Journal of Scientific Approach, **2018, 2, 1-5**
Published Online: October 4, 2018 (http://inscribepublications.com/journal/josa)
http://doi.org/10.26476/josa.2018.02.01.01

Determination of a Better Mathematical Models for Predicting Deaths due to Fire Accident in Taraba state

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Received October 13, 2017; Revised October 31, 2017; Accepted July 19, 2018

Abstract

This research is concerned with the application and comparison of mathematical models for predicting deaths due to fire accident in Taraba State. The reason for this research is because it was observed that whenever fire accident occurs, it claims lives and properties. Data were collected for the period of ten years from 2005 to 2014 from Fire Service Board Jalingo. Taraba State, Nigeria. Various models were applied, such as Poisson distribution, Exponential distribution and Negative Binomial distribution. The aim of the application of these models was to determine the best model for predicting deaths due to fire accident. It was observed that the Poisson distribution result summed to approximately 0.6 with 0.4 deviation from the exact probability of 1. The Exponential distribution summed to approximately 0.9, with 0.1 deviation from the exact probability 1. The Negative Binomial distribution summed to approximately 0.8 with 0.2 deviation from the exact probability 1. The results showed that all the models are appropriate for modeling death due to fire accident. However, exponential distribution seems to be the best model in comparison with Poisson and Negative Binomial distributions in this work.

Keywords: *Accident, Deviation, Probability, Distribution, Modeling*

1. Introduction

Accident is defined as an unexpected event with negative consequences occurring without the intension of the one suffering the consequences. Fire accident is as old as human existence. History has shown that human race has been confronted with numerous and uncountable fire disaster in one way or the other. Fire is a very good servant, but, a very bad master. As long as fire is under our control, it serves a lot of useful purposes for us, but, once it goes out of our control, it can create a lot of destruction. However, despite the presence of fire safety measures, the occurrence of accidents is oftentimes inevitable [1]. The complexity about fire is that the occurrence is most of the time inevitable due to amongst other things the inherent human complexity especially his attitude to handling vital issues [2]. "Fire is the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light and various reaction products. At a certain point in the combustion reaction called the ignition point, flames are produced. The flame is the visible portion of fire" [3].

"Fire accident does not occur most frequently but whenever it occurs, it creates harms to both lives and properties. Fire is one of humankind's oldest discoveries. It is also one of our biggest threats. A fire can destroy in a matter of minutes a home or business that has taken decades to establish [4]. Fire disaster could render a whole family homeless in a blink of a moment, a government building totally inhabitable and vital document completely burnt, and even sustainable private and public housing effort might be threatened by unexpected fire disasters [5]. Fire accidents are the accidents which occur most frequently, whose causes are the most diverse and which require intervention methods and techniques adapted to the conditions and needs of each incident. Depending on the type of fire (nature of the material ablaze), meteorological conditions (wind) and the effectiveness of the intervention, material damage can be limited (a single car, building

or production or storage warehouse installation), or affect wide areas (forest or agricultural fires, hydrocarbons, gas or other highly flammable products, storage or piping installations, harbor installations and rail or marine transport equipment) [6]. Fire accident is a menace that troubles all the countries of the world. For instance, in 2014, out of the recorded death of 7,323,187,457 in the whole world, fire accident had 41,267,889 [7]. According to the US Fire Administration (USFA), in 2008, 3,320 Americans died as a result of a fire while 16,705 Americans were injured. Eighty-four percent of civilian fire deaths occurred in residences and 315 civilian deaths were the result of an intentionally set fire. Property loss due directly to fires cost approximately $15.5 billion. Furthermore, 118 firefighters were killed on duty. Africa is not left out, for instant; in Ghana, fire incidents have become a regular occurrence, with thousands of lives and millions of dollars lost every year [8]. On October, 2011, at least 230 people were killed and 196 injured when a fuel tanker overturned and exploded in eastern Democratic Republic of Congo, unleashing a fire ball that tore through homes and cinemas packed with people watching World Cup soccer. In Nigeria, on July 25, 2015, properties worth millions of naira were also destroyed when the popular sawmill at Ibereko in Badagry, Lagos was engulfed in fire. The Nigerian gas explosion in Nnewi, Anambra State killed more than100 people. Goods worth millions of naira were destroyed by fire in Sabo market at Ikorodu. According to Taraba State Fire Service, about 23 fire incidents in 2014 were recorded, while the annual rate of fire outbreaks in Nigeria is estimated to be about 7,000 resulting in slightly more than 1,000 deaths. The Nigerian sphere is replete with agonizing tales of fire disasters. Therefore, it is difficult to keep tabs of all fire incidents in Nigeria as most of the cases go unreported. Super media [9] observed that causes of fire are in many ways. Some fires are intentionally set. Others are accidental, such as when a burning candle is placed near a highly inflammable material. Fire can occur as a result of faulty appliances or wrong electrical wiring. The main ways fire accident can occur include misuse of appliances, deliberate ignition and equipment failure (electrical malfunction), inappropriate disposition of lighted cigarettes, over heating especially with heater, misuse of cooking and lighting equipment etc. Fire accident could be fatal to those exposed to it and hence the need for prevention and protection from fire accident is necessary because fire can make homes unsafe. It can lead to the collapse of houses, loss of property or even death. Fire accidents are still under-reported, fatality, injury and accident rates are increasing, and management commitments to accident prevention remain poor [10]. To avoid fire accidents in the building the passive way of safety design, life safety provisions and the active way of fixing fire fighting appurtenances in the building cannot assure full safety. Number of variables is responsible in the fire phenomenon of the buildings, which are to be identified, assessed as fire hazard. Type of building, the activities going inside of the building, culture, behavior of the people, maintenance of the building, application of good housekeeping , fire risk management, security management, preparedness, awareness of fire, keeping away the fire sources from the combustible materials, reduction or elimination of combustible materials in side [11]. Fire accidents are increasing day to day in rural areas which results in loss of property and lives of the people. The fire spreads very quickly throughout the village and causes great damage before the firefighters arrive to the fire affected area. Hence, a new fire safety system is proposed to prevent fire accidents in villages using wireless sensor networks. By implementing this fire safety system in villages, we can detect the fire accidents and can bring the fire under control in the initial stage only without the involvement of the firefighters which reduces the cost of rescue operations [12].

1.1. Statement of the Problems

Fire accident occurs rarely but whenever it happens, it destroys life and properties and most of the times it is difficult to control when it started. This led to this study so as to find out if there is a way fire accident can be reduced or eliminated completely in Nigeria.

1.2. Aim and Objectives

The aim of this research work is to develop the model that will be good in estimating fire accident in Nigeria.

The objectives of this study are as follow;

- To develop models for estimating death due to fire accident.
- To determine the model or models that is/are good for estimating fire accident.

2. Methodology

In this paper, we compared three Mathematical methods so as to determine the one that is the best in estimating fire accident in Taraba State, Nigeria. The methods are stated below:

Poisson model, Exponential model and Negative Binomial model.

2.1. Poisson Distribution

The Poisson distribution is a discrete probability for counts of events that occur randomly in a given interval of time (or space). The "law of rare events" assumes that the total number of events will approximate a Poisson distribution if an event occurs in any of a large number of trials but the probability of occurrence in any given trial is small and assumed to be constant [13].Thus, the Poisson distribution is very appropriate for the analysis of rare events such as fire incidents.

The Poisson probability distribution describes probabilities that a random variable x that describes counts takes on values in the range 0, 1, 2, 3, …,*n*. More precisely, the probability density function describes the probability that X takes on the value *x*:

$$f(X) = p(X = x) = \frac{x^{\lambda} e^{-\lambda}}{x!}, \; x = 0, 1, 2, \ldots, \lambda > 0 \ldots (1)$$

Where, x_i is the count for one group or class, *i,* λ is the mean count over all groups, and *e* is the base of the natural logarithm. The distribution has a single parameter, λ, which is both the mean and the variance of the function.

In this work, *x* denotes the number of deaths and λ denotes the mean of the deaths

e = 2.718282, which is a mathematical constant

2.2. Exponential Distribution

The exponential distribution is often used as a model for duration and it is related to the Poisson distribution and can be used to measure the time between successes from the poison process, it also represents time interval, and it is a continuous, not discrete probability distribution [14]. We want to fit in our distribution into the exponential distribution in order to see if the distribution fits into the data. The exponential density function is

$$f(k) = \int_0^k \lambda e^{-\lambda x} \quad \ldots (2)$$

Where x ≥ 0. The parameter λ determine the rate at which event occurs.

Integrating equation (2) and substituting the value of k yields equation (3).

$$= -e^{-\lambda x}\Big|_0^k$$

$$= 1 - e^{-\lambda x} \quad \ldots (3)$$

In this work, e = 2.718282, which is a mathematical constant

λ denotes the mean of the number of deaths

and *x* denotes the number of deaths

2.3. Negative Binomial Distribution

The negative binomial distribution is an extension of the geometric distribution. Let *r* be a positive integer. Assume that independent Bernoulli trials, each with success probability *p* are conducted and let *X* denote the number of trials up to and including the r^{th} success. Then *X* has the negative binomial distribution with parameters *r* (where *r* is a fixed integer) and *p*. We then write $X \sim NB(r, p)$

The probability mass function X is

$$P(x) = P(X = x) = \binom{x-1}{r-1} P^r (1-P)^{x-r}, \; x = r, r+1, \ldots (4)$$

We say that *X* has a negative Binomial (*r, p*) distribution *x* is the number of failure that occur before the r^{th} success is observed; *r* is the probability of success.

Then we say that *x* has a negative binomial (*n, p*) distribution.

In this work, *x* denotes the number of accidents and *r* denotes the number of deaths.

3. Results and Discussion

3.1. Poisson Distribution

Table 1. Validation of Poisson distribution

Year	Number of death	Exact Probability	Poison Probability	Deviation from the Exact
2005	8	0.16	0.065278	0.094722
2006	3	0.06	0.140374	-0.080374
2007	10	0.2	0.018133	0.181867
2008	12	0.24	0.003434	0.236566
2009	9	0.18	0.0036266	0.1763734
2010	2	0.04	0.084224	-0.044224
2011	1	0.02	0.033690	-0.01369
2012	2	0.04	0.084224	-0.044224
2013	2	0.04	0.084224	-0.044224
2014	1	0.02	0.033690	-0.01369
Total	50	1	0.550898	0.449102

From **Table 1**, it is noticed that the summation of the exact probability is one (1) while that of the Poisson probability is 0.550898, approximately one (0.6). In addition the deviation from the exact is (0.449102) is approximately (0.4).This shows that the error is large and so we can conclude that the Poisson distribution is not too good for this work.

3.2. Exponential Distribution

Table 2. Validation of exponential distribution

Year	Number of death	Exact Probability	Exponential Distribution	Deviation from the Exact
2005	8	0.16	0.040379	0.119621
2006	3	0.06	0.109762	-0.049762
2007	10	0.2	0.027067	0.172933
2008	12	0.24	0.018144	0.221856
2009	9	0.18	0.0033060	0.176694
2010	2	0.04	0.134064	-0.094064
2011	1	0.02	0.163746	-0.143746
2012	2	0.04	0.134064	-0.094064
2013	2	0.04	0.134064	-0.094064
2014	1	0.02	0.163746	-0.143746
Total	50	1	0.928342	0.071658

From **Table 2**, we observed that the summation of the exact probability is one (1) while that of the Exponential probability is (0.928342) which is approximately one (1). In addition the deviation from the exact is (0.071658) and hence, we can conclude that the Exponential distribution compete favorably with the data gathered, since the deviation from the exact is approximately zero (0). This shows that Exponential distribution is a good model for this work.

3.3. Negative Binomial

Table 3. Validation of negative binomial

Year	Number of death	Exact Probability	Negative Binomial	Deviation from the Exact
2005	8	0.16	0.139292	0.020708
2006	3	0.06	0.048771	0.011229
2007	10	0.2	0.17041	0.02959
2008	12	0.24	0.205466	0.034534
2009	9	0.18	0.156335	0.023665
2010	2	0.04	0.029554	-0.009554
2011	1	0.02	0.009950	0.01005
2012	2	0.04	0.029554	0.010446
2013	2	0.04	0.029554	0.010446
2014	1	0.02	0.009950	0.01005
Total	50	1	0.828836	0.151164

From **Table 3**, it is noticed that the summation of the exact probability is one (1) while that of the negative Binomial is (0.828836) which is approximately one (1). In addition the deviation from the exact is (0.151164) and hence, we can conclude that the negative Binomial compete favorably with the data gathered, since the deviation from the exact is approximately zero (0).

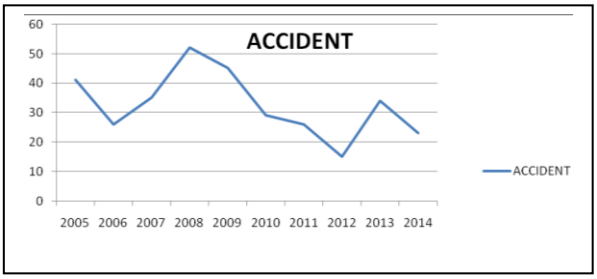

Figure 1: Graph of Accident

Looking at **Figure 1**, it is observed that accident rate is oscillating with the minimum frequency. This remarkably implies that accident rate is up-and-down at a lower rate, that is, it fluctuates.

Finally; it is seen that 2008 has the highest number of accident, and in 2005, 2006, 2013 and 2014 it decrease and 2008-2012 there is a bit lengthy decrease, 2006, 2008, 2012 there is a slight increases in fire accident. From the graph it is seen that 2012 has the lowest number of Accident. Hence the trend fluctuates with time, so it does not have a specific pattern.

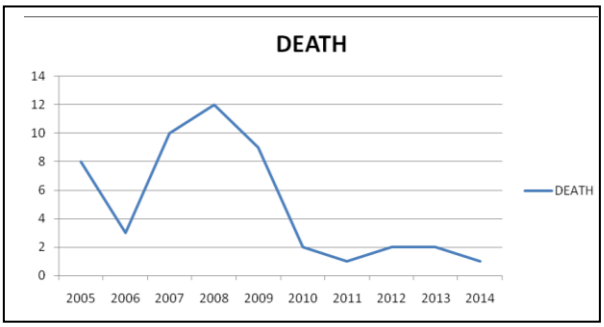

Figure 2: Graph of Death

From **Figure 2**, we were able to deduce that at a point the death rate increase and later decrease. This postulate to the fact, the decrease is as a result of proper awareness programs to rural dweller. Thus the more sensitization about fire out-break by either Government, Non-Government bodies can hence reduce death rate to the minimum.

Finally**;** we observe that in 2005, 2006, number of death decrease and 2008-2011 there is sharp decrease, 2012-2014 there is slight decrease, 2006-2008 has sharp increase, and 2011-2012 has a slight increase. 2008 has the highest number of death while 2011 and 2014 has the lowest number of death.

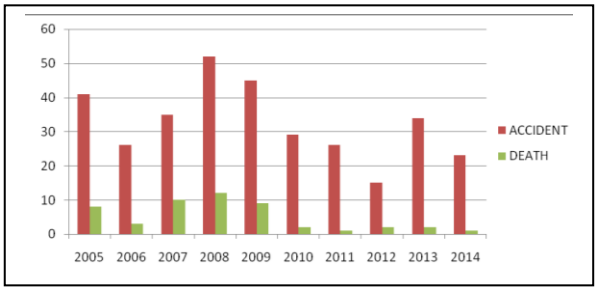

Figure 3: Graph of the Accident and Death

From **Figure 3**, it is noticed that the second compartment is less than the first compartment. This remarkably implies that, despite the fact that fire accidents have been occurring and re-occurring in our society but the death rate is at the decrease.

3.4. Discussion

In this research work, mathematical models were employed in estimating deaths due to fire accident in Taraba State. But from the Mathematical/Statistical techniques used in this study Exponential model and Negative Binomial model prove conformity as deviation from the exact is approximately zero (0). Only the Poisson model has deviation of approximately 0.4 which has high error rate.

4. Conclusion

Fire Accident is a major incident that has resulted to people's displacement, body parts disfigured, joblessness and a host of others which have rendered many hostages. Thus it has led to collapse of houses, lost of properties or even death [9].

In this research work, we employed the use of some mathematical/statistical techniques such as Poisson distribution, Exponential distribution and Negative Binomial to determine the best model for estimating fire accident. It was observed that from various techniques employed in this study the estimated value is approximately to the source data used and hence all techniques compete favorably with the data gathered. It is also observed that Poisson distribution has a high error rate which makes it not too good for the study.

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