

Comparative Analysis on EWMA and Poisson Cusum Chart in the Assessment of Road Traffic Crashes (RTC) in Osun State Nigeria

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Abstract: This study examines the daily Road Traffic Crashes (RTC) casualties in Osun state of Nigeria, Comparison of two quality control schemes identified as exponential Weighted Moving Average (EWMA) and Poisson Cumulative sum (CUSUM) control chart techniques were made using data collected from Federal Road Safety Corps (FRSC) Osun-State over a period 120 months our findings revealed that both techniques are capable of detecting small shift from mean level but Cusum is more sensitive. Furthermore, the points of change in the process are clearly identified and easily located on both schemes. The findings provide a proper diagnostic solution in the area of Road Traffic crash (RTC) reduction and control in Osun state Nigeria.

Keywords: Road Traffic Crashes (RTC) Casualties, Osun State, EWMA Control Chart, Poisson Cusum Control Chart

1. Introduction.

Road Traffic Crashes (RTC) have turned out to be a major global public health and development problem (Asogwa 1978). As a matter of fact, World Health Organization estimated that about 1.2 million people die annually from road traffic crashes of which 1.07 million of these are from low and middle income countries (peder et al,2006) of which Nigeria belongs. The impact of RTC is an economic, social, physical, psychological and public health challenge (WHO, 2004).

In Nigeria, 5,255 motor traffic crashes were recorded between Jan and June 1914 resulting in 3,254 deaths with 15,587 people sustaining injury (FRSC Website 2014). The annual loss in property resulting from RTC is put at over 100 billion Naira (the punch, 2002). In the USA, polanis (1995) estimated that the loss in property due to RTC was about 65 billion dollars in 1990 rising to 72 billion dollars by 1991. The world Health Organization stated that RTC has become the second leading cause of death after HIV/AIDS among 15-

29 years old in low and middle-income countries. It also by year 2030, RTC will rank 7th among the major diseases and injuries in the world (peden et al, 2006). Hence urgent attention is needed on road transportation system in order to minimize or eradicate RTC casualties.

RTC in Nigeria have been described as an important cause of mortality with the need for a comprehensive RTC preventive programme (Onadeko, 1983). The need to curb the excessive high rate of RTC in Nigeria has led to the establishment of the federal Road safety corps (FRSC) by the federal Government of Nigeria in 1988 with the aim to make the highways safe for the motorists and other road users. The FRSC is charged with the duty of educating the motorists and member s of the public on essence of discipline on highways, enforcement of traffic rates regulations and paying attention and care to RTC casualties among others.

In this study, EMWA and poisson CUSUM Control charts are employed in monitoring RTC causalities that Occurred between January 2010 and April 2014 in Osun state, Nigeria. The data used was collected from the FRSC, OSUN

command. These designed charts are used to detect the peak and the cumulated trend for RTC casualties that appropriate actions. World be taken by road managers in their effort to minimize RTC causalities.

2. Methodology

2.1. Design of EWMA Control Chart

EWMA control chart is one of the good alternatives to the she what control chart when we are interested in detecting small shifts (Montgomery, 2005). It's performance is approximately equivalent to that of the cussum control chart, and in some ways it is easier to set up and operate. It is typically used with individual observations.

Roberts (1959) introduced the EWMA control chart, it is sometimes called a geometric moving average (GMA). It is used extensively in time series modeling and in forecasting (box, jenking, and remsel, 1994; Montgomery et al 1990). Since the EMWA can be viewed as a weighted average of al past and current observations.

For monitoring the process mean, the EMWA control chart consists of plotting:

$$z_i = \lambda x_i + (1 - \lambda)z_{i-1}, 0 < \lambda \leq 1 \tag{1}$$

Versus time t (or sample 1).

Where λ is a constant and the starting value (required with the first sample $i=1$) is the process so that $z_0 = \mu_0$. At times the average of preliminary data is used as the starting value of the EWMA so that $z_0 = \bar{x}$.

In this equation x is the sample mean from time period t , z_i is the plotted test statistic and λ is the weight assigned to the current observation. The equation of the EWMA test statistic given in (1) can be applied to monitor any process parameter of interest.

In general, typical values of λ in the interval $0.05 \leq \lambda \leq 0.25$ work well in practice, with λ 0.05, 0.10, and 0.20 being a popular choices, although larger values may be used in forecasting and control applications. A good rule of thumb is to use smaller values of λ to detect smaller shifts. Also, $L = 3$ (the usual three sigma limits) works reasonably well, particularly with the large value of λ , although when λ is small say, $\lambda \leq 0.1$, there is an advantage on reducing the width of the units by using a value between 2.6 and 2.8.

Upper control limit (UCL) control limit (CL) and Lower control Limit (LCL) for the EWMA control chart are given respectively as:

$$UCL = \mu_0 + L\sigma \sqrt{\frac{\lambda[1-(1-\lambda)^{2i}]}{(2-\lambda)}} \tag{2}$$

$$CL = \mu_0 \tag{3}$$

$$LCL = \mu_0 - L\sigma \sqrt{\frac{\lambda[1-(1-\lambda)^{2i}]}{(2-\lambda)}} \tag{4}$$

σ = standard deviation of the object x_i .

L = Width of the control limits.

If the sample means fall within the control limits then we

can say that the process is in control with respect to the mean process while the process will be out of control if the sample means exceed the control limits.

As I increases, the term $[1 - (1 - \lambda)^{2i}]$ tends to unity. This implies that after the EWMA control has been running for several time periods, the control limits will approach steady state values.

$$UCL = \mu_0 + L\sigma \sqrt{\frac{\lambda}{(2-\lambda)}} \tag{5}$$

$$CL = \mu_0 \tag{6}$$

$$LCL = c - L\sigma \sqrt{\frac{\lambda}{(2-\lambda)}} \tag{7}$$

However, it is advisable to use the exact control limits. This will greatly improve the performance of the control chart in detecting an off target process immediately after the EWMA is started up. The EWMA control chart is always use with individual measurements. However, if rational subgroups of size $n \geq 1$ are taken, then simply replace x_i with sample mean \bar{x} and σ with sample standard deviation $\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$.

2.2. Design of Poisson Cussum Chart

The design procedure for poisson cusum for detecting an increase in count rate involves how to choose the reference value (k) and the decision interval value (h). the parameter h is primarily obtained by the desired in-control Average Run length (ARL), That is, the acceptable frequency of false out-of-control signals. After k is selected, the decision interval h is determined from tables.

2.2.1. Determining the Value of K

The parameter k is the reference value for the cussum scheme. For a poisson CUSUM, the reference value k depends on the acceptable count rate (μ_a) and on the count rate that is to be detected quickly (μ_d). Lucas (1985) gave the expression for determining reference value k_b for the poisson CUSUM as

$$k_b = (\mu_d - \mu_a) / (\ln \mu_d - \ln \mu_a) \tag{8}$$

It is necessary to wrote that if the time scale for the poisson cussum is the same as the time scale for the time – between – events cussum, the reference value k for the time – between-events cussum is the reciprocal of the reference value k_p for the poisson cussum.

2.2.2. Determining the Value of H

After chosen k , the decision interval value (h) is obtained from the table extracted from poissoncussum Average from length (AR1) with or without fast initial response (FIR), that uses a normalized reference value $k_t = k_b \times \mu_a$. Alternatively, k_t may be to determined from the $\frac{\mu_d}{\mu_a}$ ratio;

$$k_t = \frac{(\ln(\frac{\mu_d}{\mu_a}))}{(\frac{\mu_d}{\mu_a})^{-1}}$$

The value of h should give an appropriately large ARL when the process is at its desired Acceptable Quality level (AQL) and an appropriately small ARL value when the process has shifted to an undesired rejectable Quality level (RQL).

The most common application of a time-between-events cussum is to detect a decrease in the time-between counts and the ARL for this cussum is the average number of events before an out of control signal occurs.

In a time-between-events cussum, the time between out-of-control signals is directly proportional to ARL of $\frac{\mu_d}{\mu_a}$. In order to implement a time - between -events cussum, the h_t value obtained from the table is normalized to determine the decision interval value (h_b) used by the control scheme with

$$h_b = \frac{h_t}{\mu_a}$$

The cussum formula used is

$$s_i = \max (0, y_i - k + s_{(i-1)})$$

And

$$s_i = \min (0, k - y_i + s_{(i-1)})$$

For detection of mere use and decrease in time - between-events respectively.

Whenever $s_i \geq h$, an alarm is signaled in implementing the time - between - - events cussum, the parameter values h_b and k_b will be substituted for h and k.

3. Results and Discussion

Table 1. Data on Daily Road Traffic Crashes (R T C) Casualties in Osun State.

YEAR	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	SUM	AVER
2005	38	57	54	48	88	36	66	38	57	65	68	83	698	58.16
2006	64	63	64	46	57	52	59	42	78	55	93	67	740	61.66
2007	60	49	20	58	71	73	54	73	71	56	66	50	701	58.41
2008	72	74	61	82	75	70	55	57	71	58	83	72	830	69.16
2009	52	52	58	89	63	45	56	76	73	59	75	47	745	62.08
2010	24	9	20	19	16	17	12	18	28	21	28	30	242	20.16
2011	24	14	23	22	21	14	18	16	18	24	40	36	270	22.5
2012	18	24	25	23	18	38	24	24	23	22	21	28	288	24
2013	28	33	28	19	28	34	20	17	26	19	15	28	295	24.58
2014	26	24	21	19	20	19	17	29	26	29	19	23	272	22.66

From the data for 120 months, the overall mean per month is $\bar{x} = 42$ and the standard deviation $\sigma = 22$.

Thus, in order to detect changes in the mean level of accident causalities during this period, the acceptable mean level is chosen nearer to the current mean level, i. e $\mu_0 = 42$ and standard deviation, $\sigma = 22$.

Suppose the authority demands a shift of 1σ from μ_0 to be the rejectable level, then a shift of 1σ in the positive direction yields $\mu_1 = \mu_0 + 1 \sigma = 64$.

The reference value K is computed using

$$K = \frac{\mu_1 - \mu_0}{\ln \mu_1 - \mu_0}$$

$$K = \frac{64 - 42}{\ln 64 - \ln 42}$$

$$= 52.23$$

Approximately 52

Table 2. Tabular Cusum for the Road Traffic Crash (RTC) Casualties in Osun State.

MONTH(i)	(Xi)	C ⁺	N ⁺	MONTH (i)	(Xi)	C ⁺	N ⁺
1	38	0	0	61	24	0	0
2	57	0	0	62	9	0	0
3	54	0	0	63	20	0	0
4	48	0	0	64	19	0	0
5	88	25	1	65	16	0	0
6	36	9	2	66	17	0	0
7	66	32	3	67	12	0	0
8	38	41	4	68	18	0	0
9	57	55	5	69	28	0	0
10	65	82	6	70	21	0	0
11	68	125	7	71	28	0	0
12	83	199	8	72	30	0	0
13	64	12	9	73	24	0	0
14	63	35	10	74	14	0	0
15	64	70	11	75	23	0	0
16	46	99	12	76	22	0	0
17	57	133	13	77	21	0	0
18	52	167	14	78	14	0	0
19	59	208	15	79	18	0	0

MONTH(i)	(Xi)	C ⁺	N ⁺	MONTH (i)	(Xi)	C ⁺	N ⁺
20	42	239	16	80	16	0	0
21	78	296	17	81	18	0	0
22	55	356	18	82	24	0	0
23	93	457	19	83	40	0	0
24	67	573	20	84	36	0	0
25	60	8	21	85	18	0	0
26	49	13	22	86	24	0	0
27	20	0	0	87	25	0	0
28	58	0	0	88	23	0	0
29	71	0	0	89	18	0	0
30	73	19	1	90	38	0	0
31	54	40	2	91	24	0	0
32	73	82	3	92	24	0	0
33	71	143	4	93	23	0	0
34	56	208	5	94	22	0	0
35	66	287	6	95	21	0	0
36	50	364	7	96	28	0	0
37	72	20	8	97	28	0	0
38	74	62	9	98	33	0	0
39	61	113	10	99	28	0	0
40	82	194	11	100	19	0	0
41	75	298	12	101	28	0	0
42	70	420	13	102	34	0	0
43	55	545	14	103	20	0	0
44	57	675	15	104	17	0	0
45	71	824	16	105	26	0	0
46	58	979	17	106	19	0	0
47	83	1165	18	107	15	0	0
48	72	1371	19	108	28	0	0
49	52	0	0	109	26	0	0
50	52	0	0	110	24	0	0
51	58	6	1	111	21	0	0
52	89	49	2	112	19	0	0
53	63	103	3	113	20	0	0
54	45	150	4	114	19	0	0
55	56	201	5	115	17	0	0
56	76	276	6	116	29	0	0
57	73	372	7	117	26	0	0
58	59	475	8	118	29	0	0
59	75	601	9	119	19	0	0
60	47	722	10	120	23	0	0

To obtain the decision interval, h, the corresponding value of h from table C₂ of BS 5703, part 4, when k = 52, h is equal to 50. Thus the parameters of the designed cusum are k = 52 and h = 50. Therefore, an out-of-control signal will be indicated when

$$C_i = \max [0, X_i - 52 + C_{i-1}] > 50$$

The plot of the cusum values with the obtained decision interval h, is plotted in

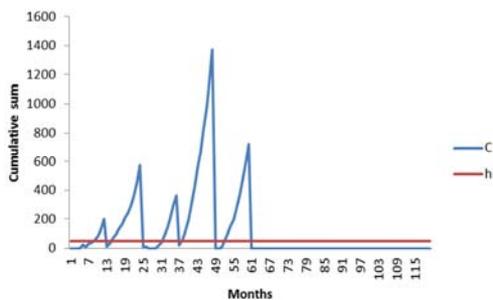


Figure 1. Cusum on Road Traffic Causalities in Osun State from the Year 2005 to 2014.

The figure above shows that road accident was out of control in 9th month, later it was out of control from the 10th months to 25th month. Further discussion reveals that road accident was in control from the 61th month until date.

Exponential Weighted Moving Average (EWMA) Analysis

The value of EWMA is; Z₀ = 24, which is also referred as μ₀ = 42.

Z is the exponential weighted moving Average of the value. In general, we have found the values to be in the interval hence for the analysis we use λ to be 0.2

$$Z_1 = \lambda X_1 + (1 - \lambda) Z_0$$

$$Z_1 = (0.2)(38) + (1 - 0.2)(42)$$

$$Z_1 = 41.2$$

Z₁ = 41.2 is the first value of Z_i

The other values of EWMA statistics are computed similarly for the ten years,

The control limits are found using

$$UCL = \mu_0 + L\sigma \frac{\sqrt{\lambda[1 - (1 - \lambda)^{2i}]}}{\sqrt{(2 - \lambda)}}$$

$$CL = \mu_0$$

$$LCL = \mu_0 - L\sigma \frac{\sqrt{\lambda[1-(1-\lambda)^{2i}]}}{\sqrt{(2-\lambda)}}$$

Where L is the width of the control limit assumed as 2.7
 The standard deviation of X_1 values = 22.41 approximately
 22

For period $i = 1$,
 The UCL = $42 + 59.4(0.2)$
 = 53.88
 The LCL = $42 - 59.4(0.2)$
 = 30.12.

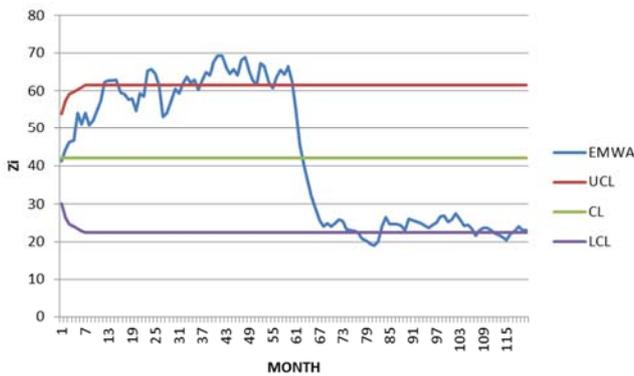


Figure 2. Graphical representation of EWMA charts of road traffic casualties in Osun State from 2005 to 2014.

The figure 2 above shows that road accident was out of control in 9th month, later it was out of control from the 10th months to 25th month. Further discussion reveals that road accident was in control from the 61th month till date.

4. Conclusion

The results from this study indicate that both charts are capable of detecting small shift from mean level but cusum is more sensitive. More so, the points of change in the process are clearly identified and easily located on both schemes. The findings provide a proper diagnostic solution in the area of Road Traffic crash (RTC) reduction and control in Osun State Nigeria.

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