International Journal of Mathematics and Statistics Invention (IJMSI)
E-ISSN: 2321 – 4767 P-ISSN: 2321 - 4759
www.ijmsi.org Volume 2 Issue 5 || May. 2014 || PP-10-19

Statistical Process Control a Tool for Town Planning Development

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ABSTRACT: *This study is aimed at designing Pareto Chart, CUSUM. The data used in this study is a secondary data from the Kwara State Town Planning and Development Authority (TPDA). It is a data of 60 months duration (Jan 2006 – Dec 2010) constituting some grouped nature of Complaints (Drainage, Encroachment/Trespass, Accessibility/Road Blockage, Miscellaneous) and four locations of complaints (Asa, Ilorin-East, Ilorin-South, and Ilorin-West). Pareto analysis, Cumulative Sum (CUSUM), Exponentially Weighted Moving Average (EWMA) control charts scheme and Chi-square analysis were designed and used to study the rate of complaints reported to TPDA. Finally, the performances of the two designed control chart schemes were compared. It was observed that Accessibility/Road Blockage has the largest number of complaints constituting over half of the whole complaints and the Drainage complaints taking about 13% of all the complaints. CUSUM chart scheme is more sensitive in detecting small shift in the process level than EWMA control chart scheme. Moreso, there was no relationship between complaints and their corresponding locations.*

KEYWORD: *CUSUM Chart, Pareto Analysis, EWMA Control Chart, Town Planning and Development Authority, Statistical Process Control*

I. INTRODUCTION

The mandate of Town Planning Authority (TPDA) is charge with the responsibility for administering the Towns, Cities and the entire Nation at large and reducing complaints by land users. This can be viewed as rendering services to the citizens of Nigeria and the more these complaints are curtailed, the better the costumers (citizens) are satisfied. The core function of TPDA among others include, enforcement of planning control, assist in the preparation and review of relevant planning legislation, providing an up to-date data base of land use planning data and information for decision making on land use and development, maintaining the register of planning application e.t.c.Statistical process control (SPC), a sub-area of Statistical Quality Control (SQC), has played a major part in the effort of many organizations and industries to improve product/service quality by using statistical tools and techniques to quickly detect the occurrence of assignable causes of process change so that investigation of the process and corrective action may be undertaken to prevent defectives from the process and improve the competitiveness of their products, services, prices and deliveries. A commonly used tool associated with statistical process control is the control chart. (Stoumbos, 2000), defined control charts as graphical tools widely used to monitor manufacturing/service process to quickly detect any change in a process that may result in a change in product/service quality. It is used for the study and control of repetitive process and is useful in determining whether a process is behaving as intended or there are some assignable causes of variation when used for process monitoring. Control chart was first developed in the 1920's by Walter Shewhart. A control chart commonly requires that samples with fixed sizes be taken at fixed intervals.

Shewhart chart has been widely used in determining shift in a process, however the main disadvantage of any of Shewhart charts is that they use only the last information of the combined process and ignore any other process given by the sequence of all points. This characteristic makes Shewhart control charts relatively insensitive to a small change in a process, because the cumulative or weight of the previous observation are disregarded. Small changes could be detected through CUSUM and EWMA control charts. These charts could be used as a complementary tool for $X - bar$, through which, small and large changes could be detected. Some authors, such as (Duncan, 1986, 1974), (Lucas, J. M., and Saccucci, M. S., 1990), (Hawkins, D. M., and Olwell, D. H., 1998), stated that the cumulative sum control chart is much more efficient than the usual $X - bar$ control chart for detecting small variations in the average. Lucas & Saccucci, (1990), presented the exponentially weighted moving average control chart, as good choice to detect small change in process average.

II. MATERIALS AND METHODS

2.1 PARETO ANALYSIS

Pareto analysis is a formal technique useful where many possible courses of action are competing for attention. In essence, the problem-solver estimates the benefit delivered by each action and then selects a number of most effective actions that deliver a total benefit reasonably close to the maximal possible.

Pareto analysis is a creative way of looking at causes of problems because it helps stimulate thinking and organize thoughts. This technique helps to identify the top portion of causes that need to be addressed to resolve the majority of problems. Once the predominant causes are identified, then the Ishikawa diagram or Fish bone Analysis can be used to identify the root causes of the problems. While it is common to refer to Pareto as "80/20" rule, under the assumption that in all situations, 20% of causes determine 80% of problems. This ratio is merely a convenient rule of thumb and should not be considered immutable law of nature. This application of Pareto analysis in risk management allows managements to focus on those risks that have the most impact on the problem.

2.2 THE CUSUM TECHNIQUE

The Cumulative Sum Chart was devised by (Page, 1954), which has been developed by many authors; (Ewan, 1963; Page, 1964; Lucas, 1976), has been proposed as an alternative to Shewarts control charts. The CUSUM chart attributes the same weight for the whole sequence, from the oldest to the most recent one. That is indirectly, it incorporate all of the information in sequence of sample values and detect small shifts in the process level more quickly. They are more meaningful graphically, as process shifts are often easily detected and its point of change can easily be located.

2.2.1 SUMMARY OF CUMMULATIVE SUM CHART (CUSUM) CHART:

Process observations: Rational subgroup size $n = 1$
Measurement type: Cumulative sum of quality characteristics
Quality characteristics type: Count data
Performance: Size of shift to detect ≤ 1.0σ
Underlying Distribution: Poisson distribution
Process mean chart centre line: The target value "k" of quality characteristics
Upper Control Limit = $S_{hi}(i) = Max[0, S_{hi}(i-1) + X_i - k_1] >$h, for positive change.
Lower Control Limit = $S_{lo}(i) = Min[0, S_{lo}(i-1) + X_i - k_2] <$-h, for negative change.
Plotted Statistics = $S_n = \sum_{i=1}^{N}(Y_i - k)$
Where, **k** is the target mean of the process.
$k = \frac{k_2 - k_1}{Ink_2 - Ink_1}$, (Lucas, J.M and Crosier, R.B., 1982),......Reference value for simultaneous low and high side scheme, where
$k_1 = \mu + f\sigma$..........Out-of-control man
$k_2 = \mu - f\sigma$ ....In-control controls
f −Size of shift = 1.0
h-the decision interval of CUSUM

2.2.2 CUSUM CHART PROCEDURE

The principal feature of CUSUM control chart scheme is the successive value, say X_i values of variables are compared with the predetermined target or reference value **k**, i.e $S_n = \sum_{i=1}^{N}(Y_i - k)$ is plotted on a chart or shown on a table. If a trend develops on the plotted point either upward or downward, it is evidence that the process mean has shifted and there is need to search for assignable sources of variation. Over a long period of time, CUSUM scheme applications for continuous variable have received considerable attention, (Ewan, W.D. and Kemp, K.W., 1960), (Brook, D and Evans, D.A., 1972). Most of CUSUM applications for continuous variables are based on the assumptions that the process is normally distributed, the reason being that the parameters to be determined are usually based on a very large and a fairly uniform sample size so that the assumptions of normality and constant variability are reasonably appropriate, (Ewan, 1963). CUSUM scheme can also be used for attribute data. That is when responses are counts such as number of defects per unit, the number of road traffic crashes within a time interval, or change in sales in auditing in administrations etc. (Lucas, 1985), proposed the design and implementation procedure of CUSUM for attribute which he called "Counted Data CUSUM". He established that the design and the implementation procedures for counted data CUSUM are similar to those of CUSUM for variables and used the Poisson and Exponential distributions as the two underlying models. It should be recalled that the Poisson distribution is used to model the number of counts observed per sampling interval, also suggested that the Poisson CUSUM should be used when it is administratively convenient to record the number of counts in a given sampling interval. When the number of counts follows a Poisson distribution, the time between events CUSUM scheme follows Exponential distribution.

2.2.3 DESIGN OF CUSUM CHART

The statistic for the counted data CUSUM is given by:
$S_i = \max(0, X_i - k + S_{i-1})$, Where X_i is the attribute to be controlled and k is the target value. If $S_i > h$ (the decision interval), an out of control of non- conformance and for the detection of decrease or increase in count rate. Thus, they are used to monitor change in count level in non-conforming situations such as in outbreak of an epidemic and rate of accident (road crashes).The procedure CUSUM control chart consist of taking samples of size 'n' and plotting the cumulative sum $S_m = \sum_{i=1}^{N}(y_{i-}k)$ versus the sample number, where y_i is the sample mean, **k** is the reference value and h is referred to as decision limits. Although, many curves and monographs have been developed for the specific value of **k** and **h**, those developed by (Goel, A. L. and Wu, S. M., 1971) and (Kemp, 1961), are commonly used.

2.3 ASSESSMENT OF THE PERFORMANCE OF CUSUM CHART
2.3.1 AVERAGE RUN LENGTH:

The Average Run Length (ARL) at a given quality level is the average number of samples taken before an out of control signal. It is expected that the Average Run Length (ARL) is high when the process is in control and low when there is a shift to an unsatisfactory level.

2.3.2 CHOICE OF CUSUM PARAMETERS

Determining the correct values of **h** and **k** to use is essential in creating a CUSUM system that will set off an alarm quickly when the mean has shifted. For this purpose, the ARLs are generally used, at good or poor process quality levels. The ARL is a function of **h** and **k** and the underlying distribution of the data studied. (Hawkins, D. M., and Olwell, D. H., 1998) gave a complete discussion on the methodology of the choice of these variables. The choice of parameter **h** and **k** is shown in table 1 [Extract from (Institution, 1982)].

2.4 THE EXPONENTIAL WEIGHTED MOVING AVERAGE (EWMA)

The Exponential Weighted Moving Average (EWMA) chart is used for monitoring process by averaging the data in a way that give less weight to old data as samples are taken and give a high weight to most recent data. It is also effective in detecting small shifts.
The EWMA chart methodology was developed by (Roberts, 1959), and later by (Wortham, A., Ringer, L., 1971), who purposed it for use by some organizations, particularly in the process industries, financial and management control as the basis of new control/performance charts system. The EWMA charting procedure is sometime used to monitor the rate of occurrence of rare events where the time between two successive occurrences is exponentially distributed. This procedure can also be used extensively in time series modeling and forecasting, (Box, G.E.P., and Jenkins, G.M., 1976, Johnson, 1961). The EWMA for individual value may be defined as:
$Z_i = wX_i + (1-w)Z_{i-1,}$ where $0 < w \leq 1$ $i = 1,2, \ldots, n, n+1,$
The above equation is due to (Roberts, 1959). The use of this control chart was first published in the article "Control chart tests based on geometric moving averages". While Shewhart charts only consider the most recent data point in testing to determine if statistical limits have been exceeded, EWMA charts consider all previous points using a weighing factor that makes the outcome more influenced by recent points.
In statistical quality control, the EWMA chart (or exponentially-weighted moving average chart) is a type of control chart used to monitor either variables or attributes-type data. While other control charts treat rational subgroups of samples individually, the EWMA chart tracks the exponentially-weighted moving average of all prior samples.

EWMA weights samples in geometrically decreasing order so that the most recent samples are weighted most highly while the most distant samples contribute very little. Although EWMA chart assumes normal distribution, it is relatively robust in the face of non-normality. The chart monitors only the process mean. EWMA Charts are generally used for detecting small shifts in the process mean and they detect shifts of 0.5sigma to 2sigma much faster than Shewhart charts with the same sample size. In brief, after multiplication by a weighting factor **w**, the current measurement is added to the sum of all former measurements, which is weighted with (**1 - w**). Thus, at each time ***t*** (***t*** **= 1, 2,...**), the test statistic Z_t.

Basically, the method is to form a new moving average at each sample point by calculating a weighted average of new value and previous moving-average. Therefore, in exponentially weighted moving average chart, all of the past data has some effect on the current value, but it rapidly loses influence.

Consider the following notations:

Z_t = Exponentially Weighted Moving Average

w = EWMA weighted parameter (**0 < w< 1**)

μ_0 = Process mean

X_{ij}= **j**th measure of **i**th subgroup, with

σ = Process standard deviation

n_i = Sample size of **i**th group

Q = sigma limit

$\bar{X}_i$= Mean of measurement in **i**th subgroup. If $n_{i=1}$, then subgroup mean reduce to the observation in the group

Each point on the chart indicates the value of exponentially weighted moving average (EWMA) for the subgroup. The EWMA for the **i**th subgroup (Z_i) is defined recursively as:

$Z_t = wX_i + (1-w)Z_{i-1}, 1 \leq 0$, Where, w is the weighted parameter (**0 ≤ w ≤1**).

2.4.1 COMPUTATION OF CONTROL LIMIT

By default, the central line on a EWMA chart indicates an estimate for **μ**, which is computed as:

$$\hat{\mu} = \bar{\bar{X}} = \frac{n_1\bar{X}_1 + \cdots + n_N\bar{X}_N}{n_1 + \cdots + n_N}$$

The default limits are computed as $q = 2.30$ (referred to as 2.30σ limits).

The upper and lower control limits are

$$UCL = \bar{\bar{X}} + q\sigma\sqrt{\frac{w}{n(2-w)}}$$

$$LCL = \bar{\bar{X}} - q\sigma\sqrt{\frac{w}{n(2-w)}}$$

Where ‘n’ is the subgroup size.

2.4.2 ASSESSMENT OF PERFORMANCE OF EWMA CHART

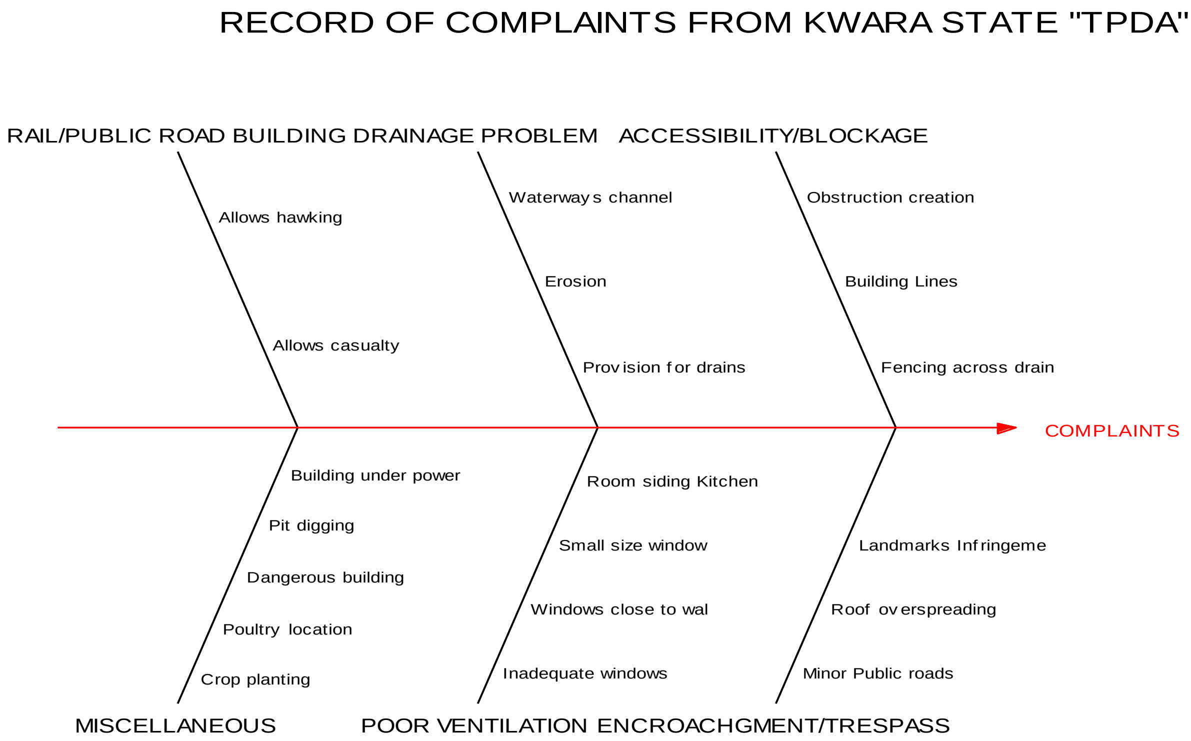
A number of authors have studied the design of EWMA control scheme based on Average Run Length (ARL) computation. Ideally, the ARL should be short when a shift occurs and should be long when there is no shift. The effect of “**w**” (weight parameter) on the ARL was described by (Roberts, 1959), who used simulation method. The ARL function was approximated by (Robinson, P. B. and Ho, T. Y, 1978).

III. ANALYSIS OF COMPLAINTS OF BUILDINGS AND CONSTRUCTIONS

The data used for this research work is a secondary data obtained from the Kwara State Town Planning and Development Authority (TPDA). It is a data of the duration of 60 months (Jan 2006 – Dec 2010) constituting some grouped nature of Complaints (Drainage, Encroachment/Trespass, Accessibility/Road Blockage, Miscellaneous) and four locations of complaints (Asa, Ilorin-East, Ilorin-South, and Ilorin-West). Pareto analysis and control chart methods are carried out. The CUSUM and EWMA techniques are designed for Complaints of Buildings and Constructions. Also, a test for the presence of independence and association in the category of the nature of complaints and the corresponding locations will be carried out.

3.1 PARETO ANALYSIS FOR THE COMPLAINTS

Carrying out the Pareto analysis, ideally, one will want to focus attention on fixing the most crucial complaints. Identifying the root-cause of the complaints, a structure was developed to streamline these complaints from which the complaints were identified by the Authority and summarized into four categories of complaints.



Furthermore, after that the nature of the complaints has been categorized into four Complaints (DRAINAGE, ENCROACHMENT/TRESPASS, ACCESSIBILITY/ROAD BLOCKAGE, MISCELLANEOUS), a Pareto diagram is obtained for the Complaints.

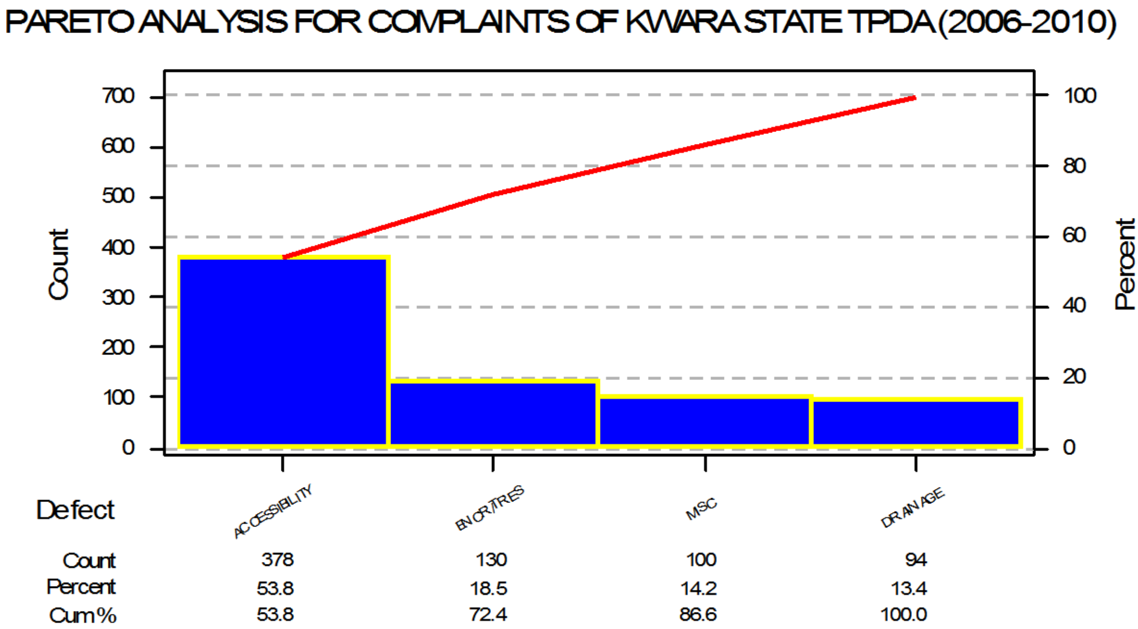


Fig.1. Pareto complaints log.

3.2 DESIGN OF CUSUM CONTROL CHART TECHNIQUE

The CUSUM chart is more effective when it is required to detect a small shift. And since it detects small shifts faster compared to Shewhart, a shift of size 1, that is, **1σ** is selected for this research work. To select an appropriate **h** and **k** that will be extremely sensitive to set off an alarm as soon as the mean has shifted, an

Extract from the British Standard 5703 Part 4 is used to determine the Reference value "**k**" and the Decision interval *"***h***"*. The ARL for this research work is set to be 10 months.
Now, if the management desires a shift size (**f**) of 1, that is **1σ**, with an ARL of 10 months, a CUSUM chart setup can thus be created through the following steps;

- Obtain Mean, $\bar{X} = 11.7$
- Obtain Standard Deviation, **σ** = 4.6
- Obtain $\mathbf{k_1}$ and $\mathbf{k_2}$, being In-control mean and Out-of-control mean respectively, in positive direction of the Target value "μ".
- $\mathbf{k_1}$ = 11.7 - (1 * 4.6) = 7.1
- $\mathbf{k_2}$ = 11.7 + (1 * 4.6) =16.3
- Obtain AQL= 11.07
- Obtain **h** and **k** from the "Extract from the British Standard 5703 Part 4" by tracing it from the AQL column; see Appendix V.
- H = 11
- K = 12

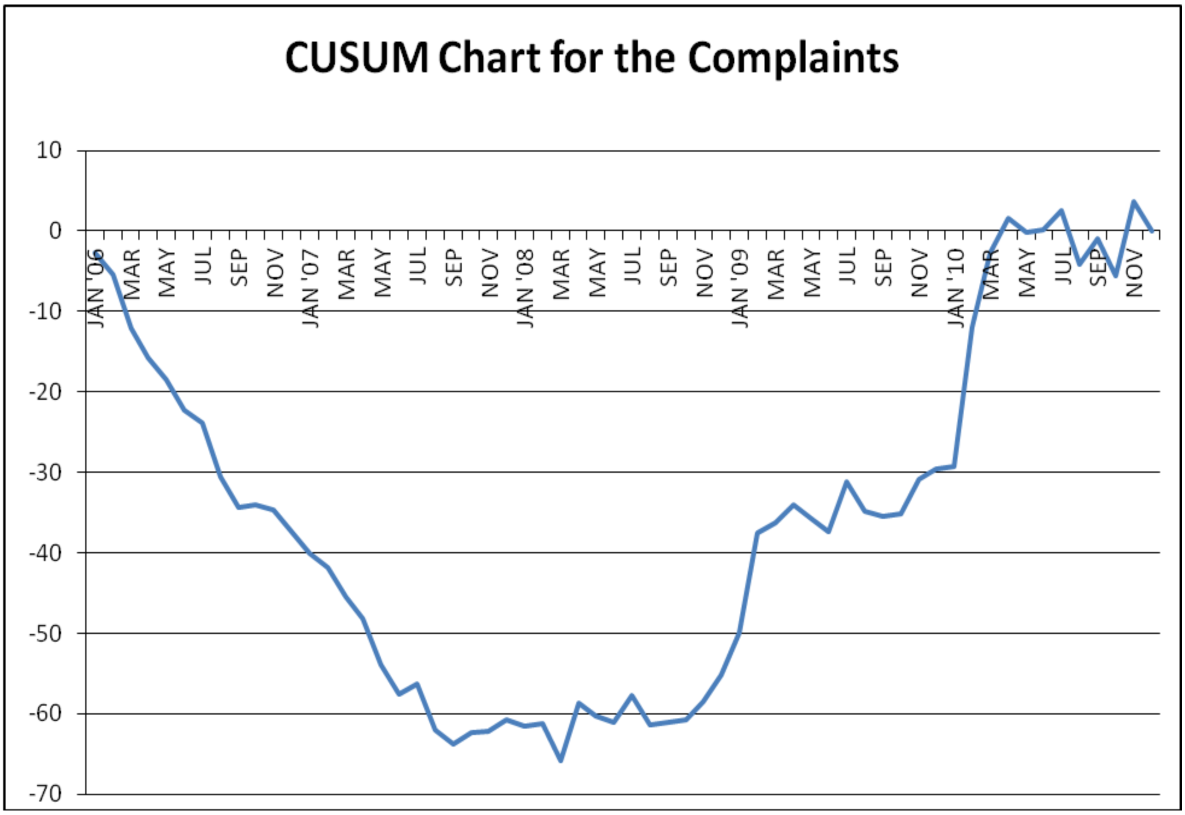


Fig.2. CUSUM complaint chart.

3.3 EWMA CHART TECHNIQUE

From the historical data, the mean is approximately (11.7) and the variance (21.16)
To design an EWMA control chart that would be sensitive to detect a small shift in a process, the following is put into consideration.

- Since a large value of **λ** gives more weight to older data, weighting factor between 0.2 - 0.3 has been suggested for this purpose (Hunter), nevertheless, 0.15 is another popular choice.
- The choice of 0.25 is selected for this research work.
- CENTRAL LINE = $EWMA_0 = \bar{X}$
- ESTIMATED VARIANCE = $\mathbf{S^2_{ewma}} = (\boldsymbol{\lambda}/(\mathbf{2}-\boldsymbol{\lambda}))\mathbf{S}^2$
- STANDARD DEVIATION = $\mathbf{S_{ewma}} = \sqrt{S^2_{ewma}}$
- CONTROL LIMITS
  $UCL = EWMA_0 + KS_{ewma}$

$LCL = EWMA_0 - KS_{ewma}$

3.3.1 COMPUTATION OF EWMA STATISTIC "Z_i"

The EWMA statistic is calculated thus;

$Z_i = [\lambda X_i + (1-\lambda)\, Z_{i-1}]$, $\quad 0 < \lambda \leq 1, \quad t = 1,2,\ldots,n$

With w = 0.15 and $Z_0 = 11.7$

Z_1	=	0.25 (9) + (1 – 0.25) 11.7	=	11.3
Z_2	=	0.25 (9) + (1 – 0.25) 11.3	=	11.0
Z_3	=	0.25 (5) + (1 – 0.25) 11.0	=	10.1
.	.	. … .		.
.	.	. … .		.
.	.	. … .		.
Z_{60}	=	0.25 (8) + (1 – 0.25) 13.8	=	12.9

CENTRAL LINE = $EWMA_0 = \bar{X} = 11.7$

ESTIMATED VARIANCE = $S^2_{ewma} = (\lambda/(2-\lambda))S^2 = \left(\frac{0.25}{2-0.25}\right) 21.16 = 3.0229$

STANDARD DEVIATION = $S_{ewma} = \sqrt{S^2_{ewma}} = \sqrt{3.0229} = 1.74$

CONTROL LIMITS

UCL $= EWMA_0 + KS_{ewma}$

LCL $= EWMA_0 - KS_{ewma}$

where **K** is a multiplicative value which is conventionally set to be 3, just as in the case of Shewart and **S** is the standard deviation obtained from the historical data.

UCL = 11.7 + (3 x 1.74) = 16.92

LCL = 11.7 - (3 x 1.74) = 6.48

The EWMA chart is displayed below with the weighting factor (λ) = 0.25, where the values of $\mathbf{Z_i}$ are plotted against sample number.

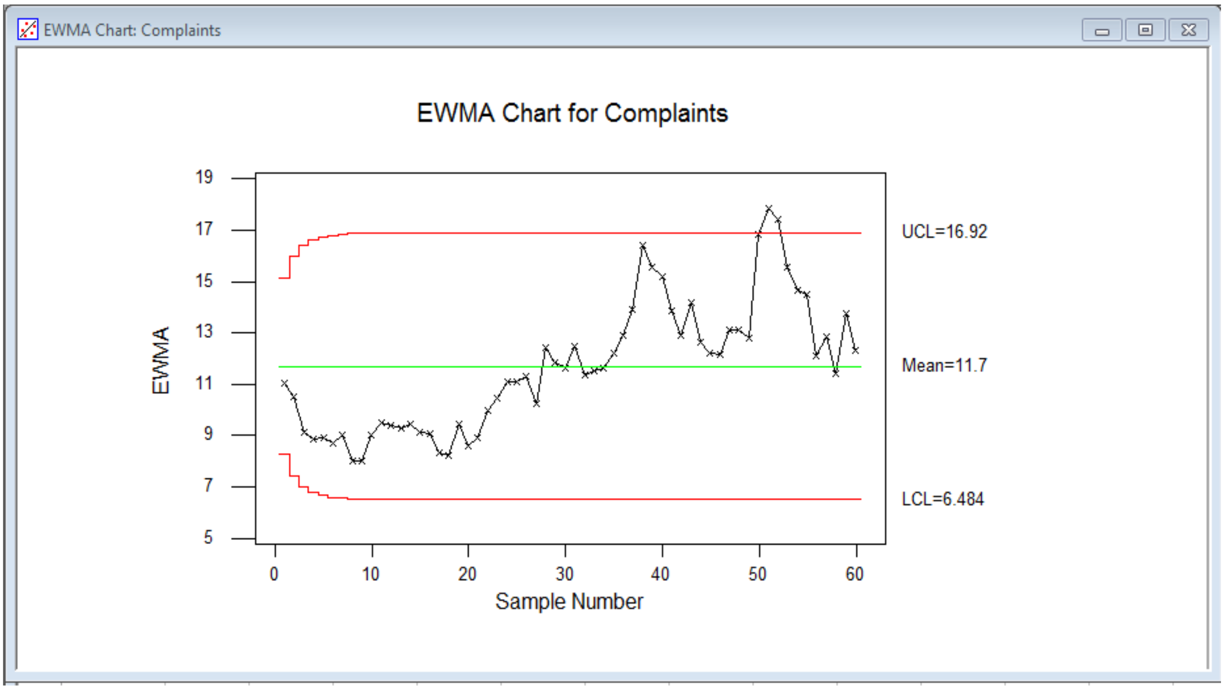


Fig.3. EWMA compaints chart

It can be observed from the EWMA control chart above that the process was out of control at the 50^{th} month to the 52^{nd} month corresponding to February 2010 – April 2010.

Table 1. **SUMMARY OF THE DATA**

Nature of Complaints	No. Of Complaints	%	Asa	%	Ilorin-East	%	Ilorin-South	%	Ilorin-West	%
Acce/R.Block	380	54	82	67	75	50	118	52	105	52
Tres/Encr	126	18	16	13	31	21	43	19	36	18
Drainage	93	13	9	8	23	15	28	12	33	16
Misc	103	15	15	12	21	14	40	17	27	14
Total	702	100	122	100	150	100	229	100	201	100

3.4 MEASURE OF ASSOCIATION

One may also want to see whether or not there exists any association between the Nature of Complaints and its Location. To perform this, the observations are classified. Although the data were collected based on four locations with the Nature of complaints categorized into four, a decision is made to reduce it to a 2X2 contingency table so as to fit into the test to be carried out.The Nature of Complaints 'Road blockage/Accessibility and Encroachment/Trespass' now collapsed into "Common complaints" and 'Drainage and Miscellaneous' into "Special complaints". Also, the Location also summarized 'Ilorin-East and Asa' into "Residentially developed" and 'Ilorin-South and Ilorin-West' into "Commercially developed".

Let **r** represent the row and *c* represent the column; such that the row varies by index row **i** = 1,…,**I** and column varies by index column **j** = 1,…,**J**

Let O_{ij} denote the cell frequency of the i^{th} row and j^{th} column.

Let e_{ij} denote the expected frequency of the i^{th} row and j^{th} column.

Row marginal total; $O_{i.} = \sum_{j=1}^{J} Oij$ and $e_{i.} = \sum_{j=1}^{J} eij$

Column marginal total; $O_{.j} = \sum_{i=1}^{I} Oij$ and $e_{.j} = \sum_{i=1}^{I} eij$

Overall total; $O_{..} = \sum_{j=1}^{J} \sum_{i=1}^{I} Oij$ and $e_{..} = \sum_{j=1}^{J} \sum_{i=1}^{I} eij$

***Hypothesis**: Location is independent of Nature of Complaints.

Table 2. **Observed Frequency**

LOCATION	NATURE OF COMPLAINTS		Total
	Common	Special	
Residentially	204	68	272
Commercially	302	128	430
Total	506	196	702

Table 3. **Expected Frequency**

LOCATION	NATURE OF COMPLAINTS		Total
	Common	Special	
Residentially	196.1	75.9	272
Commercially	309.9	120.1	430
Total	506	196	702

H_0 : There is independence

H_1 : There is no independence

$$X^2 = \sum_{j=1}^{J} \sum_{i=1}^{I} \frac{(Oij-eij)^2}{eij}$$

$$= \frac{(204-196.1)^2}{196.1} + \frac{(68-75.9)^2}{75.9} + \frac{(302-309.9)^2}{309.9} + \frac{(128-120.1)^2}{120.1}$$

$$= 1.86$$

$$\chi 2_{(1,0.05)} = 3.84$$

Decision Rule: Reject null hypothesis if X^2 calculated is greater than $\chi 2$ tabulated.

Decision: Since the X^2 calculated is less than $\chi 2$ tabulated, we accept the null hypothesis and we conclude that there is independence.

IV. RESULT AND CONCLUSION

The pareto analysis constructed using a current Statistical Software (MINITAB 15) on complaints data showed that Accessibility/Road Blockage has the largest number of complaints constituting over half of the whole complaints and the Drainage complaints taking about 13% of all the complaints.Taking observation from the retrospective analysis carried out for the pooled Complaints, it was discovered that the first segment was statistically significant and the local means were computed approximately as 10, 15, 13, 14, 5, 11 and 15 reported complaints per month. It can also be observed from the local means estimates that record of complaints tend to meander around the average throughout the segments though having it low towards the end of the process.

For the designed CUSUM Technique, values for the Estimates/Parameters are shown in tables in Appendix III. Also, the CUSUM tabulation shows the Complaints and its corresponding statistic for the period under study, it can be observed that the first out of control signaled at 10^{th} month, and was again in control until the 19^{th} month and again was out of control at the 22^{nd} month through to the 26^{th} month, and finally was out of control from the 28^{th} month to the end of the process; corresponding to October 2006, July 2007, October 2007 – February 2008, and finally April 2008 – December 2010 respectively.For the EWMA technique, a choice of the weighting factor (λ) was selected to be 0.25. Appendix IV shows the EWMA (Z_i) statistic tabulation. The values of Z_i for the Complaints were plotted against the sample number and the corresponding EWMA control chart was obtained (as shown in Chart above). It can be observed from the EWMA control chart that the process was out of control at the 50^{th} month to the 52^{nd} month corresponding to February 2010 – April 2010.

The categorical test was performed to see the independence in the Complaints, Chi-Squared ($\chi 2$) test was the one carried out. The $\chi 2$ showed an independence in the Location of Complaints and Nature of complaints.

Having carried out tests to detect small shift in the Complaints process, the results obtained from both the CUSUM and EWMA charts; showing an out of control in the process, establishes that the two charts are sensitive in detecting small shift in the mean of a process.

Also, there is independence in the category and absence of association in the category of the complaints and their corresponding locations.Conclusively, it can be established that the occurrence of a nature of complaints is independent of location.In view of out of control of the process, it is suggested that the Town Planning and Development Authority should be thorough in its approval to plans, visits and re-visits should be made to the sites of building and construction, even while still under accomplishment for proper monitoring so as to prevent some unnecessary complaints and to reduce other forth-coming complaints and there by reducing crises among land users.

Summary of Estimates/Parameters and the corresponding values for the CUSUM

Table 4. Complaints

$\bar{x}$	σ	*K*	*DI(h)*
11.7	4.6	11	12

Table 5. **C_1 and C_2 Schemes for Poisson Variable**

Event retreat AQL, Ma	Cusum Parameters for C_1 schemes*		Cusum Parameters for C_2 schemes*	
	H	K	H	K
0.1	1.5	0.75	2	0.25
0.125	2.5	0.5	2.5	0.25
0.16	3.0	0.5	2	0.5
0.2	3.5	0.5	2.5	0.5
0.25	4.0	0.5	3	0.5
0.32	3.0	1.0	4	0.5
0.4	2.5	1.5	3	1
0.5	3	1.5	2	1.5
0.64	3.5	1.5	2	2.0
0.8	5	1.5	3.5	1.5
1.0	5	2	5	1.5
1.25	4	3	5	2
1.6	5	3	4	3

2.0	7	3	5	3
2.5	7	4	5	4
3.2	7	5	5	5
4.0	8	6	6	6
5.0	9	7	7	7
6.4	9	9	9	8
8.0	9	11	9	10
10.0	11	13	11	12
10	11	13	11	12*
15	16	18	11	18
20	20	23	14	23
25	24	28	17	28

CHOICE OF PARAMETER H AND K [Extract from British Standard 5703 Part 4]

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