RESEARCH IN LOGISTICS & PRODUCTION

MODELLING FATALITIES OF ROAD ACCIDENTS IN NIGERIA

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Abstract Preponderance of road accidents is one of the major causes of death in Nigeria, but the fatality of these accidents is unknown. In this study, data on casualties of the road accidents in Nigeria are collated, statistically analysed and modelled for predicting fatality of the accidents. The strategies of minimising rise in fatality of road accidents were proposed. The results obtained showed that the fatalities of the road accidents have polynomial relationships with the population of the road users, or time. The highest annual accident fatality probability of 0.17 was obtained over the total population of the road users. The result from combined modelling of traffic population and time showed that the accident fatalities will rise in future unless roads and drivers are well cultured. The findings would be useful for demographers, safety and health workers in their planning.

Paper type: Research Paper

Published online: 30 July 2012
Vol. 2, No. 3, pp. 259-271

ISSN 2083-4942 (Print)
ISSN 2083-4950 (Online)

Keywords: *Traffic, population, road accidents, fatalities, regression*

1. INTRODUCTION

Deaths from road traffic accidents in Nigeria were ranked among the highest in the world (Adeniyi, 1985). Accidents can occur at any traffic speed, but fatality of these accidents differs, depending on the speed at which they occur. The contribution of death resulting from road traffic accident to total death rose from 38.9% in 1967 to 58% in 1974 (Adeniyi, 1985). Vehicular crashes have gotten to an unbearable level that road accidents must be attacked with all seriousness in order to minimize its fatality. In a bid to combat road accident in Nigeria, many efforts have been made by the government since 1913 with the establishment of *Federal Road Safety Corps* (FRSC) (Adeniyi, 1985). FRSC was charged with the responsibility of maintaining safety on Nigeria roads.

Globally, highway safety institutes were established to find ways of preventing motor vehicle crashes (FHWA, 2006). Findings have shown that human, vehicular, and environmental factors were the major causes of accidents on roads (Flaherty, 1974). Many vehicular institutes were equipped with a state-of-the-art crash test facility (ITE, 1999); (MTC, 2005). Data on types of vehicles mostly involved in crashes are available in literature (pubhealth, 2010); (Forthepeople, 2010). Drivers' nonchalant attitude on roads has been identified as the major cause of accidents in some quarters (JRA, 1969); (McMahon, Zegeer, Duncan, Knoblauch, Stewart & Khattak, 2005); (Hawkey, Henson, Hulse & Brindle, 1992).). Researchers have developed mechanical devices for reducing the consequences of vehicular crashes (MTC, 2005); (Forthepeople, 2010); (PEDSAFE, 2004); (AASHTO, 2001); (ADA, 2006). Vehicular factors such as crash avoidance and crashworthiness; and en-vironmental factors which include roadway designs were useful eliminators of road crashes (Forthepeople, 2010); (Safety 2010); (ITE, 1999); (FHWA, 2006); (AASHTO, 2001). Trial versions of safety systems for tractor, trailers and buses have also been reviewed to include communication by the blinking of red light on the dashboard (MTC, 2005); (USDT, 2000); (McMahon et al, 2005). Traffic crashes avoidance systems were available for use in vehicles (FHWA, 2006); (Nabti & Ridgeway, 2002); (Safety, 2010). The drivers' attention has been kept on the road by audio signals that remind them of such crashes (TDM, 2006); (NCHRP, 2004); (Pegrum, 1972). Generally, smart signs were found to be the most realistic new-age traffic safety devices because they are cheap (Zegeer, Stewart, Huang & Largerwey, 2002); (NCHRP, 2004); (TCDH, 2001). Some trucks contain GPS devices that will inform the driver of danger ahead as the truck enters a region notorious to accidents (Nelson & Allen, 1997); (Uyanga, 2000); (Safety, 2010); (pubhealth, 2010).

Many researchers have carried out some studies on how environmental conditions can cause accident on vehicles. For example, Turner, Sandt, Toole, Benz, & Patten (2004) used polychotomous response models to determine the effect of rainfall on single-vehicle crash severities. Conclusion drawn from this study was that the backward sequential logistic regression model produced the best results for predicting crash severities in rainy weather where rainfall intensity, wind speed, roadway terrain, driver's gender, and safety belt were found to be statistically significant.

Other studies on an intellectualized evaluation model for highway safety countermeasure of at-grade intersection are remarkable in that it proposes the at-grade intersection safety countermeasure system. With CRF (*crash reduction factor*) tools utilization, the effectiveness analysis of highway safety counter-measures was implemented. Based on the results from CRF analysis, the *intelletualized evaluation model* (IEM) for highway safety countermeasure was established (Okpala, 1977); (Onakomaiya, 1985); (Oyefesobi, 1977). The study that measured the criticality of road accidents due to bad road and poor infrastructural facilities is available (Kareem, Oke & Lawal, 2011).

The aforementioned studies covered the areas of vehicular crash severity, safety, and criticality. There are no identified efforts that deal with the issue of accident fatality prediction. In this study a quantitative tool is provided for predicting the fatality of road accidents in Nigeria. Data from the accurate prediction of road accident fatalities would help the demographers, safety and health workers in planning for infrastructural faculties required to maintain good roads, sound safety and healthcares delivery, respectively. The rest of the paper is presented thus: materials and methods are presented in Section 2. Section 3 is the results and discussion, while conclusion is in Section 4. At the end of the paper are the lists of references and biographical notes.

2. MATERIALS AND METHODS

2.1. Data collection and analysis

Data on accident victims were collected through questionnaire administration and oral interviews of the road safety staffers. Some data were retrieved from the document obtained from the head quarters of the *Federal Road Safety commission* (FRSC) in the various States of Nigeria. The data obtained were analyzed statisti-cally based on averages, frequency counts and probability of occurrences. The ana-lysed data were interpreted using regression approach. The nature of the accident data per annum and the outcomes of the analyses of the effects of the accidents are shown in Table 1 based on Nigerian States. Time rate (in mins) per occurence of casualty or fatal case was obtained as the ratio of time (annum, 525600 mins) considered, to the respective total number of occurences.

Table 1 Categories of accidents data per annum for the Nigerian States

State	Fatal Cases	Person Killed	Person Injured	Time/ Killed (mins)	Time/ Injured (mins)	Time/ Casualty (mins)	Time/ fatality (mins)
Abuja	1181	1993	7185	264	73	57	445
Adamawa	1633	3380	8353	156	103	45	322
Abia	1248	1594	3223	330	161	109	422
A/Ibom	2059	241 1	5670	218	91	65	256
Anambra	2060	2876	6717	183	68	55	256
Bayelsa	108	131	446	4012	1155	911	4876
Bauchi	2495	3532	10322	149	93	38	211
Benue	2837	4051	1 2323	130	94	32	186
Borno	1719	2094	6168	251	98	64	306
C/Rivers	2070	3338	7405	158	75	49	254
Delta	3126	4569	10859	115	43	34	168
Ebonyi	183	211	613	2491	1158	638	2878
Edo	3415	4437	13327	119	34	30	154
Ekiti	289	397	1060	1324	779	361	1822
Enugu	1568	2006	4264	262	104	84	336
Gombe	543	795	5130	661	399	89	970
Imo	1622	2209	5856	238	99	65	325
Jigawa	1552	2375	5940	221	185	63	339
Kaduna	3218	4846	9662	109	55	36	164
Kano	6077	7772	17559	68	26	21	87
Katsina	2444	3719	5430	141	89	57	215
Kebbi	357	454	1730	1158	389	241	1475
Kwara	1455	2570	5409	205	128	66	362
Kogi	1391	2827	7676	186	156	50	379
Lagos	9376	11369	31391	46	10	12	56
Nasarawa	873	1 491	3547	353	376	104	603
Niger	3218	5340	11765	80	76	31	164
Ondo	2338	3334	944	143	30	123	225
Ogun	5971	9041	21337	58	26	17	88
Oyo	4181	6031	2968	86	37	58	126
Osun	1386	2300	5555	229	128	67	380
Plateau	2350	4045	11002	130	99	35	224
Rivers	1577	2070	7593	254	69	54	334
Sokoto	1543	2703	6313	195	147	58	341
Taraba	543	688	9141	764	454	53	970
Yobe	881	1433	4383	367	237	90	598
Zamfara	149	236	635	2227	1282	603	3534
Total	79036	114668	278901	18081	8626	4565	24851
Average	2136	3099	7538	489	233	123	672

Table 2 Annual accident victims and population of road users

Year	Person Killed	Person Injured	Population	Total Casualty	Casualty/ fatality
1960	1083	10216	20817891	11299	5
1961	1313	10614	31890354	11927	6
1962	1578	10341	33000138	11919	6
1963	1532	7771	34148543	9303	4
1964	1769	12581	35336912	14350	7
1965	1918	12024	36566656	13942	7
1966	2000	13000	37839156	15000	7
1967	2400	1000	39155958	12400	6
1968	2808	9474	40518586	12282	6
1969	2347	8804	41926337	11150	5
1970	2893	13154	43387749	16047	8
1971	3206	14592	44897643	17798	8
1972	3921	16161	46460081	20082	9
1973	4637	18154	48076891	22691	11
1974	4992	18660	49749967	23652	11
1975	5552	20132	51481266	25684	12
1976	6761	28155	53272881	34916	16
1977	8000	30023	55126708	38023	18
1978	9252	28854	57145118	38106	18
1979	8022	21203	59131288	29225	14
1980	8736	25401	61084542	34220	16
1981	10202	26337	63210285	36539	17
1982	11382	28539	65410002	39921	19
1983	10462	28686	67686271	32328	15
1984	8830	23861	70041755	32691	15
1985	9221	23851	72479206	33074	15
1986	8154	22176	75001482	30330	14
1987	7912	22747	77611534	30659	14
1988	9077	24413	80312415	33490	16
1989	8714	23687	83107248	32401	15
1990	7755	23490	85999420	31204	15
1991	7523	25627	88992000	33150	16
1992	8701	25154	92088111	33855	16
1993	6341	22882	95293251	29224	14
1994	5407	17890	98613440	23297	11
1995	6647	14431	102050991	21078	10
1996	6364	15290	105564166	21658	10
1997	6104	15464	109200353	21568	10
1998	6538	17341	112963496	23876	11
1999	5370	17585	116859503	22955	11
2000	6521	20671	120891747	27198	13

2001	8109	22202	124938081	31261	15
2002	7407	22112	129285926	29515	14
2003	6454	18116	133785076	24568	12
2004	6452	5351	138400661	11803	6
2005	4519	15779	143175484	20298	10

Table 2 gives the nature of accident victims on yearly bases. The accident casualty is the sum of death and injured persons involved in accidents. Fatality is a measure of casulties over average fatal accident cases. Annual increase of the population of the road traffic users was established to be 3.45%. Table 3 shows the results of the probabilistic analysis of total victims. The probability of occurence was estimated as the ratio of frequency of a particular category of casualty to the total frequencies of all categories.

Table 3 Probabilistic analysis of total casualties

Category	Total casualty, Class-interval (x1000)	Mid point	Frequency	Probability
1	8-10	9	1	0.02
2	10-12	11	6	0.13
3	12-14	13	3	0.07
4	14-16	15	2	0.04
5	16-18	17	2	0.04
6	18-20	19	0	0
7	20-22	21	5	0.11
8	22-24	23	4	0.09
9	24-26	25	2	0.04
10	26-28	27	1	0.02
11	28-30	29	3	0.07
12	30-32	31	3	0.07
13	32-34	33	7	0.17
14	34-36	35	2	0.04
15	36-38	37	1	0.02
16	38-40	39	3	0.07

2.2. Mathematical modelling

Linear and nonlinear regression analyses were utilised in determining the appropriate model(s) for accurate prediction of accident fatality (casualty) based on time, Y_r, population of road users, P_o and the combination of both (Y_r, P_o). The regression models considered are: exponential, linear, logarithmic, polynomial, and power. These are expressed by Eqns. 1-5, respectively, where: C_a, is the number of accident casualties per annum; P_o, is the annual population of road users; Y_r, is the year under consideration, and $a, b, \ldots, c,$ are constant parameters of the models.

$$C_a = a\varepsilon^{bP_o} \tag{1}$$

$$C_a = aP_o + bY_r + c \tag{2}$$

$$C_a = a\ln(P_o) + b \tag{3}$$

$$C_a = aP_o^{\,n} + bP_o^{\,n-1} \ldots + c \tag{4}$$

$$C_a = aP_o^{\,b} \tag{5}$$

The appropriate predictive model was searched via the Correlation Coefficient, R, or Coefficient of Determination, R^2 and the one whose value nearest to *(1)* was chosen as accurate. The same process was carried out for predicting the size of casualty at a given time, Y_r, and combination (Y_r, P_o) variants. Fatality $C_{a/f}$ was also modelled in similar manner.

3. RESULTS AND DISCUSSION

3.1. Analyses of the accident data

The results of time rates of accident fatality (casualty) for each of the States in Nigeria are presented in Table 1. The fatality of road accidents is highest in Lagos State, where at least one fatal case of accidents was reported every 56 mins, with his corresponding casualty reports for all cases of accidents at every 12 mins. Bayelsa State recorded the least cases of accident fatality of 4876 mins interval. An average fatality time rate of 672 mins was estimated for the whole country. The results of accident fatality based on average annually accident victims with established annual population increase of 3.45 % (starting from 1960) are presented in Table 2. From this table it can be seen that accident fatality is changing erratically with increase in population. The highest fatality of 19 casualties was recorded in 1982, while the least of 4 casualties occured in 1963. The fatality results based on probability showed that highest casualty frequency counts of seven cases of road accidents were obtained annually with probability of 0.17 (Table 3).

3.2. Modelling analyses

The optimal models obtained for accident casualty and fatality prediction over time and population of road users, using Microsoft Excel[R], are presented in Figures 1-4. These models were chosen as optimal because they have highest coefficient of determination, R^2 among the regression models considered (Table 4). In the four cases, the intensity of accident fatality (casualty) have polynomial relationships with change in population of road (traffic) users, or time. The resulting models confirmed the unstable nature of accident fatality. This may happen as a result of unstable governmental policy as regard road maintenance, drivers' competence, and vehicular road worthiness. The fatality and casualty predictive models in Figures 1 and 3, on varying population of road users, would be useful by demographers in establishing the accurate population through the forecast of the death rates from road traffic accidents. Predictive models in Figures 2 and 4, would also assist the safety and health workers to plan ahead on the facility to be made available for caring the accident victims.

Table 4 Predictive model searching based on R^2

Casualty/ fatality, ($C_a/C_{a/f}$), R^2	**Linear**	**Exponential**	**Logrithmic**	**Power**	**Polynomial**
Y_r	0.2324/ 0.2052	0.3268/ 0.2740	0.4429/ 0.3794	0.5301/ 0.4718	0.8725/ 0.8270
P_o	0.0842/ 0.1013	0.0880/ 0.1525	0.1739/ 0.2171	0.2159/ 0.2904	0.6034/ 0.8027
Y_r, P_o	0.5000/ 0.7100	-	-	-	-

The optimal model for accurate prediction of accident casualty (fatality) with time and population variants is established as,

$$C_a = 1.46x10^{-5} P_o + 258.569 Y_r + 17148.274 \tag{6}$$

Where,

C_a, P_o, and Y_r are as defined before.

The multiple linear regression model in Eqn. (6) has a coefficient of determination (correlation), $R^2 = 0.5, (R = 0.71)$, which indicates that there is a good agreement among the parameters of the model (Aderoba, 1995). The resulting model shows that combined consideration of change in time and population would yield a linear relationship with the number of accident casualties.

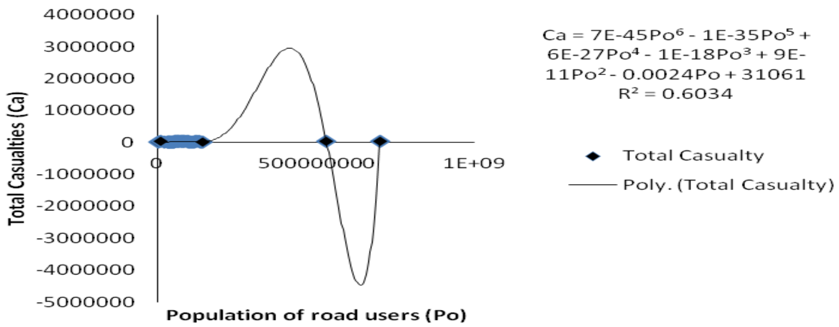

Fig. 1 Optimal model for casualty prediction over population of road users

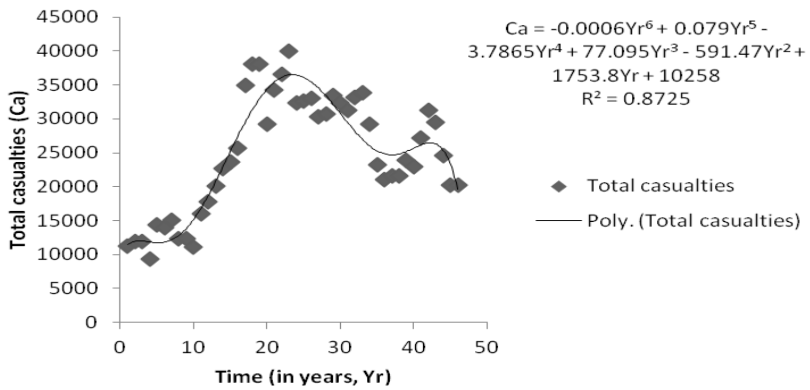

Fig. 2 Optimal model for casualty prediction over years

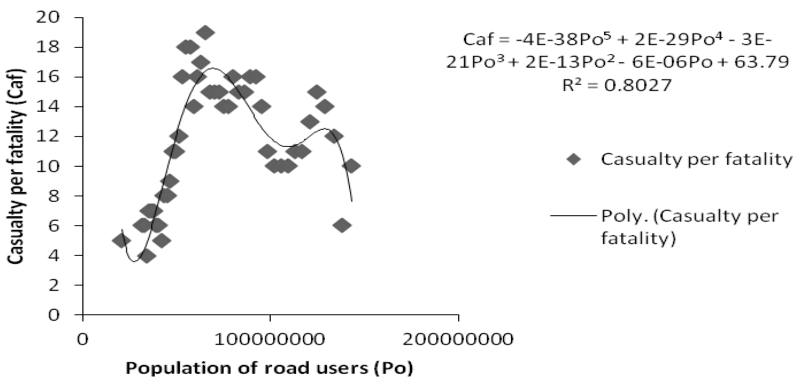

Fig. 3 Optimal model for fatality prediction over population of road users

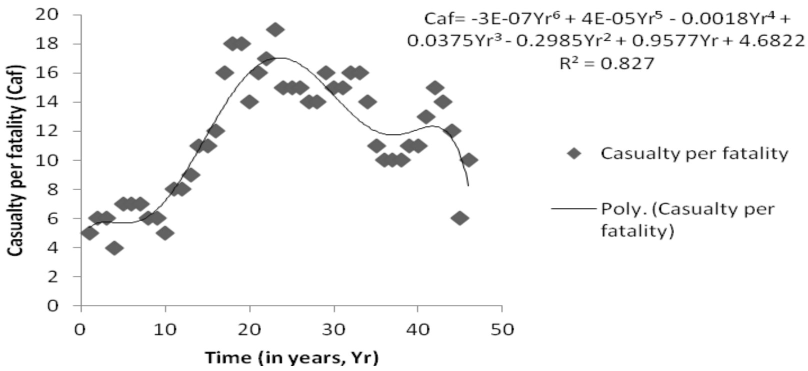

Fig. 4 Optimal model for fatality prediction over years

4. CONCLUSION

The outcomes of the study showed that vehicular accidents on Nigerian roads are highly fatal. It was also shown that the fatality of the accidents varies with road users' population and time of maintaining adequate road infrastructural facilities, driving competency, vehicle structural condition, drivers' attitude, appropriateness of road safety signs, among others. The high probability of road accident fatality in Nigeria was borne out of the fact that many of the existing roads are in deplorable conditions. Installation of good maintenance culture on the highways will reduce the pang of road accidents.

The results have shown clearly that thousands of people lost their life to the road accidents annually, and the lost will be risen in future if care is not taken. The high fatality of road accident has revealed the laxity on the part of the policy makers in the areas of provision of: essential infrastructural facilities; and effective road maintenance programme. Data from the accurate prediction of road accident fatalities would help the demographers, safety and health workers in planning for infrastructural faculties required for maintaining good roads, sound safety and healthcare delivery. It is recommended that attention should be paid to road accident prevention to avoid unplanned expenses through suplementary budgeting for the unexpected rise in accident casualties.

ACKNOWLEDGEMENTS

Authors wish to acknowledge the support given by the management of the Federal University of Technology, Akure, Nigeria in providing facilities used for this study

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BIOGRAPHICAL NOTES

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