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Original Paper

Research on Scientific Derivation of Control Limits in Control Charts

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Abstract

Control Charts (CC) are the means to "manage the process behaviour" by analysing subsequent samples at regular intervals of time.: good decisions depend on Scientific analysis of data. Often, the data are considered Normally distributed; this is not completely right; data must be analysed according to their distribution: decisions are different with different distributions, because the Control Limits of the CC depend on the distribution. We compare our findings with Shewhart findings; later we extend the ideas to deal with "rare events", with data not Normally distributed; we compare our results, found by RIT, for various cases in the literature: there is a big difference between the Shewhart CC and the Time Between Events CC; considering that, future decisions of Decision Makers will be both sounder and cheaper, when data are not normally distributed. ARL depends on the data distribution, not only on the "false alarm rate". The novelty of the paper is due to the Scientific Way of Computing the Control Limits, both for the mean and for the variance.

Keywords

Control Charts, exponential distribution, TBE, T Charts, Reliability Integral Theory

1. Introduction

Shewhart Control Charts (SCC), devised by W. A. Shewhart (1931, 1936), have been used to manage the "Production Process". They have been appreciated by Deming (1986, 1997) and Juran (1988) who introduced them in Japan, as Statistical Process Control (SPC).

One century after its invention many users do not know the scientific derivation of the formulae of Control Limits (CLs), LCL (Lower Control Limit) and UCL (Upper Control Limit): a big problem which Companies are confronting with.

CC were devised using extensively the "Normal Distribution" of the data: Shewhart (1931) book and page 36 in the (1936) book. Shewhart did not connect (to our knowledge) explicitly the CLs to the

Confidence Limits (of the Confidence Interval): due to that, later, scholars wrote many papers on control charts for TBE (Time Between Events) data and *provided wrong CLs*, so making the users to take wrong decisions [see below the "*ocean full of errors…*"].

This point is very important and surely a novelty in the literature on CC.

TBE data are analised by the use of CC_TBE by wrongly computing the CLs: if the data plots within the CLs and there is no evident pattern, then the Process is considered In Control (IC).

We considered the papers found in the web: "*ocean full of errors …*". It can be considered as a Literature Review.

This paper has the following structure: first, we introduce scientifically the concept of Confidence Interval (CI); secondly, we introduce scientifically the concept of Control Limits for the Control Charts and briefly present the Shewhart Control Charts and the Individual Control Charts (I-CC); thirdly, we show the correct CLs of CC with exponentially distributed data, comparing them with the applications dealt in the "ocean full of errors …" and we will see the Minitab wrong calculations; we will show how RIT (Reliability Integral Theory) compute correctly the CLs for I-CC_TBE; fourthly, we show several wrong cases taken form the literature. There is no specific "literature review" (but the "ocean full of errors…") because we are only interested in showing the RIT ability to correctly solve the *Control Charts for Exponentially Distributed Data*. RIT was devised by the author in 1975 well before the T Charts invention.

We cannot present the RIT due to space restriction in the journal.

2. The Concept of Confidence Interval

It is *wise* to give the concept of Confidence Interval (CI), because the author met quite a lot of scholars who did not correctly know the CI. The *Control Limits* (CLs), LCL and UCL of CC are strictly related to the *CIs*.

The concept of CI can be found in various books (e.g., Juran, 1988; Belz, 1973; Rao, 1965; Ryan, 1989; Cramer, 1961; Mood, 1963; Montgomery, 1996; Galetto, 1995-2000): only Galetto (1995-2020) connects the CIs to the *CLs* of CCs. The reader can find good ideas about the concept of CI (and many errors about it) in Galetto (1982-2015).

We cannot spend much space to this point: see the references.

Consider the data ("*INCOMPLETE samples*"): the first 5 are the TIME TO FAILURE [at 115, 149, 185, 251, 350 (hours)] and the other 5 are data on items that did not fail [NON_Failures at 350, 350, 350, 350, 350 (named "suspended items"), according to a form of "*stopping rule*"]. ASSUMING $F(t)=1-\exp[-(t/\eta)^2]$, with parameter η, and fixing CL=90% (Confidence Level), we get the CI for the Mean is μ 270.7--------582.8; GENERALLY the Statistics books do not consider the case of "INCOMPLETE samples"; they consider and provide formulae only for the "COMPLETE samples".

For Control Charts, we are incredibly lucky because the samples are always "COMPLETE samples". The CI for μ, μ_L=270.7--------582.8=μ_U, is a ***numerical interval***, computed from the sampled data: length of the CI d=μ_U-μ_L depends both on the CL and on the number of failures (*not* of the number of data). Therefore (Galetto 1982-2020), to get the CI, we need (1) a set of k data [the sample, of sample size k, partitioned into "failures" and "suspended"] (2) a CL, stated before any computation, (3) a *Probability* Distribution [depending on *parameters* (e.g., the "true" mean μ and variance σ^2) "generating" the data, from which we want to *estimate the parameters*, (4) a *Statistical* Distribution of the *estimators of the parameters* [Random Variables (RV) depending both on the RVs providing the data and on some function of the *parameters*), (5) a suitable formula to compute the CI from the k data.

The reader sees that there is a lot to be known if he wants to correctly compute the CI (and then, later, the Control Limits of the CC).

Assuming that the RV X follows the Normal Distribution (with *parameters*, mean μ and variance σ^2) the pdf (probability density function) is

$$\boldsymbol{f_X(x;\quad \mu,\sigma^2)=\frac{1}{\sqrt{2\pi}\sigma}e^{-(x-\mu)^2/2\sigma^2}} \tag{1}$$

Consider the two samples (size k=5 each, Table 1); we want to assess if the two experimental means $\bar{x}_1$ and $\bar{x}_2$ (computed from x_{ij}, i=1, 2, j=1, 2, …5) suggest us that the "true" means μ_1 and μ_2 are to be considered different with CL=99.7%.

Table 1. Data (complete samples) and Confidence Intervals

Sample	Datum	datum	datum	datum	datum	*mean*	CI_{Lower}	CI_{Upper}
1	809.4	758.4	633.9	820.6	530.9	*710.6*	*543.2*	*878.1*
2	767.2	968.4	595.3	482.5	659.9	*694.7*	*447.0*	*942.3*
pooled						*702.7*	*553.2*	*852.1*

With the Theory (Juran, 1988; Belz, 1973; Rao, 1965; Ryan, 1989; Cramer, 1961; Mood et al., 1963; Montgomery, 1996; Galetto, 1982-2020) and the Maximum Likelihood (ML) method, we compute the two experimental means $\bar{x}_1$ and $\bar{x}_2$ and the pooled mean $\bar{x}_{pooled}$ with the formulae (for complete samples) to estimate the "true" means μ_1 and μ_2 and the two "corrected" experimental variances s_1^2 and s_2^2 and the pooled variance s_{pooled}^2 to estimate the "true" variances σ_1^2 and σ_2^2.

Up to now, there is no innovation: only standard and classical known methods, for complete samples. IF, on the contrary, the samples were INCOMPLETE the "same" formulae ***would NOT*** be APPLICABLE!

The innovation arises when we compute the CIs: the author knows only few books (Cramer, 1961; Mood, 1963; Galetto, 1995-2000) that deal with CI as we do now.

Consider the Cumulative Function (CF) N(x; μ,σ^2) of the pdf (1): the CF of the RV Mean $\bar{X}$ is

$$N\left(x;\quad \mu,{\sigma^2}/{n}\right)=\int_{-\infty}^{x}\frac{1}{\sqrt{2\pi}\sigma}e^{-(y-\mu)^2/(2\sigma^2/n)}\,dy=\int_{-\infty}^{(x-\mu)/(\sigma/\sqrt{n})}\frac{1}{\sqrt{2\pi}}e^{-z^2/2}\,dz \tag{2}$$

where the parametric real function $g(x;\quad \mu,\sigma)=(x-\mu)/\sigma$ is a surface depending on μ and σ; putting $g(x;\quad \mu,\sigma)=z$, we have the "level lines" $x=\mu-z\sigma$.

Considering the plane with axes μ (abscissa) and x (ordinate); we the graph of the function x: a straight line parallel to the bisector, for any chosen values of z and of σ; there is a double infinity of lines (depending on …).

Fixing a Probability π=1-α, for the Mean $\bar{X}$, and choosing a symmetric interval, such that

$$\pi = 1 - \alpha = \int_{z_{\alpha/2}}^{z_{1-\alpha/2}} \frac{1}{\sqrt{2\pi}} e^{-z^2/2}\, dz,$$

we get $z_{\alpha/2}$ and $z_{1-\alpha/2}$ to be used in the formula $x = \mu - z\sigma$: there is a single infinity of lines (depending on σ). When σ is known, we have only two lines versus μ. At any fixed value μ_0 (of the parameter μ), we find two points L and U (not random variables!) giving a Probability Interval for the RV Mean $\bar{X}$, such that $P[L \le \bar{X} \le U] = \pi = 1 - \alpha$: vertical interval L-----U in Figure 1. When we analyse the data of the i-th sample of size k (5, in table 1) we get a number, the experimental mean $\bar{x}_i$; the horizontal line from the point (0, $\bar{x}_i$), intersects the two lines (parallel to the bisector) in two points LLC_i and ULC_u that provide the CI, LLC_i--------ULC_u. Since the two lines are associated to the probability π=1-α, **we say that** the CI, LLC_i--------ULC_u, has a CL=1-α: we are "confident" that LLC_i--------ULC_u could include the value μ_0 (a proportion 1-α of the CIs includes μ_0, *in the long-run*). NOTICE that ***the two intervals*** L----------U and LLC_i----------ULC_u ***are conceptually different***, even though they have the same length (caused by the Normal Distribution that is symmetric about the mean)!

This is of paramount importance for the Control Limits of the Control Charts.

This important point is neglected by all the authors mentioned in this paper… ("*ocean*" ...)

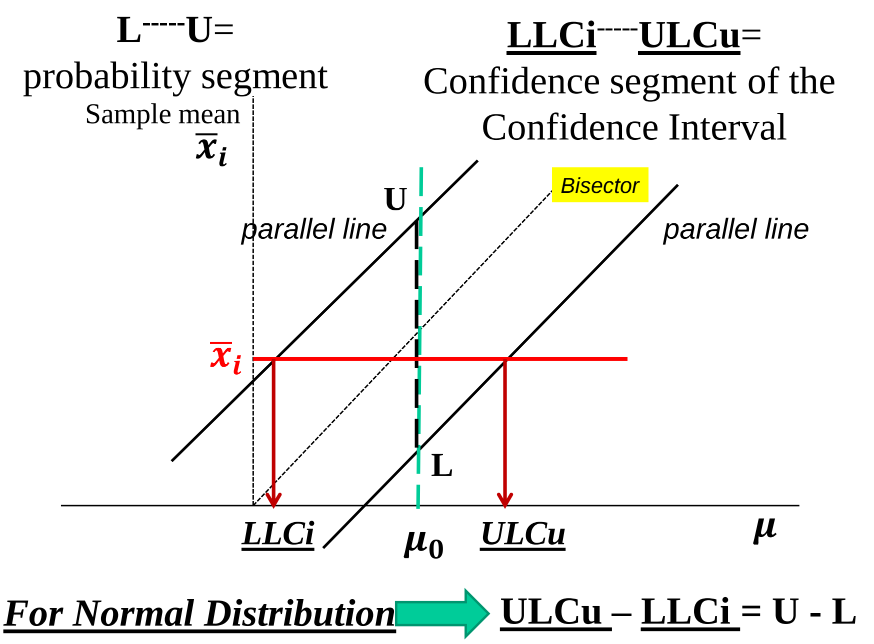

Figure 1. The TWO "Level Lines" Parallel to the Bisector for the Normal Distribution, Providing the "Probability Interval" L--------U and the Confidence Interval LLCi--------ULCu

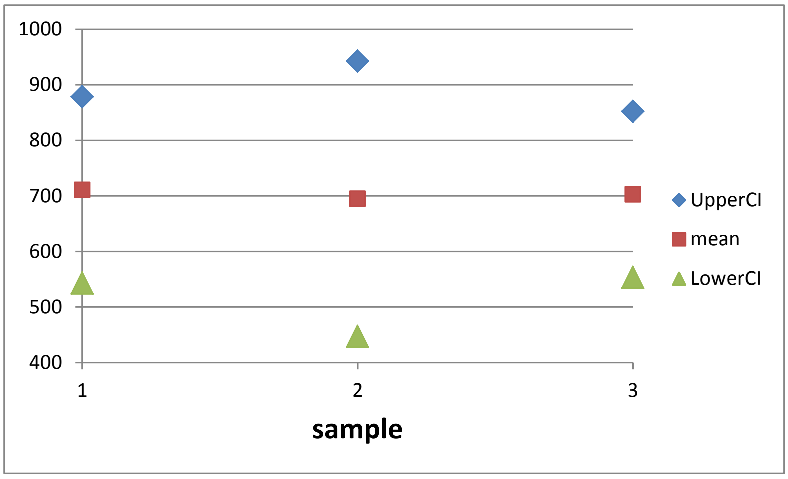

Figure 2. Confidence Intervals of the Samples in Table 1 (3=pooled sample)

Considering the symmetric pdf, we have, for the i-th sample,

$$L = \mu_0 - z_{1-\alpha/2}\sigma/\sqrt{k} \qquad U = \mu_0 + z_{1-\alpha/2}\sigma/\sqrt{k} \qquad \text{and}$$

$$LLC_i = \bar{x}_i - z_{1-\alpha/2}\sigma/\sqrt{k} \qquad ULC_i = \bar{x}_i + z_{1-\alpha/2}\sigma/\sqrt{k} \qquad (3)$$

Looking at the formulae (3), it is ***very tempting*** *to draw the WRONG conclusion that we get the CI by putting the experimental mean* $\bar{x}_i$ *in place of* the value μ_0 of the parameter μ.

This is the error that many people make when they consider distributions different from the normal one (or symmetric pdf). (*see the* "*ocean* ...")

One could use the same ideas, given before, but not the same formulae, for finding the CI of the variance σ^2 or of the standard deviation σ, or of any other quantities such as (e.g.) the p-values. The "lines" to be used for the variance σ^2 are *not parallel* to the bisector!

Formulae (3) are valid when σ is known. If the standard deviation σ is estimated from the data, normally distributed, then the quantity z computed from the normal distribution must be substituted by t taken from the t (Student) distribution: the values $t_{1-\alpha/2}$ must be used:

$$LLC_i = \bar{x}_i - t_{1-\alpha/2}s/\sqrt{k} \qquad ULC_i = \bar{x}_i + t_{1-\alpha/2}s/\sqrt{k}.$$

The CIs can be used for comparing the mean of each sample versus the means of the other sample, to assess either if they are "*statistically* different" or if they are "*statistically* equivalent". See the Figure 2: each *experimental mean* (red square) of any sample is comprised in the CI of the other sample: that means that the "true" means μ_1 and μ_2, estimated by by the *experimental means*, are "*statistically* equivalent". Any CI is the set of all the numbers "*statistically* equivalent" between them: CI is an "*equivalence class*"!

3. The Concept of Control Limits for the Control Charts

Section 2 is very important: it is the only scientific way to find the Control Limits for the CCs.

CCs are the tool for assessing the "health" of the process ("*thermometer for measuring the fever of a Process*"). CCs are a statistical tool for monitoring the "measurable output" of a Process. The "measurable output" (provided by the products produced) can be viewed as a "Stochastic Process X(t)", depending on the time t, ruled by a pdf for any set of n "RV" $X(t_i)$, i=1, 2, ..., n, at the "time instants t_i" (Mood, 1963; Rao, 1965; Rozanov, 1975; Ryan, 1989).

In many applications the data plotted (on the CC) are the means $\bar{x}(t_i)$, determinations of the RVs $\bar{X}(t_i)$, (n=number of the samples) computed from the data x_{ij}, j=1, 2, ..., k (k=sample size); x_{ij} determinations of the RVs $X(t_{ij})$ at *very close instants* t_{ij}, j=1, 2, ..., k; the RVs $\bar{X}(t_i)$ are assumed to follow a normal distribution *because* (Central Limit Theorem) they are the means of samples with sample size, k, each; usually k=5. For each RV $\bar{X}(t_i)$ we assume here that it is distributed as $\bar{X}(t_i)\sim N(\mu_{\bar{X}(t_i)}, \sigma^2_{\bar{X}(t_i)})$: this is the assumption of W. A. Shewhart on page 278 of his book (1931) and justified on page 289; here we accept this assumption for future comparisons. Another common assumption for Variable CCs is that $X(t_{ij})$ are also independents and we can compute a grand mean $\bar{\bar{X}}$ [mean of all the RVs $X(t_{ij})$] that is distributed as $\bar{\bar{X}}\sim N(\mu_{\bar{\bar{X}}}, \sigma^2_{\bar{\bar{X}}})$.

In any Production or Service process (figure 3) there is a "background noise (inherent natural variability)": a certain amount of inherent natural variability always exists in any process output (it is named "due to chance causes of variability"; W. A. Shewhart terms it "*constant systems of causes*"); such a process is said to be "statistically In Control", IC (*no fever*): in such a case all the means $\mu_{\bar{X}(t_i)}$, estimated by $\bar{x}_i = \bar{x}(t_i)$, have to be considered "equivalent (i.e. equal, $\mu_{\bar{X}(t_q)} = \mu_{\bar{X}(t_r)}$ for any q≠r)" between them and to $\mu_{\bar{\bar{X}}}$.

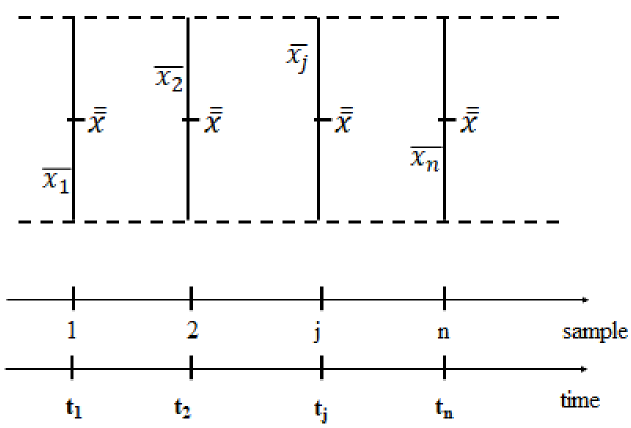

Figure 3. The Data "Means" $\bar{x}_i = \bar{x}(t_i)$ of the Process and the "Grand Mean" $\bar{\bar{x}}$ Shown

If a product has variability, in its quality characteristics, greater than the inherent natural variability we say that the process is "Out-Of-Control" [OOC (it has "*fever*")] and operating in the presence of "*assignable causes of variation*": in such a case some of the means $\mu_{\bar{X}(t_i)}$, estimated by $\bar{x}_i = \bar{x}(t_i)$, have to be considered "NOT-equivalent (i.e. statistically different)".

CCs are the tool used to understand if a process is IC or OOC.

A Variable CC (Figure 3) comprises four elements: the data plotted and 3 lines, a centre line $\bar{\bar{x}}$, a lower line LCL and an upper line UCL. If a point plots outside of the control limits (or there are significant patterns) then we interpret it as evidence that the process is OOC: investigation is needed to find the "assignable causes of variation". The CLs are determined in such a way that if the process output has only chance (random) variability, that is, it is IC (In Control), then the data plotted in the control chart are 99.7% between LCL and UCL (and there are no significant patterns).

In Figure 3 the determinations of the RVs $\bar{X}(t_i)$ and $\bar{\bar{X}}$ are shown. So far we used known ideas.

Let's now use the concepts of the section 2. Let's consider first the CI of the unknown mean μ of the process. We act in this way: (1) we fix the probability π=1-α=0.9973, (2) we collect n (usually n>20) samples, of size k each (usually k=5), [N > 100 x_{ij} measures (N=nk)], (3) we compute the "*experimental mean*" $\bar{x}_i$ and the "*experimental standard deviation* s_i" of each i-th sample, (4) the "*experimental grand mean*" $\bar{\bar{x}}$ of all the n samples and the "*experimental standard deviation s*", (5) we draw the two lines parallel to the bisector with the "*experimental standard deviation s*" and we find the value $t_{1-\alpha/2}$ related to the "*probability interval* L-----U", (6) drawing the horizontal line at value $\bar{\bar{x}}$ (figure 1, with $\bar{\bar{x}}$ in place of $\bar{x}_i$ and N in place of n) intersecting the two parallel lines we find the "*Confidence Interval* $^{(N)}LLC_l$--------$^{(N)}ULC_u$" of the unknown mean μ of the process [here, the index $^{(N)}$ states that the CI is computed with the total N data (NOTICE)].

The "*CI* $^{(N)}LLC_l$--------$^{(N)}ULC_u$" of the unknown mean μ of the process is not suitable to compare each mean $\mu_{\bar{X}(t_i)}$, estimated by the "*experimental mean*" $\bar{x}_i$, to $\mu_{\bar{\bar{X}}}$, estimated by the grand mean $\bar{\bar{x}}$, and to all the other means $\mu_{\bar{X}(t_i)}$, i=1, 2, …, n: if the Process is IC the variation of the means $\mu_{\bar{X}(t_i)}$ is "stable", i.e. we have to use the "*experimental variability* $s/\sqrt{k}$" (related to $\mu_{\bar{\bar{X}}}$) and not $s/\sqrt{N}$ (as done before). Doing that we have, for each sample, the formulae $LLC_i = \bar{\bar{x}} - t_{1-\alpha/2}s/\sqrt{k}$ and $ULC_i = \bar{\bar{x}} + t_{1-\alpha/2}s/\sqrt{k}$, which provide the CLs of the CC

$$LCL = \bar{\bar{x}} - t_{1-\alpha/2}s/\sqrt{k} \quad \text{and} \quad UCL = \bar{\bar{x}} + t_{1-\alpha/2}s/\sqrt{k} \qquad (4)$$

The formulae (4) allow us to compare each mean $\mu_{\bar{X}(t_q)}$, q=1, 2, …, n, to any other mean $\mu_{\bar{X}(t_r)}$ r=1, 2, …, n, and to the grand mean $\mu_{\bar{\bar{X}}} = \mu$; hence, so doing, we assess if the process is IC or OOC (see the figure 3, where the process is IC).

$$\bar{\bar{X}} \pm 3\frac{\sigma}{\sqrt{n}} = 13{,}540 \pm 3\frac{440}{\sqrt{20}} = \begin{cases} 13{,}245 \\ 13{,}835, \end{cases}$$

and

$$\bar{\sigma} \pm 3\frac{\sigma}{\sqrt{2n}} = 423 \pm 3\frac{440}{\sqrt{40}} = \begin{cases} 214 \\ 632. \end{cases}$$

Excerpt 1. From Shewhart book

Generally, in the CC use, we set 3=$t_{1-\alpha/2}$, both for the CC of μ and of σ (even though the distribution of the "variability σ" is far from being normal!). See, in the excerpt 1, what Shewhart (1931) wrote on page 294 of his book, where $\bar{X}$ stands for our $\bar{\bar{x}}$ and σ stands for our s; $\bar{\sigma}$ is the "estimated mean standard deviation if all the s_i" and n stands for our sample size k.

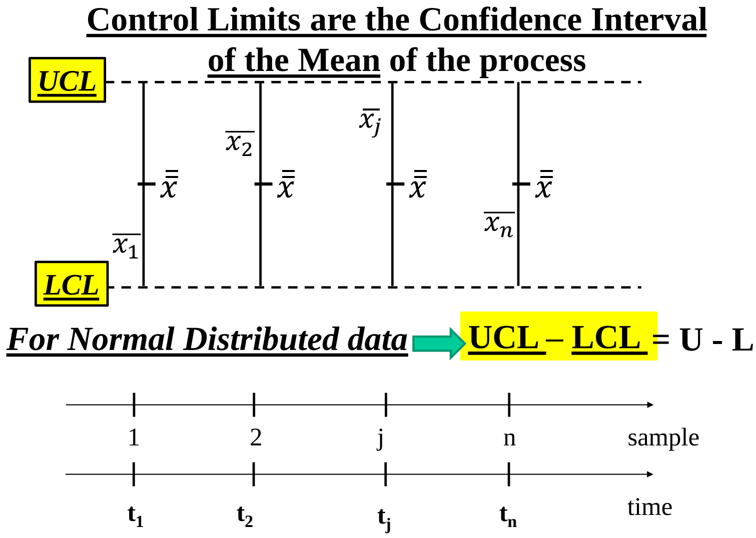

Figure 4. Control Limits LCL$_X$----UCL$_X$=L----U (Probability Interval), for Normal Data

Naming X the "quality characteristic" providing the quality of the product, produced by the production process, it is customary to write the following formulae for the CCs: $LCL_X = \bar{\bar{x}} - A_2\bar{R}$, $CL_X = \bar{\bar{x}}$, $UCL_X = \bar{\bar{x}} + A_2\bar{R}$ (the coefficient $\underline{A_2}$ depending on the sample size k). The interval LCL$_X$------UCL$_X$ (CLs, on the horizontal axis, in figure 2 and on the vertical axis, in figure 5) is the CI with "Confidence Level" 1-α=0.9973 for the unknown mean $\mu_{X(t)}$ of the Stochastic Process X(t).

A similar CC is drawn for the range by making a "**bigger** *mental leap*" [the distribution of $\bar{R}$ is not normal!] (the coefficient $\underline{D_3}$ and $\underline{D_4}$ depending on the sample size k) $LCL_R = D_3\bar{R}$, $CL_R = \bar{R}$, $UCL_R = D_4\bar{R}$. The interval LCL$_R$-----UCL$_R$ is the CI with CL=1-α=0.9973 for the unknown Range of the Stochastic Process X(t).

Notice that the Control Interval for normally distributed data **UCL$_X$-LCL$_X$=U-L** (Probability Interval) and that LCL$_X$ can be obtained from L by substituting μ with $\bar{\bar{x}}$; the same for UCL$_X$ and U.

It is customary to use both the previous formulae also for NON_normal data: in such a case the NON_normal data are transformed in order to "produce Normal data" and to apply the formulae.

Sometimes we have few data and then we use the so called "*individual control charts*" I-CC.

The I-CC are very much used for exponentially distributed data: they are named "rare events Control Charts for TBE (Time Between Events) data", I-CC_TBE.

There are scholars in the "*ocean full of errors …*" who do not know how to correctly compute the Control Limits. To show this big problem about the I-CC for TBE we use the data in Table 2.

Table 2. Lifetime Data y_i (from Montgomery's Book). ***Notice that k=1 (Sample Size)***

286	948	536	124	816	729	4	143	431	8
2837	596	81	227	603	492	1199	1214	2831	96

Table 2 shows the *lifetimes* of a case [Example 7.6 in the Montgomery (1996) book]. The data are (exponentially distributed).

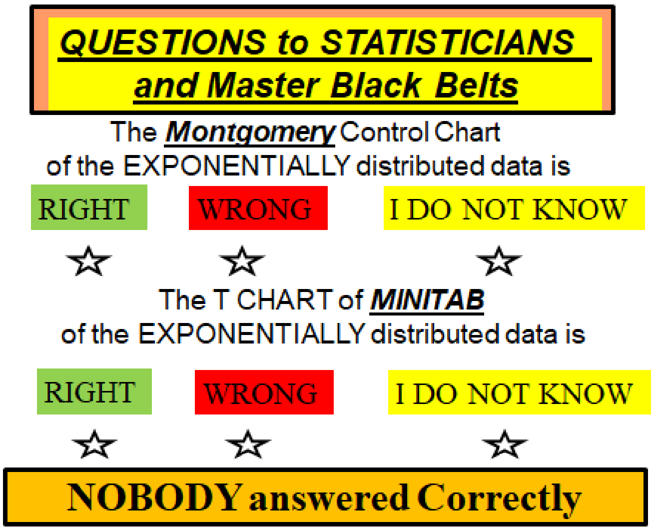

Figure 5. Question asked to MBB and Statisticians and Experts

On December 2019 the author asked a question in a post at the site iSixSigma: https://www.isixsigma.com/topic /control-charts-non-normal-distribution related to CC. The cases were related to control charts where the data are exponentially distributed. The first of the cases was taken from the book of D. C. Montgomery [Table 2]. The author knew about that since 1996.

The iSixSigma "experts" (Figure 5) were unable to provide a correct way to solve the cases and did not wanted to accept that the Montgomery's solution was doubtful because *he finds that the process is In Control (IC)*, while actually the process is Out Of Control (OOC); at least 70 Master Black Belts, of several countries (Italians as well), and more than 60 "experts" (statisticians, professionals, engineers, …) have been asked to find the solution (Figure 5) of the two cases of CC, in three "social" groups: iSixSigma, Academia.edu and Research Gate. Up to now, June 2023, nobody provided any good solution to the problem!

Any scholar wanting to learn CC with normal distribution, exponential and Weibull distribution can usefully read the book "Statistical Process Management" (Galetto 2019).

4. Individual Control Charts (I-CC) and Exponentially Distributed Data

The I-CC have sample size k=1 for I-CC; see figure 6. The "grand mean" $\bar{\bar{x}}$, in this case, becomes the mean $\bar{x}$. To compute the CLs (LCL and UCL) we are forced to use the differences $x_{i+1} - x_i$; we compute the n-1 ranges and then we can use the usual formulae, for the Normal distributed data [i=1, …, n-1 (n=total number of data)].

What do the scholar who do not have the right Theory?

They transform the data to have "transformed data" Normally distributed.

D. C. Montgomery did that: he transformed the Exponential data into Weibull data with shape parameter β=1/3.6, as suggested by Nelson.

He did not care if the transformation would give sound analysis: he used it blindly.

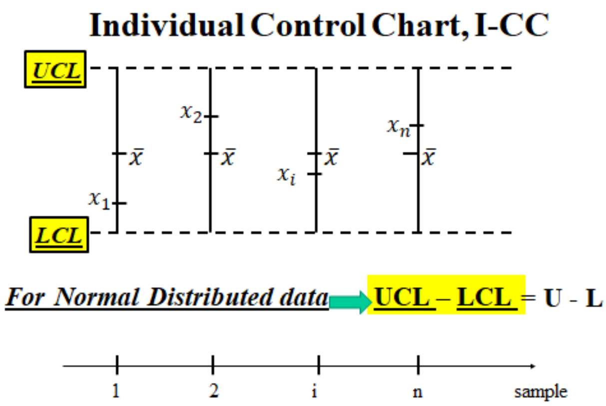

Figure 6. Individual Control Chart. ***Notice that k=1 (sample size)***

Before using a transformation, any scholar should see if it is suitable, because, as said by Deming (1986, 1997), "*Management need to grow-up their knowledge because experience alone, without theory, teaches nothing what 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.*" and, moreover, "*It is necessary to* ***understand the theory*** *of what one wishes to do or to make.*"

The transformed data are $x_i=y_i^{1/3.6}$; Montgomery uses a I-MR Chart: in the upper graph the individual x_i are plotted with their mean $\bar{x}$ and control limits and in the lower graph the individual moving ranges $MR_i=|x_i - x_{i+1}|$ are plotted with their mean $\overline{MR}$ and control limits [Figure 7].

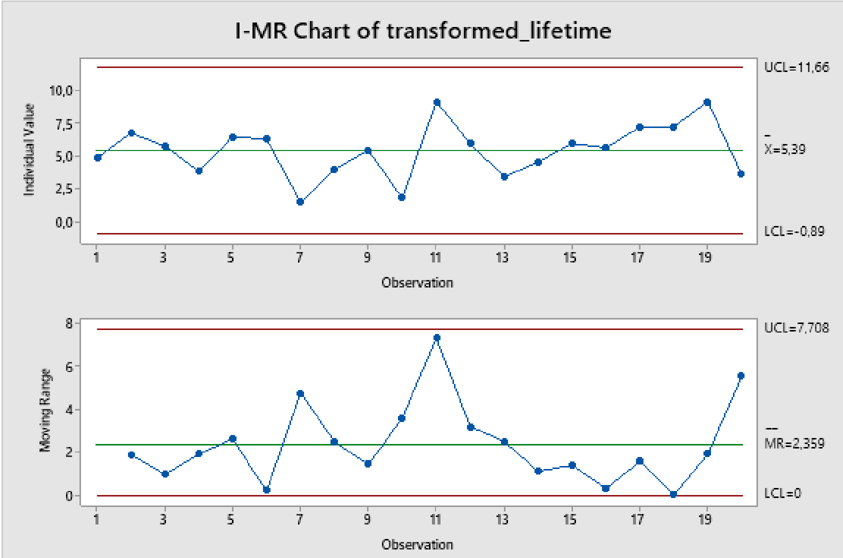

Figure 7. Individual and Moving Range Chart of *"Transformed"* Montgomery Data (as Suggested by Nelson). Minitab 19&20&21 Used (F. Galetto).

According to the Figure 7, Montgomery writes "*Note that the control charts indicate* a state of control, *implying that the failure mechanism for this valve is constant…*".

Is this a true picture of the process? NO: "In Control" depends on the formulae used!

SixPack, JMP, SAS provide the same picture of the process.

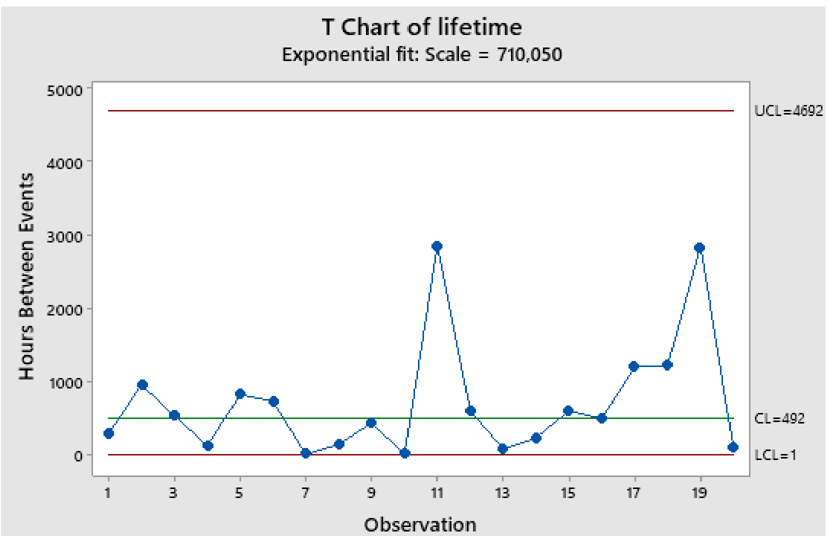

Figure 8. T Chart of Montgomery Data. Minitab 19&20&21 Used (F. Galetto).

The *discussants*, in iSixSigma (https://www.isixsigma.com), suggested using Minitab Software and "*T Charts*", considering them the good method to deal with "rare events" (Galetto, 2019, 2020).

The T Chart (Figure 8) shows the process "In Control", again. Is this a true picture of the process? NO. After these findings, the author tried to inform the "Scientific Community" about the problems of Control Charts for TBE (Time Between Event): wrong Control Limits in them.

Actually, the process is Out Of Control!

At that time, we analysed more than 100 documents [looking for them in the Web…] (***notice*** that one of the authors is very well known; he has *6969 Citations*! Does that mean that he authored good papers? Absolutely not!)]; see the "*ocean full of errors by* ...". All the papers in the *"ocean …"* have the same problem: wrong CLs; ALL the AUTHORS confound the concepts, by stating that LCL and UCL (that actually are the Confidence Limit!) are the limits L and U of the Probability Interval.

They were (and are) "*lead into temptation and delivered into evil*" by the (*inapplicable*) formulae, that are applicable only for the normal data and ***not*** for exponential data, in spite of the wrong statements (excerpt 2) about "*limits… typical in the vast literature…*" and "*The problem … exponential distribution is well-defined and solved*".

They use wrongly the Probability Interval L------U as though it were the LCL------UCL and put the estimates, either $\bar{t}$ or $1/\bar{t}$, of the parameters in place of the parameters, θ or λ=1/θ. See the excerpt 2: "the *temptation* and the *evil*". Notice that an author (*"ocean ..."*) is Associated Editor. of …

Let's hope that the Peer Reviewers and readers practice "*metanoia*" (Deming 1997) and remember his statements given before…"*devastating effects of incompetent teaching and faulty applications.*"

Reliability Integral Theory (RIT) solves the problem of computing the Control Limits for Control Charts, especially for I-CC_TBE, exponentially distributed data.

Minitab "T Charts" are wrong; the same is the method suggested in the paper "Boxplot-based Phase I …", *QREI*: wrong. The paper uses the same data in Table 2. Those authors obviously find the process "In Control": Figure 9. Using RIT the Galetto could draw the Figure 10, where the reader can see both the wrong Control Limits of the Control Chart from Minitab and the right Lower Limit (the dotted line) forced on the graph, by FG.

The Figure 10 is very important: it shows the wrong CLs [LCL, UCL] derived from the formulae valid when the data are normally distributed, and the right correct LCL (the dotted line for TBE) computed with RIT. The "original" Minitab 20&21 I-Chart shows two "wrong" Out Of Control points (above the wrong UCL) that does not actually exist.

Being the data exponentially distributed, also the ranges are exponentially distributed (Galetto books) and OOC. We see that actually the process is "Out Of Control".

All the wrong methods in the *"ocean full of errors by ...."* (see the Excerpt 2, with 8 authors) cannot find that actually the process is "Out Of Control".

The "ocean full of errors by…"
Dovoedo and Chakraborti, "Boxplot-based Phase I Control Charts for Time Between Events", *QREI*, Kumar, Rakitzis, Chakraborti, Singh (2022), "Statistical design of ATS-unbiased charts with runs rules for monitoring exponential time between events", *CS-TM*, Jones, Champ, "Phase I control charts for times between events", *QREI*, Fang, Khoo, Lee, "Synthetic-Type Control Charts for Time-Between-Events Monitoring", *PLoS ONE*, Kumar, Chakraborti, "Improved Phase I Control Charts for Monitoring Times Between Events" *QREI*, Dovoedo "Contribution to outlier detection methods: Some Theory and Applications", (*found online, 2021, March*), Liu, Xie, Sharma, "A Comparative Study of Exponential Time Between Event Charts", *QT&QM*, Frisén, "Properties and Use of the Shewhart Method and Followers", *SA*, Woodall "Controversies and Contradictions in Statistical Process Control", *JQT*, Kittlitz "Transforming the exponential for SPC applications". *JQT*, Schilling, Nelson "The effect of non-normality on the control limits of X charts", *JQT*, Woodall "The use of control charts in health-care and public health surveillance", *JQT*, Xie, Goh, Kuralmani, "Statistical Models and Control Charts for High-Quality Processes", (Boston, MA: *Kluwer Academic Publisher*, 2002), Xie, Goh, Ranjan, "Some effective control chart procedures for reliability monitoring", *RE&SS*, Xie, "Some Statistical Models for the Monitoring of High-Quality Processes", Boston, chapter 16 in the book *Engineering Statistics (Pham Editor): Springer-Verlag*, Zhang, Xie, M., Goh, "Economic design of exponential charts for time between events monitoring", *IJPR*, Zhang, Xie, Goh "Design of exponential control charts using a sequential sampling scheme", *IIE Transactions*, Zhang, Xie, Goh, Shamsuzzaman "Economic design of time-between-events control chart system", *CIE*, Santiago, Smith, "Control charts based on the Exponential Distribution", *QE*, Nasrullah, Aslam, "Design of an EWMA adaptive control chart using MDS sampling", *JSMS*, Balamurali, Aslam, "Variable batch-size attribute control chart", *JSMS*. On September 2022, the author looked (in the web) for other TBE papers and books to see their way of dealing with "Rare Events" Control Charts; he copied 77 pages of documents (several from Consultants) and downloaded 32 papers (Open Source). Several Journals asked from 15 $ to 60 $, to download a paper. The Open Source are: "Control Chart: Charts for monitoring and adjusting industrial processes", "TOOL #6 - XBar & R Charts", "Integrating Quality Control Charts with Maintenance", "A Brief Literature Review", "Paper SAS4040-2016, "Improving Health Care Quality with the RAREEVENTS Procedure Bucky Ransdell, SAS Institute Inc.", "Performance Criteria for Evaluation of Control Chart for Phase II Monitoring", "(Thesis) A Comparative Study of Control Charts for Monitoring Rare Events in Health Systems Using Monte Carlo Simulation", "A study on the application of control chart in healthcare", "Control Charts for Monitoring the Reliability of Multi-State Systems", "Part 7: Variables Control Charts2, "A Control Chart for Gamma Distribution using Multiple Dependent State Sampling", "A Variable Control Chart under the Truncated Life Test for a Weibull Distribution", "Plotting basic control charts: tutorial notes for healthcare practitioners", "Appendix 1: Control Charts for Variables Data – classical Shewhart control chart", TRUNCATED ZERO INFLATED BINOMIAL CONTROL CHART FOR MONITORING RARE HEALTH EVENTS", "Comparison of control charts for monitoring clinical performance using binary data", "A number-between-events control chart for monitoring finite horizon production processes", "Rare event research: is it worth it?", "Quality Improvement Charts: An implementation of statistical process control charts for R", "Control Chart Overview", "Statistical Process Control Monitoring Quality in Healthcare", "A Control Chart for Exponentially Distributed Characteristics Using Modified Multiple Dependent State Sampling", "Synthetic-Type Control Charts for Time-Between-Events Monitoring", "A systematic study on time between events control charts", "Lifestyle Management through System Analysis Monitor Progress", "Multivariate Time-Between-Events Monitoring – An overview and some (overlooked) underlying complexities", "A Comparison of Shewhart-Type Time-Between-Events Control Charts Based on the Renewal Process", "Control Charts for Monitoring Time-Between-Events-and-Amplitude Data", "How to Measure Customer Satisfaction Seven metrics you need to use in your research".
The "ocean full of errors by…"

Typical statement by ALL ...

A uniform model the exponential TBE charts is that the occurrence of events is modelled by a Poisson process, and the time between events X_i (i=1, 2, …) re independent and identically distributed random variables with pdf $f(x) = \theta^{-1}\exp(-x/\theta)\, for\ x \geq 0$, 0 otherwise, where θ is the "mean time between events".
The Control Chart plots the quantity produced before observing an ev
The Control Limits can be calculated as

$$LCL = \theta\ln(1-\alpha/2), \qquad UCL = \theta\ln(\alpha/2)$$

Liu J., Xie M., Sharma P., "A Comparative Study of Exponenti Time Between Event Charts", *Quality Technology & Quantitati Management*, 2006 Issue 3, pp. 347-359

ACTUALLY LCL≠L and UCL≠

Another statement by INCONPETENTS

To construct a t chart, we determine the control limits ba on a false alarm rate (α) of 0.0027, equaling that of individual chart of normal data, and use the median as centreline". Whenever historical estimates are not availab the scale parameter θ can be estimated using maxim likelihood. …. because both control limits and the centerl are functions of solely θ, by the invariance property MLEs the estimates are 0.00135 $\bar{t}$, 6.60773 $\bar{t}$, and log(2) $\bar{t}$.

$$LCL_T = 0.00135\,\bar{t}, \qquad UCL_T = 6.60773$$

E. Santiago, J. Smith, Control charts based on the Exponential Distribution, Quality Engineering, Vol. 25, Issue 2, 85-96

ACTUALLY LCL≠L and UCL≠

Typical statement by

Suppose LCL and UCL denote the lower and upper control limits of the Phas t_r-chart respectively. Then for a given false alarm rate (FAR) α_0, they can be obta from $P(T_r < LCL|IC) = P(T_r > UCL|IC) = \alpha_0/2$ according to the equal tail probabil approach. Thus, we have (see also Kumar and Baranwal (2019))

$$\mathrm{LCL} = \frac{\chi^2_{2r,\alpha_0/2}}{2\lambda_0} = \frac{A_1}{\lambda_0} \text{ and } \mathrm{UCL} = \frac{\chi^2_{2r,1-\alpha_0/2}}{2\lambda_0} = \frac{A_2}{\lambda_0}$$

where $A_1 = \frac{\chi^2_{2r,\alpha_0/2}}{2}$, $A_2 = \frac{\chi^2_{2r,1-\alpha_0/2}}{2}$ are the design constants and λ_0 is the known or sp fied IC rate parameter value. The $\chi^2_{2r,a}$ denotes the a-th quantile of the chi-square di bution with $2r$ degrees of freedom. The center line (CL) of the t_r-chart can considered as the median of the IC distribution of T_r and it is given by $\mathrm{CL} = \frac{\chi^2_{2r,0.5}}{2\lambda_0}$.

TBE data following Exponential distribution are with r=1

ACTUALLY LCL≠L and UCL≠U

Excerpt 2. Typical Wrong Formulae Picked from the *"Ocean Full of Errors…"* (8 authors)

We can transform the Exponential data into Weibull data, as suggested by D. C. Montgomery, who used the idea of Nelson, and by the Johnson's transformation. T Minitab 20&21 I-Charts do not show the real Out Of Control points (transformed … below the dotted line: it shows them because the author forced the software to show the dotted line.

All the (Minitab, JMP, SAS) Charts suggests us that the process is In Control. The dotted lines show, on the contrary, that the process is Out Of Control.

Therefore we clearly see that we need the right and scientific method to analyse the data and derive the correct Control Charts: data transformations can hide the truth.

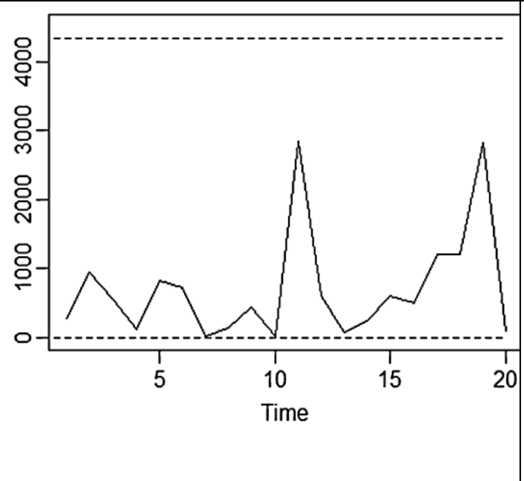

Figure 9. Chart of Montgomery Data Analysed in "Boxplot-based …", *QREI,* 2011

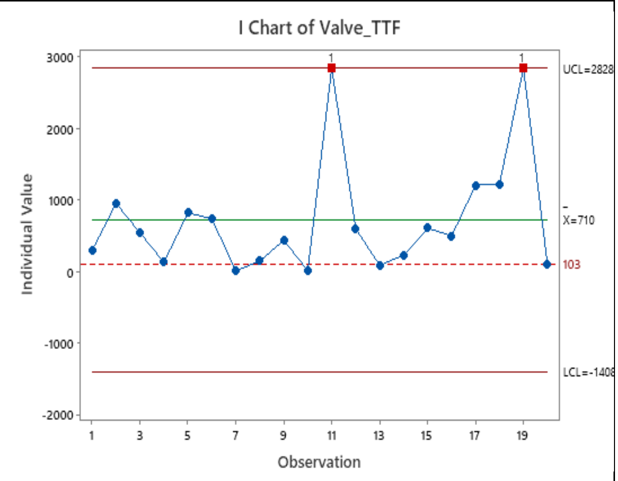

Figure 10. Galetto_I-Chart for Valves Data. *Dotted line=right correct LCL:RIT Is Used*

The author asked many [>>100] "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: the readers have the dimension of the problem.

The author wrote also to the editors of *QREI*, *QT&QM*, *JQT*, *RE&SS*, *QE*, *JSMS*, *IJRAS&ET* and to the management of Minitab Inc. about their wrong T-Charts: the letters are not yet been published: the papers are wrong and, obviously, neither the Editors nor the Minitab management cannot acknowledge that: this is another point of risk for the author!

Nobody took care of the problem, and nobody provided the correct way to compute the CLs (LCL and UCL) of the Control Charts for the TBE data (see the "*ocean…*").

This disaster is due to a very diffused error about the concept of CI: the CLs (LCL and UCL) of any type of Control Charts are actually the limits of the Confidence Intervals, with Confidence Level (CL) 0.9973 (i.e. 0.0027 risk of "possible" wrong decision).

All of them make confusion between the concepts of L and U with the LCL and UCL….

This proves the truth of Deming's statements [1986] *"It is a hazard to copy", "It is necessary to **understand the theory** of what one wishes to do or to make."*

To find the correct limits the reader should apply RIT, Reliability Integral Theory (Galetto 1981-94, 1982-94, 2010, 2015, 2016), devised in 1977 by Fausto Galetto when working at FIAR (General Electric). After that he was Reliability Manager at Fiat Auto [now Stellantis] and, at the same time he was Professor of Reliability Methods (Padua University. Faculty of Statistics) (1981-94, 1982-94). Later he was Quality Director at IVECO and then Professor of Quality Management at Turin Politecnico.

Due to the space restriction in the journal, we cannot present RIT (see references).

In Galetto's books RIT is extended to Reliability Tests, for estimating parameters and testing of hypothesis, for any type of distributions. This solves the *Time Between Events* Control Charts Problem.

At the end of a reliability test, at time t [started at $t_0=0$], we know the instants of the failures t_i of each item and then the empirical sample D={t_1, t_2, …, t_{n-1}, t}; we write the integral equations: $R_j(t|t_j) = \bar{W}_j(t|t_j) + \int_{t_j}^{t} b_{j,j+1}(s|t_j)R_{j+1}(t|s)ds, \quad j = 0, 1, \dots, \; n-1,$ and $R_{n-1}(t|t_{n-1}) = \bar{W}_{n-1}(t|t_{n-1})$.

The determinant of the integral system **detB(s|r)** depends on the parameter λ, the failure rate λ of the identical units. For estimating λ, we have $\det[B(s|r;\ \lambda, D) = \lambda^{n-1}\exp[-tot(t)$, where $tot(t) = \sum_1^{n-1} t_i + (t - t_{n-1})$ is the "Total Time on Test" generated by n items tested until the n-1 failure with the test ending at time t; we have the *empirical sample* D that constrains the integral equations; if we want that our "total sample of n items" has the maximum probability, given the constraint D, we get the equation $\frac{\partial \ln detB(s|r;\ \lambda,D)}{\partial\lambda} = (n-1) - \lambda tot(t) = 0$. The CI (symmetric) for the parameter θ [the MTTF of any unit] can be obtained by solving the two equations, with θ unknown and $\boldsymbol{t_o}$ the "known" observed $\boldsymbol{t_o} = tot(t) = \sum_1^n t_i$ determination of the RV Total Time on Test $T(t)$, whose solution is θ_L and θ_U, with Confidence Level CL=1-α.

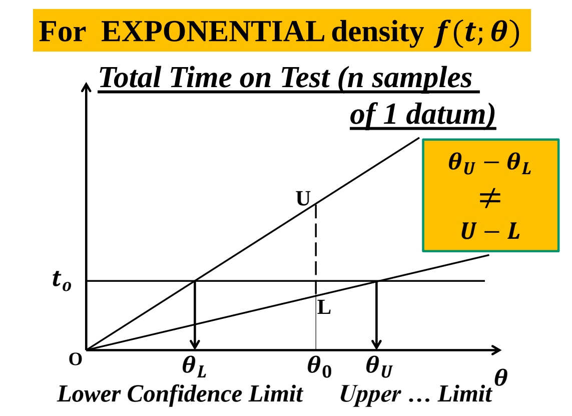

Figure 11. Confidence Interval of the MTTF $K = K_1^n$ and $K = K_2^n$

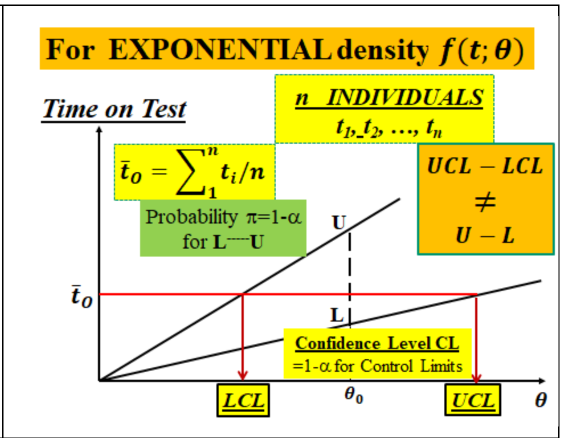

Figure 12. LCL and UCL for the I-CC_TBE, using RIT. $K = K_1^1$ and $K = K_2^1$

Remember that in this case k=1 (sample size)

The two equations are $R_0(t_O;\ \theta_L) = \alpha/2$, $R_0(t_O;\ \theta_U) = 1 - \alpha/2$. Since the reliability of any unit is exponential $R(t|\theta) = \exp(-t/\theta)$, (see the Figures 11 and 12) the function $t/\theta = K$ is a straight line $t = K\theta$, with angular coefficient K in the plane with abscissa θ and ordinate t: for the Figure 11 the coefficient K_1^n is related to α/2 and n (the number of data) while K_2^n is related to 1-α/2 and n; for the figure 12 the coefficient K_1^1 is related to α/2 and 1 (the individual datum) while K_2^1 is related to 1-α/2 and 1. Thus, we have two lines, passing through the origin O [with linear scale, in Figure 11 and

12]; putting $\theta=\theta_0$ the two lines intercept the **vertical segment L----U (probability interval)**, which has probability $\pi=1-\alpha$ that the "time to failure", Random Variable T, of any unit [vertical axis named "Total Time on Test" (Figure 11), because we consider all the data], when $\theta=\theta_0$, is in the interval **L----U**. The angle $L\hat{O}U$ depends on the values $\alpha/2$, $1-\alpha/2$ and n (the number of data). Acting as we did for the normal case (see Figure 1), with the known quantity $\boldsymbol{t_o}=tot(t)=\sum_1^n t_i$ [observed determination of the RV $T(t)$], we can draw the horizontal line intersecting the two lines through the origin: the abscissas of intersections are the two numbers θ_L and θ_U, depending on the values $\alpha/2$, $1-\alpha/2$ and n: θ_L and θ_U are the Lower limit and the Upper limit of the CI of the MTTF of each unit, with CL=$1-\alpha$. It is evident, for any intelligent person, that the two segments **L----U** (vertical) and **θ_L----θ_U** (horizontal) are two *different* intervals with clear *different* meaning and obvious *different lengths* $\theta_U-\theta_L\neq$U-L! All the documents, known to the author, make this BIG ERROR: they confound the segment **L----U**, a "**Probability segment**", with the segment **θ_L----θ_U**, which is a "***Confidence segment***"! See the "*ocean full of ....*" and Excerpt 2 (8 authors).

RIT solves the Montgomery case (TBE CC). We have to look at the figure 12 (similar to 11, but with different lines). Now the angular coefficient K are K_1^1 related to $\alpha/2$ and 1 (the single datum) while K_2^1 is related to $1-\alpha/2$ and 1. As before we have two lines, passing through the origin O [with linear scale, in figure 12]; at $\theta=\theta_0$ the two lines intercept the **vertical segment L----U (probability interval)**, that has probability $\pi=1-\alpha$ that the "time to failure", Random Variable T, of any unit [vertical axis named "Time on Test" (consider the single data)]. The angle $L\hat{O}U$ depends on the values $\alpha/2$, $1-\alpha/2$ and 1.

Acting in Figure 12 (as done for 11), with the known quantity "*mean observed time to failure*" $\overline{t_o}=\boldsymbol{t_o}/\text{n}=tot(t)/n=\sum_1^n t_i/n$ [observed determination of the RV $T(t)/n$], we can draw the horizontal line intersecting the two lines through the origin: the abscissas of intersections are the two numbers LCL and UCL, depending on the two chosen values $\alpha/2$, $1-\alpha/2$ and 1 (the single data). As a matter of fact, in the I-CC, the CLs LCL and UCL must be consistent with the "individual" times to failures: we want to analyse if they are significantly different from the "true mean θ", estimated by the "*mean observed time to failure*" $\overline{t_o}=\boldsymbol{t_o}/\text{n}$. Therefore the CLs are the values satisfying the previous two equations with $\boldsymbol{t_o}$ replaced by $\overline{t_o}=\boldsymbol{t_o}/\text{n}$, that is the next two equations $R(\overline{t_o};\ LCL)=\alpha/2$, $R(\overline{t_o};\ UCL)=1-\alpha/2$ for any single unit; so we have 20 CIs [all equal], given $\overline{t_o}$ and CL=$1-\alpha$ [0.9973]; *remember that in this case k=1 (sample size)*: I-CC!

With the Montgomery's data the picture of Figure 12 would be unreadable.

Hence we transform logarithmically both the axes and get the Figure 13. LCL and UCL are the abscissas of points intercepted by the horizontal line $\overline{t_o}=\boldsymbol{t_o}/\text{n}$ with the two lines passing through $-\infty$ (the transformed origin of Figure 12): hence, the ***CI***. The n=20 lifetimes in table 2 can be considered as the "transition times" (failure times, exponentially distributed) between the states of a stand-by system of 20 units: the Up-states are 0, 1, …, 19, and 20 (n) is the Down-state; t_i is the "time to failure" from state i-1 to state i: they are the "individuals". The reliability $R_0(t|\theta)$ [the system reliability given the parameter θ)] is, as well, the Operating Characteristic Curve (Galetto 1981-94, 2010, 2016) of the reliability test, given t: the pdf of any transition is $f(t;\ \mu,\sigma)=(1/\theta)\exp(-t/\theta)$; [see Figure 13].

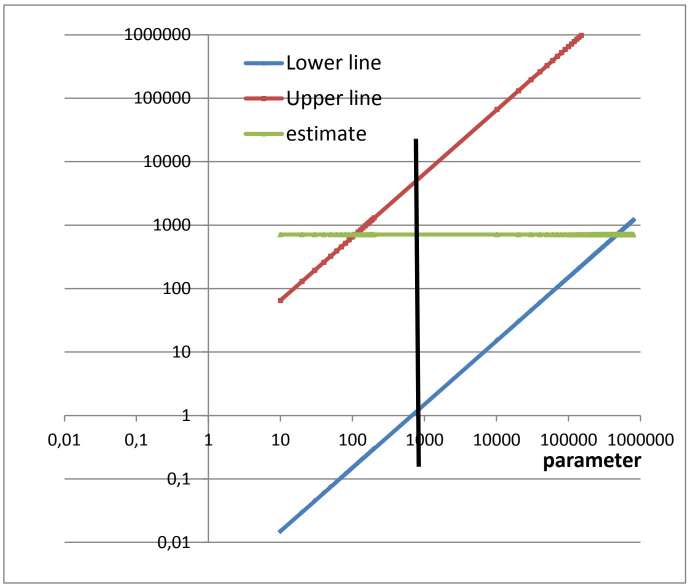

Figure 13. (F. Galetto) LCL and UCL for the TBE Control Chart of Montgomery data, Using RIT. [logarithmic scales] Remember that in this case k=1 (sample size)

It is evident, for any intelligent person, that the two segments **L----U** and ***LCL----UCL*** are two *different* intervals with clear *different* meaning and obvious *different lengths* UCL-LCL≠U-L! All the documents, known to the author, make this BIG ERROR: they confound **L----U** (a "**Probability segment**") with ***LCL----UCL***, which is a "***Confidence segment***"!

Does the number of Citations of the authors floating in the "*ocean full of errors by incompetents*" mean Quality of those authors and of their papers? Is a "Quality author" an "associated editor of… (in the *ocean*)"? Greater citations then greater Quality? NO.

The reader perhaps thinks that the problem of wrong decisions could happen only for the Montgomery case. Actually all the papers in the "*ocean full…*" have the same problem: wrong Control Limits of the Control Charts, both for the mean and for the variance. These Galetto ideas are particularly useful and can be used also for the Control Charts of the variance.

If those authors had considered the concepts given here, many readers could learn good ideas instead of learning the wrong methods in the next session. They should have had the same attitude of J. Juran who, at the Vienna Conference, mentioned the paper "*Quality of methods for quality is important*" (Galetto, 1989) in the plenary session.

5. Cases from "Peer Reviewed" papers and Conclusion

Consider papers from the "*ocean…*"; we do not show here their data; we show only the right CC. *First case*: "Improved Phase I ….. Events" published by *QREI*, 2014. The two authors provide a wrong solution *found neither* by the Peer Reviewers nor by the Editor). The authors say: "*Table … 30 failure time data generated from a Poisson distribution … LCL=-53.9213 and UCL=47.2320. …we set the LCL=0. It can be seen from Figure* (our 14) *that* the eleventh observation 52.32 plots outside the UCL, *which indicates an OOC situation … Note that for these data, neither the Dovoedo and Chakraborti nor… indicates any OOC situation.*" Notice that the "wrong" CC shows an OOC situation that should not be there and various IC that should not be there… (Figure 15)

Using RIT the n=30 TBE can be considered as the "transition times" (failure times, exponentially distributed) between states of a stand-by system of 30 units. We get the figure 15: we solved the two equations $R(\overline{t_O};\ LCL)=\frac{\alpha}{2}$ *and* $R(\overline{t_O};\ UCL)=1-\alpha/2$.

Comparing the Figures 14 and 15, it becomes very clear that the CC from "*Improved Phase…*" presents *5 errors* about OOC. Reader, could you think that "Improved Phase… " is scientific and this paper is not? How can the CC from "Improved Phase…" be good?

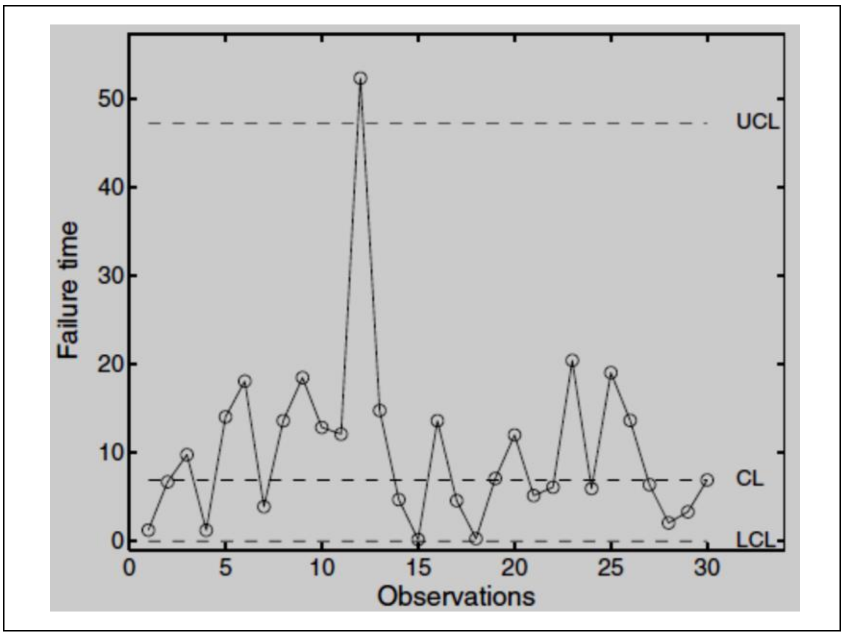

Figure 14. [Excerpt] Control Chart from "Improved Phase… for Monitoring TBE"

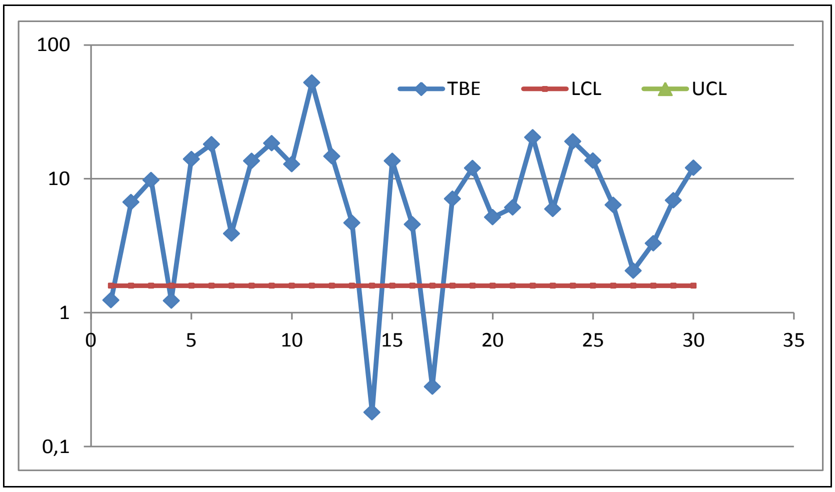

Figure 15. Control Chart, by RIT, for "Improved Phase for Monitoring TBE" Data; Vertical Axis Logarithmic. UCL is >100.

Simulations (five million!) show that only < 5% of the computations are correct…

We agree with those authors writing "*Further work is necessary on the OOC performance of these charts*": the further Work must be to STUDY (see Deming!). We ask the reader: do you think that these findings are not supported by Theory and Methods?

Second case: the paper "Control charts … Exponential Distribution", published in *QE* is no better. The authors find the process IC: actually it is OOC (Figure 16)

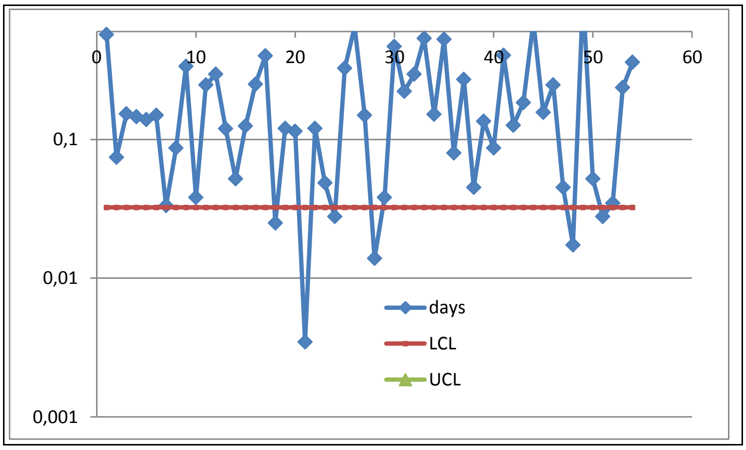

Figure 16. Control Chart of Minitab Authors' Paper Data (Urinary); Vertical Axe Logarithmic. *RIT used* (F. Galetto)

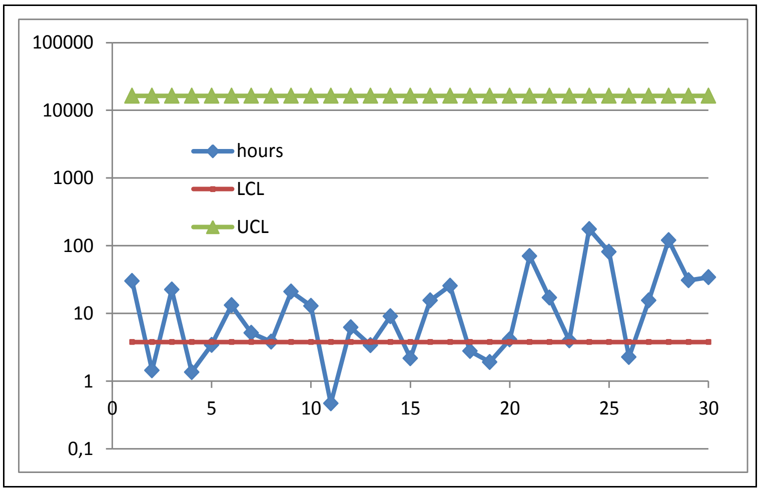

Figure 17. Control Chart of Xie et al. TBF Data; Vertical Axe Logarithmic. *RIT Used* (F. Galetto)

Third case: the paper "Some effective … for reliability monitoring", published in *RE&SS*. Qualified authors Xie, Goh, Ranjan. Again WRONG Control Limits! See Figure 17. A very good result for a Peer Reviewed paper! The two Peer Reviewers did not know the Theory. *"It is necessary to understand the theory of what one wishes to do or to make."* [Deming]

Table 3. Comparison of Results from the Paper "Statistical Design of ATS…." and RIT

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

Forth case: the paper "*Statistical design of ATS-unbiased … time between events*", we find a new wrong case copied from Santiago and Smith (2013): the CLs are wrong.

According to the Kumar et al. computations, the CLs are: LCL=31.36 and UCL=1943.22, quite different from those of Santiago & Smith. The cause is not explained by the authors… It is interesting what we find with RIT. See Table 6 (where we used the same scale of Kumar et al.). Both the methods, "*t1 Chart*" and "*ATS–unbiased t1 Chart*", from the paper "Statistical design of ATS-unbiased …" provide wrong Control Limits. They say: "*It can be observed that … detects a signal at the 67th point.*" The 67th point is <0.63; obviously it is also <1.835 (the LCL of Galetto). A very strange conclusion is drawn: "*… ATS unbiased t2-chart gives an OOC for the first time at the 36th point, while using the modified scheme… the chart detects an OOC, at the 30th point.*" "*Because the ATS-unbiased t1-chart … OOC at the 67th point whereas the ATS unbiased t2-chart … OOC at the 30th point, the example supports … that monitoring the times to every 2nd event (r>1) can speed up the detection of shifts in* *the process parameter.*" It is not clear (to us) why the authors write also: "*ATS unbiased t2-chart gives an OOC for the first time at the* ***36th*** *point, while using the modified scheme, the chart detects an OOC at the* ***30th*** *point.*" IF there is an OOC at the "***36th*** *point*" (for the non_modified scheme) and there is an OOC at the "***30th*** *point*" (for the Modified Scheme) ***why*** it is ***NOT OOC*** the "***22nd*** *point*"<"*30th point*"? The authors do not tell us. The Peer Reviewers and the editor did not find that!

At this point, it should be clear that several Journals have been going on publishing ***wrong*** papers on I-CC_TBE [Individual Control Charts for TBE (Time Between Events)] data, exponentially distributed. Does, now, 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 a scientific idea? Absolutely not! This is due to lack of knowledge of the Sound Theory of the CC.

The errors are in papers published by reputed Journals, written by reputed authors and analysed by reputed Peer Reviewers, who did not find the errors: moreover, they were and are read by reputed readers, who did not find the errors (see the "*ocean full of errors …*").

None less, they are wrong…. A true disaster. Their "formulae (wrong)" are used by the Minitab software (also JMP, SixPack, SAS, ...). The users of such software take wrong decisions based on the "wrong formulae"… Worse, "the Software Management", informed of the errors did not take any Corrective Action: a very good attitude towards Quality!

Those Journals publishing wrong papers on CC for "rare events" should, for future research about CC, accept the letters sent to their Editors and provide them to their Peer Reviewers, to avoid costly errors and decisions: the letters are not yet been published: the papers are wrong and obviously the Editors cannot acknowledge that. They did not used *metanoia* (Deming, 1997). That is the big real problem: big errors of "well reputed" people make a lot of danger, and nobody (known to the author …), but the author (FG), takes care of teaching the students to use their own brain in order not to be poisoned by incompetents. (Galetto, 1982-2023)

How many Statisticians, Professors, Certified Master Black Belts, practitioners, workers, students, *all over the world, learned, are learning and will learn wrong methods and took and will take wrong decisions?* 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 and in the "*ocean full of errors …*"…), otherwise he risks being passed off…

In spite of all these proofs, the discussant who suggested the paper of J. Smith did not believe to the evidence (see the "ocean …"). He raised the problem that it could happen only by chance: he believed only in simulations (as do all who do not know Theory)! After ten million of simulations F. Galetto got that T Charts (Minitab and in all wrong papers) were wrong 93.3% of the times! We think that it should be enough…

The author, many times, with his documents, tried to compel several scholars to be scientific (from Galetto 1998 to Galetto 2023, in the References): 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 (Galetto, 1989). He always asked his students to *use their own Intelligence*, in order to avoid being poisoned by incompetents. He helped them with his papers presented at the HEI (Higher Education Institutions) Conferences since 1998. We saw that data need to be analysed with suitable methods devised on the basis of Scientific Theory and not on methods in fashion, in order to generate the correct CC. RIT is able to deal with many distributions and then usable for many types of data and make Quality Decisions. We 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.

The author has been always fond of Quality in his activity; for that reason, he wrote several papers and books showing scientific methods versus many wrong methods and presented them in several national and International Conferences: he wanted to diffuse Quality (from Galetto 1989 to Galetto 2023, in the References). The truth sets you free!

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) we would need at least 80 more pages in this paper: we, obviously, cannot do that. Therefore we ask the readers to look at some of the author's documents.

A last gem: few days ago the author came across the book "*Six Sigma for the next millennium, a CSSBB guidebook*" where he found "I would like to *acknowledge support* from the following individuals and organizations. (*Name*) *at MINITAB* graciously allowed me to plunder examples and other riches contained in this easy-to-use, yet profoundly powerful statistical software. *MINITAB is always my weapon of choice when assessing problems from the statistical point of view*." And so on … *Minitab…*!!!

"It is necessary to understand the theory of what one wishes to do or to make." (Deming, 1986)

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