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The Effect of Pavement Condition on Traffic Safety: A Case Study of Some Federal Roads in Bauchi State

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Abstract: *The cost of highway accidents in terms loss of lives, injuries and road closures is a major strain on the Nigerian economy. It has therefore become pertinent to explore the causes of such accidents from a road condition perspective with a view to limiting their frequency and degree of severity. Three federal roads in Bauchi State were considered for this study; Bauchi - Jos, Bauchi - Gombe and Bauchi - Yobe Border, respectively. The pavement condition data indicated that Bauchi - Jos rouate has the highest Road Condition Score (RCS) while Bauchi - Gombe route has the lowest RCS. The Jos route also accounted for the highest number of accidents and fatalities despite having the best pavement condition, while the Yobe route accounted for the least number of accidents and fatalities. The results support the general view that there is no strong correlation between pavement condition and traffic safety, however some design and planning issues like the degree of curvature of horizontal and vertical curves and number of towns/villages on the routes seem to play an important role in traffic safety.*

I. Introduction

Traffic accidents most especially highway crashes result in high fatalities and various degrees of live changing injuries that cause huge economic loses to the country.The World Bank (2012) estimates that road crashes cost approximately 1 to 3 percent of a country's annual Gross National Product (GNP).Using current figures, this is approximately₦346 billion to ₦1.039 trillion, which is even more than the ₦183 billion, 2013 budget of the Federal Ministry of Works (Budget Office of Nigeria, 2013). Available records for the year 2011 showed that 4,372 people were killed and a further 17, 464 suffered various injuries as a result of traffic accidents (Federal Road Safety Commission, 2011). Thus, it has become imperative to investigate the causes of such accidents with a view to limiting their frequency and severity from a pavement condition viewpoint among other major causes like driver behaviour, traffic operations and safety measures, vehicle condition and traffic law enforcement.

Many studies have established that among the major causes of road accidents, driver behaviour has been judged to be most important where road and vehicle condition are in very good state (Jacobs and Baguely, 2004).This can be seen from the Figure 1, which shows the four elements that affect traffic safety namely; driver behaviour, vehicle condition, pavement condition and environment as well as the interaction between the factors represented by the hatched areas.

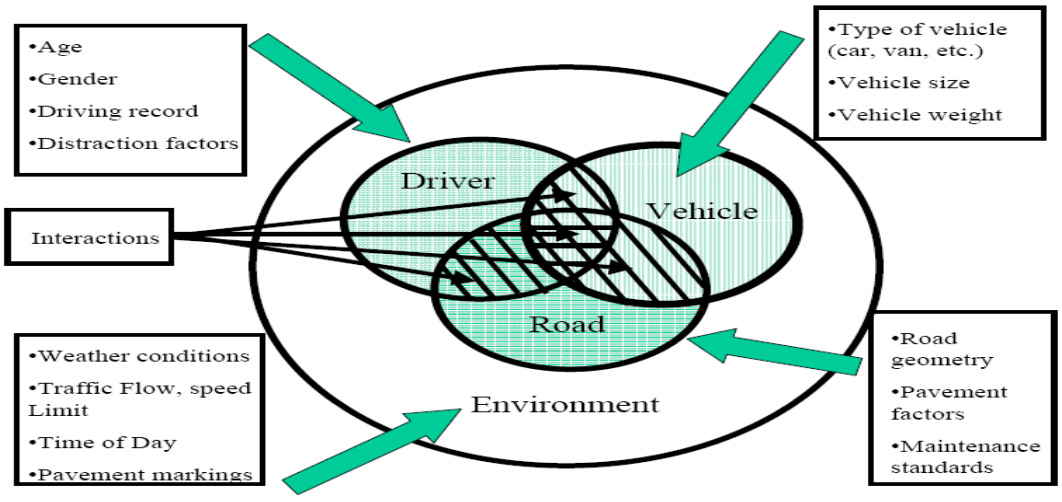

Figure 1-Road safety factors and interactions

Source: (Tighe et al, 2001)

To examine the effect of pavement condition on road crashes some research studies investigated the effect of pavement characteristics on accident generationor prevention and, in particular, the effect of pavement condition individually or in combination with otherfactors of the road environment. Among them, Craus et al. (1991) investigated the effect of pavement surfacecondition on traffic accidents and concluded that there is no significant unilateral correlation between thesetwo parameters. However, some accident reduction can be expected if pavement skidresistance is quite high and the shoulder is wider than 2m and in good condition.This could be quite significant in the case of Nigerian roads where the shoulder is sometimes not more than 2m when it is available.

Al-Masaeid (1997) investigated the effect of pavement condition, road geometry, and roadside conditions onrural road accidents and found that the pavement condition had significant effect on single- and multiplevehicleaccident rates, but no statistical influence on the total accident rate. Further, the number of sharphorizontal curves and the roadside condition were found to have a significant effect on single-vehicleaccident rates. The number of vertical curves and the number of intersections were found to have asignificant influence on multiple-vehicle accidents.

Studies of the relationships between geometric design and road accidents in Kenya and Jamaica and research in Chile and India showed that apart from traffic flow, junctions per kilometre was the most important factor related to accidents, followed by horizontal and vertical curvature.The study proposed using accident reduction and prevention measures as a way of meeting the challenges of traffic safety in developing countries. The measures as developed by Transport and Road Research Laboratory (TRRL) of UK are summarised in Figure 2. They include by-passing of towns/villages on major routes, limiting the degree of curvature on curves, use of lay-bys by local food sellers, buses and taxis in order to reduce congestion and improve visibility etc(Robinson and Thagesen, 2004).

(Sjölinder et al, 1997 as cited in Ihs, 2004) looked at the relationship between traffic safety and road surface condition where the road surface condition was described in terms of rut depth and unevenness. The results indicated that ruts possibly seem to have a tendency to improve traffic safety while unevenness has the opposite effect. Ihs (2004) investigated the relation between traffic safety and road surface condition for the Swedish National Road Administration's (SNRA) further corroborated the findings in the earlier study. The results showed that the accident ratio increases with increasing unevenness higher (International Roughness Index, IRI).

There are various pavement condition rating systems in use globally including but not limited to Pavement Condition Index (PCI), Present Serviceability Rating (PSR), Present Serviceability Index (PSI), International Roughness Index (IRI) and Maintenance Needs Index (MNI) among others (Theberge, 1987; WSDOT, 2005).Nigeria has currently not adopted any of the globally recognised rating systems, but uses a rating system that is classified only according to the state of the pavement. It uses descriptors like Good and Bad, and does not use a scoring system with numbers as is available with the internationally recognised ones.

II. Methodology

Two pavement condition rating systems were examined among the many pavement performance models developed by various researchers. The first rating system considered is the one proposed by Owolabi et al (2012), who developed the Pavement Condition Score (PCS), that combines, in a systematic manner, severity levels of the distress types occurring within a given road section into a scale of 1 to 100, where 1 represents a very poor pavement and 100 a pavement in excellent condition. The distress categories considered include potholes, cracks, rut and patches, which are major features of Nigerian roads. The pavement condition rating for the PCS is presented in Table 1.

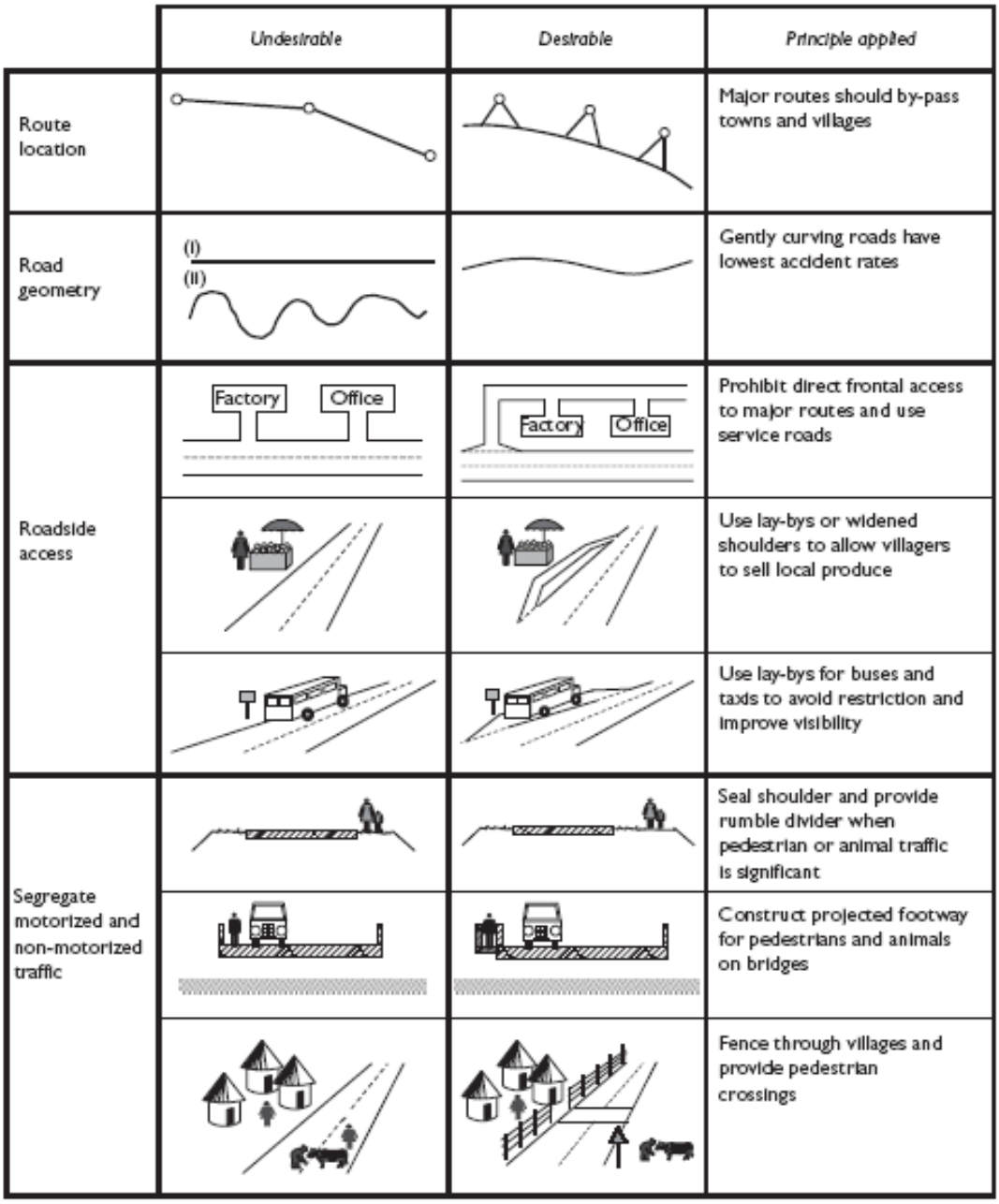

Figure 2-Examples of effects of engineering design on road safety
Source: TRRL Overseas Unit (1988). In: ((Robinson and Thagesen, 2004)

The Federal Roads Maintenance Agency, (FERMA)uses four pavement condition ratings; bad, poor, fair and good were used by FERMA in assessing the road condition. The FERMA pavement rating system is presented in Table 2.

Table 1- Pavement Condition Score (PCS) Rating

PCS	**Pavement Condition**
80-100	Excellent
65-79	Very Good
55-64	Good
45-54	Fair
35-44	Poor
0-34	Unacceptable

Table 2- FERMA's Pavement Condition Rating

Condition	Description
Good	Stable pavement structure with asphalt overlay. No or very few potholes, or alligator cracks.
Fair	Stable pavement structure with asphalt overlay. Has potholes not exceeding $100m^2$ per km length.
Poor	Presence of undulating road sections,alligator cracks and cluster potholes with few failed sections.
Bad	Predominantly unstable road sections, wide alligator cracks with many failed section up to subgrade,pavement washout, peaty surface. Not safe for vehicular traffic

Table 3 – Scoring system used in the study

Condition	Score
Good	5.00
Fair	3.33
Poor	1.67
Bad	0

Comparing Table 1 and 2, it is apparent that because the pavement conditions as set out in Table 1 are not clearly defined, assignment of a score within the given range is a bit of challenge. However, in Table 2 the description of the pavement conditions is clearly outlined and defined without ambiguity, which makes it convenient for use than the PCS. In view of the foregoing, the rating system of FERMA was used in this study. However, because their rating score system is qualitative, values from 0 to 5 where assigned to the score to make it quantitative as shown in Table 3.

In order to capture the true state of the route, the scores in Table 3 are weighted in relation to the condition of the length of pavement. For example on the Bauchi to Gombe route; 58 km was considered to be in poor condition while 97 km is deemed to be fair condition out of a total length of 155 km. The weighting calculation for this route is shown in Equation 1;

$$\frac{58 \times 1.67}{155} + \frac{97 \times 3.33}{155} = 2.71 \qquad (1)$$

Similar calculations were also carried for the other two routes and the corresponding weighted Road Condition Scores (RCS)presented in Table 4.

Pavement condition data was obtained from the Bauchi field office of FERMA. Average Daily Traffic (ADT) data was also obtained from FERMA. While the traffic accident data was collected from the Federal Road Safety Commission, (FRSC) Bauchi command office.Three major Federal Roads (trunk A) where considered; Bauchi to Jos, Bauchi to Yobe border, and Bauchi to Gombe.

The summary of the data from the two sources is presented in Tables I through IIIin the appendix.

III. Results And Discussion

1.1. Relationship between Number of Traffic Crashesand Road Condition

Figure 3 shows the relationship between the Normalised Number of Crashes in the year 2012 with respect to the Average Daily Traffic (ADT) and the RoadCondition Score(RCS). From the figure it is seen that there is a discernable relationship between the two however this weaken by scatter as evidenced by the R^2value of 0.466. This is in agreement with the findings ofCraus *et al.* ,(1991) and , Al- Masaeid (1997). The variation in the RCS for the three routes is shown in Figure 4and Table 4. It shows that the Bauchi - Jos route and the Bauchi - Yobe Border route have the highest scores of 4.26 and 4.20 respectively. The Bauchi - Gombe route yieldedthe lowest score of 2.71.It can be seen that the Bauchi - Jos route, which has the best RCS also gave the highest frequency of crashes of the three roads under consideration. This could be attributed to a number of factors; higher traffic volume, more vertical and horizontal curves and more towns and villages on the route.

The Bauchi - Jos route has a higher traffic volume because it is the major gateway to Abujaand Southern part of Nigeria for people in the North Eastern part of the country. The direct correlation between traffic volume and highway crashes has been established by Marchesini and Weijermars (2010). Thus, it is expected that whenever the traffic volume increases there is normally an associated increase in the accident rate as seen in this case.

The degree of curvature of vertical and horizontal curves also has a direct bearing on the accident rate as stated previously. The Bauchi - Jos route has the highest number of curves amongst the three routes and expectedly the highest number of crashes.

From the results in the appendix, it is seen that along the Jos route, there are some notable black spots like Panshanu, Toro, Narabi, Magama and Zaranda villages. Panshanut has the highest accident rate for all the three routes. Its unique features that could have contributed to such a high incidence of traffic crashes are; it is located just after a horizontal and vertical curve, and there is security check point at the spot. A similar situation also applies to Narabi, while Toro, Magama and Zaranda are busy towns along the major route. All of these further reinforces the need for careful planning and proper design as a tool for accident reduction as suggested by Robinson and Thagesen (2004)

Table 4- Road condition

Route	Road condition Score	Total No of Crashes in 2012	Total No injured in 2012	Total No killed in 2012	Total No injured/ Total No of crashes	Total No Killed/ Total No of crashes	Average Daily Traffic, ADT
Bauchi - Jos	4.26	102	284	61	2.78	0.60	7000
Bauchi- Gombe	2.71	71	310	54	4.37	0.76	4000
Bauchi - Yobe Border	4.2	43	213	31	4.95	0.72	4200

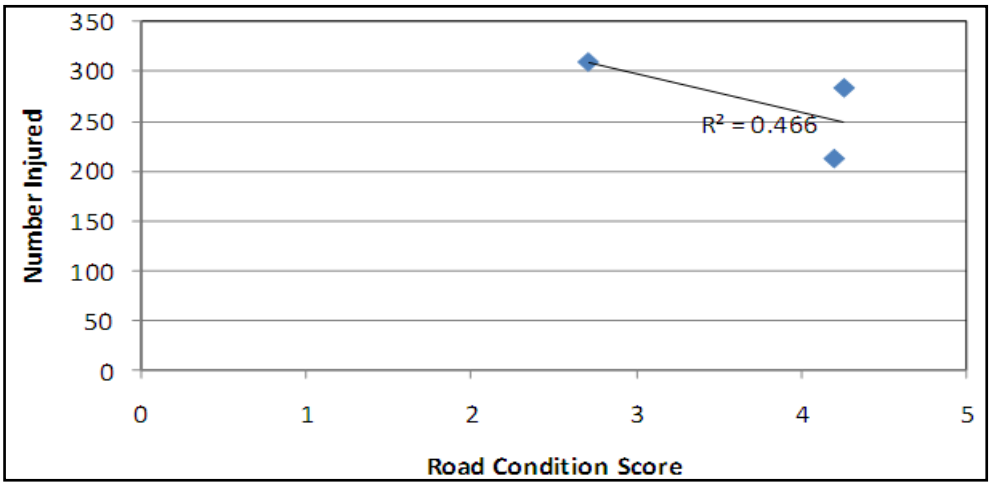

Figure 3- Relationship between Normalised Number of Crashes and Road Condition Score (RCS)

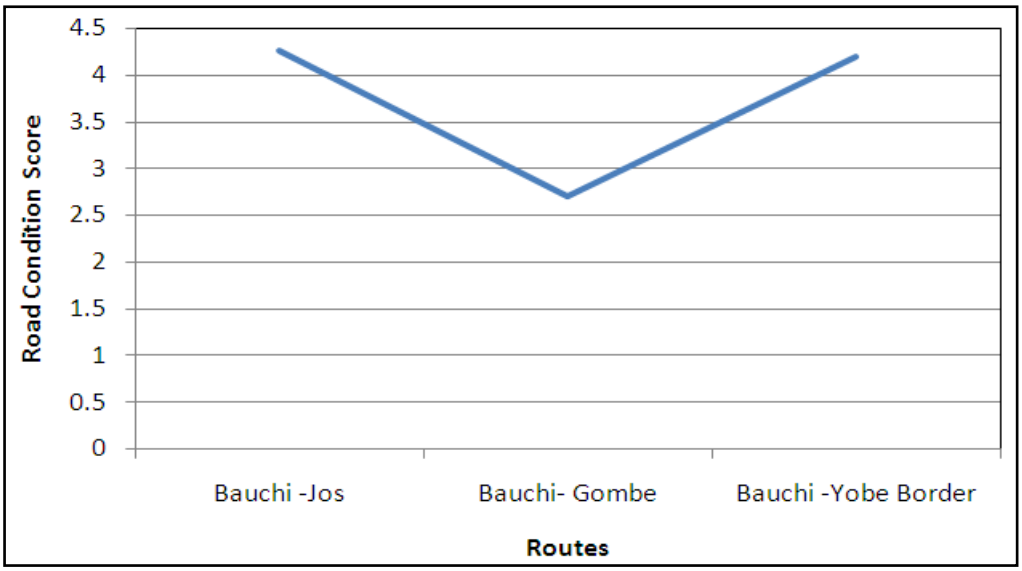

Figure 4 – Variation of RCS among the three routes

1.2. Relationship between Number of People Injured/Killed and Road Condition

The relationship between the Normalised number of people Injured/killed and RCS is shown in Figures5 and 6. It can be observed there seems is a significant correlation between the variables. The goodness of fit, R^2 = 0.88 and 0.96 for Number injured Vs RCS and Number killed Vs RCS, respectively. The strong correlation is evident from the values of R^2 close to 1, which further reinforces the view that there is correlation between pavement condition and number of traffic accidents.

Interestingly, it is seen from the Figures 5and 6, and Figure 7, which shows the variation of number of crashes/number killed/number injured among the routes.Even though the Jos route has the highest number of crashes it does not account for the highest number of those injured in the crashes. The Gombe route, which has the lowest RCS score of the three routes, has the highest number of those injured. Perhaps there is a link between the severity of accidents and road condition, even though the effect is not statistically significant. However, a closer look at the data reveals that most of the casualty figure; infact more than a third is accounted for by the month of December 2012.

Significantly, the number of crashes and number killed among the routes almost follow the same pattern and trend as seen from Figure 7. Indicating that there is a significant correlation between the number of crashes and number of people killed as seen in Figure 6.

The severity index of the accidents from Table 4 shows that, the Bauchi Gombe route which has the lowest RCS score also has the highest fatality rate of 0.76 killed per crash. The severity index for the number of people injured per crash shows the Yobe route has the highest rate of 4.95 people injured per crash. In both cases, the Jos route accounts for the lowest rate of those killed and injured per crash even though it has a higher traffic volume than the other two routes.

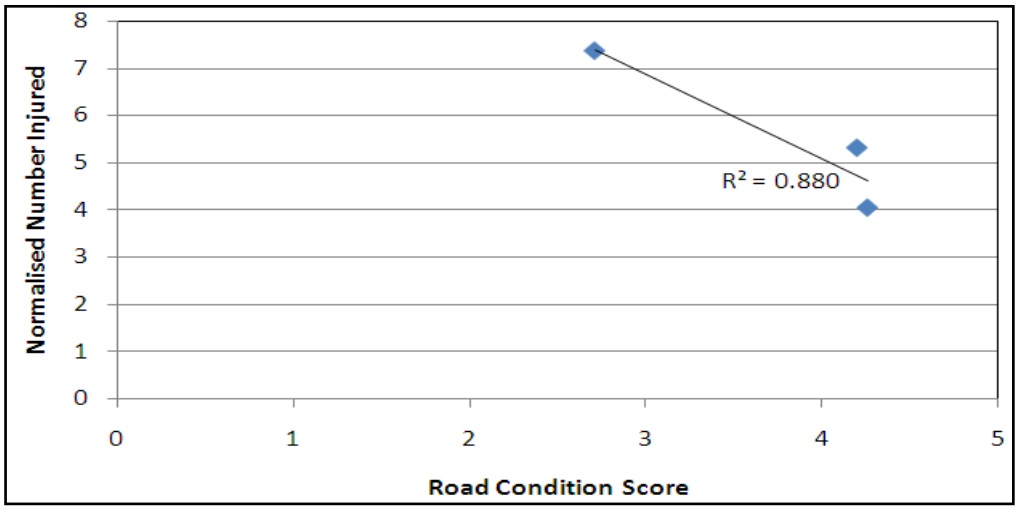

Figure 5- Relationship between Number of people Injured and RCS

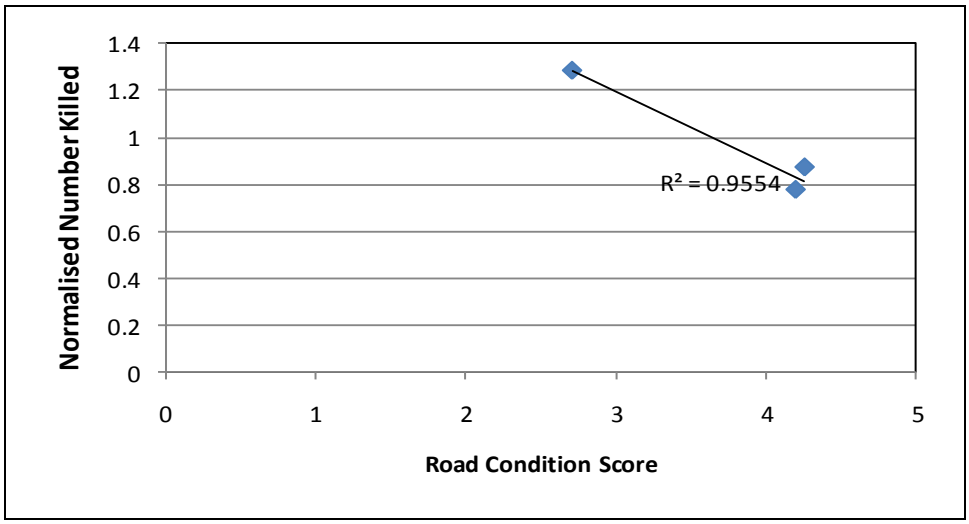

Figure 6 - Relationship between Number of people killedand RCS

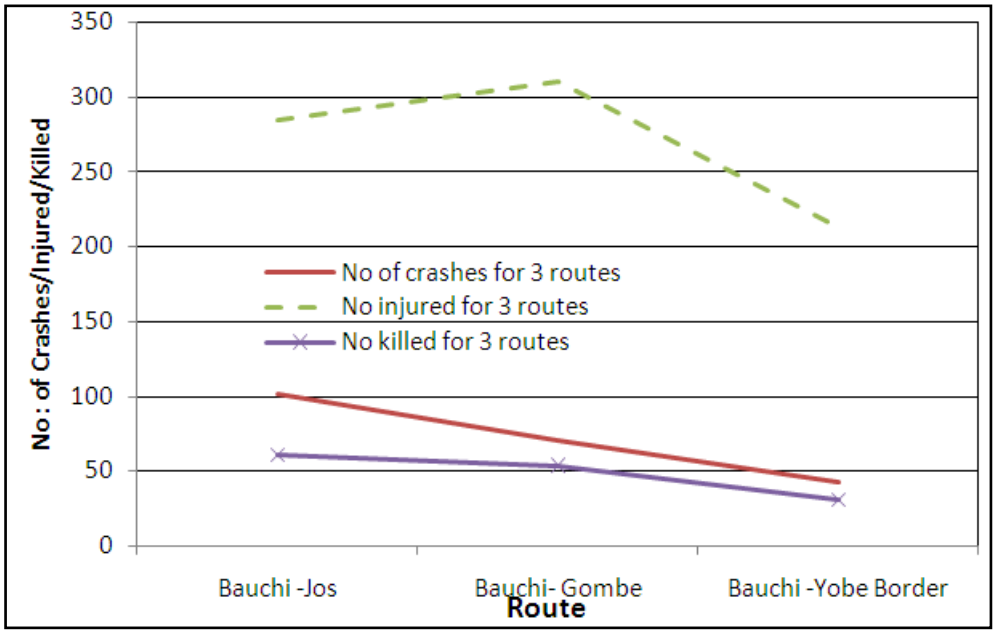

Figure 7 - Variation of Number: of Crashes/Injured/Killed among the three routes

IV. Conclusions

1. The results of the study have shown that there is astatistically significant effect of pavement condition on traffic safety as a whole when the ADT is taken into account.
2. Design considerations like horizontal and vertical curvatures, number towns/villages/intersections on major routes have significant impact on traffic safety.
3. Most of the accidents are near vertical and horizontal curves, security check points, towns and villages, as well as intersections.
4. The severity index from the number of crashes shows that the highest fatality rate is 0.76 (Bauchi - Gombe route) while the lowest rate of 0.60 (Bauchi - Jos route) people killed per crash is rather alarming.
5. The severity index from the number of crashes shows that the highest injury rate is 4.95 (Bauchi - Yobe Border route) while the lowest rate is 2.78 (Bauchi - Jos route) people injured per crash.

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Appendix I

Bauchi –Jos- Road condition and traffic crashes

Month	Accident			Road Condition	Location
	No of cases	Injured	Killed		
January	12	17	11	First 90km BAU- JOS :Good -, Next 24 km Fair-	KM0,1,2,Panshanu,magama[2], Narabi,Rinji[2],M.Bkt, R. Zym.
February	18	24	16	" "	km-1.5[2],Zaranda, Buzaye, Toro[3],Magama[6],Badikko, Narabi, Panshanu[3]
March	9	25	2	" "	megastation, Galoji F. S, Toro[3],Panshanu[2]
April	14	30	6	" "	Buzaye,Tahsan Kaji,km-0,3[2],4,R. Zym, Panshanu[2], Toro[3],Magama, M. Bkt.
May	11	66	3	" "	Wuntin Dada, Zaranda, panshanu[3], R. Zym,Nabordo, Magama,Toro[2], Babale
June	5	18	3	" "	Km33- (Dogul), M Bkt., Panshanu, R. Zym., T Fln.
July	6	33	7	" "	Zull , Buzaye, Panshanu[2], Toro[2]
August	4	7	1	" "	Buzaye, Dunagal, Km 0, 1
September	3	4	1	" "	Buzaye, km- 0.5, Zaranda
October	10	38	6	" "	Km-0, 2, Zaranda,Narabi, Panshanu, Zanga Zanga, Nabordo,Babale
November	5	9	3	" "	Km-1,2, Gada Biyu, Panshanu, Rinji
December	5	13	2	" "	Wuntin Dada,Narabi[2], Panshanu, Rinji
Total	102	284	61		

Appendix II

Bauchi –Yobe Border- Road condition and traffic crashes

Month	Accident			Road Condition	Location
	No of cases	Injured	Killed		
January	8	23	4	Good - 137km, Fair- 47km	km-140[2],km-110[2],km-100, km- 98,
February	5	13	12	Good - 137km, Fair- 47km	Km-110[3],111,Konkyel
March	7	47	7	Good - 137km, Fair- 47km	km20,25,105,112,135,
April	9	29	3	Good - 137km, Fair- 47km	Turum, Km-3,141,106,110, 85, Opp GSS, Nahuta,
May	4	20	1	Good - 137km, Fair- 47km	km- 0, 3, 5, 6
June	5	24	1	Good - 137km, Fair- 47km	km-100, 62, 111, 208, 136
July	7	16	8	Good - 137km, Fair- 47km	km-116, 101, 58, 118, Lago, 90, 88.
August	3	14	6	Good - 137km, Fair- 47km	Kili, Soro, Turum
September	3	13	-	Good - 137km, Fair- 47km	Km-111, 101, 126
October	7	55	3	Good - 137km, Fair- 47km	km-0,118,102, 91, 114,58, Turum,
November	5	8	1	Good - 137km, Fair- 47km	Km-10, 111, 114 Turum,Nahuta,
December	8	48	8	Good - 137km, Fair- 47km	km-0,123, 86, 69,72,83, 78, 112,
Total	71	310	54		

Appendix III

Bauchi –Gombe - Road condition and traffic crashes

Month	Accident			Road Condition	Location
	No of cases	Injured	Killed		
January	4	1	6	Fair - 90km, Poor- 26km	Bagurja Bridge ,Gen Hosp. Alkaleri,Tashan maidawa, ALK - BAU
February	4	9	-	Fair - 90km, Poor- 26km	Bagurja Bridge ,Gen Hosp. Alkaleri,Tashan Maidawa,ALK - BAU
March	4	5	-	Fair - 90km, Poor- 26km	12km, 8km, frm ALK - BAU
April	5	19	2	Fair - 90km, Poor- 26km	Dungulbi, Inkel railway,12km (kurwala), 2km,1km frm ALK - BAU
May	2	4	-	Fair - 90km, Poor- 26km	km- 14(Arawa), km18 frm ALK -BAU
June	2	23	3	Fair - 90km, Poor- 26km	km- 4, km18 frmALK- GME
July	1	12	-	Fair - 90km, Poor- 26km	Natsira
August	2	5	1	Fair - 90km, Poor- 26km	Bagurja , Arawa
September	4	27	2	Fair - 90km, Poor- 26km	Shalhuri,km 2, 3 ALK - BAU,
October	4	23	5	Fair - 90km, Poor- 26km	Jalgalwa, Arawa, Kurwala,km-44 ALK-GME
November	1	6	-	Fair - 90km, Poor- 26km	Km-8 Alk-GME
December	10	79	12	Fair - 90km, Poor- 26km	kalajanga, Tashan Maidawa,Wuroduwa, Sabon Gwaram, Kurwala, km 18 ALK-GME[2],Tsohon Gwaram, Lakkau, Tahsan Turmi
Total	43	213	31		