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REVIEW

Quality Decisions Based on Time between Events Data Analysis

Fausto Galetto*

Independent Scholar, Past Lecturer at Politecnico di Torino, Turin, 10110, Italy

ABSTRACT

Good decisions (Quality Decisions) depend on scientific analysis of data. Data are collected, generally, in two ways: 1) one sample of suitable size, 2) subsequent samples, at regular intervals of time. Often the data are considered normally distributed. This is wrong because the data must be analysed according to their distribution: Decisions are different. In several cases the data are exponentially distributed: we see how to scientifically deal with Control Charts (CC) to decide; this is opposite to what gives the T Charts that are claimed to be a good method for dealing with "rare events": The Minitab Software (19 & 20 & 21) for "T Charts" is considered. The author will compare some methods, found in the literature with the author's Theory RIT (Reliability Integral Theory): We will see various cases found in the literature. Classical Shewhart Control Charts and the TBE (Time Between Events) Control Charts have been considered: it appears that with RIT the future decisions will be both sounder and cheaper, for data is exponentially distributed. The novelty of the paper is in the scientific way of dealing with the Control Charts and their Control Limits, both with normally distributed data and with exponentially distributed data. In this way, a lot of wrong published papers on "Time Between Events" are to be discarded, even if their authors claim "We used Standard Statistical methods, typical in the vast literature of similar papers". The author had to self-cite because it seems the only one that has been fighting for years for "Papers Quality"; he humbly asked the readers to inform him if some people did the same.

Keywords: Control Charts; Exponential distribution; TBE Box-plot method; Rare Event Charts; Minitab; RIT

1. Introduction

When the author was attending a post on Acedemia.edu (March 2021) he was invited to read the paper [1] "Boxplot-based Phase I Control Charts for Time Between Events" (BCCTBE) published in the

*CORRESPONDING AUTHOR:
Fausto Galetto, Independent Scholar, Past Lecturer at Politecnico di Torino, Turin, 10110, Italy; Email: fausto.galetto@gmail.com

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magazine Quality and Reliability Engineering International. Soon after he read "Statistical design of ATS-unbiased charts with runs rules for monitoring exponential time between events", Communications in Statistics—Theory and Methods [2], where there is the same type of errors about the Control Limits as Dovoedo and Chakraborti [1] and the papers [3-23]. The author tried several times, to inform the "Scientific Community" about the problems of Control Charts for TBE (Time Between Event): Wrong Control Limits in them: He had no success.

In this paper I will use the Reliability Integral Theory (RIT) of Reliability Tests, for various cases found in the literature, when the data are exponentially distributed (Poisson Statistical Process).

On September 2, 2022, the author looked for TBE (Time Between Event) papers and books to see their way of dealing with "Rare Events" Control Charts; he copied 77 pages of documents (several from Consultants) and of Journal wanting, from 15 $ to 60 $, to download a paper. 32 papers were Open Source and were downloaded.

Up to now, in September 2022, the author found a desperate situation: All the papers have the same problem, generated by Ignorance about the fundamental concepts of Confidence Limits, at a specified Confidence Level.

All the documents [1-24] have the same problem: Wrong formulae for the Control Limits (LCL and UCL). The author [25] and M. Sivo (in ResearchGate) raised the question about Control Limits and Confidence Limits. An answer was given in "Six Sigma_ Hoax against Quality_Professionals Ignorance and MINITAB WRONG T Charts" [25]. Looking at documents from 1 to 10 in the references, it came out that the "Box-plot" method was a competitor of another method that the author had asked (for discussion) in a post at site iSixSigma: https://www.isixsigma.com/topic /control-charts-non-normal-distribution related to control charts [25] by saying that the author was looking for a solution of Two cases for Master-Black-Belts-dec-2019", with data are exponentially distributed (see Figure 1). The first of the cases were taken from the book of D. C. Montgomery [26]; the author knew about that since 1996; Montgomery dealt with it in all the later editions of the book [26]. The iSixSigma "experts" were unable to provide a correct way to solve the cases and did not want to accept that Montgomery's solution was doubtful because he finds that the process is In Control (IC), while actually, the process is Out Of Control (OOC). To date, in September 2022, nobody (in iSixSigma, Academia.edu] and Research Gate) provided any good solution to the problem (see **Figure 1**).

Letters (not mentioned in the References) sent to the Editors of the Journals "*Quality Engineering, Quality Technology & Quantitative Management, Quality and Reliability Engineering International, Communications in Statistics - Theory and Methods, PLOS one, …*" are not yet been published: the papers [1-24] are wrong and obviously the Editors cannot acknowledge that. In 2020 the author showed [25] the drawbacks of TBE Control charts in "Six Sigma_ Hoax against Quality_Professionals Ignorance and MINITAB WRONG T Charts", HAL Archives Ouvert.

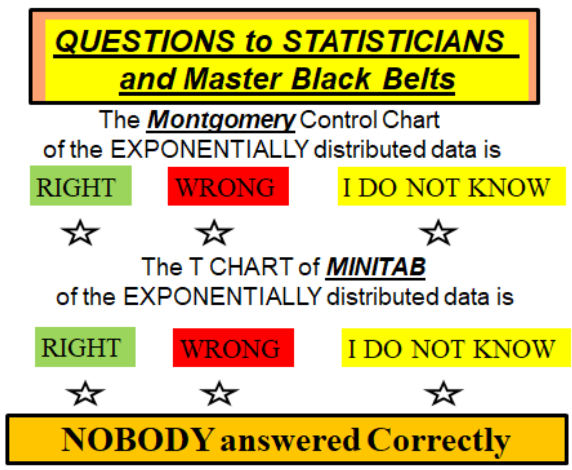

Figure 1. Question to MBB and Statisticians and Experts.

Control Charts are a statistical tool for monitoring the "measurable output" of a Process (Production or Service Process).

The "*Box-plot*" uses the data taken from Montgomery [26]; I will use the same data for comparison between the two methods, "*Box-plot*" and "*T Charts*" and the Reliability Integral Theory (RIT) of Reliability Tests, for various cases found in the literature, when the *data are exponentially distributed (Poisson*

Statistical Process). Since T Charts are claimed to be a good method for dealing with "rare events", I consider, as well, the Minitab Software (19 & 20 & 21) for "*T Charts*".

The "measurable output" of the Process can be viewed as a "Stochastic Process X(t)", ruled by a probability density for any set of n "Random Variables RV" $X(t_1)$, $X(t_2)$, …, $X(t_n)$, considered at the "time instants" t_1, t_2, …, t_n, of the "Stochastic Process X(t)". X(t) can be multidimensional or unidimensional: generally in applications there is a single measured quality characteristic X(t); such control charts (CC) are routinely called univariate SPC (Statistical Process Control) charts in the literature.

The data plotted are the means $\bar{x}(t_i)$, determinations of the Random Variables $\overline{X}(t_i)$, i=1, 2, ..., n (n=number of the samples) computed from the collected data x_{ij}, j=1, 2, ..., k (k=sample size); x_{ij} are the determinations of $X(t_{ij})$ at *very close instants* t_{ij}, j=1, 2, ..., k; $\overline{X}(t_i)$ are normally distributed *because* they are the means of k data (usually k=5). The Random Variable $\overline{X}(t_i)$, is the mean, at time t_i, of the k RVs $X(t_{ij})$ j=1, 2, ..., k, sampled, at very near times t_{ij}; the distribution is $\overline{X}(t_i) \sim N(\mu_{\overline{X}(ti)}, \sigma^2_{\overline{X}(ti)})$ with mean $\mu_{\overline{X}(ti)}$ and variance $\sigma^2_{\overline{X}(ti)}$; a common assumption for Variable Control Charts is that the RVs (random variables) $X(t_{ij})$are independents and anybody can compute a grand mean $\overline{X}$ [mean of all the RVs $X(t_{ij})$] distributed as $\overline{\overline{X}} \sim Nx(\mu_{\overline{X}}, \sigma^2_{\overline{X}})$. In **Figure 2** the determinations of the RVs $\overline{X}(t_i)$ and $\overline{X}$ are shown.

An application in the papers [1-8] draws the author's attention: The papers considered Montgomery's case and did not solve it correctly.

Therefore the readers are confronted with the following situation: Several scholars, who published papers in "good and reputed" Journals, after "Peer Review" have been dealing wrongly with the way of using *Control Charts for Exponentially Distributed Data*. MINITAB, as well, with its T Charts, provides wrong Control Charts for Exponentially Distributed Data; the same for SAS.

The author for many years has been showing [25,27-41] the many drawbacks present in various books and papers: Wrong definitions of the term Quality, wrong control charts for Exponentially Distributed Data, wrong Design of Experiments cases…

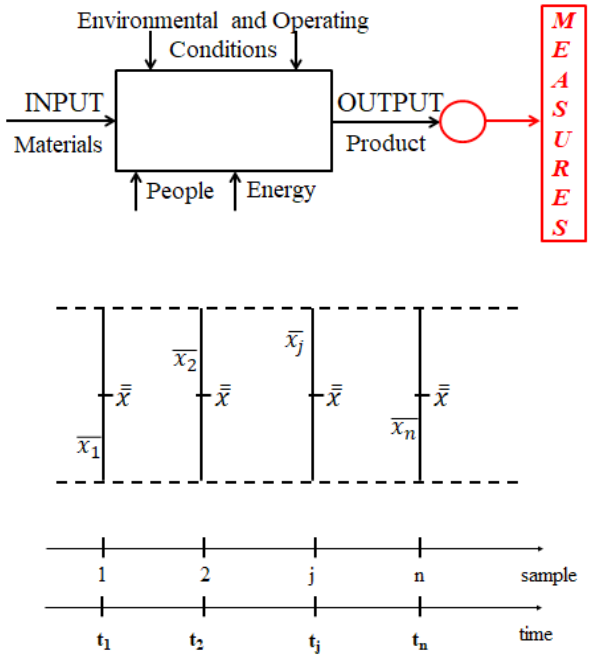

Figure 2. The process and the data "means" shown.

Suppose now that someone thinks that *"The problem of monitoring TBE that follows an exponential distribution is well-defined and solved"*. I do not agree that *"nobody could solve scientifically the cases"*.

He is wrong.

But, which chance has this paper been accepted? If the reader (PR, Editor) does not know RIT he would reject the paper.

Suppose, as well, that someone looks either more at the "style" of the paper or at the way of writing the references (or citing them) than to the scientific content for the solution of the problem of monitoring TBE that follows an exponential distribution, thinking that the paper sounds as a lecture: which chance has this paper to be accepted?

Suppose, finally, that someone writes *"We do not know this author and are not familiar with his work. His claim about our formulas being wrong is not justified by any facts or material evidence. Our limits are calculated using standard mathematical statistical results/methods as is typical in the vast literature of similar papers."* which chance has this paper been accepted?

In my humble opinion, it is better a paper *"sounding like a lecture"* than several *"scientific (???, actually wrong) papers with the wrong theory."*

This paper has the following structure: First, I briefly present the Shewhart *Control Charts and the Individual Control Charts*; second, I analyse the method "(BCCTBE)"; third, the reader will see the Minitab calculations for the T Charts; finally I show the correct control limits of charts with exponentially distributed data, with the applications dealt in [1-24]. There is no specific "literature review" because I am only interested in showing the RIT ability to solve correctly the *Control Charts for Exponentially Distributed Data*. (Boxplot-based CCTBE and MINITAB T Charts): RIT was devised by the author in 1975 (47 years ago) well before the T Charts invention and BCCTBE.

The paper is important because all the papers [known by the author] on the TBE (Time Between Events) Control Charts are based on the same wrong formulae: *"limits calculated using* ***standard mathematical statistical*** *results/methods as is* ***typical in the vast literature of similar papers****". The two authors forgot that "many wrongs do not make a right"...*

Let's hope that the Peer Reviewers (of this paper) have better knowledge than those authors, referees, and Journals Editors.

2. The theory of Control Charts

I describe, very briefly, the Shewhart Control Charts (CC) [42,43]: I provide the formulae used and connect them to the concept of Confidence Interval (CI). I ask the readers to look at the books [42,43].

The technique was used extensively during World War II both in the UK and in the US. In the 1950s, the Shewhart ideas have been greatly appreciated by Deming [44,45] and Juran [46] who introduced them in Japan. The success in Japan spurred the interest in the West…

This section is important for the readers to understand the problems with the CCs for Normal and Exponentially Distributed Data.

The theory behind the (Shewhart) CC is very simple: the RV *means* $\overline{X}(t)$ of each sample, at time t, drawn from the "Stochastic Process" X(t) can be approximated as "*normally distributed*" (*Central Limit Theorem*); the Control Limits are derived accordingly. Several papers, two in the references [22,23] use the Normal distribution (for the np Control Charts).

In any Production or Service process (**Figure 2**), modelled by the "Stochastic Process" X(t), there is a "background noise", which generates a variable output: A certain amount of inherent natural variability always exists in any process output (it is called "due to chance causes of variability"); a process is declared "statistically In Control", IC. If a product (output of the process) has variability, in its quality characteristics, greater than the inherent natural variability we say that the process is an Out-Of-Control process (OOC) and operating in the presence of "*assignable causes of variation*". The Control Charts are a tool used to understand if a process is IC (In Control) or OOC [47-51].

The Theory of W. Shewhart, devised almost a century ago [42,43] in the 1920s, at Bell Telephone Laboratories, plots [the determinations of the "Stochastic Process" $\overline{X}(t_i)$ providing] the means $\bar{x}(t_i)$, i=1, 2, ..., n (n=number of the samples) computed from the collected data x_{ij}, j=1, 2, ..., k (k=sample size); x_{ij} are the determinations of $X(t_{ij})$ at *very close instants* t_{ij}, j=1, 2, ..., k; $\bar{x}(t_i)$ follow a normal distribution. The RV mean (at time t_i) $\overline{X}(t_i)$, of the (k sampled, at very near times t_{ij}), RVs $X(t_{ij})$ j=1, 2, ..., k, is distributed as $\overline{X}(t_i) \sim N(\mu_{\overline{X}(ti)}, \sigma^2_{\overline{X}(ti)})$ with mean $\mu_{\overline{X}(ti)}$ and variance $\sigma^2_{\overline{X}(ti)}$; a common assumption for Variable Control Charts is that the RVs (random variables) $X(t_{ij})$ are independents and we can compute a grand mean $\overline{\overline{X}}$ [mean of all the RVs $X(t_{ij})$] distributed [47] as $\overline{\overline{X}} \sim Nx(\mu_{\overline{\overline{X}}}, \sigma^2_{\overline{\overline{X}}})$; with this assumption we can draw two lines [see formula (1)] which have the probability π=1-α=0.9997 of comprising the RVs $\overline{X}(t_i)$, due to the Central Limit Theorem

$$\mathbf{L}=\mu_{\bar{\bar{x}}} - 3\sigma_{\bar{\bar{x}}}, \qquad \mathbf{U}=\mu_{\bar{\bar{x}}} + 3\sigma_{\bar{\bar{x}}} \tag{1}$$

Formulae (1) are true when the parameters $\mu_{\overline{\overline{X}}}$ and $\sigma_{\overline{\overline{X}}}$ are completely known: in such a case, the Probability $P\{L \le \overline{X} \le U\}$ is 0.997 because, for any

Normal distributed RV X, we have $P\{\mu - 3\sigma \leq X \leq + 3\sigma\}$=0.997. Unfortunately they are not known and we collect the data x_{ij} from the process X(t) and estimate them: therefore we ***should not*** use (1) to compute the Control Limits LCL and UCL of the CC.

Consider (**Figure 3**) the Probability $P\{L \leq \overline{X} \leq U\}$; I can transform it into the following $P\{[(\mu_{\overline{X}} - 3\sigma_{\overline{X}}) - \mu_{\overline{X}}]/\sigma_{\overline{X}} \leq (\overline{X} - \mu_{\overline{X}})/(\sigma_{\overline{X}}) \leq [(\mu_{\overline{X}} + 3\sigma_{\overline{X}}) - \mu_{\overline{X}}]/\sigma_{\overline{X}}\}$and, from that, I get the true Probability Statement $P\{-3 \leq (\overline{X} - \mu_{\overline{X}})/\sigma_{\overline{X}} \leq 3\}$=0.997.

I write the true Probability Statement $P\{-t_{1-a/2} \leq (\overline{X} - \mu_{\overline{X}})/S_{\overline{X}} \leq t_{1-a/2}\}=1-a$; from this I derive the other Probability Statement $P\{\mu_{\overline{X}} - t_{1-a/2}S_{\overline{x}} \leq \overline{X} \leq \mu_{\overline{X}} + t_{1-a/2}S_{\overline{x}}\}=1-a$; the two quantities RVs $L=\mu_{\overline{X}} - t_{1-a/2}S_{\overline{X}}$ and $U=\mu_{\overline{X}} + t_{1-a/2}S_{\overline{x}}$ are two random straight lines parallel to the bisector in the plane with abscissa the "true" mean μ and ordinate the grand mean $\overline{X}$.

When, from the collected data, we estimate the grand mean $\overline{\overline{x}}$ and the standard deviation $S_{\overline{X}}$ we have two lines (out of the infinite we can draw for any value of $S_{\overline{X}}$) as in **Figure 3**.

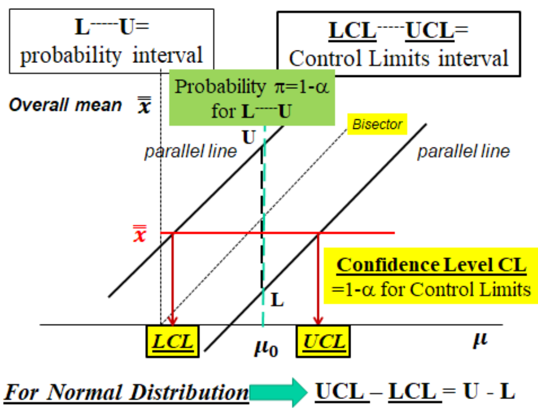

Figure 3. Probability interval L----U and Control Limits LCL----UCL, for Normal data

For a stated value μ_0 we have the vertical probability segment L-----U (one out of the infinite …): $L=\mu_0 - t_{1-a/2}S_{\overline{X}}$ and and $U=\mu_0 + t_{1-a/2}S_{\overline{X}}$.

From the estimate of the grand mean $\overline{\overline{x}}$ (on the vertical axis) we draw the Horizontal line intersection of the two above-mentioned parallel lines: we get the *Horizontal Confidence Interval* LCL-----UCL segment: its abscissas are the limits of the *Confidence Interval* ***LCL(imit)***$= \overline{\overline{x}} - t_{1-a/2}S_{\overline{X}}$ and ***UCL(imit)***$= \overline{\overline{x}} - t_{1-a/2}S_{\overline{X}}$.

These two values are drawn as horizontal lines in **Figure 4**.

For Control Charts, since the parameters $\mu_{\overline{X}}$ and $\sigma_{\overline{X}}$ are *unknown*, we usually estimate them and write the Control Limits:

$$LCL_X = \overline{\overline{x}} - A_2\overline{R}, \qquad UCL_X = \overline{\overline{x}} + A_2\overline{R} \tag{2}$$

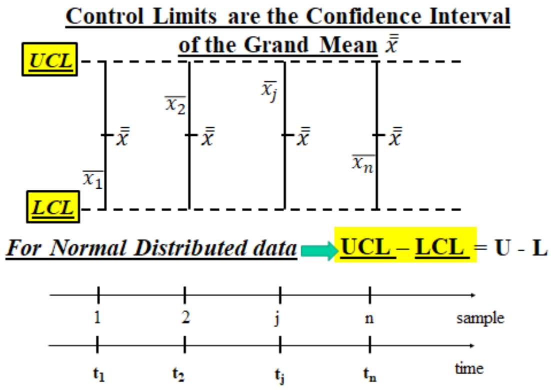

Figure 4. Control Limits LCL----UCL=L----U (Probability interval), for Normal data

It is clearly seen that the interval LCL_X-------UCL_X (Control Limits, on the horizontal axis, in **Figure 3** and on the vertical axis, in **Figure 4**) are the Lower Confidence Limit and Upper Confidence Limit [with "Confidence Level" 1-α=0.9997] of the unknown mean $\mu_{X(t)}$ of the Stochastic Process X(t); $\overline{R}$ is the "mean of the ranges r_i" [determination of the RV $\overline{R}$ = $\sum r_i/n$], by putting $A_2\overline{R}=t_{1-a/2}S_{\overline{X}}$. $r_i = \max(x_{ij}) - \min(x_{ij})$ of the i-th sample [determination of the RV R_i], and A_2 depending on the sample size k (as t depends on the degrees of freedom).

A similar control chart is drawn for the range by making a "**big** *mental leap*" [because the distribution of $\overline{R}$ is not normal.] and using the formulae (1) [which are probabilistically true] changing them into the statistical formulae (3) where we have the determinations of RVs (the coefficient D_3 and D_4 depend on the sample size k)

$$LCL_R=D_3\overline{R}, \quad CL_R=\overline{R}, \quad LCL_R=D_4\overline{R}, \tag{3}$$

The interval LCL_R-------UCL_R is the "Confidence Interval" with "Confidence Level" 1-α=0.9997 for the unknown Range of the Stochastic Process X(t).

Notice that **UCL-LCL=U-L** for normally distributed data, as a *consequence of the parallelism*. (**Figure 3**)

From the papers on CC it is clear that people (researchers, professors, practitioners) who use both the formulae (2) and (3) also for NON_normal data by transforming them in order to "produce Normal data" and to apply formulae (2) and (3) are failing.

This is especially dome when we use the so-called "*individual control charts*" I-CC (we have little data): in such a case we use the following figure.

3. Individual Control Charts (I-CC) and exponentially distributed data

Consider the data in **Table 1** [Example 7.6 in the Montgomery book [26] (7^{th} edition, as reported in the paper [25])], where he writes "*A chemical engineer wants to set up a control chart for monitoring the occurrence of failures of an important valve. She has decided to use the number of hours between failures as the variable to monitor*". *Notice* that Minitab 19&20&21 show the same problems). Since the data are not normal I cannot use the ideas in **Figure 2**. The readers must be very careful.

The paper *Boxplot-based Phase I Control Charts for Time Between Events* [1] uses the same data (in **Table 1**). The authors (DC) [1] write "*As an illustration, consider the example in Montgomery in which a chemical engineer wishes to control the average time between failures of a valve. She observed 20 times between failures for this valve. JC uses these data, …, as an illustration of their two-sided control chart. Note that the data with all 20 observations do not fail the Anderson–Darling test for the exponential distribution. From Minitab, the Anderson–Darling statistic is found to be 0.53 with a P-value = 0.44.*" Notice that JC is the authors of the paper [3].

The readers will see their (wrong) solution in the next session.

Formulae (2) and (3) should not be used because the data are few, 20, and exponentially distributed; **Figure 5** shows the Control Limits. Using [wrongly] those formulae one finds **Figures 6 and 7**. [25] *Notice that k=1 (sample size).*

See **Figure 6**: according to **Figure 6**, using the formulae (2), the "*process is OOC*" (Out Of Control): Two points are "above" UCL [25].

Table 1. Lifetime data (exponentially distributed, from Montgomery's book):*k=1 (sample size)*

Failure #	lifetime	Failure #	lifetime	Failure #	lifetime
1	286	8	143	15	603
2	948	9	431	16	492
3	536	10	8	17	1199
4	124	11	2837	18	1214
5	816	12	596	19	2831
6	729	13	81	20	96
7	4	14	227		

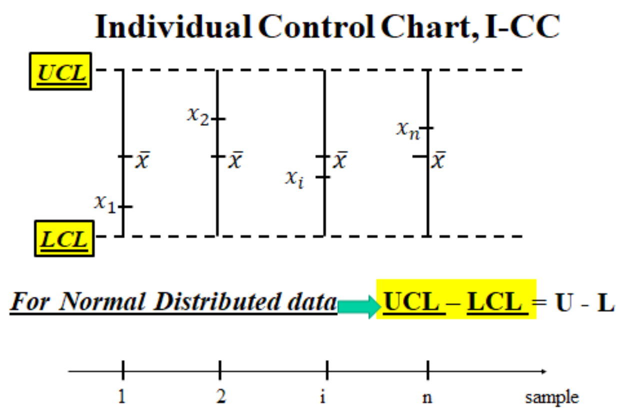

Figure 5. Individual Control Chart. *Notice that k=1 (sample size)*

Also the Moving Ranges CC shows two other points OOC.

All the software used provides the same picture of the process [25].

This is not the true picture of the process: these OOC depend on the formulae used [25].

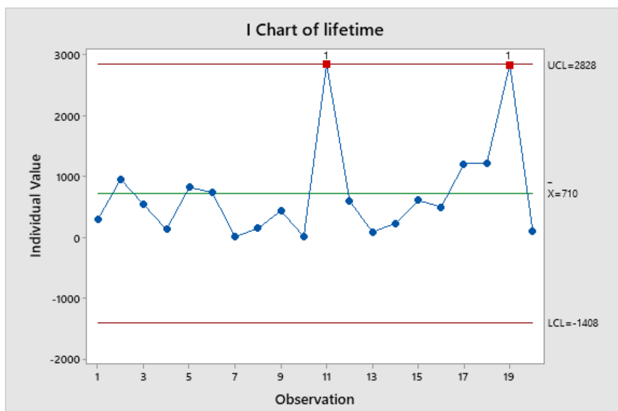

Figure 6. Individual chart lifetime. Minitab 19 & 20 & 21 used

Transforming the exponential data into Weibull data with shape parameter β=1/3.6 (the idea is due to Nelson) the original (exponential) data y_i become $x_i=y_i^{1/3.6}$ (Weibull) data; Montgomery uses a I-MR

Chart (see **Figure 7**) and writes [26] "*Note that the control charts indicate* a state of control, *implying that* ..."

This is not the true picture of the process: These IC depends on the formulae used [25].

Before acting this way, any scholar should see if it is suitable, because, as said by Deming, "*Management need to grow-up their knowledge because experience alone, without theory, teaches nothing that to do to make Quality"* and "*The result is that hundreds of people are learning what is wrong. I make this statement on the basis of experience, seeing every day the devastating effects of incompetent teaching and faulty applications."* [Deming (1986)]

Figures 6 and 7 provide *two contradictory conclusions*.

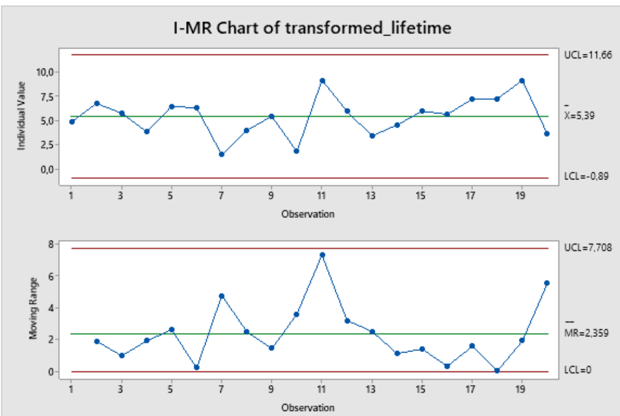

Figure 7. Chart of *"transformed"* lifetime (Nelson suggestion). Minitab 19&20&21 used (F. Galetto).

Assuming that T Charts are a good method to deal with "rare events" [25] (Minitab, JMP, SAS, ...) one gets **Figure 8**; see *the paper* "Six Sigma_Hoax against Quality_Professionals Ignorance and MINITAB WRONG T Charts" [25]. The process is "In Control", again.

Actually, the process is Out Of Control.

The author found himself in such a situation during several International Conferences, Courses, Seminars and reading papers: wrong methods. Many times he invited scholars and professors to be scientific [27-41]. In particular see the paper [39], very useful for the next parts. The author had to self-cite because it seems he has been the only one that has been fighting for years for "Papers Quality"; he humbly asks the readers to inform him if some people did the same.

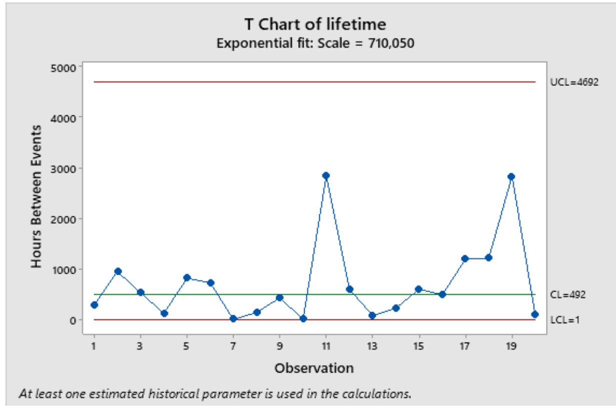

Figure 8. T Chart of Montgomery lifetime data. Minitab 19 & 20 & 21 used (F. Galetto).

4. Box-plot Control Charts (I-CC) for Time Between Events (TBE)

Now we see a bit of Theory in the papers [1,3,5] and the document [6]. The Box-plot based Control Charts (BpCC) are very similar to the Shewhart Control Charts. BpCC uses the median (instead of the mean) and the interquartile range (instead of the ranges) of the collected data.

Denoting as F(x) the [continuous] cumulative distribution of the RV X, one can find the abscissas x_1, x_2, x_3, so that $F(x_1)=1/4$, $F(x_2)=2/4$, $F(x_3)=3/4$; x_2 is the median and x_3-x_1 is the interquartile range.

For BpCC one estimate F(x) from the nk collected data; let $\hat{F}(x)$ [a step function with nk steps] the estimate of F(x): He then chooses the three abscissas $\widehat{x_1}, \widehat{x_2}, \widehat{x_3}$ satisfying the relationships

$\hat{F}(\widehat{x_1}) \cong 0.25 \quad \hat{F}(\widehat{x_2}) \cong 0.5 \quad \hat{F}(\widehat{x_3}) \cong 0.75$

The two authors define the LCL and UCL.

$$LCL_X = \widehat{x_2} - k_L[\widehat{x_3} - \widehat{x_1}] \quad CL_X = \widehat{x_2} \quad UCL_X = \widehat{x_2} - k_U[\widehat{x_3} - \widehat{x_1}] \quad (2b)$$

where the coefficients, for a significance level α_0=0.01 and sample size 20, are k_L=4.617 and k_U=15.56 (to be applied to Montgomery's case). The name "*nominal false alarm rate*" is the quantity α_0. Notice that (2b) have the same structure as (2).

Therefore I do not understand their claim that "the proposed control charts are comparable to other charts, in their performance."

Those authors *consider the example in Montgomery* [data in our **Table 1**]; they find:

$UCL=q2+k_U(q3-q2)=X(10)+k_U(X(16)-X(10))=4341.552$

$LCL=q2-k_L(q2-q1)=X(10)-k_L(X(10)-X(5))=-533.616$

They put LCL=0 because of LCL<0. They, wrongly, say that the process is IC. Note that JC's two-sided control chart leads to the same conclusion. Notice: JC is the author of the paper [3].

Their **Figure 1** (cited above) is the one called **Figure 9** [even if it is an Excerpt from the paper].

Compare **Figures 8 and 9**: *Both show no out-of-control.* The Process is considered *IC.*

The reader will see, on the contrary, that this is wrong.

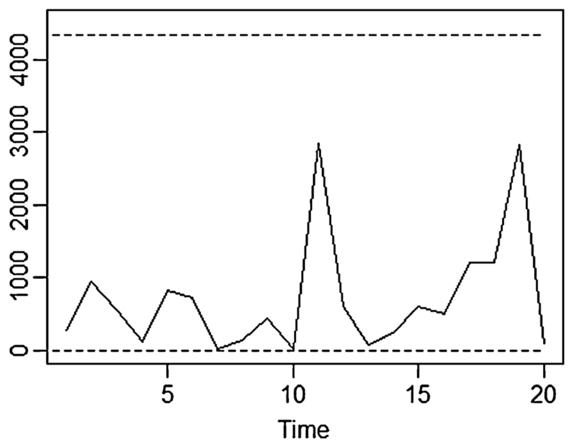

Figure 9. Chart of Montgomery lifetime data analysed by Dovoedo et al., "Boxplot-based … for TBE". *Quality and Reliability Engineering International* 2011.

5. T Charts and exponentially distributed data: Part 1

Now I give the ideas of two Minitab authors [21]: They provide "*0.00135* $\bar{t}$*, 6.60773* $\bar{t}$*, and log(2)* $\bar{t}$" [21] [(see formulae (4)]. The paper, "Peer Reviewed", has wrong formulae (4) [25]:$\bar{t}$ is the estimate of the parameter θ, determination of the Random Variable $\overline{T}$/m, the ratio of the "total time on a test" $\overline{T}$ and the number of failures m (m=20 in this case)] [25].

$$LCL_T = 0.00135\,\bar{t} \qquad CL_T = \ln(2)\,\bar{t} \qquad UCL_T = 6.60773\,\bar{t} \quad (4)$$

A lot of papers present formulae (4).

One of last papers I found is "A Comparative Study of Exponential Time Between Event Charts By Liu J., Xie M., Sharma P.", *Quality Technology & Quantitative Management*, 2006 [7]. **Figure 10** is made from an excerpt in the paper [7] (see) proving the author's attitude. The last 2022 is, "Statistical design of ATS-unbiased charts with runs rules for monitoring exponential time between events [by N. Kumar, A. C. Rakitzis, S. Chakraborti, T. Singh (2022)], *Communications in Statistics—Theory and Methods* [2]…

This proves the truth of Deming's statements mentioned above "*It is a hazard to copy",* etc…

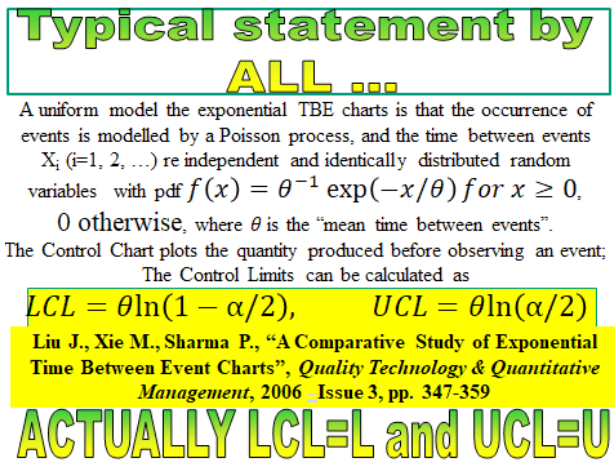

Figure 10. Typical statement about Individual Control Charts, with Exponential distributed data

Minitab, JMP, SAS "*T Charts*" are wrong: the Reliability Integral Theory (RIT) proves that. The readers are invited to read the author's books [47-56], "Six Sigma_Hoax against Quality_Professionals Ignorance and MINITAB WRONG T Charts", HAL Archives Ouvert, 2020 [25] and F. Galetto "Minitab T-Charts and Quality Decisions", Journal of Statistics and Management System, 2021.

6. Some basics of RIT (Reliability Integral Theory)

RIT was devised in 1977 by Fausto Galetto when he was working at FIAR (a division of General Electric); it is fully explained in the author's books [47-56]. Here I give only the formulae to solve the cases.

The System I consider starts in State 0, at time 0: All the units are reliable.

The general formula of the reliability of a g* units stand-by system [47-56] is given in the following matrix formula (5)

$$R(t) = \overline{W}(t) + \int_0^t B(s)R(t-s)ds \quad (5)$$

where R(t) is the vector of the reliabilities $R_i(t)$ of the Up-states, i=0, 1, …, g*-1, B(s) is the square matrix of the kernels $b_{ij}(s)$ [related to the transition probabilities $b_{ij}(s)ds$] between the Up-states and $\overline{W}(t)$ the diagonal matrix of the probabilities of remaining in each Up-state, for the time mission t. From (5) I get the EQUIVALENT matrix equation

$$R(t) = u + \int_0^t AR(t-s)ds \quad (6)$$

where u is the column vector $[1, 1, …,1]^T$ and A the matrix of the *constant transition rates*.

When one considers the exponential kernels, formulae (5) [and (6)] provide the *fundamental system of the Reliability Integral Theory, for Markov processes*.

In F. Galetto's books [47-56] RIT is extended to Reliability Tests, for estimating parameters and testing hypotheses. Consider a system of (g* units); it has g* Up-states (0, 1, 2, …, g*-1) with transition rate λ, where λ=1/θ and θ is the MTTF of any units; one wants to estimate θ: It is the «*system associated to a reliability test*». This solves the *Time Between Events* Charts Problem.

The evolution (versus t) of the test is the same as the evolution of a standby system for the interval 0---t. The reliability of any item [n are the items on test] determines the instants of the transitions of the "*system associated (to the reliability test)"*; the state g* is the "down-state", at which the test is over. One gets the following fundamental system of Integral Theory of Reliability Tests [F. Galetto, holding for any distribution of the time to failures of the units], for i=0, 1, …, g-1, where he assumes that r is the entrance time instant when he begins observing the system.

$$R_i(t|r) = \overline{W}_i(t|r) + \int_r^t b_{i,i+1}(s|r)R_{i+1}(t|s)ds \quad (7)$$

In matrix form it is

$$R(t|r) = \overline{W}(t|r) + \int_r^t B(s|r)R(t|s)ds \quad (8)$$

The component $R_0(t|0)$ is the probability that the physical sample does not experience the g^{th} failure during the interval r=0-----t (t end of the test). At the end of the test, we have the empirical sample D={t_1, t_2, …, t_{g-1}, t_g, t}; so we get

$$R_j(t|t_j) = \overline{W}_j(t|t_j) + \int_{t_j}^t b_{j,j+1}(s|t_j)R_{j+1}(t|s)ds$$
$$\text{for } i = 0, 1, ..., g-1, \ R_g(t|t_g) = \overline{W}_g(t|t_g) \quad (9)$$

From (8) and (9) I compute the determinant **det-B(s|r)** [depending on λ]: λ is estimated, from

$$\det[B(s|r; \lambda, D) = \lambda^g \exp[-T(t)] \quad (10)$$

where $T(t) = \sum_1^g t_i + t(n-g)$ is the "Total Time on Test" generated by n items tested until the g^{th} failure. At the end of the test of the equations (8) and (9) are constrained by D; deriving by λ, compute given the constraint D, I obtain exactly the same result as one can obtain with the Maximum Likelihood method.

From the documents [25,47-56] and F. Galetto "Minitab T-Charts and Quality Decisions", Journal of Statistics and Management System, 2021, anybody can obtain the Confidence Interval (symmetric) for the parameter θ [which is the MTTF of any unit] by finding the quantities θ_L and θ_U satisfying (11), with given t_o the "known (at the end of the test)" observed Total Time on Test *T*(*t*), and Confidence Level CL=1-α

$$R_0(t_O; \theta_L) = \frac{\alpha}{2}, R_0(t_O; \theta_U) = 1-\alpha/2 \quad (11)$$

7. T Charts and exponentially distributed data: Part 2

Let's apply RIT to the data in **Table 1**. The n=g*=20 lifetimes (exponentially distributed; t_i "time to failure " from state i-1 to state i: They are the "*individuals*") are the "transition times" between states of a stand-by system of 20 units: The state 20 (g*) is the Down-state. The reliability $R_0(t|\theta)$ [the system reliability $R_0(t|\theta)$ given the parameter θ)] is, as well, the Operating Characteristic Curve of the reliability test, given t: The pdf (probability density function) of any transition ("*individual*") is $f(t; \mu,\sigma) = (1/\theta)\exp(-t/\theta)$; (**Figure 11**).

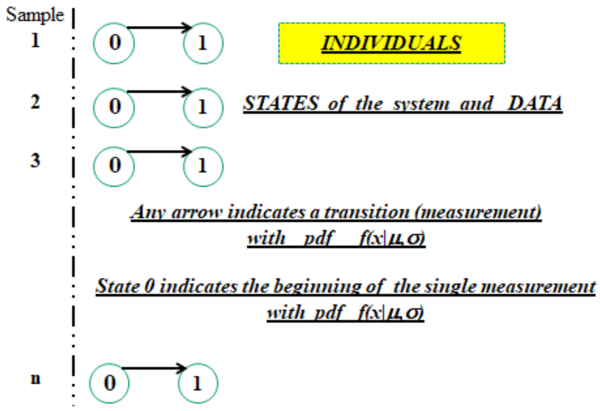

Figure 11. TBE States for the Individual Control Chart for Table 1 lifetime data.

Consider the Probability $P\{\boldsymbol{A} \le T(t) \le \boldsymbol{B}\} = 1-\alpha$ that the Random Variable "Total Time On Test *T*(*t*)", and g data, is comprised in the interval ***A*****---*B***; one can transform it to the following $P\{2\boldsymbol{A}/\theta_0 \le 2T(t)/\theta_0 \le, 2\boldsymbol{B}/\theta_0\} = 1-\alpha$ with θ_0 a known quantity. By RIT he gets the equivalent Probability Statement $P\left\{T(t)/\left[\chi^2_{1-\frac{\alpha}{2}}(2g)/2\right] \le \theta_0 \le T(t)/\left[\chi^2_{\frac{\alpha}{2}}(2g)/2\right]\right\} = 1-\alpha$.

When we have the "*individuals*" (**Figure 13**) we want to find the Probability $P\{\boldsymbol{L} \le T_0 = T(t)/n \le \boldsymbol{U}\} = 1-\alpha$ that we can transform into the following $P\{2\boldsymbol{L}/\theta_0 \le 2T_0/\theta_0 \le 2\boldsymbol{U}/\theta_0\} = 1-\alpha$. Since the reliability of any unit is exponential $R_0(t|\theta) = \exp(-t/\theta)$, (**Figures 5 and 13**) the function $t/\theta = K$ is a straight line $t = K\theta$, with angular coefficient *K*, related either to α/2 or to 1-α/2, in the plane with abscissa *θ* and ordinate *t*: two lines intersecting in the origin (**Figure 13**); at $\theta=\theta_0$ we have the **vertical segment L---U (probability interval)**, that has probability CL=1-α that the "time to failure", Random Variable T, of any single unit is in **L---U**.

The result of this analysis [of **Table 1** lifetime data] is given in **Figure 12**, with logarithmic axes to see the values. See now **Figures 11, 12, 13.** The Control Limits LCL and UCL must be consistent with the single t_i lifetimes ("*individuals*"): we want to assess if they are significantly different from the "*mean observed time to failure*" $\overline{t_o}$= $\boldsymbol{t_o}$/n. They are the values satisfying the two equations (12) for any single unit; so we have 20 Confidence Intervals [all equal, by solving formulae (12)], given $\overline{t_o}$ and CL=1-α [CL=0.997],

$$R_0(\overline{t_0};\, LCL) = \frac{\alpha}{2}, \quad R_0(\overline{t_0};\, UCL) = 1-\frac{\alpha}{2} \tag{12}$$

Remember that in this case k=1 (sample size) and $\overline{t_o}$= $\boldsymbol{t_o}$/n: I-CC.

Formula (12) proves how wrong are all the authors in the first 21 referenced papers[1-21] and in many other you can find on the Web.

With the data from **Table 1 Figure 13** would be unreadable; then I made **Figure 12**. LCL and UCL are the abscissas of the points of interception with the horizontal line $\overline{t_o}$= $\boldsymbol{t_o}$/n: It is the ***Confidence interval***. (as in Figure 3, for the Normal Distribution: The same type of reasoning.)

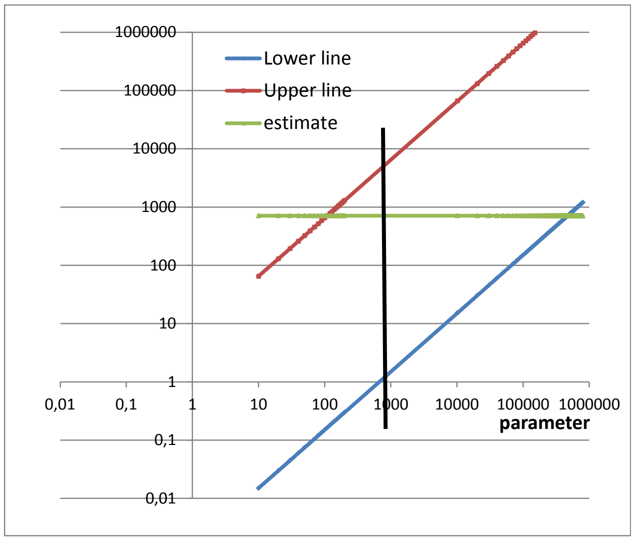

Figure 12. RIT LCL and UCL for the Individual Control Chart of Table 1 data [logarithmic scales].

Any intelligent person should realise that the two segments **L---U** (vertical) and ***LCL*****---*UCL*** (horizontal) are two *different* intervals with clearly *different* meanings and obviously *different lengths* UCL-LCL ≠ U-L. All the documents, known to the author, make this BIG ERROR: they confound the vertical segment, which is a "**Probability segment**" with the horizontal segment, which is a "***Confidence segment***".

Formulae (4) and **Figure 10** made from "A Comparative Study of Exponential Time Between Event Charts", *Quality Technology & Quantitative Management* [7] (see **Figure 13**, as well), consider the segments **L---U** (vertical) as though it were the Confidence Interval. This is completely WRONG.

Simple example with 2 data: t_1 and t_2, of a 2 units stand-by system. The matrix equation (5)

$R(t)=\overline{W}(t)+\int_0^t B(s)\ \ R(t-s)ds$ provides the solution $R_0(t)=\exp(-t/\theta)[1+t/\theta]$, which allows us to find the Confidence Interval of the MTTF (considering g*=2). Formulae (12) $R_0(\overline{t_o};\ LCL\ )=\alpha/2$ and $R_0(\overline{t_o};\ UCL\ )=1-\alpha/2$, for each sample, remembering that in this case k=1 (sample size), allow computing the Control Limits [that is the Confidence Interval for each sample, of size k=1. horizontal line], via the mean $\overline{t_o}; = (t_1+t_2)$ and CL=1-α=0.997 [**Figure 13**]. Formulae (4), on the contrary, $LCL_T=0.00135\,\bar{t}$ $CL_T=\ln(2)\,\bar{t}$, $UCL_T=6.60773\,\bar{t}$, with $\bar{t}=\overline{t_o}$ providing the vertical line **L----U**, at the **abscissa** $\bar{t}=\theta_0$ (**Figure 12**).

Look at **Figure 10**, as well; does the reader see that those formulae are the same as $LCL_T=0.00135\,\bar{t}$ $CL_T=\ln(2)\,\bar{t}$, $UCL_T=6.60773\,\bar{t}$, with $\theta=\bar{t}$? The Authors, the Peer Reviewers and the Editors of the Journals *Quality Engineering, Quality Technology & Quantitative Management, Quality and Reliability Engineering International, Communications in Statistics - Theory and Methods, PLOS one*, ... are wrong.

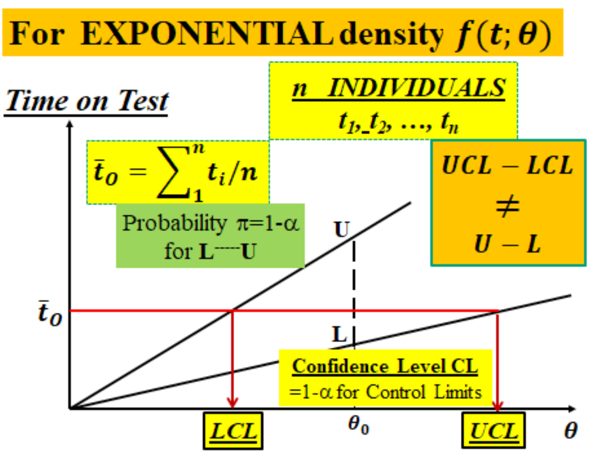

Figure 13. RIT LCL and UCL for the Individual Control Chart of Table 1 data.

All the authors do not realise that, *when the data are Normally distributed*, they have UCL-LCL=U-L (same length...) *notwithstanding* L----U and LCL----UCL are two *different* intervals with *different* meaning. Very likely for the users the error does not have any effect (see **Figures 3 and 4**)... The error is there, but it has no consequences, because for Normal data, formulae (12) $R_0(\bar{\bar{x}};\ LCL)=\alpha/2$ and $R_0(\bar{\bar{x}};\ UCL)=1-\alpha/2$, **for each sample**, of (sample size) k=5, with $\bar{t}_O=\bar{\bar{x}}$, provide formulae (2) above, here repeated $LCL_X=\bar{\bar{x}}-A_2(k=5)\bar{R}$ $CL_X=\bar{\bar{x}}$ $UCL_X=\bar{\bar{x}}+A_2(k=5)\bar{R}$, the same result of the classical theory (assuming R known).

From **Figures 12 and 14**, it is very clear that, for the **Table 1** lifetime data, the TBE Control Charts tell us (the Theory shows the truth) that the process is OOC (Out Of Control). *Notice* the plural "TBE Control Charts" because also the differences $|t_i-t_{i+1}|$ are exponentially distributed, as well; see **Figure 15**.

This proves again the truth of Deming's statement "*…people are learning what is wrong.*", "*It is necessary to understand the theory…*"

There is a deep ignorance of "Professionals" about the Control Charts with Exponentially Distributed Data.

See both **Figures 8 and 14**: The reader can CLEARLY see both the wrong Control Limits of the Control Chart *and the right Lower Limit (the dotted line)*. Also the ranges are OOC (**Figure 15**).

Figure 16 is very important: It shows the wrong Control Limits [LCL, UCL] derived from the formulae (2), which are valid when the data are normally distributed, and the *right correct LCL* (the dotted line for TBE) *computed with RIT*. The "original" Minitab 19 & 20 & 21 I-Chart shows two "wrong" Out Of Control points that do not actually exist; moreover it does not show the real OOC points below the dotted line: it shows them because the author forced the software to draw the *correct LCL* (the dotted line). The Minitab LCL is wrong, as well.

Anybody can transform the Exponential data into Weibull data, as suggested by D. C. Montgomery, who used the idea of Nelson.

He gets the wrong Control Charts, showing the Process IC (the opposite of the truth), as well…

The related I-Chart is in **Figure 17**: It shows the wrong Control Limits [LCL, UCL] derived from the formulae (2), now valid because the transformed data are normally distributed, and the *right correct LCL* (the dotted line) *computed with RIT*. Minitab 19 & 20 & 21 I-Chart does not show only the real Out Of Control points below the dotted line: It shows them because the author forced the software to show the dotted line.

The same happens with Johnson's transformation (**Figure 18**).

Any reader can clearly see that anybody needs the right and scientific method to analyse the data and derive the correct Control Charts: Data transformations can hide the truth.

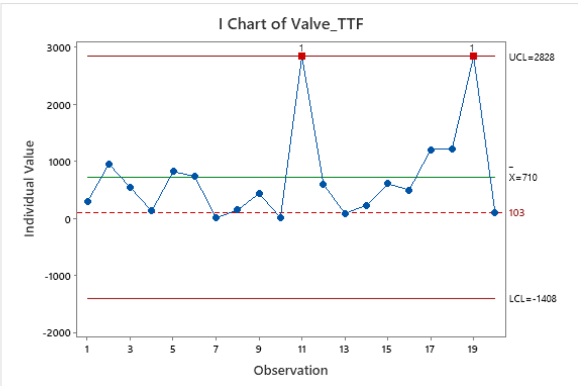

Figure 16. RIT I-Chart of Valve_TTF for Table 1 data . *The dotted line is the right correct LCL.*

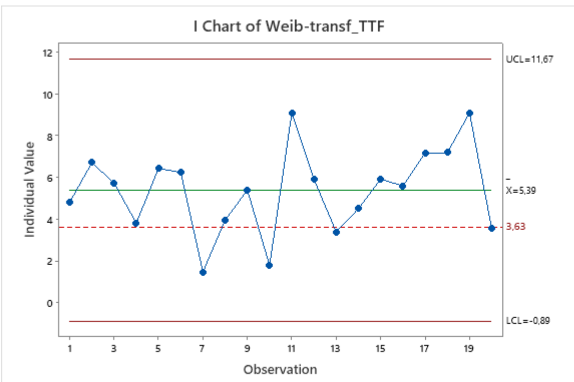

Figure 17. RIT I-Chart of Weib-transf_TTF for Table 1 data [transformed into Normal data, by Weibull transformation]. *The dotted line is the right correct LCL.*

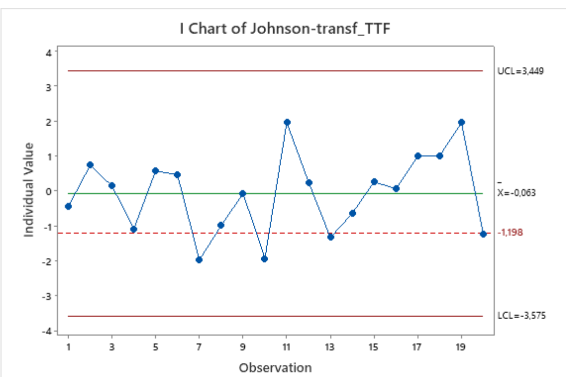

Figure 18. RIT I-Chart of Johnson-transf_TTF for Table 1 data [transformed into Normal data, by the Johnson's transformation]. *The dotted line is the right correct LCL.*

8. Time between events exponentially distributed data: From the paper "Improved Phase I Control Charts for Monitoring Times Between Events"

Now the readers can see how RIT can solve a case, found in a paper [5] published by *Quality and Reliability Engineering International* (whose editor is D.C. Montgomery). The two authors provide a wrong solution found neither by the Peer Reviewers nor by the Editor). Nevertheless, they "*thank D. Montgomery, Co-editor, for his interest and encouragement.*"

In their Abstract they claim that "their charts are ***more robust*** (i.e. less sensitive to unwanted OOC" than competitors).

The authors say that the data follow a Poisson Distribution with θ=0.1; they find LCL=–53. (put to 0) and UCL=47.2; we see that the process is OOC because 52.32 plots above the UCL; they claim that for **Table 2** data "*neither the Dovoedo and Chakraborti, nor the Jones and Champ control chart indicates any OOC situation.*"

Table 2. Time between failures data ("Improved Phase… for Monitoring TBE".[5]).

Failure #	TBE	Failure #	TBE	Failure #	TBE
1	1.24	11	52.32	21	6.09
2	6.69	12	14.75	22	20.41
3	9.77	13	4.69	23	5.93
4	1.23	14	0.18	24	19.03
5	14.03	15	13.61	25	13.65
6	18.07	16	4.57	26	6.37
7	3.90	17	0.28	27	2.06
8	13.61	18	7.08	28	3.30
9	18.47	19	12.00	29	6.91
10	12.85	20	5.15	30	12.08

Their Control Charts is the **Figure 19**. Notice that the "wrong" Control chart shows an Out Of Control (OOC) situation that should not be there and various In Control (IC) that should not be there… Now I use RIT.

As done in the previous section, now n=g*=30 TBE

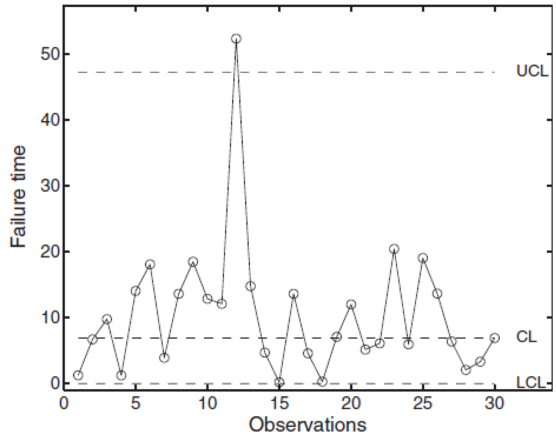

Figure 19. Control Chart from "Improved Phase… for Monitoring TBE". [5] *Remember that in this case k=1 (sample size).*

See the **Figure 19**. The Control Limits LCL and UCL must be consistent with the t_i "Time between failures": We want to assess if they are significantly different from the "*mean observed time to failure*" $\bar{t}_o$ = $\boldsymbol{t}_{\boldsymbol{o}}$/n. They are the values satisfying the two equations (12) for any single unit; so we have 30 Confidence Intervals [all equal, by solving formulae (12)], given $\bar{t}_o$ and CL=1-α [CL=0.997], $R_0(\bar{t}_O;\ LCL) = \alpha/2, R_0(\bar{t}_O;\ UCL) = 1-\alpha/2$

Remember that in this case k=1 (sample size) and $\bar{t}_o$ = $\boldsymbol{t}_{\boldsymbol{o}}$/n: I-CC.

Formula (12) proves how wrong all authors in the first referenced 21 papers [1-21].

Comparing **Figure 19** and **Figure 20**, it becomes very clear that the Control Chart from "Improved Phase… for Monitoring TBE" [5] presents 5 errors about OOC.

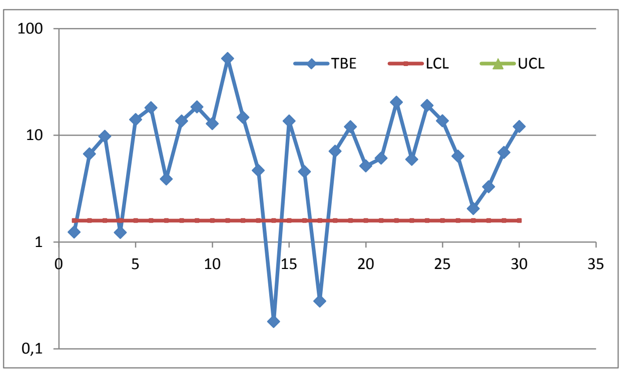

Figure 20. Control Chart of the data from "Improved Phase… for Monitoring TBE". [5]; vertical axe logarithmic; UCL is >100. RIT used (F. Galetto). Remember that in this case k=1 (sample size).

How can the Control Chart from "Improved Phase… for Monitoring TBE" [5] be good?

See their "absurd" Concluding remarks: "…IC robustness property …more than *Jones/Champ* and *Dovoedo/Chakraborti charts*".

Simulations made by F. Galetto (five million.) show that < 5% of the computations provide the correct decisions about IC and OOC…

I agree with those authors that "*Further work is necessary on the OOC performance of these charts*" [5]: The further Work must be to STUDY (see Deming.) to avoid "Huge costs of DIS-quality applications/decisions"…

9. Other cases from papers "Peer Reviewed"

The case presented before was taken from Peer Reviewed papers published in good and reputed Journals.

Now we see some other cases that show very clearly that the problem of Control Charts for TBE (Time Between Events) must be studied and solved using a sound Theory.

Consider the paper [21] and the good qualifications of both the authors [21]: Santiago/Smith both were (are now?) at Minitab, Inc.

The T Charts and the Box-plot methods *compute WRONG Control Limits*. And therefore the process is considered In Control, but it is not: **Figure 21**. The data are in **Table 3**.

F. Galetto analysis, with RIT, shows that the ***Process is OOC*** (Out of Control) ….

Consider also the paper of the "Qualified authors" Xie, M., Goh, T. N., Ranjan, P. (2002) "*Some effective control chart procedures for reliability monitoring*", Peer Reviewed by qualified Referees, published in Reliability Engineering & System Safety [16]. Again WRONG Control Limits.

Their data are in **Table 4**.

At least 10% of the data are Out Of Control: Xie et al. did not found that. Does the reader consider a very good result for a Peer Reviewed paper? See **Figures 10 and 22**.

Table 3. Urinary Tract Infection Data (from E. Santiago, J. Smith, Control charts based on the Exponential Distribution, *Quality Engineering* [21]).

Datum #	UTI (days)	Datum #	UTI (days)	Datum #	UTI (days)
1	0.57014	19	0.03819	37	0.12014
2	0.07431	20	0.24653	38	0.11458
3	0.15278	21	0.29514	39	0.00347
4	0.14583	22	0.11944	40	0.12014
5	0.13889	23	0.05208	41	0.04861
6	0.14931	24	0.12500	42	0.02778
7	0.03333	25	0.25000	43	0.32639
8	0.08681	26	0.40069	44	0.64931
9	0.33681	27	0.02500	45	0.14931
10	0.01389	28	0.27083	46	0.24653
11	0.03819	29	0.04514	47	0.04514
12	0.46806	30	0.13542	48	0.01736
13	0.22222	31	0.08681	49	1.08889
14	0.29514	32	0.40347	50	0.05208
15	0.53472	33	0.12639	51	0.02778
16	0.15139	34	0.18403	52	0.03472
17	0.52569	35	0.70833	53	0.23611
18	0.07986	36	0.15625	54	0.35972

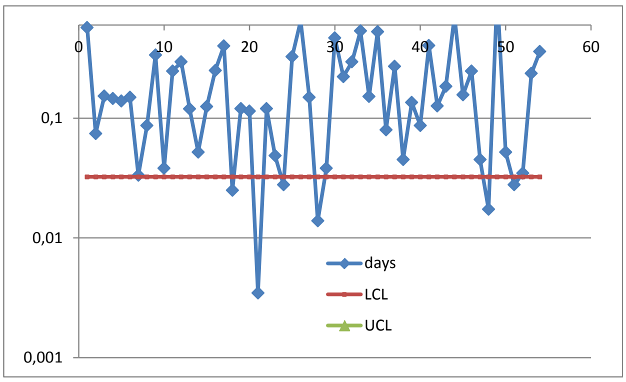

Figure 21. Table 3 Control Chart (of UTI); vertical axe logarithmic. (F. Galetto). *Remember that in this case k=1 (sample size).*

The two Peer Reviewers [16] should have known the Theory. "*It is necessary to understand the theory of what one wishes to do or to make.*" [Deming 1996]

It is clear that the shown methods (but RIT) compel their users to take wrong decisions, caused by the authors' qualifications….

Table 4. Time between failures (TBF) of a component. [16]

Failure #	TBF	Failure #	TBF	Failure #	TBF
1	30.02	11	0.47	21	70.47
2	1.44	12	6.23	22	17.07
3	22.47	13	3.39	23	3.99
4	1.36	14	9.11	24	176.06
5	3.43	15	2.18	25	81.07
6	13.2	16	15.53	26	2.27
7	5.15	17	25.72	27	15.63
8	3.83	18	2.79	28	120.78
9	21,00	19	1.92	29	30.81
10	12.97	20	4.13	30	34.19

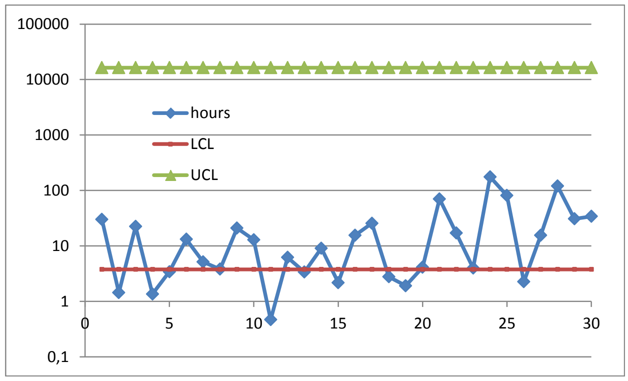

Figure 22. Control Chart of Xie et al. TBF data; vertical axe logarithmic. ***RIT used*** (F. Galetto). *Remember that in this case k=1 (sample size).*

From the paper [2] one finds a new wrong case copied from Santiago and Smith (2013) [21]. I do not report the data… Notice that the Control Limits are wrong (remember **Figure 10**).

Notice the "red and dashed lines" in **Figure 23**: They are "the control limits for the ATS-unbiased t1-chart with the {1/1,M:3/4} scheme…". Obviously, they are WRONG: **Table 5**.

The authors write [2]: "An example … *application of the proposed ATS-unbiased chart … we consider the data provided in Table B2 in Santiago and Smith (2013). .... First, for r=1, we obtain the lower and upper control limits for the basic ATS-unbiased t1-chart, which are equal to LCL=0.63 and UCL=2093.69, respectively. In a similar manner,* "the values of the control limits for the ATS-unbiased t1-chart with the {1/1,M:3/4} scheme, are equal to LCL=31.36 and UCL=1943.22, respectively"... *the* ***ATS-unbiased t1-chart*** *with and without the runs rule scheme* ***detects a signal at the 67th point***." "*Thus, we next investigate monitoring the process by considering the times to every 2nd event and using the ATS-unbiased t2-chart.* " OMISSIS….

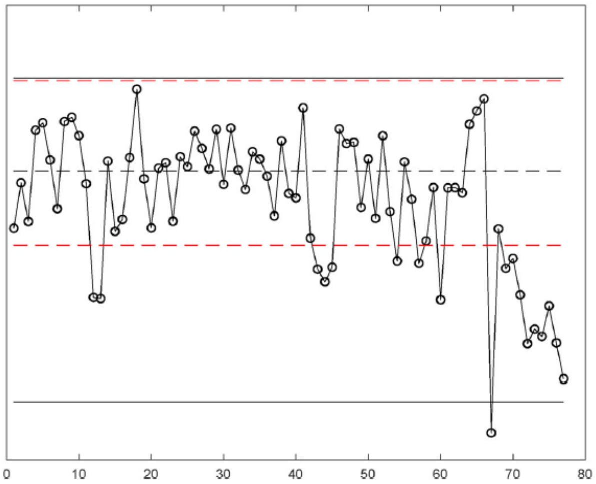

Figure 23. Control Chart from the paper [2] "Statistical design of ATS-unbiased charts with runs rules for monitoring exponential time between events", published in *Communications in Statistics - Theory and Methods*, DOI: 10.1080/03610926.2022.2092143 *k=1 (sample size)*.

It is interesting what I find with RIT. See **Table 5**.

Table 5. Comparison of results from the paper [2] and RIT.

Type of Method	LCL	UCL	Comment
N. Kumar et al. "t1 Chart"	0.63	2093.69	Both LCL and UCL are lower than Scientific
N. Kumar et al. "ATS–unbiased t1 Chart…"	31.36	1943.22	LCL is 17 times higher than Scientific and UCL is 24% of Scientific
F. Galetto **RIT**	1.835	7940.01	Scientific

Both the method from the paper [2] provide wrong Control Limits: The decision based on the process would be wrong, with the proposed methods.

10. Discussion

It should now be clear that several Journals published wrong papers on Control Charts (CC) for TBE (Time Between Events) data, exponentially distributed.

Does the reader think that the statement "*The problem of monitoring TBE that follow an exponential distribution is well-defined and solved"*. I do not agree that "nobody could solve scientifically the cases" has to be considered scientific?

Absolutely not. This is due to a lack of knowledge of the Sound Theory of the CC, generated by wrong knowledge of the basic concepts about Confidence Intervals.

It is a true disaster: It seems that nobody found the errors. Neither the Peer Reviews nor the Editors of the "good" Journals.

Many wrongs do not make a right.

Their "wrong formulae" are used by JMP, SAS, Minitab software.

The users of such software took and will take wrong decisions based on the "wrong formulae"…

Those Journals should, for future research about CC, accept the letters sent to their Editors.

I wrote letters to the Editors of *Quality Engineering*, *Quality and Reliability Engineering* and *Communications in Statistics_Theory and Methods* to inform them and the readers of the Journals about the errors on Control Limits for TBE Charts, to avoid costly errors and decisions. They have not been published yet…

To publish them they must understand the problem…

It is a big real problem: Big errors and nobody (known to the author), but F. Galetto, is taking care of teaching the students to use their own brains in order not to be poisoned by incompetents (**Figures 20 and 21**); for this reason the author self-cited himself (I ask the readers to signal him if other people have been sowing as many errors as he did).

The last document with errors [2] I found, published in 2022, uses the data on earthquakes that are shown (from the paper [21]): The Control Limits are again wrong.

The questions in Figure 1 give the readers some hints to think how many Statisticians, Certified MBB, …., *all over the world, are learning the wrong methods and will take the wrong decisions? And are teaching wrong methods…*

Writing this paper I think that I helped people (the readers, the Editors, the Peer Reviewers and other

Scholars) to avoid being cheated by the many wrong teachers running in the Disqualify Vicious Circle (**Figure 24**).

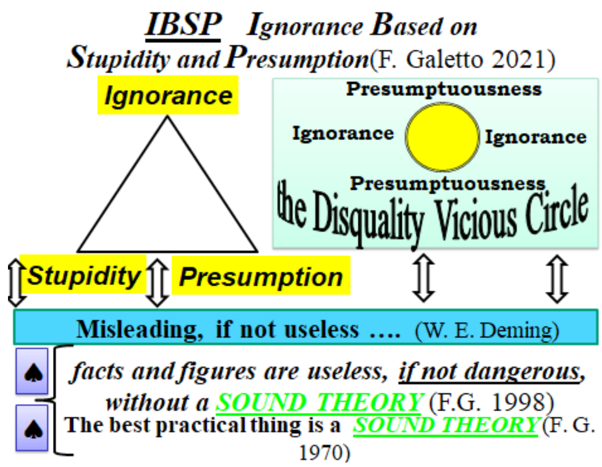

Figure 24. The Disquality Vicious Circle.

The author hopes that the Peer Reviewers of this paper have better knowledge than the discussants (in the various forums, iSixSigma, Research Gate, Quality Digest, Academia.edu and …), otherwise he risks being passed off…

In spite of all these proofs, the discussant who suggested the paper of J. Smith did not believe the evidence. He raised the problem that it could happen only by chance: He believed only in simulations ((like all who do not know Theory). After ten million simulations, F. Galetto got the result that T Charts (Minitab and in all wrong papers) were wrong 93.3% of the time.

I think that it should be enough…

But is it? No…, due to the ideas in **Figure 24**.

Figure 25 shows the author's position in teaching [Qualitatem Docere]: The "epsilon Quality, driven by Intellectual hOnesty and by Gedanken Experimente".

Figure 24 shows the real problem with the Minitab, JMP and SAS T Charts and the Box-plot based method.

The author many times (more than those you find in the references) tried to compel several scholars to be scientific [25,27-41,47-56]: He did not have success.

Only Juran appreciated the author's ideas when he mentioned the paper "Quality of methods for quality is important" at the plenary session of EOQC Conference, Vienna [28].

Figure 25. The "epsilon Quality, driven by Intellectual hOnesty and by Gedanken Experimente".

For the control charts, it came out that RIT proved that the T Charts, for rare events and TBE (Time Between Events), used in the software Minitab, SixPack, JMP or SAS are wrong. So the author increased the h-index of authors publishing the wrong papers [1-24].

Since the basic rules for Control Charts are based on the "Central Limit Theorem", many "professionals" transform the data to make them "almost Normally Distributed"; this behaviour can be dangerous as I showed before.

If the reader considers that the author asked many [>>50] "Statisticians and Certified Master Black Belts and Minitab users (you can find them in various forums such as ReasearchGate, iSixSigma, Academia.edu, Quality Digest, … and in several Universities)" and *nobody* could solve scientifically the cases, he has the dimension of the problem.

The author hopes that the Peer Reviewers of this paper have better knowledge than the discussants (in the various forums, iSixSigma, Research Gate and …), otherwise he risks being passed off…

In spite of all these proofs, the discussant who suggested the paper of J. Smith did not believe the evidence. He raised the problem that it could happen only by chance: He believed only in simulations (as do all the people who do not know Theory). After ten million simulations F. Galetto got that T Charts (Minitab and in all wrong papers) were wrong 93.3% of the time.

I think that it should be enough…

Figure 25 shows the author's position in his teaching at Turin Politecnico [Qualitatem Docere]: the "epsilon Quality, driven by Intellectual hOnesty and by Gedanken Experimente".

11. Conclusions

Any scholar needs and must analyse data with suitable methods devised on the basis of Scientific Theory and not on methods in fashion [1-25], in order to generate the correct Control Charts, with correct Control Limits.

RIT is able to deal with many distributions (exponential included) and then is usable for many types of data [47-56] and makes Quality Decisions.

First, I briefly presented the Shewhart Control Charts and the Individual Control Charts; second, I analysed the method "(BCCTBE)"; third, I showed the Minitab calculations for the T Charts; I showed the correct control limits of charts with exponentially distributed data, with the applications dealt in the referenced papers. I showed the RIT ability to solve correctly the *Control Charts for Exponentially Distributed Data*. RIT was devised by the author in 1975 (47 years ago) well before the T Charts invention and BCCTBE.

I showed various cases (from books and papers) where errors were present due to the lack of knowledge of a Sound Theory of Control Charts and of RIT.

RIT allows scholars (managers, students, professors) to find sound methods also for the ideas shown by Wheeler in his Quality Digest documents.

The truth sets you free.

Deficiencies in products and methods generate a huge cost of DIS-quality (poor quality) as highlighted by Deming and Juran. Any book and paper is a product (providing methods). The books presenting financial considerations about reliability with wrong ideas and methods generate huge cost for the Companies using them. The methods given in our documents provide the route to avoid such costs, especially when RIT gives the right way to deal with Preventive Maintenance (risks and costs), Spare Parts Management (cost of unavailability of systems and production losses), Inventory Management, cost of wrong analyses and decisions.

In order to show the several wrong ideas and methods related to financial and business considerations about quality in several books (not given in the references) I would need at least 30 more pages in this paper: I, obviously, cannot do that. Therefore I ask the readers to look at some of the documents [27-56], including the "Several Papers and Documents in the Research Gate Database, 2014".

I end with the statements of two authors in one of the papers [1-25] who provided WRONG Control Charts, with WRONG Control Limits; they wrote, about F. Galetto comments:

"*We do not know this author and are not familiar with his work. His claim about our formulas being wrong is not justified by any facts or material evidence. Our limits are calculated using standard mathematical statistical results/methods as is typical in the vast literature of similar papers.*"

The complete document is available for any interested reader (write to F. Galetto).

The dramatic problem for TBE Control Charts is this: "*Limits are calculated using standard mathematical statistical results/methods as is* ***typical in the vast literature of similar papers****.*" This is the proof of how many "scholars" diffuse wrong ideas.

See **Figures 1, 9, 12, 20, 21** and **Table 5**.

As the last information, the readers must consider that the ARL (Average Run Length) for Individual Control Charts for TBE is quite different from the usual formula they can find in books: ARL=1/α [56].

The author had to self-cite because it seems the only one that has been fighting for years for "Papers Quality"; he humbly asks the readers to inform him if some people did the same.

Conflict of Interest

There is no conflict of interest.

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