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EVALUATING THE EFFECT OF NIGERIA ROAD SAFETY STRATEGY ON ROAD TRAFFIC CRASHES IN THE SIX GEO-POLITICAL ZONES USING 3^k FACTORIAL DESIGN

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ABSTRACT

Road Traffic Crashes (RTCs) has become a major challenge and threat to human health and safety. This research was conducted to investigate the effect of Nigeria Road Safety Strategy (NRSS) on RTCs in the six geo-political zones of the country. The dataset used was obtained from the annual records of Federal Road Safety Commission (FRSC) over a five year period (2016 – 2020).The dataset was subjected to Bartlett's test of Homogeneity assumption which was not violated. Duncan Multiple Range Test was carried out to evaluate the differences in the groups. Three levels of road traffic crashes (no of cases, total casualties, and number of people involved) in the two regions of the Northern (North-Central, North-East and North-West) and Southern (South-West, South - South and South - East) Nigeria with six geo-political zones were modeled by linear regression analysis, and further subjected to 3^2 Factorial Designs with Analysis of Variance (ANOVA), using R-statistical package. Results of the study shows that total cases and the corresponding number of people involved in RTCs in the two regions are significant. 97% and 96% of the total variations in RTCs were explained by the variations in geo-political zones in both regions respectively. This affirms the fact that the models for the two regions were different with the rate of RTCs higher in the northern region than in the southern region.

Keywords: Factorial design, Interaction effect, Main effect, ANOVA, Replication

INTRODUCTION

Road traffic crash has been proved to be a significant reason of violent deaths in Nigeria after Boko Haram insurgency and the recent trend of banditry. Road traffic crashes have been reported to be the third-leading cause of overall fatalities in Nigeria as reported by the Federal Road Safety Commission (FRSC) in its 2018 annual report. FRSC also stated in its 2016 bulletin that, over 4,000 lives and estimated United States $8billion were lost through road traffic crashes. In order to improve the current road and driving situation in Nigeria, the Federal Road Safety Corp, some Non-Governmental Organizations (NGOs) such as: Arrive Alive Road Safety Initiative (AARSI), Road Safety Officers' Wives Association (RSOWA); Private Donors such as United Bank of Africa (UBA), Shell plc.**;** representatives of the Global Road Safety Partnership (GRSP) collaborate under the Nigerian Road Safety Partnership (NRSP) to provide a joint platform to promote, support and coordinate data driven programs and projects in support of the Nigerian Government Road Safety action plan. Some of these programmes include: Motor Vehicle Administration (MVA) Department of the FRSC created in 1992, Lagos State Traffic Management Authority (LASTMA) established in 2000, Lagos State Motor Vehicle Administration Agency (MVAA), established in 2007.

In an attempt to reduce the growing menace of unchecked and preventable consequences of road traffic accident, the Federal Government of Nigeria put in place some safety measures among which the institutionalization of the strategic plan called the National Road Safety Strategy (NRSS). The NRSS came up with a vision to have a country where road traffic crash results in no death, and a goal of reducing road traffic crash fatalities by 35% by the year 2018. The main aim of this research is to use **3^k** factorial design to model the effectiveness of NRSS on Road Traffic Crashes in Nigeria with specific objectives to: Investigate whether or not the NRSS actually have any effect on road traffic accident in the country regardless of zones. Determine the effect of human population on Road Traffic Crashes in the country. Model the number of Road Traffic Crashes (RTCs) for adequate description of the various observations in the data of the number of RTC.

Ayamah and Darwah (2015), in an investigation carried out on "the effect of NRSS II on the reduction of Road Traffic Accidents (RTAs) in Ashanti region of Ghana", used two-factor factorial design with mixed factors for a five-year period of the second NRSS in the country using manual analysis and MINITAB computer software program. The researcher came out with a conclusion that the campaign on NRSS II actually helped in the reduction of the seriousness of RTAs within the region.

Olagunju (2018), while evaluating the implementation of the Nigeria Road Safety Strategy (NRSS) and Road Traffic Crashes (RTCs) discovered that the overall accomplishment level of NRSS was about 57%, an indication that NRSS has not been substantially implemented as at the time of the research. The author attributed this to the fact that the implementation of NRSS has just been carried out for about a year claiming that the Strategy was approved in February 2017 and that the implementation Committee was constituted in August, 2017 after the approval. The author used the combination of both primary and secondary datasets; questionnaires were distributed to stakeholders and datasets from existing record of FRSC were used for comparison with simple percentage for analysis. It is of note that the author based his conclusion on a year/period of implementation of NRSS whereas this study examined the last five years' datasets to ascertain the level of accomplishment of the NRSS.

Osowole et al., (2019), in their work used various statistical models such as the Negative Binomial Regression (NBR) model to estimate, with landmark confidence, the apex cause(s) of the RTC in Nigeria. In their investigations, it was observed that a gross reduction in the estimates of the assessment criteria for the NBR model is an indication of its better performance. Moreover, the NBR considered showed that all the seven input variables were statistically significant. Over-speeding and sign light violation were the most likely variables inducing road traffic accidents followed by route violation, loss of control, break failure, poor weather and fatigue in that order. The NBR model on which the seven-point factors are all statistically significant are more realistic and therefore, provides future research opportunity for effectiveness in the implementation of Road Safety Management. The modeling of road traffic fatalities is one of the focus areas of this study. However, modeling with factorial design is a necessity when the possibility of interaction among factors of interest exists. This study thereby concentrated on the consequences of an institutionalized scheme -NRSS on the fatalities which occur on road.

Onakomaiya (1991) as cited by Gbadamosi, 1997, sought to find reasons why road traffic accidents had continued to be on the increase and concluded that "safety has been the most neglected aspect of road transportation in Nigeria", this situation that can be blamed on the failure of the past governments and decision makers to appreciate the magnitude of the problem and attendant costs of road traffic accidents to the national economy.

Enekelekele & Etuk (2019) strived to institute a model of best fit for the Road Traffic Accidents (RTAs) causative factors in Nigeria. The authors considered the use of Poisson Regression, Poisson Generalized Regression, Negative Binomial Regression and Generalized Negative Binomial Regression for the occurrence of road traffic crashes in Nigeria. The Poisson Regression model reportedly, failed to capture over-dispersion, an unusual data interpretation variation on RTAs contributory factor. Fortunately, other forms of Poisson Regression models such as the Negative Binomial Regression and Generalized Negative Binomial Regression were also used in the estimation and all factors of consideration were significant. The authors noted that the Negative Binomial Generalized Regression Model contains the least Akaike Information Criterion (AIC) based on the selections of the overall best-fitted model.

Zhong et al., (2011), as cited by Ojo et al (2014), Dauran et al., (2020) also shared similar opinions. Using a 3^k factorial design, which is what this study focused on, would expose, with highest level of precision, the effectiveness of the factors of consideration. A critical review of the studies shows that majority of the scholars concentrated on modeling the causative factors of traffic crash datasets using either Poisson Regression Model, Negative Binomial Regression (NBR), Generalized Negative Binomial Regression (GNBR), Artificial Neural Network (ANN) Model or Simple Percentage Comparison among others. Thus, this study aimed on determining the extent to which the execution of the institutionalized scheme has been of help in the reduction rate of road traffic fatalities. The study was carried out using 3^2 Factorial Design which will not only model the casualty factors but also find the interactions, if any, and determine the level of such interactions. The study was restricted to investigating the extent to which NRSS has influenced Road Traffic Crashes (RTCs) in Nigeria, by obtaining RTC datasets from the annual records of Federal Road Safety Corps of Nigeria with specific reference to the period 2016 - 2020. Interest was concentrated on the six (6) geo-political zones in Nigeria.

MATERIALS AND METHOD

A $\mathbf{3^2}$ factorial design deals with a factorial arrangement with 2 factors: **Geo-political Zones** serving as the row factor and the **Road Traffic Crashes** serving as the column factor with each at three levels (Montgomery, 2001). Three Geo-political zones were used to represent the levels for the row factor while, number of cases, total casualties, and number of people involved were used to represent the levels for road traffic crashes. Data from the existing records of FRSC and other relevant agencies were obtained for the last five (5) years, 2016 - 2020 which serve as the experimental units. Computer software, R-programming language was used to analyze the data.

Bartlett's Statistics for Testing Homogeneity Assumption

Homogeneity assumption was tested using Bartlett's Test. The test statistic of Bartlett's can be computed using the following formulae:

$$K^2 = \frac{1}{c}\left[df_T \, log_e MSE - \sum_{i=1}^{k} df_i log_e S_i^2\right] \sim X_{k-1,\alpha}^2 \qquad (1)$$

$$MSE = \frac{1}{df_T}\left[\sum_{i=1}^{k} df_i \, S_i^2\right]$$

$$c = 1 + \frac{1}{3(k-1)}\left\{\sum_{i=1}^{k} \frac{1}{df_i} - \frac{1}{df_T}\right\}$$

Decision Rule: Reject if K^2 is greater than chi-squared calculated. Otherwise, accept.

Shapiro-Wilk W Test for Normality Assumption

Normality assumption can be conducted on any data set, before Analysis of Variance so as to ascertain that such data comes from normal distribution. Shapiro-Wilk test was used because of its ability to sustain in parametric situations. Shapiro-Wilk statistical test was further used to test for departure from exponential distribution. The test statistic is stated as follows:

$$\boldsymbol{W} = \frac{\boldsymbol{n}}{\boldsymbol{n-1}}\left\{\frac{[\bar{x} - \boldsymbol{x}_{(1)}]^2}{\sum_{i=1}^{n}[\boldsymbol{x}_{(i)} - \bar{x}]^2}\right\},$$

where n = ordered sample values (2)

R-statistical package was employed to ease the calculations and to obtain all relevant estimates of the model. The probability values were compared with the value of the type I error for decision with a view to making valid and reasonable conclusion. The Analysis of Variance models with and without interaction that were used in this study is stated as follows:

$$y_{ij} = \mu + \alpha_j + \beta_i(\alpha\beta)_{ij} + \rho_{ij} \qquad (3)$$

$$y_{ij} = \mu + \alpha_j + \beta_i + \rho_{ij} \qquad (4)$$

Post-Hoc Analysis

Post-Hoc range tests and Pair-Wise comparisons were used to determine which means differ. The test statistic for Duncan Multiple Range Test is stated as

$$R_p = D_{p,dfe;\alpha}\sqrt{\frac{MSE}{\bar{r}}}:$$

Three-level full factorial designs

The three-level design is written as a 3^k factorial design. It means that *k* factors are considered, each at 3 levels. These are (usually) referred to as low, intermediate and high levels and numerically expressed as 0, 1, and 2 respectively. This research used a $\mathbf{3^2}$ factorial design (2 factors at 3 levels each) which has a 3 X 3 different single experiments. The mathematical model for this design is given as:

$$Y_{ijv} = \mu + A_i + B_j + (AB)_{i+j} + (AB)_{i+2j}^2 + E_{ijv} \qquad (5)$$

$(AB)_{i+j} + (AB)^2_{i+2j} = (AB)_{i,j}$ i = (0, 1, 2);
j = (0, 1, 2); v = (1, . . . , r)

$\sum_{i=0}^{2} A_i = \sum_{j=0}^{2} B_j = \sum_{i=0}^{2} AB_r = \sum_{j=0}^{2} AB_s^2 = 0;$

$r = (i+j)_3$, $s = (i+2j)_3$

r is the number of observations obtained for each treatment combinations.
The variation between the 9 single treatments in the experiment has a total of 8 degree of freedom. If **r** replicated observations for each of the treatment combinations are obtained, the expressions for the main and interaction effect can be expressed as:

$$\hat{A}_i = \frac{y_{i.}}{r.3^{2-1}} - \frac{y_{..}}{r.3^2} \qquad y_i = \sum_{i=0}^{a} y_{ij}$$
$$y_{..} = \sum_{i=0}^{a}\sum_{j=0}^{b} y_{ij} \qquad (6)$$

$$SSA = r.3^{2-1}\sum_{i=0}^{2} \hat{A}_i^2 \qquad (7)$$

$$\hat{B}_j = \frac{y_{.j}}{r.3^{2-1}} - \frac{y_{..}}{r.3^2} \qquad y_j = \sum_{j=0}^{b} y_{ij} \qquad (8)$$

$$SSB = r.3^{2-1}\sum_{j=0}^{2} \hat{B}_j^2 \qquad (9)$$

$$\widehat{AB}_0 = \frac{y_{00}+y_{21}+y_{12}}{r.3^{2-1}} - \frac{y_{..}}{r.3^2} \qquad (10)$$

$$\widehat{AB}_1 = \frac{y_{10}+y_{01}+y_{22}}{r.3^{2-1}} - \frac{y_{..}}{r.3^2} \qquad (11)$$

$$\widehat{AB}_2 = \frac{y_{20}+y_{11}+y_{02}}{r.3^{2-1}} - \frac{y_{..}}{r.3^2} \qquad (12)$$

$$SSAB = r.3(\widehat{AB}_0^2 + \widehat{AB}_1^2 + \widehat{AB}_2^2) \qquad (13)$$

$$\widehat{AB}_0^2 = \frac{y_{00}+y_{11}+y_{22}}{r.3^{2-1}} - \frac{y_{..}}{r.3^2} \qquad (14)$$

$$\widehat{AB}_1^2 = \frac{y_{10}+y_{21}+y_{02}}{r.3^{2-1}} - \frac{y_{..}}{r.3^2} \qquad (15)$$

$$\widehat{AB}_2^2 = \frac{y_{20}+y_{01}+y_{12}}{r.3^{2-1}} - \frac{y_{..}}{r.3^2} \qquad (16)$$

$$SSAB^2 = r.3\left(\left(\widehat{AB}_0^2\right)^2 + \left(\widehat{AB}_1^2\right)^2 + \left(\widehat{AB}_2^2\right)^2\right) \qquad (17)$$

$$SST = (SSA + SSB + SSAB + SSAB^2 + SS_{RESIDUAL}) \qquad (18)$$

The corresponding Mean Sum of Squares and F- Statistics are obtained as follows:

$$MS\ (EFFECT) = \frac{SS(EFFECT)}{Degree\ of\ Freedom}$$ and,

$$F_{EFFECT} = \frac{MS(EFFECT)}{MS(RESIDUAL)}$$

RESULTS AND DISCUSSION

The linear regression model using R resource depicts that total cases and number of people involved in RTC(s) are significant in the Northern geopolitical zones as evidenced in table1 above.

Table 1: Regression Analysis for the Northern Geopolitical Zones

Variables	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2764.4	396.9	6.964	3.66e-08 ***
Total cases	13169.6	561.3	23.461	< 2e-16 ***
People involved	5655.4	561.3	10.075	5.09e-12 ***
factor(zone) ne	-1742.4	561.3	-3.104	0.00371
factor(zone)nw	-741	561.3	-1.32	0.19516
Casespi:factor(zone) NE	-7247.2	793.9	-9.129	6.69e-11 ***
Casestc:factor(zone) NE	-2131.4	793.9	-2.685	0.0109
Casespi:factor(zone)NW	-1161	793.9	-1.462	0.15229
Casestc:factor(zone)NW	1369	793.9	1.724	0.0932
Multiple R-squared	0.9748			
Adjusted R-squared	0.9692			
Residual standard error	0. 6312			
degrees of freedom	36			
F-statistic	174.2			
p-value	< 2.2e-16			

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Keys: NE = North-East; NW= North-West

$$Y = 2764.4 + 13169.6X_1 + 5655X_2 - 1742.4X_3 – 741X_4 – 7247.2X_5 – 2131.4X_6 – 1161X_7 +1369X_8 + 0.6312$$

The coefficient of determination (R^2) is as high as 0.9748 and produced a standard error of 0.6312 indicating that about 97% of the total variation in road traffic crashes in the northern region is explainable by the variations in geo-political zones while only about 3% could be explained by other variables outside the model. The low standard error indicates the efficiency of the model. The F-statistic value (174.2) shows that the overall model is statistically significant at 1 % and 5 % levels of significance. This indicates that all the explanatory variables simultaneously explain the variations in the model. Result showed that total cases and number of people involved in road traffic crashes in the North-West geo-political zone are not significant due to their corresponding p-values greater than 0.05.

Table 2: Analysis of Variance (ANOVA) for Northern Geopolitical Zones

Source of Variation	Df	SS	MS	F value	Pr(>F)
Cases	2	806513947	403256974	511.89	< 2e-16 ***
Factor(zone)	2	208843257	104421629	132.55	< 2e-16 ***

Cases:factor(zone)	4	82688976	26.24	30.43	3.08e-10 ***
Residuals	36	28360169	787782		

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

There is main effect of total cases (F(2, 36) = 511.89; P<0.01) and number of people involved (F(2,36) = 132.55; p<0.01) that is, there is difference between at least 2 of the means, as well as an interaction between them(F(4, 36) = 30.43; p < 0.01) which shows that all variables are statistically significant at 95 % confidence interval.

Bartlett Test of Homogeneity of Variances`
Bartlett's K-squared = 40.855, df = 2, p-value = 1.344e-09
Bartlett test of homogeneity of variances reveals that there is difference in the population variances therefore it can statistically be concluded that the population variances are not all the same
(Heteroscedasticity).

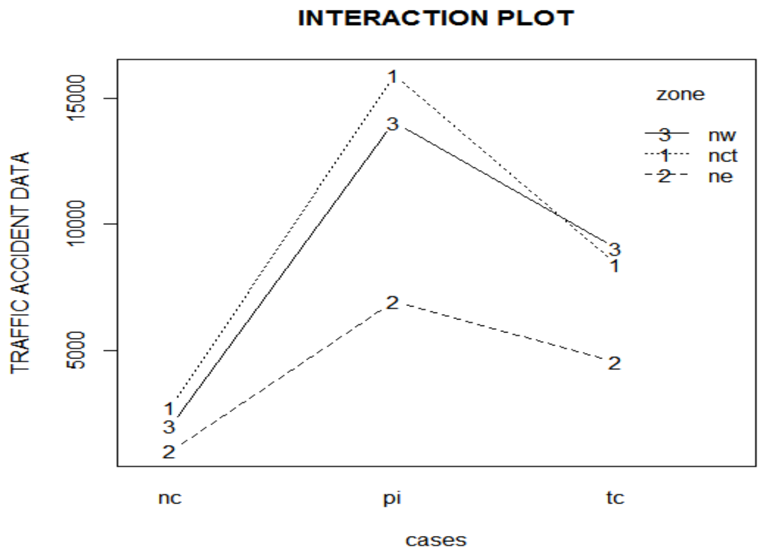

Figure 1: Interaction Plot of RTC in the Northern Geopolitical zones

Table 3: Posthoc Test of interaction among variables in Northern geo-political zones

```
$cases
             diff       lwr       upr p adj
pi-nc 10366.867  9574.682 11159.051     0
tc-nc  5401.267  4609.082  6193.451     0
tc-pi -4965.600 -5757.785 -4173.415     0

$`factor(zone)`
              diff       lwr        upr     p adj
ne-nct -4868.6000 -5660.785 -4076.4152 0.0000000
nw-nct  -671.6667 -1463.851   120.5182 0.1099376
nw-ne   4196.9333  3404.749  4989.1182 0.0000000
```

There is difference between the main effects of the two groups. This is an indication that each group mean is significantly different from the other group

Table 4: Regression Analysis for the Southern Geopolitical Zone

Variables	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1055.8	412.8	2.557	0.014902
Total cases	2707.6	583.8	4.638	4.52e-05 ***
People involved	7426	583.8	12.719	6.98e-15 ***
Factor(zone) SS	-396.8	583.8	-0.68	0.501076
Factor(zone) SW	911.6	583.8	1.561	0.127178
Cases pi: factor(zone) SS	-3312.2	825.7	-4.012	0.000291 ***
Cases tc: factor(zone) SS	-1100.8	825.7	-1.333	0.190833
Cases pi: factor(zone) SW	5584.4	825.7	6.764	6.72e-08 ***

Cases tc: factor(zone) SW	2089.6	825.7	2.531	0.015893 *
Multiple R-squared	0.9647			
Adjusted R-squared	0.9568			
Residual standard error	0.9231			
Degrees of freedom	36			
F-statistic	122.8			
p-value	< 2.2e-16			

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Keys: SS = South-South, SW = South-West, SE = South-East, tc =total cases, pi = people involved

$$Y = 1055.8 + 2702.6X_1 + 7426X_2 - 396.8X_3 + 911.6X_4 - 3312.2X_5 - 1100.8X_6 + 5584.4X_7 + 2089.6X_8 + 0.9231$$

Table 4 above shows that total casualties and number of people involved in road traffic crashes, in the Southern region, are statistically significant. This fact was further reinforced as evident by coefficient of determination (R^2) estimated at 0.9647) which shows that the referred model generates high coefficient of determination with standard error of 0.9231. This is an indication that about 96% of the total variation in RTC in the Southern region is explainable by variations in geo-political zones that is, RTC data varies largely by geo-political zones while 4% could be explained by other factors not used in the model. The F-Statistic value (122.8) shows that the overall model is statistically significant at 99% and 95% confidence levels, this is because the p-value is lesser than 0.05 at 1 % and 5 % respectively. This means that all the explanatory variables simultaneously explain the variations in the model. The p-values for South-south zone (0.501076), South-west zone (0.127178), and number of people involved in RTC in the South-west zone (0.190833) are all greater than 0.05 which indicates that they are statistically insignificant in the explanation of the dependent variable.

Table 5: Analysis of Variance (ANOVA) For Southern Region

Source of Variation	Df	SS	MS	F value	Pr(>F)
cases	2	513379969	256689985	301.22	< 2e-16 ***
factor(zone)	2	220073199	110036599	129.13	< 2e-16 ***
cases: factor(zone)	4	103737311	25934328	30.43	4.2e-11 ***
Residuals	36	30677618	852156		
Total	44				

Significant. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 5 reveals that there is main effect of total cases ($F(2, 36) = 301.22$; $P<0.01$) and people involved ($F(2,36) = 129.13$; $p<0.01$) that is, difference between at least 2 of the means, as well as an interaction between them($F(4, 36) = 30.43$; $p < 0.01$) which shows that all variables are statistically significant at 95 % confidence interval.

Bartlett's test of Homogeneity of Variances

Bartlett's K-squared = 30.343, df = 2, p-value = 2.577e-07

Bartlett's test Homogeneity of variances reveals that there are differences in the population variances, and it can be statistically concluded that the population variances are not all the same (heteroscedasticity).

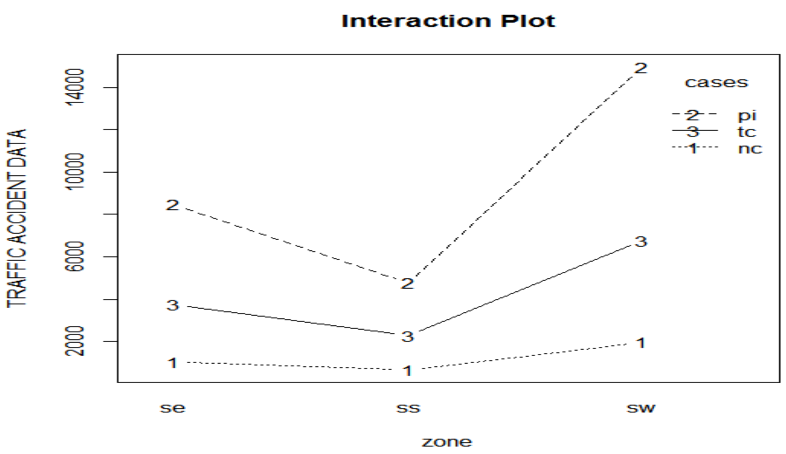

Figure 2: Interaction Plot of RTC for Southern Zones

Table 6: Post hoc test of interactions among RTC data in the Southern Geo-political zones

$cases

	diff	lwr	upr	p adj
pi-nc	8183.4	7359.484	9007.316	0
tc-nc	3037.2	2213.284	3861.116	0
tc-pi	-5146.2	-5970.116	-4322.284	0

$`factor(zone)`

	diff	lwr	upr	p adj
ss-se	-1867.8	-2691.716	-1043.884	8.4e-06
sw-se	3469.6	2645.684	4293.516	0.0e+00
sw-ss	5337.4	4513.484	6161.316	0.0e+00

From the interaction shown in Figure 2, there seems to be differences between total cases and number of people involved in road traffic crash. There seems to be a main effect of geo-political zone results in higher record of traffic accident in Southern region. There does not seems to be any effect of people involved. There seems to be no difference between the groups overall. Table 6, shows that there are differences between the main effects of the groups, which reveal that each group mean is significantly different from each other group. The hypotheses set in this study were tested using Analysis of Variance (ANOVA). Findings indicate that high percentages of variations in RTCs in both regions were explained by variations in geopolitical zones (97% for Northern and 96% for Southern region). All explanatory variables simultaneously explain the variations in the models. Also, human population affects the rate of RTCs to a greater extent, high record of traffic crashes were obtained in areas of high population densities. The F-Statistic for Northern zones (174.2) is greater than that of the Southern zones (122.5).

CONCLUSION

3^k factorial design was successfully applied for road traffic crashes, the result shows that total cases and number of people involved in road traffic crashes are significant in both Northern geopolitical zones and Southern geopolitical zones are significant. The model was determined and it was found to be 97% and 96% for both Northern and Southern geopolitical region respectively. The interaction between number of cases and the people involved are also significant at 5%. By and by, human population also has a great impact on the number of road traffic crashes recorded during the period as it was observed that the rate of road traffic crashes were higher in the Northern region than in the Southern region. The result of the Turkey-test shows that some geo-political zones in the North and South respectively road traffic crashes depend largely on zones while the comparison of the Least Square Models (LSMs) for the Northern and Southern geopolitical zones shows that the two regions were affected interchangeably. The study, therefore, concluded that the implementation of Nigeria Road Safety Strategy has positive influence in the reduction of Road Traffic Crashes in the two regions of the country. Future researches need to consider vehicular population and road network.

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