Moving Average Control Charts using Uncertain Information for Various Sampling Schemes

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Abstract

Present article proposes the neutrosophic moving average (NMA) control chart under neutrosophic statistics (NS) based on multiple dependent state (MDS), Repetitive and multiple dependent state repetitive (MDSR) sampling schemes. The neutrosophic moving average control chart is useful to monitor the process mean in the industries when the measurements expressed in terms of uncertainty or fuzzy or interval. In this circumstance, the existing monitoring designs could not be useful for the monitoring of mean accident or injury data. In the present investigation neutrosophic moving average control chart is developed under the NS. The chart coefficients of the proposed control chart are obtained using Monte Carlo simulation under NS. A comparative study between the three sampling schemes of neutrosophic moving average control chart under neutrosophic statistics (NS) is given. Two real examples from accident and injury data are taken to investigate the accomplishment of the proposed chart. Based on the simulation study and real data, the proposed chart is out performed over the existing control charts.

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1. Introduction

In statistical quality control (SQC) the main aim of staging of the manufacturing process is ended with decreasing the number of non-conforming items in the production process. An important area of SQC is the control charts techniques, which are more useful to monitor production process, whether the process would be under control or not. More control charts have been considered to monitor the production process for various situations. The control charts are the visual demonstration of SPC, whose main intention is to assurance and get better the quality of end product granting to the customers satisfaction. Contrastingly, SQC methods are employed to monitor the quality of items from the raw material to the end of the product. Moreover, control charts are sensible vigilant about the change in the process and hence supportive to recognize the causes of this changes in the production process. It is rightly pointed out that the Shewhart control charts are powerful and easy to apply tools in the industry to monitor the production process, whereas they are suitable to detect the more largish shift in the production process. To address these situations, in the literature there are some alternatives to the Shewhart control chart namely the moving average (MA), cumulative sum (CUSUM), and exponentially weighted moving average (EWMA) control chart. The advantages of the foresaid charts are more effective to discover a miniature change in the production process. A diminutive concentration has been brought in to the study control charts based on MA under different lines of work. Some works on MA control chats for various lines of work can be seen in [1-7].

Nowadays, globally researchers and quality control engineers in statistical process control have been studying both acceptance sampling (AS) and control chart plan in most of the industries for the high quality manufacturing process monitoring. The technique of control chart is practiced by quality engineers in industries to monitor production process while manufacturing whereas AS frequently applied for the evaluation of the end product. Hence, both control chart and AS techniques are essential tools for the manufacturers in a competitive globe to manufacture the products with highest quality.

In addition to the Shewhart control chart procedures, an improvement of Shewhart control chart techniques were developed in literature namely repetitive, multiple dependent state (MDS), multiple dependent state repetitive (MDSR) sampling attribute and variable control charts etc. In statistical process control, to take a decision on whether the process is "in a state of statistical control" or not could be based on graphing the chart statistics such that if the sample point plots within or outside the upper control limit (UCL) and lower control limit (UCL). In the usually practice, if the sample points fall outside the control limits then the process is out-of-control and the rapid corrective action is carried to bring back the process into in-control state. Instead of deciding the process is in-control or out-of-control from the sample points at single time, in recent years more researchers concentrated on single, MDS, repetitive and MDSR sampling control charts for monitor the production process. Numerous authors developed classical control charts based on single sampling (SS), MDS sampling, repetitive sampling (RS) and MDSR sampling in literature including but not exhaustive [8-19].

The traditional control charts available in the literature can be suitable to used when all measurements are determined from the manufacturing process, whereas in some situation like monitoring weather conditions, in rainy season level of water flow in the rivers etc. are uncertain or fuzzy. If the measurements are uncertain or fuzzy instead of existing control charts one can apply a fuzzy approach control charts. [20] rightly pointed out that "fuzzy control charts are more sensitive than traditional ones; hence, they provide better quality products". Some more articles on fuzzy approach control charts can be found in [21-32].

[33] pointed out that "the fuzzy logic that provides information about the measure of truth and falseness is the special case of neutrosophic logic". Measure of indeterminacy is an additional measurement in neutrosophic logic. [34] introduced the neutrosophic statistics (NS) and he criticized that NS is a generalization of the classical statistics. Recent years some researchers are concentrated on different works in NS based studies and corresponding control charts including [35-45].

Aforesaid literature shows that a good research has been done on control charts under classical statistics, fuzzy and NS approaches. By investigating the past works and to the best of our knowledge, there is no work on moving average control chart under NS based on MDS, Repetitive and MDSR sampling schemes. The present study aims that development of neutrosophic moving average (NMA) control chart based on MDS, Repetitive and MDSR sampling schemes and assess its efficiency as compared with on hand MA control charts. In Section 2, we outline the proposed neutrosophic moving average control chart based on MDS, Repetitive and MDSR sampling schemes. In Section 3, a simulation study is carried out and a comparison of the proposed chart with the counterpart chart is described in Section 4. The Illustrative example is described in Section 5. In the final section, the conclusion and future recommendations are displayed.

2. Methodology

Suppose that $Y_N = Y_L + b_N I_N; I_N \in [I_L, I_U]$ be a neutrosophic random variable comprises of the variable based on classical statistics Y_L and indeterminate part $b_N I_N; I_N \in [I_L, I_U]$. The neutrosophic $Y_N \in [Y_L, Y_U]; I_N \in [I_L, I_U]$ reduces to Y when I_L=0. Suppose $n_N \in [n_L, n_U]$ presents the neutrosophic group size. Suppose that $\bar{Y}_{iN} \in [\bar{Y}_{iL}, \bar{Y}_{iU}]$ denotes the neutrosophic sample average for ith subgroup. Here we assume that Y_{ijN} follows the neutrosophic normal distribution with a population mean $\mu_N \in [\mu_L, \mu_U]$ and variance $\sigma_N^2 \in [\sigma_L^2, \sigma_U^2]$, for $i = 1, 2, ...$ and $j = 1, 2, ..., n$. By following [46], NMA statistic is defined as

$$NMA_{iN} = \frac{\bar{Y}_{(i)N} + \bar{Y}_{(i-1)N} + ... + \bar{Y}_{(i-w+1)N}}{w_N};\ w_N \in [w_L, w_U] \quad (1)$$

Where $w_N \in [w_L, w_U]$ shows the span at a time i. Note here that the statistic is given in Eq. (1) is similar to the exponentially weighted moving average (EWMA) statistic. The main difference between MA statistic and the EWMA statistic is the sensitivity that each statistic shows in the calculation of the data. The EWMA gives the higher weights to the current values while the MA gives equal weight to all values in the data, see [47].

The $NMA_{iN} \in [NMA_{iL}, NMA_{iU}]$ statistic in neutrosophic form can be written as

$$NMA_{iN} = NMA + c_N I_N;\ I_N \in [I_L, I_U] \tag{2}$$

where NMA is the determined part and $c_N I_N;\ I_N \in [I_L, I_U]$ is indeterminate parts of $NMA_{iN} \in [NMA_{iL}, NMA_{iU}]$. The MA statistic mentioned by [46] is a special case of the proposed $NMA_{iN} \in [NMA_{iL}, NMA_{iU}]$.The proposed $NMA_{iN} \in [NMA_{iL}, NMA_{iU}]$ becomes MA statistic if I_L =0. The neutrosophic mean and variance of $NMA_{iN} \in [NMA_{iL}, NMA_{iU}]$ when the process is an in-control $i \ge w_N;\ w_N \in [w_L, w_U]$ are given as follows:

$$E_N(NMA_{iN}) = \mu_{0N};\ NMA_{iN} \in [NMA_{iL}, NMA_{iU}], \mu_{0N} \in [\mu_{0L}, \mu_{0U}] \tag{3}$$

and

$$V_N(NMA_{iN}) = \frac{\sigma_N^2}{n_N w_N};\ NMA_{iN} \in [NMA_{iL}, NMA_{iU}], n_N \in [n_L, n_U], w_N \in [w_L, w_U], \sigma_N^2 \in [\sigma_L^2, \sigma_U^2] \tag{4}$$

The projected control chart comprise of the following two neutrosophic control limits:

$$LCL_{1N} = \mu_{0N} - \frac{k_{1N}\sigma_N}{\sqrt{n_N w_N}};\ n_N \in [n_L, n_U], w_N \in [w_L, w_U], \sigma_N \in [\sigma_L, \sigma_U], \mu_{0N} \in [\mu_{0L}, \mu_{0U}]$$

$$LCL_{2N} = \mu_{0N} - \frac{k_{2N}\sigma_N}{\sqrt{n_N w_N}}$$

$$UCL_{2N} = \mu_{0N} + \frac{k_{2N}\sigma_N}{\sqrt{n_N w_N}}$$

$$UCL_{1N} = \mu_{0N} + \frac{k_{1N}\sigma_N}{\sqrt{n_N w_N}}$$

Where $k_{1N} \in [k_{1L}, k_{1U}]$ and $k_{2N} \in [k_{2L}, k_{2U}]$.

The moving control chart is memory-based control chart. Therefore, the control chart parameters will be determined using the neutrosophic Monte Carlo simulation. The chart parameters are obtained using neutrosophic Monte Carlo simulation study given in next section.

3. Neutrosophic Monte Carlo Simulation

The neutrosophic Monte Carlo (NMC) simulation method for the proposed NMA control chart is introduced in this section. If the manufacturing process follows neutrosophic normal distribution mean with out-of-control process mean $\mu_{1N}=\mu_{0N}+c\sigma_N;\mu_{1N}\in[\mu_{1L},\mu_{1U}]$, where c is a shift constant. Let $r_{0N}\in[r_{0L},r_{0U}]$ be the specified neutrosophic average run length (ARLN) when the process is in-control state, for more details, the reader may refer to [47]. The NMC simulation is stated as follows:

Step-1: Generate a random sample of size $n_N\in[n_L,n_U]$ from the neutrosophic standard normal distribution with $\mu_{0N}\in[\mu_{0L},\mu_{0U}]$ and variance $\sigma_N^2\in[\sigma_L^2,\sigma_U^2]$. Compute $\bar{Y}_{iN}\in[\bar{Y}_{iL},\bar{Y}_{iU}]$ for i^{th} subgroup.

Step-2: Compute the statistic $NMA_{iN}\in[NMA_{iL},NMA_{iU}]$ and plot it on $LCL_N\in[LCL_L,LCL_U]$ and $UCL_N\in[UCL_L,UCL_U]$. Note the first out-of-control value, which is called the run length.

Step-3: Repeat the process 10,000 times and compute the neutrosophic average run length (ARLN) and neutrosophic standard deviation of run length (SDRLN). Choose $k_N\in[k_L,k_U]$ for which ARLN for in control process, say $\text{ARL}_{0N}\geq r_{0N}$; $\text{ARL}_{0N}\in[\text{ARL}_{0L},\text{ARL}_{0U}]$.

Step-4: Generate a random sample of size $n_N\in[n_L,n_U]$ from the neutrosophic standard normal distribution with $\mu_{1N}\in[\mu_{1L},\mu_{1U}]$ and variance $\sigma_N^2\in[\sigma_L^2,\sigma_U^2]$. Compute $\bar{Y}_{iN}\in[\bar{Y}_{iL},\bar{Y}_{iU}]$ for ith subgroup.

Step-5: Compute the statistic $NMA_{iN} \in [NMA_{iL}, NMA_{iU}]$ and plot it on $LCL_N \in [LCL_L, LCL_U]$ and $UCL_N \in [UCL_L, UCL_U]$. Note the first out-of-control value, which is called the run length for the shifted process.

Step-3: Repeat the process 10,000 times and compute the ARLN and SDRLN, say $\text{ARL}_{1N} \in [\text{ARL}_{1L}, \text{ARL}_{1U}]$ at $\mu_{1N} \in [\mu_{1L}, \mu_{1U}]$ for various values of c.

Using the NMC simulation process, $\text{ARL}_{1N} \in [\text{ARL}_{1L}, \text{ARL}_{1U}]$ and SDRLN for various c, $n_N \in [n_L, n_U]$ and $w_N \in [w_L, w_U]$ are determined and placed in Tables 1-6. From Tables 1-6, the following trends can be noted in the values of $\text{ARL}_{1N} \in [\text{ARL}_{1L}, \text{ARL}_{1U}]$.

1. For the fixed values of $w_N \in [w_L, w_U]$, the values of $\text{ARL}_{1N} \in [\text{ARL}_{1L}, \text{ARL}_{1U}]$ decreases as $n_N \in [n_L, n_U]$ increases.
2. The values of $\text{ARL}_{1N} \in [\text{ARL}_{1L}, \text{ARL}_{1U}]$ increases as r_{0N} increases from 300 to 370.

3.1 Algorithm for MDS Repetitive

Step1: We generated 2500 random sample of size $n_N \in [n_L, n_U]$ for normal distribution and the sample mean $\bar{Y}_{iN} \epsilon [\bar{Y}_{iL}, \bar{Y}_{iU}]$ is computed, for these 2500 samples the plotting statistics $NMA_{iN} \in [NMA_{iL}, NMA_{iU}]$ is computed and plotted over the MDS repetitive control chart. Where $k_{1N} \in [k_{1L}, k_{1U}]$ and $k_{2N} \in [k_{2L}, k_{2U}]$ are specified.

Step 2: The process is declared in control if lies in inner limits or if proceeding m_N lies in between outer limits and repeat otherwise. The run length is computed if the plotting statistics plot a point outside the outer control limits or if the process lies in the inner two limits for say rep time's then Run length is computed as the point that lies out of limit minus rep times.

Step 3: Steps 1 and 2 are repeated 10000 time and the $\mathrm{RL}_N \in [\mathrm{RL}_L, \mathrm{RL}_U]$ is computed for each run if the mean and standard deviation of $\mathrm{RL}_N \in [\mathrm{RL}_L, \mathrm{RL}_U]$ are equals to specified r_{0N} say [300,300] and [370,370] then those pairs of $k_{1N} \in [k_{1L}, k_{1U}]$ and $k_{2N} \in [k_{2L}, k_{2U}]$ are selected as plan parameters.

3.1.1 Shifted Process:

Step 1: We generated 2500 random sample of size $n_N \in [n_L, n_U]$ for normal distribution for certain amount of shift in the mean say c and the sample mean $\bar{Y}_N \in [\bar{Y}_L, \bar{Y}_U]$ is computed, for these 2500 samples the plotting statistics $NMA_{iN} \in [NMA_{iL}, NMA_{iU}]$ is computed and plotted over the MDS repetitive control chart for those k's that where determined for in control process.

Step 2: The Neutrosophic average run length and its standard deviation for shift in mean is computed.

Step 3: Process is repeated 10000 times to obtain the ARLN and SDRLN and is presented in Tables 1 and 2.

3.2 Algorithm for MDS

Step1: We generated 2500 random sample of size $n_N \in [n_L, n_U]$ for normal distribution and the sample mean $\bar{Y}_{iN} \in [\bar{Y}_{iL}, \bar{Y}_{iU}]$ is computed, for these 2500 samples the plotting statistics $NMA_{iN} \in [NMA_{iL}, NMA_{iU}]$ is computed and plotted over the MDS repetitive control chart Where $k_{1N} \in [k_{1L}, k_{1U}]$ and $k_{2N} \in [k_{2L}, k_{2U}]$ are specified.

Step 2: The process is declared in control if lies in inner limits or if proceeding m_N lies in between outer limits. The Run length is computed if the plotting statistics plot a point outside the outer control limits or if the process does not lie in the inner two limits for say m_N time's .

Step 3: Steps 1 and 2 are repeated 10000 time and the $\text{RL}_N \in [\text{RL}_L, \text{RL}_U]$ is computed for each run if the mean and standard deviation of $\text{RL}_N \in [\text{RL}_L, \text{RL}_U]$ are equals to specified r_{0N} say [300,300] and [370,370] then those pairs of $k_{1N} \in [k_{1L}, k_{1U}]$ and $k_{2N} \in [k_{2L}, k_{2U}]$ are selected as plan parameters.

3.2.1 Shifted Process:

Step 1: We generated 2500 random sample of size $n_N \in [n_L, n_U]$ for normal distribution for certain amount of shift in the mean say c and the sample mean $\bar{Y}_{iN} \in [\bar{Y}_{iL}, \bar{Y}_{iU}]$ is computed, for these 2500 samples the plotting statistics $NMA_{iN} \in [NMA_{iL}, NMA_{iU}]$ is computed and plotted over the MDS repetitive control chart for those k's that where determined for in control process.

Step 2: The Neutrosophic average run length and its standard deviation for shift in mean is computed.

Step 3: Process is repeated 10000 times to about ARLN and SDRLN and is presented in Table 3 and 4.

3.3 Algorithm for Repetitive Sampling

Step1: We generated 2500 random sample of size $n_N \in [n_L, n_U]$ for normal distribution and the sample mean $\bar{Y}_{iN} \in [\bar{Y}_{iL}, \bar{Y}_{iU}]$ is computed, for these 2500 samples the plotting statistics $NMA_{iN} \in [NMA_{iL}, NMA_{iU}]$ is computed and plotted over the MDS repetitive control chart Where $k_{1N} \in [k_{1L}, k_{1U}]$ and $k_{2N} \in [k_{2L}, k_{2U}]$ are specified.

Step 2: The process is declared in control if lies in inner limits The run length is computed if the plotting statistics plot a point outside the outer control limits or if the process d lie in the inner two limits if repeat the sample .

Step 3: Steps 1 and 2 are repeated 10000 time and the $\mathrm{RL}_N \in [\mathrm{RL}_L, \mathrm{RL}_U]$ is computed for each run if the mean and standard deviation of $\mathrm{RL}_N \in [\mathrm{RL}_L, \mathrm{RL}_U]$ are equals to specified r_{0N} say [300,300] and [370,370] then those pairs of $k_{1N} \in [k_{1L}, k_{1U}]$ and $k_{2N} \in [k_{2L}, k_{2U}]$ are selected as plan parameters.

3.3.1 Shifted Process:

Step 1: We generated 2500 random sample of size $n_N \in [n_L, n_U]$ for normal distribution for certain amount of shift in the mean say c and the sample mean $\bar{Y}_{iN} \in [\bar{Y}_{iL}, \bar{Y}_{iU}]$ is computed, for these 2500 samples the plotting statistics $NMA_{iN} \in [NMA_{iL}, NMA_{iU}]$ is computed and plotted over the MDS repetitive control chart for those *k*'s that where determined for in control process.

Step 2: The Neutrosophic average run length and its standard deviation for shift in mean is computed.

Step 3: Process is repeated 10000 times to about ARLN and SDRLN and is presented in Table 5 and 6.

4. Comparative Study

Here, we compare the performance of MDS repetitive over the MDS and repetitive control charts under the neutrosophic environment in terms of ARLN and SDRLN. The developed control chart is the expansion of the MDS and repetitive mean control chart based on neutrosophic statistics studied in this paper. We have provided the values of $\mathrm{ARL}_{1N} \in [\mathrm{ARL}_{1L}, \mathrm{ARL}_{1U}]$ and SDRLN for three charts in Table 7 when $r_{0N} \in [370, 370]$. It is observed that from Table 7 as ARLN and SDRLN for the developed control chart shows smaller indeterminacy intervals of $\mathrm{ARL}_{1N} \in [\mathrm{ARL}_{1L}, \mathrm{ARL}_{1U}]$ and $\mathrm{SDRL}_{1N} \in [\mathrm{SDRL}_{1L}, \mathrm{SDRL}_{1U}]$ when compared with the MDS and repetitive control charts. For instance, when c=0.15, the values of ARLN and SDRLN for the proposed charts are [129.54, 65.7] and [128.33, 63.57], respectively. Whereas, the corresponding values based on MDS chart are [134.32, 79.79] and [130.16, 74.84]; and for repetitive control chart are [140.55, 80.85] and [138.59, 76.97] respectively. Using the comparative study in Table 7, it is noticeable that once c=0.15, the developed control chart shows the shift in the process between 129th and 66th sample whereas MDS chart is expected to detect the shift between 134th and the 79th sample; whereas repetitive chart is expected to detect the shift between 140th and the 80th sample. Hence we conclude that the developed MDS repetitive control chart under neutrosophic environment is more efficient than the MDS and repetitive control charts for detecting the speedy shift in the course of action.

5. Real Example

Monitoring of Road Accidents and Injuries using Real Data

Two real data sets are given to illustrate the developed control chart and its competitors MDS and repetitive control charts as an application in this section. The data sets related to the injuries and accidents of Saudi Arabia and are collected from the website https://data.gov.sa/ Data/en/ dataset/1439/resource/e6a973aa-32a8-4fa2-964c-78bcf0e8bf58. These data sets were already discussed to monitor the road injuries and the number of accidents using control chart by authors [48] and [49].

The first data set used to illustrate the developed control chart to monitor road accident data for every day in a year, which is shown in Table 8. The aim of this illustration is monitor the road accidents for the various days of the week. The obtained mean $\bar{Y}_{iN} \in [\bar{Y}_{iL}, \bar{Y}_{iU}]$ and the chart statistics $NMA_{iN} \in [NMA_{iL}, NMA_{iU}]$ are given in Table 8. The control limits of three charts are displayed in Table 9. The implementation of the developed MDSR, MDS and repetitive control charts for monitoring of road accidents are depicted in Figure 1. In Figure 1, first chart is for MDS, middle chart is for repetitive and third chart is for MDSR. The charts depicted in Figure 1 gives a clear understanding that some points are in indeterminate intervals and a number of points are close to control limits which shows that there may be a shift in road accidents. At the same time, from first and second charts in Figure 1indicate moving average values of the number of road accidents are under control. Hence by comparing the three charts in Figure 1, it is noticeable that the developed control chart shows the decision-makers can expect a shift in road accidents. Hence the proposed control chart could give an alert and recognize the factors reason the shift in road accidents.

The second data set used to illustrate the developed control chart to monitor injury data of various age ranges of people in different months of the year is reported, which is shown in Table 10. The aim of this illustration is monitor the injury of people in various months of the year is a variable of interest here. The obtained mean $\bar{Y}_{iN} \in \left[\bar{Y}_{iL}, \bar{Y}_{iU}\right]$ and the chart statistics $NMA_{iN} \in \left[NMA_{iL}, NMA_{iU}\right]$ are given in Table 10. The control limits of three charts are displayed in Table 11. The implementation of the developed MDSR, MDS and repetitive control charts for monitoring the injury of people are depicted in Figure 2. In Figure 2, first chart is for MDS, middle chart is for repetitive and third chart is for MDSR. The charts depicted in Figure 1 gives a clear understanding that some points are in indeterminate intervals and a number of points are close to control limits which shows that there may be a shift in the injury of people. At the same time, from first and second charts in Figure 1indicate moving average values of the number of the injury of people are under control. Hence by comparing the three charts in Figure 2, it is noticeable that the developed control chart shows the decision-makers can expect a shift in the injury of people. Hence the proposed control chart could give an alert and recognize the factors reason the shift in the injury of people.

6. Monitoring of Road Accidents and Injuries using Simulated Data

In this section, the performance of the developed control chart could be studied using simulation data. The simulated data is generated from the neutrosophic normal distribution. It is assumed that the process is in-control at neutrosophic mean $\mu_{0N} \in [0,0]$ and variance $\sigma_N^2 \in [1,1]$. The first 20 values are generated at mean $\mu_{0N} \in [0,0]$ and variance $\sigma_N^2 \in [1,1]$ and the next 20 values are generated from the shifted process when c=0.30, $n_N \in [3,5]$, $m_N \in [2,4]$ and $w_N \in [3,5]$. The values of the neutrosophic statistic $NMA_{iN} \in \left[NMA_{iL}, NMA_{iU}\right]$ are computed for three control charts and displayed in Table 12. The chart limits for three control charts for simulated data are displayed in Table 13. The implementation of the developed MDSR, MDS and repetitive control charts for monitoring the injury of people are depicted in Figure 3. In Figure 3, first chart is for MDSR, middle chart is MDS for and third chart is for Repetitive. At the specified parameters, the proposed chart should detect the shift in the process from the 34th sample to the 39th sample. Whereas, MDS and Repetitive control charts fail to detect the shift in the process. The simulation study showed that the proposed control chart edge to detect in a shift in the process and earlier as compared to the existing charts. Therefore, proposed MDSR chart more helpful to detect the shift in the process.

7. Concluding Remarks

A neutrosophic moving average (NMA) control chart under neutrosophic statistics using multiple dependent state repetitive, multiple dependent state repetitive and Repetitive sampling schemes are developed. The NMA control chart for the normal distribution was offered under the neutrosophic statistics. The chart coefficients of the proposed control chart are obtained using simulation under NS. The confrontation study demonstrated the domination of the developed chart as compared with the existing NMA under multiple dependent state repetitive and Repetitive sampling schemes. Two real examples from accident and injury data are taken to investigate the methodology of the proposed chart. The proposed chart shows the better performed over the existing control charts. The proposed chart using environment of EWMA statistics under neutrosophic could be extended for future research.

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Table 1: ARLN and SDARLN for MDSR when $n_N \in [3,5]; w_N \in [3,5]; m_N \in [2,4]$.

c	$k_{1N} \in$[1.1887, 1.1494]		$k_{1N} \in$[1.2136, 1.1969]	
	$k_{2N} \in$[2.971, 2.9038]		$k_{2N} \in$[3.0419, 2.9852]	
	ARLN	SDRLN	ARLN	SDRLN
0.00	[300.05,301.9]	[290.31,286.56]	[371.81,370.91]	[364.89,364.45]
0.05	[276.09,236.28]	[273.73,231.15]	[339.76,301.59]	[328.46,293.35]
0.06	[262.45,219.65]	[260.7,216.47]	[326.24,278.24]	[321.62,272.64]
0.08	[238.8,174.8]	[235.03,170.9]	[297.4,226.97]	[288.66,226]
0.10	[213.71,140.69]	[211.67,141.95]	[267.09,176.84]	[262.48,172.33]
0.12	[187.05,110.6]	[184.34,108.83]	[229.1,138.37]	[227.39,136.75]
0.15	[149.79,77.03]	[147.99,74.37]	[183.81,93.53]	[181.7,90.88]
0.20	[102.12,42.17]	[100.37,39.21]	[124.35,49.73]	[122.56,46.47]
0.25	[67.93,24.63]	[66.95,21.92]	[82.29,28.64]	[79.85,26.42]
0.30	[46.18,15.48]	[44.66,12.87]	[54.84,17.25]	[53.01,14.6]
0.40	[22.05,7.95]	[20.72,4.68]	[25.59,8.41]	[24.17,5.21]
0.50	[11.58,5.81]	[10.05,1.87]	[12.95,5.91]	[11.39,2.03]
0.60	[6.86,5.21]	[5.15,0.77]	[7.36,5.24]	[5.67,0.86]
0.70	[4.78,5.05]	[2.73,0.34]	[5.01,5.06]	[3.07,0.37]
0.80	[3.79,5.01]	[1.55,0.13]	[3.87,5.01]	[1.67,0.14]
0.90	[3.35,5]	[0.92,0.05]	[3.38,5]	[0.96,0.05]
0.95	[3.23,5]	[0.71,0.04]	[3.26,5]	[0.75,0.03]
1.00	[3.15,5]	[0.56,0.02]	[3.16,5]	[0.56,0.02]

1.25	[3.02,5]	[0.18,0]	[3.02,5]	[0.17,0]
1.50	[3,5]	[0.02,0]	[3,5]	[0.05,0]
1.75	[3,5]	[0.01,0]	[3,5]	[0,0]
2.00	[3,5]	[0,0]	[3,5]	[0,0]
2.50	[3,5]	[0,0]	[3,5]	[0,0]
3.00	[3,5]	[0,0]	[3,5]	[0,0]

Table 2: ARLN and SDARLN for MDSR when $n_N \in [5,7]; w_N \in [3,5]; m_N \in [2,4]$.

c	$k_{1N} \in$ [1.2318,1.1909]		$k_{1N} \in$ [1.2129,1.2816]	
	$k_{2N} \in$ [2.9571,2.9046]		$k_{2N} \in$ [3.0444,2.9591]	
	ARLN	SDRLN	ARLN	SDRLN
0.00	[300.89,301.59]	[293.45,291.25]	[369.69,366.92]	[355.23,357.96]
0.05	[254.5,223.77]	[252.03,222.4]	[325.16,267.86]	[319.34,264.51]
0.06	[235.14,198.53]	[228.16,194.84]	[303.34,240.72]	[300.9,234.19]
0.08	[204.59,152.69]	[203.42,153.95]	[257.65,182.2]	[250.12,180.32]
0.10	[174.32,114.38]	[172.23,111.34]	[214.81,138.66]	[208.48,135.36]
0.12	[143.37,85.15]	[143.08,83.9]	[177.32,102.29]	[173.16,100.43]
0.15	[105.39,57.05]	[104.59,54.18]	[129.54,65.7]	[128.33,63.57]
0.20	[63.24,28.6]	[61.36,26.13]	[76.3,33.48]	[75.59,31.55]
0.25	[38.75,16.66]	[37.25,13.77]	[45.67,18.49]	[44.37,16.03]
0.30	[24.44,10.51]	[23.53,7.56]	[27.82,11.41]	[26.64,8.37]
0.40	[10.65,6.2]	[8.93,2.45]	[11.76,6.46]	[10,2.84]
0.50	[5.84,5.24]	[3.96,0.86]	[6.09,5.31]	[4.21,0.99]
0.60	[4.03,5.04]	[1.87,0.31]	[4.12,5.06]	[1.97,0.37]
0.70	[3.36,5.01]	[0.93,0.11]	[3.4,5.01]	[1,0.1]
0.80	[3.13,5]	[0.51,0.04]	[3.12,5]	[0.47,0.03]
0.90	[3.04,5]	[0.26,0]	[3.04,5]	[0.24,0]
0.95	[3.02,5]	[0.17,0]	[3.02,5]	[0.18,0]
1.00	[3.01,5]	[0.13,0]	[3.01,5]	[0.13,0]
1.25	[3,5]	[0.02,0]	[3,5]	[0.01,0]
1.50	[3,5]	[0,0]	[3,5]	[0,0]
1.75	[3,5]	[0,0]	[3,5]	[0,0]
2.00	[3,5]	[0,0]	[3,5]	[0,0]
2.50	[3,5]	[0,0]	[3,5]	[0,0]
3.00	[3,5]	[0,0]	[3,5]	[0,0]

Table 3: ARLN and SDARLN for MDS when $n_N \in [3,5]; w_N \in [3,5]; m_N \in [2,4]$.

c	$k_{1N} \in [2.4469, 2.5016]$		$k_{1N} \in [2.5796, 2.5542]$	
	$k_{2N} \in [3.1585, 3.0434]$		$k_{2N} \in [3.0653, 3.2212]$	
	ARLN	SDRLN	ARLN	SDRLN
0.00	[301.95,302.42]	[303.65,299.07]	[371.55,370.72]	[365.08,352.96]
0.05	[285.14,244.22]	[281.49,239.96]	[340.77,290.35]	[332.22,285.72]
0.06	[269.58,222.77]	[264.78,217.62]	[322.26,272.35]	[317.99,265.45]
0.08	[242.47,187.46]	[241.12,186.48]	[293.84,221.72]	[288.47,215.74]
0.10	[217.13,151.17]	[212.25,148.07]	[259.39,181.75]	[252.82,176.03]
0.12	[190.79,121.28]	[185.78,118.67]	[226.96,143.86]	[222.83,138.25]
0.15	[156.48,89.34]	[153.2,83.23]	[181.63,103.29]	[177.97,101.08]
0.20	[108.74,55.55]	[105.23,51.19]	[130.02,61.3]	[127.34,55.9]
0.25	[77.24,35.69]	[74.87,31.71]	[91.25,40]	[89.54,35.59]
0.30	[55.25,24.9]	[51.39,21.49]	[65.24,27.64]	[61.71,23.43]
0.40	[30.54,13.64]	[28.33,9.67]	[34.92,14.66]	[32.61,10.69]
0.50	[18.76,8.52]	[16.44,5.21]	[20.8,9.59]	[18.5,5.87]
0.60	[12.27,6.27]	[9.7,2.79]	[13.33,6.33]	[11,2.88]
0.70	[8.82,5.44]	[6.41,1.38]	[9.4,5.51]	[7.22,1.53]
0.80	[6.6,5.16]	[4.27,0.75]	[6.97,5.17]	[4.78,0.79]
0.90	[4.57,5.04]	[2.81,0.28]	[4.86,5.05]	[3.14,0.37]
0.95	[4.19,5.02]	[2.29,0.23]	[4.43,5.02]	[2.62,0.24]
1.00	[3.9,5.01]	[1.92,0.15]	[4.09,5.01]	[2.11,0.15]
1.25	[3.2,5]	[0.76,0]	[3.23,5]	[0.8,0.01]
1.50	[3.03,5]	[0.24,0]	[3.03,5]	[0.25,0]
1.75	[3,5]	[0.06,0]	[3.01,5]	[0.1,0]
2.00	[3,5]	[0.02,0]	[3,5]	[0.02,0]
2.50	[3,5]	[0,0]	[3,5]	[0,0]
3.00	[3,5]	[0,0]	[3,5]	[0,0]

Table 4: ARLN and SDARLN for MDS when $n_N \in [5,7]; w_N \in [3,5]; m_N \in [2,4]$.

c	$k_{1N} \in [2.4929, 2.495]$		$k_{1N} \in [2.5206, 2.5703]$	
	$k_{2N} \in [3.0419, 3.0453]$		$k_{2N} \in [3.1871, 3.1688]$	
	ARLN	SDRLN	ARLN	SDRLN
0.00	[303.68,300.37]	[296.91,296.43]	[371.65,377.29]	[365.6,369.31]
0.05	[263.99,219.69]	[260.59,216.16]	[322.01,274.8]	[317.58,274.73]
0.06	[243.32,198.84]	[242.11,191.67]	[301.97,246.76]	[296.03,238.3]
0.08	[214.5,157.11]	[213.54,155.49]	[253.35,194.5]	[251.47,191.9]
0.10	[181.16,122.61]	[177.31,117.97]	[219.75,149.41]	[216.14,142.91]

0.12	[149.3,94.12]	[144.96,89.46]	[180.51,115.94]	[178.85,114.17]
0.15	[116.23,68.17]	[116.06,63.79]	[134.32,79.79]	[130.16,74.84]
0.20	[74.24,38.88]	[71.82,35.15]	[83.06,45.14]	[79.67,40.74]
0.25	[48.62,25.23]	[46.02,21.61]	[55.07,28.22]	[52.87,24.58]
0.30	[33.46,17.28]	[31.03,13.45]	[36.78,19.2]	[33.93,15.34]
0.40	[17.17,9.9]	[14.77,6.17]	[19.25,10.63]	[16.44,6.81]
0.50	[10.3,6.35]	[8.05,2.89]	[11.13,6.49]	[8.69,3.05]
0.60	[7.03,5.4]	[4.72,1.31]	[7.4,5.47]	[5.02,1.45]
0.70	[4.61,5.09]	[2.84,0.52]	[4.71,5.13]	[2.95,0.64]
0.80	[3.79,5.02]	[1.78,0.23]	[3.82,5.02]	[1.8,0.25]
0.90	[3.37,5]	[1.07,0.08]	[3.41,5]	[1.15,0.09]
0.95	[3.25,5]	[0.85,0.04]	[3.28,5]	[0.91,0.02]
1.00	[3.15,5]	[0.62,0.01]	[3.17,5]	[0.67,0.03]
1.25	[3.01,5]	[0.13,0]	[3.01,5]	[0.15,0]
1.50	[3,5]	[0.04,0]	[3,5]	[0.02,0]
1.75	[3,5]	[0,0]	[3,5]	[0.01,0]
2.00	[3,5]	[0,0]	[3,5]	[0,0]
2.50	[3,5]	[0,0]	[3,5]	[0,0]
3.00	[3,5]	[0,0]	[3,5]	[0,0]

Table 5: ARLN and SDARLN for repetitive when $n_N \in [3,5]; w_N \in [3,5]; m_N \in [2,4]$.

c	$k_{1N} \in [2.8918,2.8087]$		$k_{1N} \in [2.9589,2.8941]$	
	$k_{2N} \in [2.1778,2.4832]$		$k_{2N} \in [2.4019,2.2933]$	
	ARLN	SDRLN	ARLN	SDRLN
0.00	[299.88,297.47]	[290.43,288.1]	[372.33,373.9]	[363.81,361.98]
0.05	[278.29,244.52]	[272.28,243.12]	[344.4,303.97]	[335.62,298.78]
0.06	[267.28,228.37]	[265.58,223.95]	[330.54,281.62]	[318.89,278.82]
0.08	[244.57,186.46]	[241.33,183.84]	[297.41,228.23]	[290.62,222.34]
0.10	[221.2,154.82]	[217.59,151.63]	[268.26,188.42]	[267.38,185.97]
0.12	[195.19,123.69]	[191.74,120.65]	[238.42,150.08]	[232.68,146.12]
0.15	[159.62,91.62]	[155.45,88.54]	[196.49,108.16]	[198.53,105.26]
0.20	[114.52,56.92]	[113.02,53.93]	[136.9,64.8]	[134.83,61.6]
0.25	[81.11,36.12]	[79.34,32.88]	[95.48,40.51]	[91.98,37.96]
0.30	[56.58,24.73]	[54.53,21.41]	[67.62,26.45]	[65.71,23.72]
0.40	[30.62,13.39]	[29.24,10.39]	[36.34,13.39]	[34.65,10.54]
0.50	[17.72,6.02]	[16.16,5.85]	[20.83,4.34]	[19.21,5.22]
0.60	[11.42,1]	[9.91,0]	[12.85,1.01]	[11.04,0.3]
0.70	[7.43,1]	[5.74,0]	[8.58,1]	[6.86,0]
0.80	[3.54,1]	[3.62,0]	[5.24,1]	[4.46,0]
0.90	[2.36,1]	[2.29,0]	[2.88,1]	[2.98,0]

0.95	[1.93,1]	[1.85,0]	[2.39,1]	[2.37,0]
1.00	[1,1]	[0.07,0]	[1.12,1]	[0.73,0]
1.25	[1,1]	[0,0]	[1,1]	[0,0]
1.50	[1,1]	[0,0]	[1,1]	[0,0]
1.75	[1,1]	[0,0]	[1,1]	[0,0]
2.00	[1,1]	[0,0]	[1,1]	[0,0]
2.50	[1,1]	[0,0]	[1,1]	[0,0]
3.00	[1,1]	[0,0]	[1,1]	[0,0]

Table 6: ARLN and SDRLN for repetitive when $n_N \in [5,7]; w_N \in [3,5]; m_N \in [2,4]$.

c	$k_{1N} \in [2.8845, 2.822]$		$k_{1N} \in [2.9525, 2.8866]$	
	$k_{2N} \in [2.2466, 2.1596]$		$k_{2N} \in [2.2431, 2.4645]$	
	ARLN	SDRLN	ARLN	SDRLN
0.00	[300.64,300.92]	[289.78,297.56]	[370.23,371.57]	[357.93,361.41]
0.05	[255.63,233.24]	[253.96,230.54]	[310.21,279.78]	[306.06,275.64]
0.06	[248.63,211.93]	[246.5,207.11]	[293.6,253.2]	[285.92,247.82]
0.08	[214.22,163.09]	[208.73,160.26]	[260.05,195.23]	[255.44,190.54]
0.10	[178.98,128.24]	[178.67,125.74]	[217.4,151.09]	[217.87,146.6]
0.12	[155.96,99.12]	[154.53,96.37]	[181.53,116.82]	[178.6,111.76]
0.15	[120.25,69.2]	[117.14,66.36]	[140.55,80.85]	[138.59,76.97]
0.20	[75.72,39.59]	[73.05,36.85]	[86.94,45.94]	[84.71,42.13]
0.25	[48.76,23.93]	[46.58,21.31]	[56.81,28.87]	[54.84,26.09]
0.30	[33.2,15.98]	[31.76,12.98]	[37.77,18.49]	[36.29,15.58]
0.40	[16.98,4.51]	[15.39,5.43]	[17.86,9.73]	[16.45,6.61]
0.50	[9.52,1]	[7.9,0.18]	[9.89,1.12]	[8.16,1.04]
0.60	[4.09,1]	[4.2,0]	[4.35,1]	[4.54,0]
0.70	[2.44,1]	[2.39,0]	[2.55,1]	[2.58,0]
0.80	[1,1]	[0,0]	[1,1]	[0,0]
0.90	[1,1]	[0,0]	[1,1]	[0,0]
0.95	[1,1]	[0,0]	[1,1]	[0,0]
1.00	[1,1]	[0,0]	[1,1]	[0,0]
1.25	[1,1]	[0,0]	[1,1]	[0,0]
1.50	[1,1]	[0,0]	[1,1]	[0,0]
1.75	[1,1]	[0,0]	[1,1]	[0,0]
2.00	[1,1]	[0,0]	[1,1]	[0,0]
2.50	[1,1]	[0,0]	[1,1]	[0,0]
3.00	[1,1]	[0,0]	[1,1]	[0,0]

Table 7: Comparison between Three Control Charts.

c	MDS Repetitive		MDS		Repetitive	
	$k_{1N} \in [1.2129, 1.2816]$		$k_{1N} \in [2.5206, 2.5703]$		$k_{1N} \in [2.9525, 2.8866]$	
	$k_{2N} \in [3.0444, 2.9591]$		$k_{2N} \in [3.1871, 3.1688]$		$k_{2N} \in [2.2431, 2.4645]$	
	ARLN	SDARLN	ARLN	SDARLN	ARLN	SDARLN
0.00	[369.69, 366.92]	[355.23, 357.96]	[371.65, 377.29]	[365.6, 369.31]	[370.23, 371.57]	[357.93, 361.41]
0.10	[214.81, 138.66]	[208.48, 135.36]	[219.75, 149.41]	[216.14, 142.91]	[217.4, 151.09]	[217.87, 146.6]
0.12	[177.32, 102.29]	[173.16, 100.43]	[180.51, 115.94]	[178.85, 114.17]	[181.53, 116.82]	[178.6, 111.76]
0.15	[129.54, 65.7]	[128.33, 63.57]	[134.32, 79.79]	[130.16, 74.84]	[140.55, 80.85]	[138.59, 76.97]
0.20	[76.3, 33.48]	[75.59,31.55]	[83.06, 45.14]	[79.67, 40.74]	[86.94, 45.94]	[84.71, 42.13]
0.25	[45.67, 18.49]	[44.37,16.03]	[55.07, 28.22]	[52.87, 24.58]	[56.81, 28.87]	[54.84, 26.09]
0.30	[27.82, 11.41]	[26.64,8.37]	[36.78, 19.2]	[33.93, 15.34]	[37.77, 18.49]	[36.29, 15.58]
0.40	[11.76, 6.46]	[10,2.84]	[19.25, 10.63]	[16.44, 6.81]	[17.86, 9.73]	[16.45, 6.61]
0.50	[6.09, 5.31]	[4.21,0.99]	[11.13, 6.49]	[8.69, 3.05]	[9.89, 1.12]	[8.16, 1.04]
0.60	[4.12, 5.06]	[1.97,0.37]	[7.4, 5.47]	[5.02, 1.45]	[4.35, 1]	[4.54, 0]
0.70	[3.4, 5.01]	[1,0.1]	[4.71, 5.13]	[2.95, 0.64]	[2.55, 1]	[2.58, 0]
0.80	[3.12, 5]	[0.47,0.03]	[3.82, 5.02]	[1.8, 0.25]	[1, 1]	[0, 0]
0.90	[3.04, 5]	[0.24,0]	[3.41, 5]	[1.15, 0.09]	[1, 1]	[0, 0]
0.95	[3.02, 5]	[0.18,0]	[3.28, 5]	[0.91, 0.02]	[1, 1]	[0, 0]
1.00	[3.01, 5]	[0.13,0]	[3.17, 5]	[0.67, 0.03]	[1, 1]	[0, 0]
1.25	[3, 5]	[0.01,0]	[3.01, 5]	[0.15, 0]	[1, 1]	[0, 0]
1.50	[3, 5]	[0,0]	[3, 5]	[0.02, 0]	[1, 1]	[0, 0]
1.75	[3, 5]	[0,0]	[3, 5]	[0.01, 0]	[1, 1]	[0, 0]
2.00	[3, 5]	[0,0]	[3, 5]	[0,0]	[1, 1]	[0, 0]
2.50	[3, 5]	[0,0]	[3, 5]	[0,0]	[1, 1]	[0, 0]
3.00	[3, 5]	[0,0]	[3, 5]	[0,0]	[1, 1]	[0, 0]

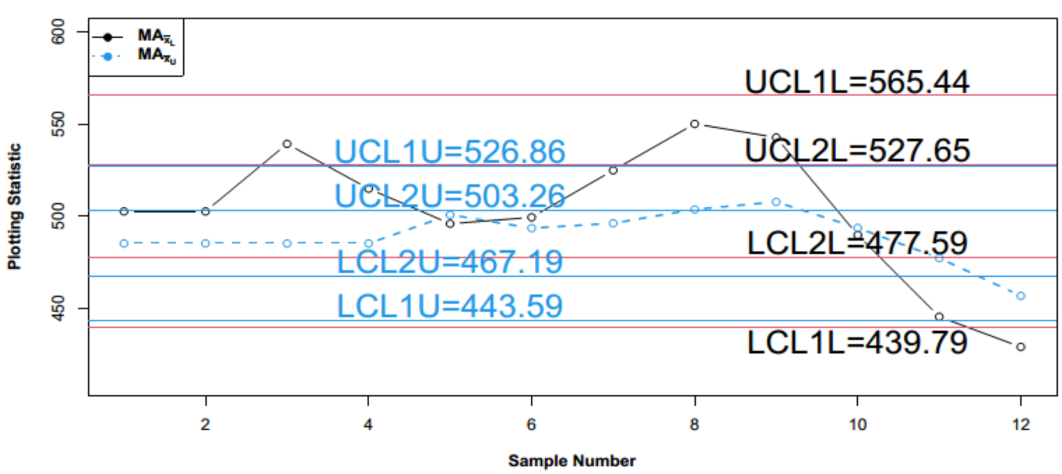
Table 8: Road Accidents Data in Saudi Arabia.

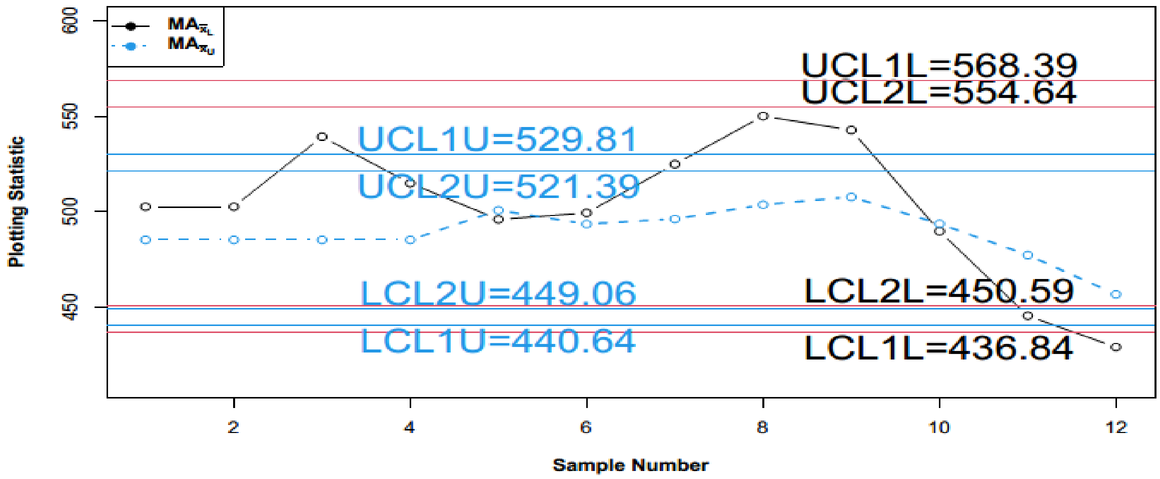
Months	SAT	SUN	MON	TUE	WED	THU	FRI	$\bar{Y}_{iN}$	NMA_{iN}
January	426	601	596	586	574	583	407	[556.6,539]	[502.62,485.23]
February	487	812	525	476	421	498	413	[544.2,518.86]	[502.62,485.23]
March	406	789	551	427	412	498	398	[517,497.29]	[539.27,485.23]
April	448	614	458	407	491	486	407	[483.6,473]	[514.93,485.23]
May	423	611	518	457	427	482	412	[487.2,475.71]	[495.93,500.77]
June	530	590	563	475	479	511	372	[527.4,502.86]	[499.4,493.54]
July	493	623	511	587	587	528	396	[560.2,532.14]	[524.93,496.2]
August	453	652	579	578	552	503	427	[562.8,534.86]	[550.13,503.71]
September	491	546	503	498	488	517	410	[505.2,493.29]	[542.73,507.77]
October	378	412	422	413	382	456	373	[401.4,405.14]	[489.8,493.66]
November	394	533	449	380	393	405	394	[429.8,421.14]	[445.47,477.31]
December	402	576	517	397	388	419	307	[456,429.43]	[429.07,456.77]

Table 9: Limits of three Charts for Road Accidents data.

Mean	[502.62,485.23]		NSD	[79.93,83.24]
	LCL1	LCL2	UCL2	UCL1
MDSR	[439.79,477.59]	[527.65,565.45]	[443.59,467.19]	[503.26,526.86]
MDS	[436.84,450.6]	[554.64,568.39]	[440.64,449.06]	[521.39,529.81]
Repetitive	[441.55,453.05]	[552.19,563.68]	[444.51,452.96]	[517.49,525.95]

Figure 1: The developed and existing control charts for road accidents data.





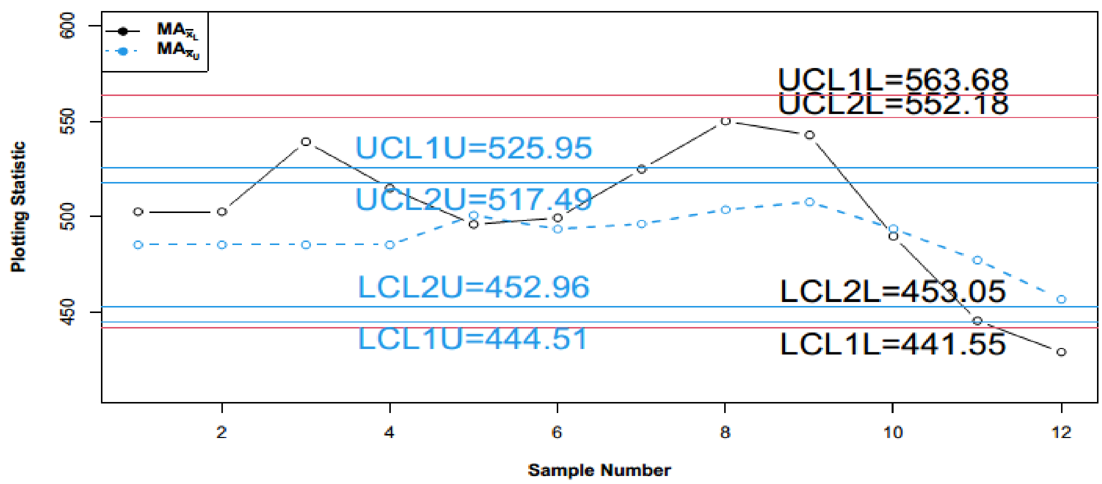


Table 10: The Injuries Data in Saudi Arabia.

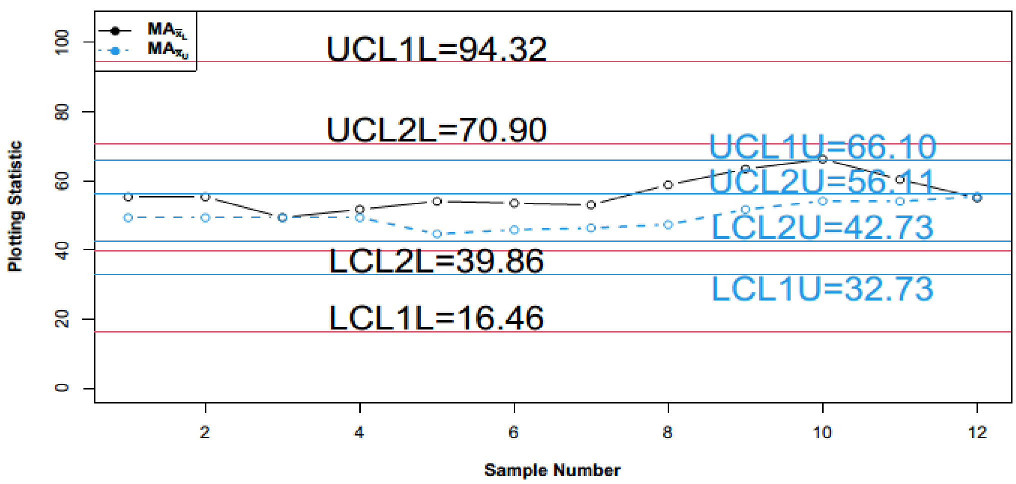
	Age					$\bar{Y}_{iN}$	NMA_{iN}
Months	Less than 18	18 to 30	30 to 40	40 to 50	More than		
January	14	59	62	49	27	[45,42.2]	[55.39,49.42]
February	11	61	54	39	41	[42,41.2]	[55.39,49.42]
March	21	92	71	41	48	[61.33,54.6]	[49.44,49.42]
April	16	79	61	36	36	[52,45.6]	[51.78,49.42]
May	12	74	61	29	23	[49,39.8]	[54.11,44.68]
June	18	86	75	33	29	[59.67,48.2]	[53.56,45.88]

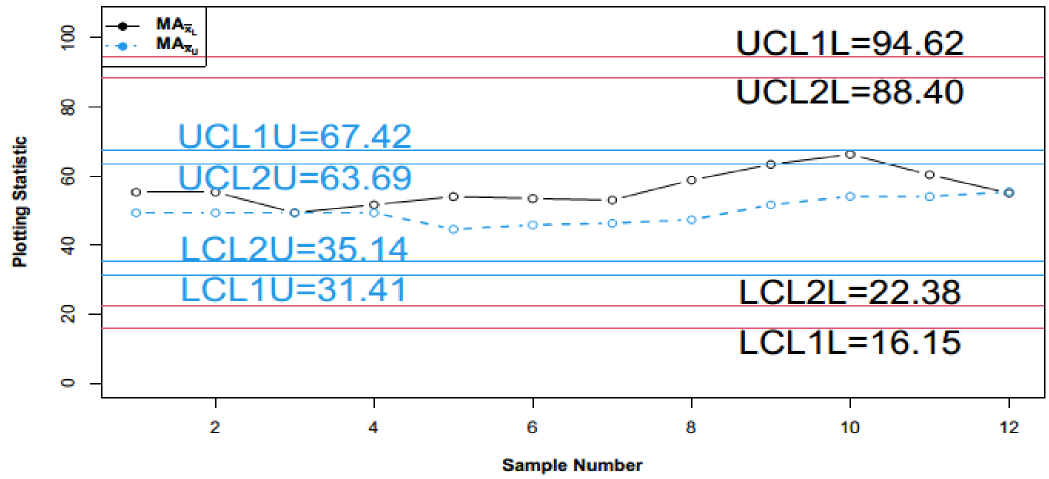
July	15	76	61	29	38	[50.67,43.8]	[53.11,46.4]
August	22	89	88	55	44	[66.33,59.6]	[58.89,47.4]
September	25	103	92	62	55	[73.33,67.4]	[63.44,51.76]
October	15	89	74	48	34	[59.33,52]	[66.33,54.2]
November	17	74	55	54	39	[48.67,47.8]	[60.44,54.12]
December	15	96	61	44	38	[57.33,50.8]	[55.11,55.52]

Table 11: Limits of three Charts for Injuries Data.

mean	[55.39,49.42]		NSD	[38.25,27.94]
	LCL1	LCL2	UCL2	UCL1
MDSR	[16.46,39.86]	[70.92,94.32]	[32.73,42.73]	[56.11,66.1]
MDS	[16.16,22.38]	[88.4,94.62]	[31.41,35.14]	[63.69,67.42]
Repetitive	[17.6,26.68]	[84.1,93.17]	[33.28,35.64]	[63.19,65.55]

Figure 2: The developed and existing control charts for injuries data.





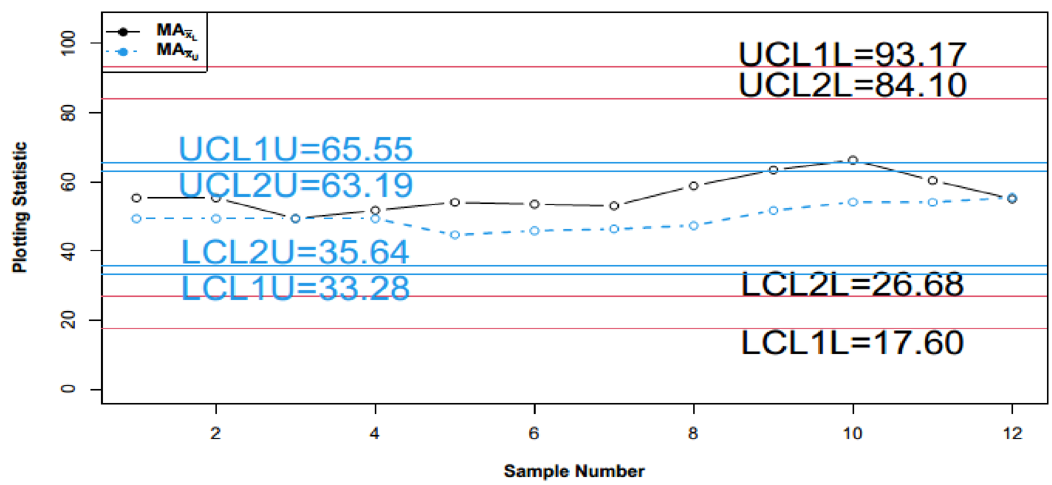


Table 12: The simulated data is for three charts with $n_N \in [3,5]$; $m_N \in [2,4]$ and $w_N \in [3,5]$.

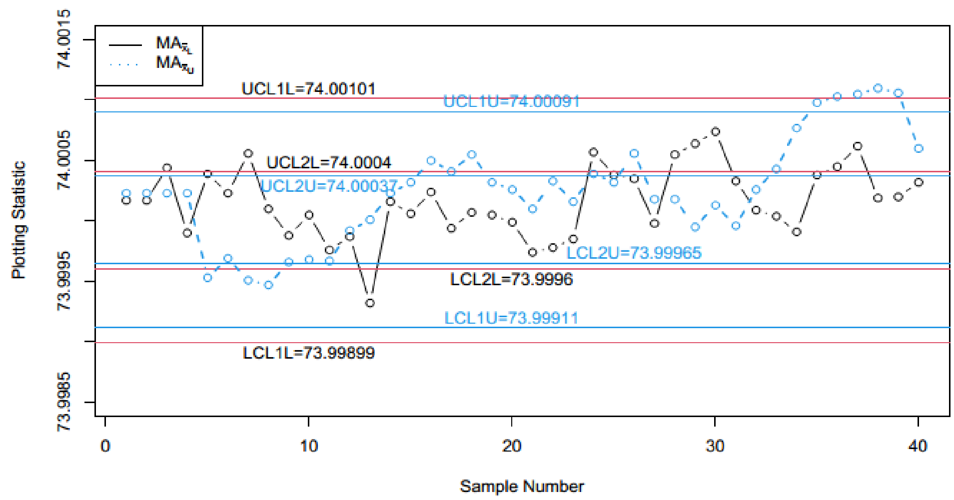
S. No.	MDSR	MDS	Repetitive
1	[74.00017,74.00023]	[74.00014,74.00018]	[74.00013,74.00019]
2	[74.00017,74.00023]	[74.00014,74.00018]	[74.00013,74.00019]
3	[74.00044,74.00023]	[74,74.00018]	[73.99945,74.00019]
4	[73.9999,74.00023]	[74.00029,74.00018]	[73.99947,74.00019]
5	[74.00039,73.99953]	[74.00036,73.99988]	[73.99985,73.99976]
6	[74.00023,73.99969]	[74.00042,73.99987]	[74.00015,73.99961]

7	[74.00056,73.99951]	[74.00011,74.00005]	[74.00002,73.99951]
8	[74.0001,73.99947]	[73.9998,74.00003]	[74.00007,73.99936]
9	[73.99988,73.99966]	[73.99951,73.99975]	[74.00023,73.99953]
10	[74.00005,73.99968]	[73.99981,73.99996]	[74.00074,73.99963]
11	[73.99976,73.99967]	[73.99974,73.99977]	[74.00083,73.99969]
12	[73.99987,73.99992]	[74.00004,73.99966]	[74.00063,73.99946]
13	[73.99932,74.00001]	[74.00019,73.99979]	[73.99994,73.99981]
14	[74.00016,74.00023]	[74.00036,73.99979]	[73.99999,73.99982]
15	[74.00006,74.00032]	[74.00014,73.99991]	[73.99997,73.99981]
16	[74.00024,74.0005]	[74.00009,74.0001]	[74.00023,74]
17	[73.99994,74.00041]	[73.99997,74.00006]	[73.99998,74.00015]
18	[74.00007,74.00055]	[74.00025,74.00023]	[73.99992,74.00011]
19	[74.00005,74.00032]	[74.00018,74.00026]	[73.99966,74.00027]
20	[73.99999,74.00026]	[74.00019,74.00014]	[73.99977,74.00043]
21	[73.99974,74.0001]	[73.99996,74.00044]	[73.99963,74.00035]
22	[73.99978,74.00033]	[73.99995,74.00068]	[74.00019,74.00056]
23	[73.99985,74.00016]	[74.00038,74.00054]	[74.00045,74.00058]
24	[74.00057,74.00039]	[74.00068,74.00054]	[74.00087,74.00042]
25	[74.00038,74.00032]	[74.00069,74.00041]	[74.00037,74.00042]
26	[74.00035,74.00056]	[74.00024,74.0005]	[73.9999,74.00046]
27	[73.99998,74.00018]	[73.99991,74.00042]	[73.99974,74.0005]
28	[74.00055,74.00018]	[73.99983,74.00037]	[74.00005,74.00055]
29	[74.00064,73.99995]	[73.99999,74.0004]	[74.00038,74.0006]
30	[74.00074,74.00013]	[74.0004,74.00026]	[74.0002,74.00073]
31	[74.00033,73.99996]	[74.00043,74.00019]	[74.00003,74.00055]
32	[74.00009,74.00026]	[74.00007,73.99991]	[74.00023,74.00052]
33	[74.00004,74.00043]	[73.99996,74.00002]	[74.00015,74.00071]
34	[73.99991,74.00077]	[73.99996,73.99976]	[74.00042,74.0006]
35	[74.00038,74.00098]	[74.00028,74.00009]	[74.00003,74.00043]
36	[74.00045,74.00103]	[74.0002,74.00005]	[74.00011,74.00061]
37	[74.00062,74.00105]	[74.00029,74.00028]	[74.0001,74.00071]
38	[74.00019,74.0011]	[74.00029,74.00029]	[74.00046,74.00035]
39	[74.0002,74.00106]	[74.00037,74.00063]	[74.00061,74.00047]
40	[74.00032,74.0006]	[74.00038,74.00081]	[74.00056,74.00035]

Table 13: Limits of three Charts for simulated data.

Mean	[74,74.00001]		SD	[0.0010, 0.0015]
	LCL1	LCL2	UCL2	UCL1
MDSR	[73.99899,73.9996]	[74.0004,74.00101]	[73.99911,73.99965]	[74.00037,74.00091]
MDS	[73.99898,73.99914]	[74.00086,74.00102]	[73.99904,73.99924]	[74.00078,74.00098]
Repetitive	[73.99901,73.9992]	[74.0008,74.00099]	[73.99914,73.99932]	[74.0007,74.00088]

Figure 3: The developed and existing control charts for simulated data.



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UCL1U=74.00091
UCL2L=74.0004
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LCL2U=73.99965
LCL2L=73.9996
LCL1U=73.99911
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Plotting Statistic
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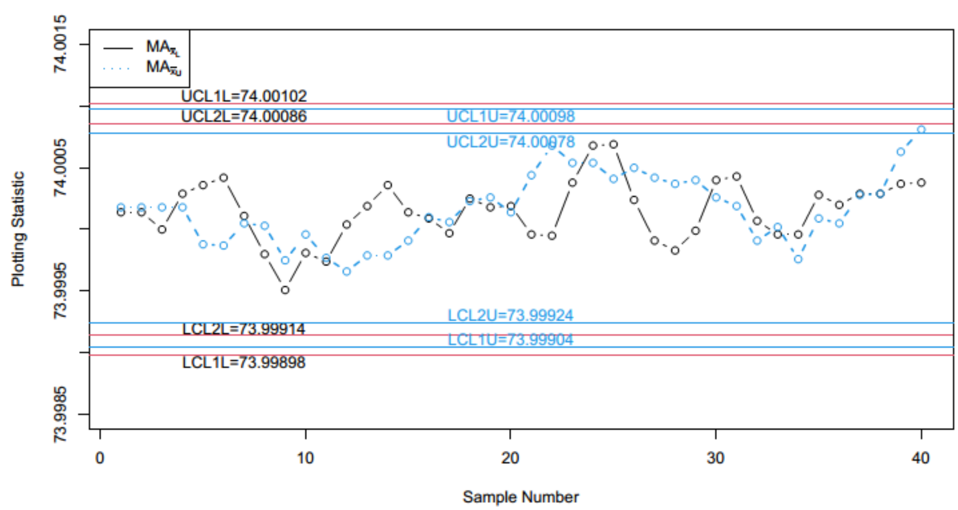
74.0005
73.9995
73.9985
0
10
20
30
40
Sample Number



MA
MA
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LCL2L=73.99914
LCL1U=73.99904
LCL1L=73.99898
Plotting Statistic
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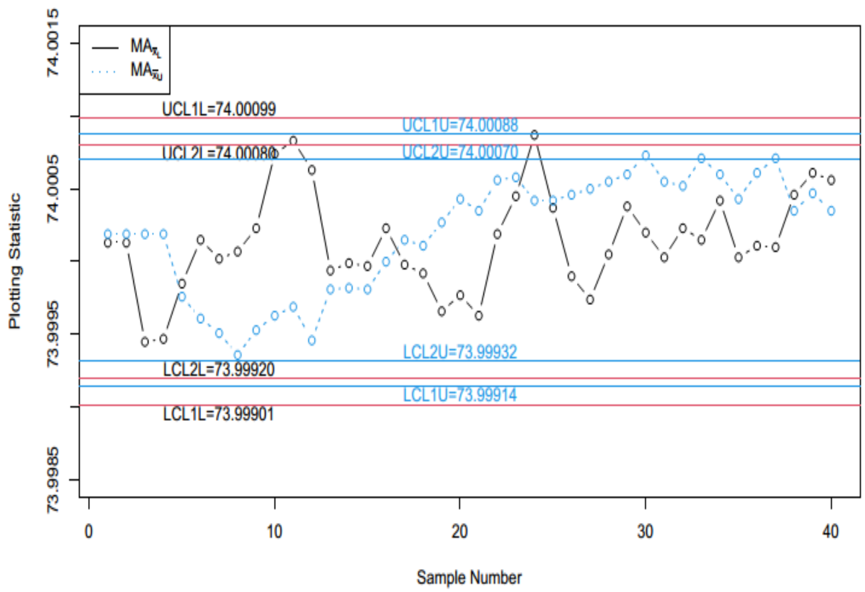
74.0005
73.9995
73.9985
0
10
20
30
40
Sample Number



Biographies

Prof. Muhammad Aslam is the founder of Neutrosophic Inferential Statistics (NIS), Neutrosophic Circular Statistics (NCS), Neutrosophic Applied Statistics (NAS), and Neutrosophic Statistical Quality Control (NSQC). He is the author of four books.

Gadde Srinivasa Rao is presently working as a Professor of Statistics at the Department of Mathematics and Statistics, The University of Dodoma, Tanzania. He boasts more than 170 publications in different peer-reviewed journals in national and international well-reputed journals. His papers have been cited more than 2136 times with an h-index of 24 and an i-10 index of 55 (Google Coalitions). He is a reviewer of more than 70 well-reputed international journals. He is the author of three book/ book chapters published in Springer Nature and Elsevier. His research interests include statistical inference, statistical process control, applied Statistics, acceptance sampling plans, reliability estimation and Neutrosophic statistics. He got world scientists' recognition in AD Scientific Index- 2023. He got the first rank among the faculty member at the University of Dodoma, Tanzania.

Nasrullah Khan is currently working as Associate Professor in the College of Statistical Sciences, University of the Punjab. He has diverse experience of working in the various institute. He started his carrier from Crop Reporting Services, Punjab after that he joined Pakistan Bureau of Statistics, where he remained involve in the processing of Survey and Census data. He joined lectureship in FGEI institutes in 2010 after that in 2015 he joined Jhang Campus of University of Veterinary and animal Sciences, Lahore. He has published more than 60 research articles in national and international Journals. He has interest to work in the field of Biostatistics, Statistical Quality Control and Official Statistics.