rehabilitation relationships and the effect of such relationship on traffic flow have been largely neglected in Nigeria. The only study which has attempted to incorporate spatial aspects to the impact of road transport and regional development by Taaffe et.al (1963). The main thrust of that study was an attempt to examined the relationship between highway length and socio-economic development in Nigeria. The study of taaffe et.al (1963) utilized data for the year 1950s and concerned the distribution of socio-economic development. Two things are of interest concerning Taaffe et.al study; firstly, the data used concerned the period when Nigeria's economy was mainly agricultural one, secondly, between 1980-1970s witness a massive development of road network coupled with industrial infrastructural as well as urban growth. In light of the preceding discussion, it is of interest to evaluate and sequence highway for rehabilitation in northern Nigeria which incorporate data on (spatial variables) such as population of urban centres, distances as well as volume of traffic flow along the road networks in Northern Nigeria.

Scope of the Study

The study specifically focuses on highways rehabilitation in Northern Nigeria. These highways are chosen because they constitute the major volume of traffic tonnage.

Also the choice of volume of traffic (for analysis) is to underscore the fact that highways constitute a very large proportion of the total traffic passing through the region. The marketing of petroleum and related products and Agricultural food and cash crops are transported through these highways.

The study specifically focuses on road distances. The focus on road distance is to underscore the fact that highways in the present day Nigeria constitute the major mode of evaluating import from ports to hinterland. In fact almost all cargos were evacuated by roads. The focus on population of urban centre is to under score the fact that people are the major generators of trip in complementarities region.

The highways to be investigated (which are divided into sections) are shown in Fig. 1. The linkages are as follows:

1. Gboko-Makurdi-Lafia-Jos
2. Gboko- Lokoja- Ilorin
3. Lokoja- Abuja
4. Gboko- Maiduguri
5. Yola- Mubi- Maiduguri
6. Ilorin- Kontagora- Jega- Sokoto
7. Ilorin- Bida- Abuja
8. Kontagora- Kaduna
9. Abuja- Kaduna- Zaria- Kano
10. Zaria- Gusau- Sokoto
11. Abuja- Keffi- Lafia
12. Kaduna- Jos- Bauchi
13. Kano- Jos
14. Kano- Katsina
15. Bauchi- Gombe- Yola

16. Kano- Potiskum- Maiduguri
17. Bauchi- Potiskum
18. Gombe- Maiduguri

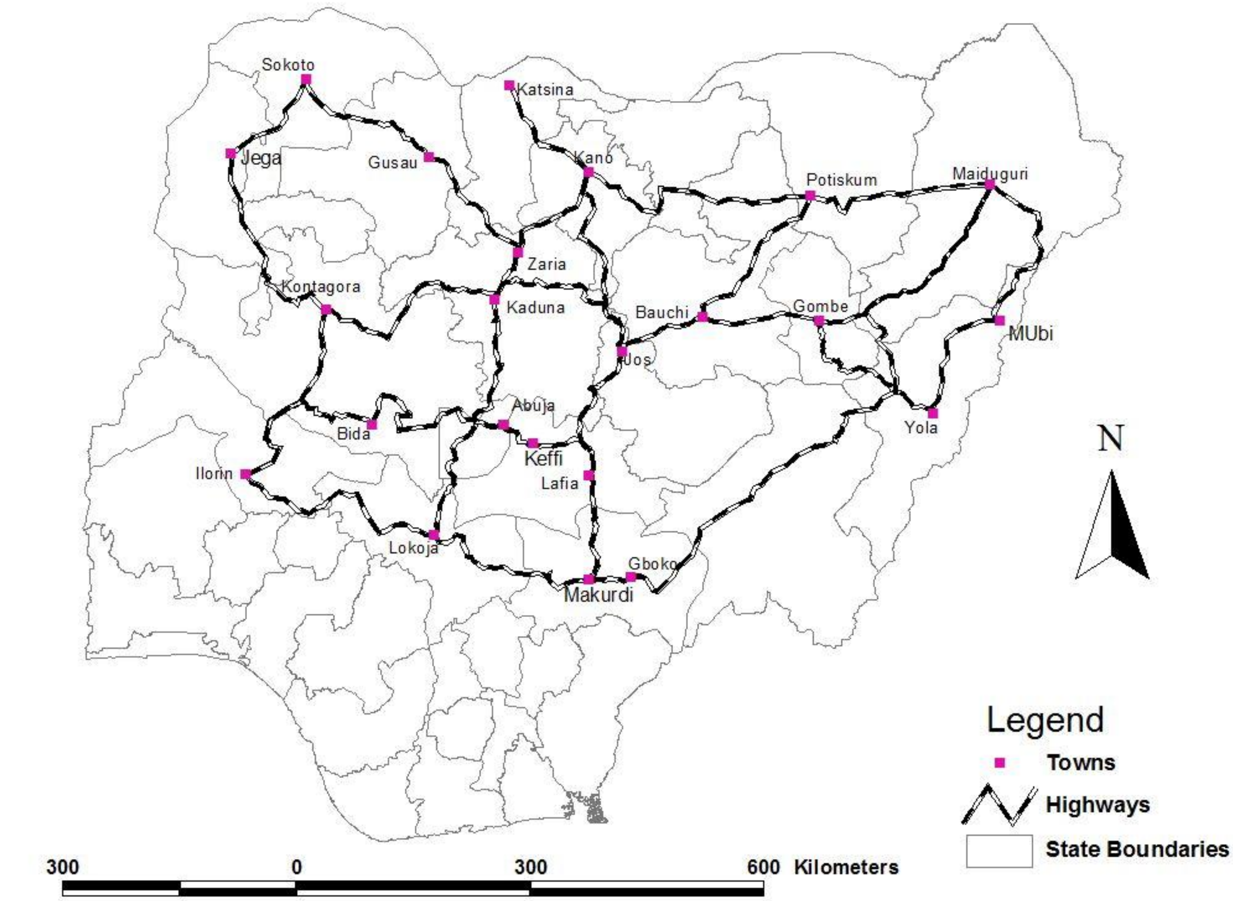

Fig. 1: THE FEDERAL HIGHWAY SYSTEMS IN NORTHERN NIGERIA

Method of the Study

Data Sources

Data sources for the Linear Assignment Model (LAM) include population of urban centres, length of highway as well as traffic generated along highways. The population of urban centres were collected from National Population Commission (NPC) Abuja. The length of highways (kilometre) were extracted using arcview 3.2a GIS software. Information on volume of traffic flow on highways were obtained from Federal Ministry of Transportation, Department of Land Transportation, Abuja.

Analytical Methods

The dynamic programming model used was adopted from Bellman (1954) and Wagner (2000).

DYNAMIC PROGRAMMING

$\text{Max} \sum KX_i$ ______________________ (1)

s.t $\sum^{n}_{k=1} KX = 1$ ________________________(2)

$\sum^{n}_{t=1} KX = 1$ ___________________________ (3)

To convert the problem statement (1) through (3) in to dynamic programming version, define:

$g^{(n)}$= maximum value obtained when each position when each position distributed optimally to road a, road b ….Road r)

$y;^{(n)}$ = distribution amount of Road; that yield $g_{j\ (n)}$ i.e if $y_{j(n)}$= 1

where

g is the rank of the Road

n is the number of position to be distributed among the Roads

j is the index of the Road

$g_{j(n)}$=Maximum (R_j(y) + g_{j-1}(n-y)) for j= a,b…………r ______ (*)

$g_{0(n)}$ = 0 for j= 0

this optimality equation is also called dynamic programming equation (DP) or Bellman equation.

Where n= 0,1 ……………..N and the maximization is over only non negative integer value of y that satisfies $y \leq n$. in word, the recursion (*) states that the rank from optimally distributing N (number roads) to the roads (a,b…….r) can be calculated by finding a best Road j, decision y taking into both its immediate rank impact R_j(y) and the rank impact from having (n-y) position remaining to distribute optimally to road a,b………r-1

The computation start with the last stage j=1, since it in given that, the values of $g_{a(n)}$ are trivially easy to find in particular position Road a, increase as more ranks are uncounted.

$g_{a(n)}$= $R_{a(n),}$ and $y_{a\ (n)}$=n for n=0,1…………,18.

Table 2 shows the data used in assigning priorities to highways.

Table 2: Data used in assigning priority to Highways

S/n	Highways	Highway length (kms)	Traffic Generated	Population served
1	Gboko- Makurdi-Lafiya-Jos	385	12,926	1,380,364
2	Gboko- Lokoja- Ilorin	613	1,914	967,198
3	Lokoja- Abuja	173	8,549	973,828
4	Gboko- Maiduguri	816	146	880,428
5	Yola- Mubi- Maiduguri	405	17,546	589,839
6	Ilorin- Kontagora- Jega-Sokoto	703	13,351	1,186,057
7	Ilorin- Bida- Abuja	479	11,202	1,379,749

8	Kontagora- Kaduna	279	2,522	912,028
9	Abuja- Kaduna- Zaria- Kano	402	436,689	2,674,433
10	Zaria- Gusau- Sokoto	379	62,568	1,219,120
11	Abuja- Keffi- Lafiya	196	79,637	1,201,943
12	Kaduna- Jos- Bauchi	358	23,556	1,347,212
13	Kano- Jos	268	8,698	1,120,902
14	Kano- Katsina	161	35,681	1,046,043
15	Bauchi- Gombe- Yola	369	15,408	530,157
16	Kano- Potiskum- Maiduguri	595	4,699	1,454,952
17	Bauchi- Potiskum	218	2,188	399,686
18	Gombe- Maiduguri	302	5,375	789,492

Source: Compiled by Author

Table 3 shows the place matrix which indicates the number of times in which a highway finishes 1^{st} , 2^{nd} , 3^{rd} and so on.

Table 3: Place Matrix which Summarizes the number of attributes Finishing in each place alternative or criteria used.

Rank

Highways	**1^{st}**	**2^{nd}**	**3^{rd}**	**4^{th}**	**5^{th}**	**6^{th}**	**7^{th}**	**8^{th}**	**9^{th}**	**10^{th}**	**11^{th}**	**12^{th}**	**13^{th}**	**14^{th}**	**15^{th}**	**16^{th}**	**17^{th}**	**18^{th}**
1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0
3	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2
5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0
6	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0
7	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0
8	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0
9	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
10	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
11	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0
14	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0
16	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
17	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1
18	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1

Note 1- 18 refer to the highways used in the study

In the case of highway number 1 (Gboko- Makurdi-Lafia- Jos highway) it finishes 3^{th} ones, 6^{th} ones and 11^{th} ones. Consequently, the ranks in Table 3 were obtained directly from values in Table 2. The place matrix therefore makes a direct input into the assignment problem, that it represents the objectives function of the assignment algorithm. The specific dynamic programming formulation solved (results) is as follows:

Ranking

Maximize $X = 0X_{a1}+ 0X_{a2}+ 1X_{a3}+ 0X_{a4}+ 0X_{a5}+ 1X_{a6} + 0X_{a7}+ 0X_{a8}+ 0X_{a9}+ 0X_{a10}+ 1X_{a11}+ 0X_{a12}+ 0X_{a13}+$
$0X_{a14}+ 0X_{a15}+ 0X_{a16} + 0X_{a17}+ 0X_{a18} + 0X_{b1}+ 0X_{b2}+ 0X_{b3}+ 0X_{b4}+ 0X_{b5}+ 0X_{b6} + 0X_{b7}+ 0X_{b8}+$
$0X_{b9}+ 0X_{b10}+ 0X_{b11}+ 1X_{b12}+ 0X_{b13}+ 0X_{b14}+ 0X_{b15}+ 0X_{b16} + 1X_{b17}+ 0X_{b18}+ 0X_{c1}+ 1X_{c2}+ 0X_{c3}+$
$0X_{c4}+ 1X_{c5}+ 0X_{c6} + 0X_{c7}+ 0X_{c8}+ 0X_{c9}+ 0X_{c10}+ 1X_{c11}+ 0X_{c12}+ 0X_{c13}+ 0X_{c14}+ 0X_{c15}+ 0X_{c16} +$
$0X_{c17}+ 0X_{c18}+ 0X_{d1}+ 0X_{d2}+ 0X_{d3}+ 0X_{d4}+ 0X_{d5}+ 0X_{d6} + 0X_{d7}+ 0X_{d8}+ 0X_{d9}+ 0X_{d10}+ 0X_{d11}+$
$0X_{d12}+ 0X_{d13}+ {}_{1}X_{d14}+ 0X_{d15}+ 0X_{d16} + 0X_{d17}+ 2X_{d18}+ 0X_{e1}+ 0X_{e2}+ 0X_{e3}+ 0X_{e4}+ 0X_{e5}+ 0X_{e6} +$
$0X_{e7}+ 0X_{e8}+ 0X_{e9}+ 0X_{e10}+ 0X_{e11}+ 0X_{e12}+ 1X_{e13}+ 0X_{e14}+ 1X_{e15}+ 1X_{e16} + 0X_{e17}+ 0X_{e18}+ 0X_{f1}+$
$0X_{f2}+ 0X_{f3}+ 0X_{f4}+ 0X_{f5}+ 0X_{f6} + 0X_{f7}+ 1X_{f8}+ 0X_{f9}+ 0X_{f10}+ 1X_{f11}+ 0X_{f12}+ 0X_{f13}+ 0X_{f14}+ 0X_{f15}+$
$0X_{f16} + 1X_{f17}+ 0X_{f18}+ 0X_{g1}+ 0X_{g2}+ 0X_{g3}+10X_{g4}+ 0X_{g5}+ 0X_{g6} + 0X_{g7}+ 0X_{g8}+ 0X_{g9}+ 1X_{g10}+$
$0X_{g11}+ 0X_{g12}+ 0X_{g13}+ 1X_{g14}+ 0X_{g15}+ 0X_{g16} + 0X_{g17}+ 0X_{g18}+ 0X_{h1}+ 0X_{h2}+ 0X_{h3}+ 0X_{h4}+ 0X_{h5}+$
$1X_{h6} + 0X_{h7}+ 0X_{h8}+ 0X_{h9}+ 0X_{h10}+ 0X_{h11}+ 0X_{h12}+ 1X_{h13}+ 1X_{h14}+ 0X_{h15}+ 0X_{h16} + 0X_{h17}+$
$0X_{h18}+ 2X_{i1}+ 0X_{i2}+ 0X_{i3}+ 0X_{i4}+ 0X_{i5}+ 0X_{i6} + 0X_{i7}+ 0X_{i8}+ 0X_{i9}+ 0X_{i10}+ 0X_{i11}+ 1X_{i12}+ 0X_{i13}+$
$0X_{i14}+ 0X_{i15}+ 0X_{i16} + 0X_{i17}+ 0X_{i18}+ 0X_{j1}+ 1X_{j2}+ 0X_{j3}+ 0X_{j4}+ 0X_{j5}+ 0X_{j6} + 0X_{j7}+ 0X_{j8}+ 0X_{j9}+$
$1X_{j10}+ 0X_{j11}+ 0X_{j12}+ 0X_{j13}+ 0X_{j14}+ 0X_{j15}+ 0X_{j16} + 0X_{j17}+ 0X_{j18} + 0X_{k1}+ 0X_{k2}+ 2X_{k3}+ 0X_{k4}+$
$0X_{k5}+ 0X_{k6} + 1X_{k7}+ 0X_{k8}+ 0X_{k9}+ 0X_{k10}+ 0X_{k11}+ 0X_{k12}+ 0X_{k13}+ 0X_{k14}+ 0X_{k15}+ 0X_{k16} + 0X_{k17}+$
$0X_{k18} + 0X_{l1}+ 0X_{l2}+ 0X_{l3}+ 0X_{l4}+ 1X_{l5}+ 0X_{l6} + 1X_{l7}+ 1X_{l8}+ 0X_{l9}+ 0X_{l10}+ 0X_{l11}+ 0X_{l12}+ 0X_{l13}+$
$0X_{l14}+ 0X_{l15}+ 0X_{l16} + 0X_{l17}+ 0X_{18} + 0X_{m1}+ 0X_{m2}+ 0X_{m3}+ 0X_{m4}+ 1X_{m5}+ 0X_{m6} + 0X_{m7}+$
$0X_{m8}+1X_{m9}+ 0X_{m10}+ 0X_{m11}+ 0X_{m12}+ 0X_{m13}+ 0X_{m14}+ 0X_{m15}+ 0X_{m16} + 0X_{m17}+ 0X_{m18} + 1X_{n1}+$
$0X_{n2}+ 0X_{n3}+ 0X_{n4}+ 1X_{n5}+ 0X_{n6} + 0X_{n7}+ 0X_{n8}+ 0X_{n9}+ 1X_{n10}+ 0X_{n11}+ 0X_{n12}+ 0X_{n13}+ 0X_{n14}+$
$0X_{n15}+ 0X_{n16} + 0X_{n17}+ 0X_{n18} + 0X_{o1}+ 0X_{o2}+ 0X_{o3}+ 0X_{o4}+ 0X_{o5}+ 0X_{o6} + 0X_{o7}+ 0X_{o8}+ 2X_{o9}+$
$0X_{o10}+ 0X_{o11}+ 0X_{o12}+ 0X_{o13}+ 0X_{o14}+ 0X_{o15}+ 0X_{o16} + 1X_{o17}+ 0X_{o18} + 0X_{p1}+ 1X_{p2}+ 0X_{p} \quad {}_{q}$
${}_{3}+ 0X_{p4}+ 0X_{p5}+ 0X_{p6} + 0X_{p7}+ 1X_{p8}+ 0X_{p9}+ 0X_{p10}+ 0X_{p11}+ 0X_{p12}+ 0X_{p13}+$
$0X_{p14}+ 1X_{p15}+ 0X_{p16} + 0X_{p17}+ 0X_{p18} + 0X_{q1}+ 0X_{q2}+ 0X_{q3}+ 1X_{q4}+ 0X_{q5}+ 0X_{q6} + 0X_{q7}+ 0X_{q8}+$
$0X_{q9}+ 0X_{q10}+ 0X_{q11}+ 0X_{q12}+ 1X_{q13}+ 0X_{q14}+ 0X_{q15}+ 0X_{q16} + 0X_{q17}+10X_{q18} + 0X_{r1}+ 0X_{r2}+$
$0X_{r3}+ 0X_{r4}+ 0X_{r5}+ 0X_{r6} + 1X_{r7}+ 0X_{r8}+ 0X_{r9}+ 0X_{r10}+ 0X_{r11}+ 0X_{r12}+ 0X_{r13}+1X_{r14}+ 1X_{r15}+ 1X_{r16}$
$+ 0X_{r17}+ 0X_{r1}$ **…………………………………………………………………………………….(4)**

Subject to

$X_{a1}+ X_{a2}+ X_{a3}+ X_{a4}+ X_{a5}+ X_{a6} + X_{a7}+ X_{a8}+ X_{a9}+ X_{a10}+ X_{a11}+ X_{a12}+ X_{a13}+ X_{a14}+ X_{a15}+ X_{a16} + X_{a17}+ X_{a18} = 1$

$X_{b1}+ X_{b2}+ X_{b3}+ X_{b4}+ X_{b5}+ X_{b6} + X_{b7}+ X_{b8}+ X_{b9}+ X_{b10}+ X_{b11}+ X_{b12}+ X_{b13}+ X_{b14}+ X_{b15}+ X_{b16} + X_{b17}+ X_{b18} = 1$

. . . . . .

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. . . . . .

$X_{r1}+ X_{r2}+ X_{r3}+ X_{r4}+ X_{r5}+ X_{r6} + X_{r7}+ X_{r8}+ X_{r9}+ X_{r10}+ X_{r11}+ X_{r12}+ X_{r13}+ X_{r14}+ X_{r15}+ X_{r16} + X_{r17}+ X_{r18} =$
1**……………………………………………………………………………………. (5)**

$X_{a1}+ X_{b1}+ X_{c1}+ X_{d1}+ X_{e1}+ X_{f1} + X_{g1}+ X_{h1}+ X_{i1}+ X_{j1}+ X_{k1}+ X_{l1}+ X_{m1}+ X_{n1}+ X_{o1}+ X_{p1} + X_{q1}+ X_{r1} = 1$

$$X_{a2}+ X_{b2}+ X_{c2}+ X_{d2}+ X_{e2}+ X_{f2} + X_{g2}+ X_{h2}+ X_{i2}+ X_{j2}+ X_{k2}+ X_{l2}+ X_{m2}+ X_{n2}+ X_{o2}+ X_{p2} + X_{q2}+ X_{r2} = 1$$

. . . . . .

. . . . . .

. . . . . .

$$X_{a18}+ X_{b18}+ X_{c18}+ X_{d18}+ X_{e18}+ X_{f18} + X_{g18}+ X_{h18}+ X_{i18}+ X_{j18}+ X_{k18}+ X_{l18}+ X_{m18}+ X_{n18}+ X_{o18}+ X_{p18} + X_{q18}+ X_{r18} = 1 \ldots\ldots\ldots\ldots \textbf{(6)}$$

The solution to the problem in equations 4, 5 and 6 is given in table 5.

Results Obtained from Dynamic Programming Approach

In this section, we specifically examined priorities or ranks to be given to high ways for the purpose of rehabilitation. The Bellman's equation is therefore used in the aspect of the analysis. Table 3 shows the data used in assigning priorities to highways. Table3 shows the place matrix which indicates the number of times in which a highway finishes 1st, 2nd, 3rd, and so on while table 4 below shows the computation of the Dynamic programming solved as follows:

Table 4 summarizes the computations obtained from dynamic programming

	a		b		c		d		e		f	
	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$
0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	0,1	0	0	0	0,1	0	0,1	0	0,1	0
2	2	0	0,12	0	1,0	1	0	1	0	1	0	1
3	3	1	0	1	0,2	1	0,1	1	0,1	0	0,1	1
4	4	0	1	1	0,1,2	1	0,1,2	1	0,1,2	1	0,1,2	1
5	5	0	2	1	2	2	0	2	0	2	0	2
6	6	1	0,3	1	2	2	0,2	2	0,1	2	0,1	2
7	7	0	1,4	1	2	2	0,1,2	2	0,1,2	2	0,1,2	2
8	8	0	2,6	1	2,5	2	0,1,2,3	2	0,1,2,3	2	0,1,2,3	2
9	9	0	3,6	1	2,5	2	0,1,2,3,4	2	0,1,2,3,4	2	0,1,2,3,4	2
10	10	0	4,7	1	2,5	2	1,2,3,4,5,6	2	0,1,2,3,4,5	2	0,1,2,3,4,5,8	2
11	11	1	0,5,8	1	2,5	2	1,2,3,4,5,6,7	2	0,1,2,3,4,5,6	2	0,1,2,3,4,5,6,8	2
12	12	0	1,6,9,12	1	2,5	2	1,2,3,4,5,6,7	2	0,1,2,3,4,5,6,7	2	0,1,2,3,4,5,6,7,8	2
13	13	0	2,7,10,12	1	2,5	2	1,2,3,4,5,6,7,8	2	0,1,2,3,4,5,6,7,8	2	8	2
14	14	0	3,8,11,12	1	2,5,11	2	1,2,3,4,5,6,7,8,9	2	0,1,2,3,4,5,6,7,8,9	2	8	3
15	15	0	12	2	4,2,5,11	2	1,2,3,4,5,6,7,8,9,10	2	0,1,2,3,4,5,6,7,8,9,10	2	8	3
16	16	0	5,10,12,13,16	1	1,2,5,11	2	1,2,3,4,5,6,7,8,9,10,11	2	0,1,2,3,4,5,6,7,8,9,10,11	2	8,11	3
17	17	0	6,11,13,14,16	1	2	3	0	3	0	3	0,8,11	3
18	18	0	12	2	0,2,3,5,11	1	1	3	0,3,13	3	0,8,11	3

	g		h		i		j		k		l		m		n		o		p		q		r	
	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$	$y_{i(n)}$	$g_{i(n)}$
0	o	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0,1	0	0,1	0	1	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2
2	0	1	0	1	1	2	0,1	2	0,1	2	0,1	2	0,1	2	2	3	0	3	0	3	0	3	0	3
3	0,1	1	0,1	1	1	3	0,2	3	0	3	0	3	0	3	0,2	3	0,1	3	0,1,2	3	0,1	3	0,1	3
4	0,1,2,4	1	0,1,2	1	1	3	0,1,2	3	3	4	0	4	0	4	0,1	4	0	4	0,2	4	0	4	0	4
5	0	2	0	2	1	3	2	4	3	4	0,1	4	0,1	4	5	5	0	5	0	5	0	5	0	5
6	0,1,4	2	0,1	2	1	4	0,4	4	3	5	0	5	0	5	0,1	5	0,1	5	0,1,2	5	0	5	0,1	5
7	0,1,2,2	2	0,1,2	2	1	4	0,1,2	4	3	5	0,1	5	0,1	5	1	6	0	6	0,2	6	0	6	0	6
8	0,1,2,3,4	2	0,1,2,3,6	2	1	4	2	5	3	6	0	6	0	6	0,1	6	0,1	6	0,1,2	6	0,1	6	0,1	6
9	4	3	0	3	1	4	2	5	3	6	0,1	6	0,1	6	1	7	0	7	0,2	7	0	7	0	7
10	4	3	0,1	3	1	5	0,2	5	3	6	0,1,2	6	0,1,2	0	1	7	0,1	7	0,1,2	7	0,1	7	0,1	7
11	4	3	0,1,2,6	3	1	5	0,1,2	5	3	7	0	7	0	7	0,1	7	0,1,2	7	2	8	0	8	0	8
12	4	3	0,1,2,3,6	3	1	5	2	6	3	7	0,1	7	0,1	7	1	8	0	8	0,2	8	0,1	8	0,1	8
13	0,4	3	0,1,2,3,4,5,6	3	1	5	2	6	3	7	0,1,2,5	7	0,1,2,5	7	1	8	0,1	8	0,1,2	8	0,1,2,4	8	0,1,2	8
14	0,1,4	3	0,1,2,3,4,5,6	3	1	5	2	6	3	7	0,1,2,3,5	7	0,1,2,3,5	7	1	8	0,1,2	8	2	9	0	9	0	9
15	0,1,2,10	3	6	3	1	5	2	6	3	8	0	8	0	8	1,4	8	0,1,2,5	8	2	9	0,1,2,4	9	0,1	9
16	0,1,2,3,4,10	3	6	3	1	6	0,2,6	6	3	8	0,1,5	8	0,1,5	8	1	9	0	9	0,2	9	0,1,2,3,4	9	0,1,2	9
17	4	4	0,6	3	1	6	0,1,2,6	6	3	8	0,1,2,5	8	0,1,2,5	8	1	9	0,1	9	0,1,2	9	0,1,2,3,4	9	0,1,3	9
18	4	4	0,1,6	4	1	6	2	7	3	8	0,1,2,3,5	8	0,12,35	8	1	9	0,1,2,9	9	2	10	0,4	10	0	10

- Road r has it's optimal $g_{(n)}$ (i.e became 1st) at the 15th position.
- Road q became optimal 1st at the 13th position
- Road p " " " 8th position
- Road 0 " " " 17th "
- Road n " " " 10th "
- Road m " " " 9th "
- Road l " " " 7th "
- Road k " " " 3rd "
- Road j " " " 2nd "
- Road i " " " 1st "
- Road h " " " 14th "
- Road g " " " 4th "
- Road f " " " 11th "
- Road e " " " 16th "
- Road d " " " 18th "
- Road c " " " 5th "
- Road b " " " 12th "

- Road a " " " 6th "

To conclude, you employed the recursion (in table 4) to obtain an optimal solution by beginning the computations at the final stage j=a and finding $g_{a(0)1}$ $g_{a(1)}$ …………$g_{a(N).}$ you then continued by finding $g_{b(0),}$ $g_{b(1)}$………………………$g_{b(N).}$ you proceed in the same fashion for successively larger values of j until you finally found $g_{s(N).}$ you then discovered an actual optimal allocation by tracing back, beginning with $y_{s(N)}$, to obtain the values of yi that together yielded $g_{s(N).}$ the following result in table 5

Table 5 Ranks Priority given to highways using Dynamic Programming

Highways		Ranks
Gboko- Makurdi-Lafiya- Jos	a	6th
Gboko- Lokoja- Ilorin	b	12th
Lokoja- Abuja	c	5th
Gboko- Maiduguri	d	18th
Yola- Mubi- Maiduguri	e	16th
Ilorin- Kontagora- Jega- Sokoto	f	11th
Ilorin- Bida- Abuja	g	4th
Kontagora- Kaduna	h	14th
Abuja- Kaduna- Zaria- Kano	i	1st
Zaria- Gusau- Sokoto	j	2rd
Abuja- Keffi- Lafia	k	3rd
Kaduna- Jos- Bauchi	l	7th
Kano- Jos	m	9th
Kano- Katsina	n	10th
Bauchi- Gombe- Yola	o	17th
Kano- Potiskum- Maiduguri	p	8th
Bauchi- Potiskum	q	13th
Gombe- Maiduguri	r	15th

Table 5 therefore give the priorities or ranks given to each highway in terms of rehabilitation. As a result, the Abuja-Kaduna-Zaria-Kano highway ranks first and is given the highest priority in terms of road rehabilitation. This implies that road *i* has it optimal in the first position, which signifies that road *i* the Abuja-Kaduna-Zaria-Kano highway is the optimal road network in the entire region. The Zaria–Gusa–Sokoto highway ranks second; Abuja-Keffi-Lafia ranks third, while the Ilori-Bida-Abuja ranks fourth and Lokoja-Abuja ranks fifth. The highways with lowest ranks include Gombe-Maiduguri (15th), Yola-Mubi-Maiduguri (16th), Bauchi-Gombe-Yola (17th) and Gboko-Maiduguri (18th).

Table 6 Results obtained for Sequencing highway Rehabilitation using Dynamic Programming

Year	Highway
1	I
2	J
3	K and g
4	C and a

5	L and p
6	M and n
7	F and b
8	Q and h
9	R and r
10	O and d

1st year 2011

Abuja- Kaduna- Zaria- Kano

2nd year 2012

Zaria- Gasau- Sokoto

3rd year 2013

Abuja- Keffi- Lafia

Ilorin- Bida- Abuja

4th year 2014

Lokoja- Abuja

Gboko- Makurdi- Lafia- Jos

5th year 2015

Kaduna- Jos- Bauchi

Kano- Potiskum- Maiduguri

6th year 2016

Kano- Jos

Kano- Katsina

7th year 2017

Ilorin- Kontogora- Jega- Sokoto

Gboko- Lokoja- Ilorin

8th year 2018

Bauchi- Potiskum

Kotongora- Kaduna

9th year 2019

Gombe- Maiduguri

Yola- Mubi- Maiduguri

10th year 2020

Bauchi- Gombe- Yola

Gboko- Maiduguri

Sequencing Highway Rehabilitation Using the Dynamic Programming

In this section an attempt is made to sequence highway rehabilitation over the ten years period from 2011-2020. The need for temporal sequencing is based on the general lack of funds. As a result there might be a need to breakdown or reduce the yearly financial burden. Table 7 shows the matrix of highway scheduled preferences. The preferences are basically on the following:

1. The rating or priority given to highway
2. The 10 points preference scale (see Table 1)

As a result highways which are highly rated are given high values in the first year, while those with low rating have low values.

Therefore, the Abuja-Kaduna-Zaria-Kano highway in (*i* in table 7) has a high rating of 10 for the year 2011. (Recall that a value of 10 in the preference scale implies absolute importance). Also highway such as Bauchi-Gombe-Yola and Gboko-Maiduguri (o and d) 17th and 18th which have low rating are given low values for the year 2011.

Table 7 Place matrix for highway schedule preference using dynamic programming

Highway	1st 2011	2nd 2012	3rd 2013	4th 2014	5th 2015	6th 2016	7th 2017	8th 2018	9th 2019	10th 2010
A				8						
B							6			
C			4	9						
D										8
E									6	
F						3	7			
G			6							
H								8		
I	9	0	0							
J	4	8	0							
K		3	7							
L				3	7					
M					4	9				
N						8				
O									4	9
P					6					
Q							4	9		
R								3	7	

The value given to highway is based on a preference scale ranging from 1 to 10. See table 1.

Table 1: Preference Scale

Intensity importance	**Definition**
0-5	Weak Important
6	Important
7-8	Strongly important
9-10	absolutely important

Summary and Conclusion

This study had earlier set out to evaluate and to sequence highway rehabilitation in northern Nigeria. The rehabilitation of highways is set against their importance to the regional economy as well as the gradual decay of highways in the region.

The results obtained show that high priority roads include the Abuja – Kaduna – Zaria – Kano highway, Lokoja – Abuja highway, Zaria- Gusau- Sokoto highway and Abuja – Keffi – Lafia highway while lowly rated roads includes the Gboko – Maiduguri highway, Bauchi- Gombe- Yola highways as well as Ilorin – Kontagora – Jega –Sokoto highways.

The rehabilitation of the roads was therefore sequenced over ten years periods (2011,2012, 2013,2014,2015,2016,2017,2018,2019 and 2020).

The dynamic programming model basically sequenced the rehabilitation of highly rated roads for the year 2011 while lowly rated roads sequenced for rehabilitation in the year 2019 as well as 2020.

As a result high priority highways such as Abuja – Kaduna – Zaria – Kano highways was scheduled for rehabilitation in the first year while the Gboko- Maiduguri highway and *Ilorin* – Kotagora – Jega – Sokoto highways were scheduled for rehabilitation in the year 2020.

The methodology of this study is propose for adoption in future highway planning in the study region. A policy of proper highway maintenance may well strengthen the development effort of the region. This follows the view of Sammer (1981) that highways could assists in developing the economies of backward regions.

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