Aligning the Six Sigma Performance Metric

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Abstract

Many corporations and consultants have proposed and used the term Process Sigma also called Z-score as a universal metric to measure performance of processes, products, and also company goals. The current calculation method gives a Z-score of negative infinity for a process with zero percent yield, 1.5 for a process with 50% yield, 6 for a process with 99.99966 % yield, and positive infinity for a process with 100% yield. There has been lot of discussions and concerns raised about the current calculation methods and the need for a more acceptable, intuitive, and standardized Process Sigma or Z-score. This paper proposes a modified method of Process Sigma calculation and compares the proposed method with the one currently in use.

Introduction:

In the mid 80s Motorola initiated a program to drive down its defects to a bare minimum and named it Six Sigma. The Six Sigma methodology in its original avatar provided a structured way to find opportunities for improvement in production processes and address them. Later, especially with its adaptation by GE, the Six Sigma methods gained a wider acceptance and are now being utilized for the improvement of all the business processes ranging from human resources to finance and design. While Six Sigma is the name given to this process quality improvement methodology, sigma is also used as a metric of the process capability of any business process or the business itself.

The common terminology for describing the metric of business or business process performance is called Process Sigma, or Z-score. Z-Score, supposedly provides a universal standard performance metric across the board for vastly different type of processes, measurements, etc. According to this standard, a process sigma of 6 implies of 3.4 defects per million opportunities. This value of 6 is obtained by accounting the fact that any process in control can still provide a drift of about 1.5 Sigma. A yield value of 0% is equivalent to negative infinity, 50% yield is equivalent to 1.5 sigma, and 99.99966% is equivalent to 6 Sigma, and 100 % yield is equivalent to positive infinity. The range of Z-score from –infinity to +infinity gives a false sense of symmetry, the truth is that a numerical 0 sigma is not equivalent to 50% yield; in fact it is 1.5 Z-Score that equals 50% yield. This asymmetry is due to the belief that any process variability in the long term changes by about 1.5 on Z-scale from its short term variations.

Besides the asymmetry in the measurement system, the question is also being asked about the appropriateness or meaning of negative sigma value. Quite a while ago, I was in a project presentation where a Black Belt pointed out that the process performance is negative on the Sigma Scale. While I was aware of the methods and the logic used for these numbers, the question remains "what is intuitive meaning of it?" What does the negative Sigma Value mean? What is the meaning of Zero Score? As a manager, how should you react to improvements and reward the Sigma value gains?

While, anyone mathematically minded will argue that it is simply a definition, however, the fact that the questions are being asked about its appropriateness, challenges the community to develop a metric that makes more engineering as well as business sense. This article is an attempt to propose a modification to the current Z-score calculation method, and start a dialogue in the community to come up with a consensus for the metric. Given the wide business use of Z-score, standardization and alignment of the metric with common sense is important.

While debating the meaning or effectiveness of this method, I ran into another project presentation where the process yield was very low with a low Sigma Value. A small effort by the team made a significant change in the Sigma Score. While the whole management team was excited about the greatness of work done by the project lead due to visibly big change in the Sigma Score, their excitement was not as high for another project which initial performance score was very high and the team was charged to make improvement in an already higher performing process. It is bothersome that we are using a metric that is not a clear reflection of the effort required to improve processes at various levels of initial Sigma values. Table I demonstrates that irrespective of initial process performance, and due to the symmetry of the bell curve and our method of calculating Z score, the corresponding increment in the Sigma score is same for the same amount of yield improvement. For example, a process improvement in DPMO by 100,000 for the initial DPMO of 600,000 or initial DPMO of 400,000 has same leads to same value of Sigma score change. Common sense will tell you that improving a process yield when the process is on the very low end of performance is a lot easier than improving the process yield for a process which is performing to the superior side of the performance scale.

Table I: Comparison of Process Performance Improvement symmetry towards 50% yield. [The asymmetry comes from incorporating 1.5 shift which is not included here]

Improvement in DPMO	Initial Yield <= 50%			Final Yield >= 50%		
	Initial DPMO	Initial Z-Score	Final Z-Score	Initial DPMO	Initial Z-Score	Final Z-Score
1	1000000	-infinity	-4.753	1	4.753	+infinity
1	999999	-4.753	-4.611	2	4.611	4.753
1	999996.6	-4.500	-4.445	4.4	4.445	4.500
100000	800000	-0.842	-0.524	300000	0.524	0.842
100000	700000	-0.524	-0.253	400000	-0.253	0.524
100000	600000	-0.253	0	500000	0	0.253
100000	500000	0	0.253	600000	-0.253	0

This begged the question whether there should be a metric that is more intuitive in understanding the initial Sigma Values and subsequent changes in Sigma value. Should there be a metric that also attempt, if not accounts for the relative effort required in the improvement? This paper presents the method that looks into this question too.

Current Method for Calculating Sigma Score

The method used in the calculation of a process performance on the Sigma Scale requires one to consider that all percentage defects are represented by the portion of the area on a standard normal curve, which extends from a point Z-value away to the right from the center (mean line) to the infinity. Figure 1 illustrates the definition of Z-Score. By this definition, the Sigma Value for a 100% yield process would be infinity, 3.4 Defect Per Million Opportunity (DPMO) process will be about 4.5, further a 50% yield process will have Sigma score of zero, and negative infinity for the 0% yield process. Of course, it becomes a bit more confusing once you bring in

1.5 shift in Sigma value to account for the long term/short term conversions. If you assume that the data above reflects the long term performance, then respective short term performance will be obtained by adding 1.5 to the long term values. The respective performance scores would be negative infinity, 6, 1.5, and infinity, respectively. The shift of 1.5 is attributed to Motorola proposals that a process has tighter variance in the short term. In long term, due to issues like weather, setup, shift change, batch change, operator change, etc., the variation in the process increases leading to a performance impact of about 1.5 on Z-Scale.

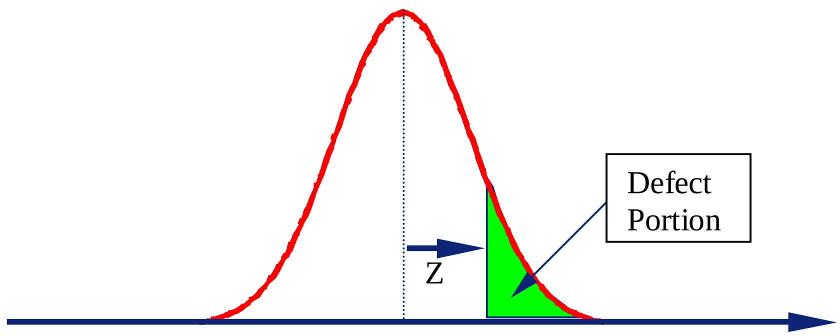

Figure 1: Illustration of Z-Score Calculation.

New Method for Calculating Performance Score

New method sets the boundaries that zero Sigma will represent 0 yield and infinite Sigma will represent 100% yield. Zero Sigma for Zero yield constraint is imposed to address the issue of intuitive understanding. For the Z score for any specified process yield, the shaded area to the right reflects the area equivalent to the ½ of the DPMO. The left tail of the curve represents the remaining half. The distance of the inner edge of these areas represents the process Sigma.

Since the term Six Sigma has been so much in the hearts and minds of Six Sigma practitioners, an attempt has been made to keep the definition as much the same as possible. However, in the new method, accounting for process shift by 1.5 Sigma poses a big challenge. The standard way of adjusting for process shit then will make zero percent yield to be either –1.5 or 1.5 Sigma based on whether the baseline data represents short term or long term process performance.

It is quite arguable also to accept the shift of 1.5 irrespective of the process current performance level as the current method does. However if one were to think that the set of data is short term, then in case of 0% short term yield would be 0 Sigma. Now, adjusting for the long term effect, still the process performance would be 0% yield. However the old method would of the adjustment for shift would make a case of Process Sigma of –1.5. It is clear that a centered process, if the short term data provides zero yield, the long term performance would definitely be supporting the 0% yield – there is nothing worse than 0% yield. To account for these anomalies, a scale adapted by Dr, Berryman. Dr. Berryman is credited with creation of Performance score cards where he also used a multiplier to account for the long term/short term process variations. The method used a factor of 1.3 for converting between the long and short term performance values. For example, a process with short term performance of 6 Sigma would have long term Z-Score of about 4.61.

For illustration purposes, suppose we have a process with 80% yield. We will then assume that the process is centered and there is 10% reject from the each end of the distribution. Putting the 10% reject on the right side of the curve would give us a Z score of 1.282 as opposed to 0.842 on the old scale. Table II shows the values of Z score using old and new method with adjustment for long/short term capability. The original data is assumed to be long term. The new method is illustrated in Figure 2.

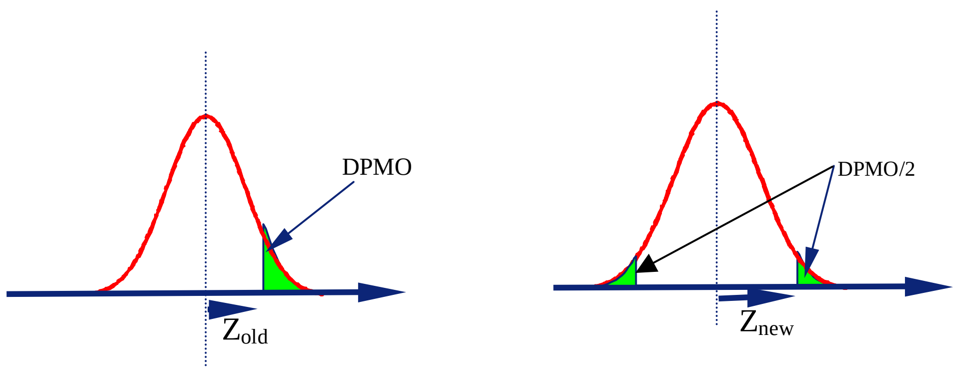

Figure 2. Illustrating the difference of the two methods of calculating process Sigma.

Table II. Comparing the process performance obtained using the two methods.

		Old Method		New Method	
DPMO	% Yield	Z Score Long Term	Z score Short Term	Z Score Long Term	Z Score Short Terms
1000000	0	-infinity	-infinity	0	0
999996.6	0.00034	-4.5	-3	0.0000043	0.0000056
999000	0.1	-3.090	-1.59	0.0012533	0.00163
990000	1	-2.326	-0.826	0.012533	0.0163
900000	10	-1.28155	0.218	0.12566	0.1634
800000	20	-0.8416	0.6584	0.2533	0.3293
700000	30	-0.5244	0.9756	0.3853	0.5009
600000	40	-0.2533	1.247	0.5244	0.6817
500000	50	0	1.5	0.6745	0.8768
400000	60	0.2533	1.7533	0.8416	1.094
300000	70	0.5244	2.0244	1.0364	1.3473
200000	80	0.8416	2.3416	1.2816	1.6661
100000	90	1.2816	2.7816	1.6449	2.1384
10000	99	2.326	3.826	2.5758	3.3485
1000	99.9	3.090	4.59	3.2905	4.2776
3.4	99.99966	4.49985	5.99985	4.64505	6.03856
0	100	Infinity	Infinity	Infinity	infinity

Table II indicates that for the same amount of yield improvement, the change in process Sigma value is higher for initially higher yielding process. Converse of this could also be that for the same process, and the same amount of improvement, the lower yielding process will take less effort compared to that of higher yielding process. This provides an opportunity for project lead to get better differentiation for his/her effort on improving a process which is already performing well. Figure 3 shows that rate of change in Sigma Score increases as the initial yield increase (meaning effort level increasing) for the new method. While the old method, it is symmetric about 50% yield and change in Sigma Value is minimum for processes with yield in the vicinity of 50%. A process yield change from 40% to 50% and from 50% to 60% has Z-Score change of 0.2533 using old method while the new method will changes it by 0.1501 and 0.1671. Intuitively, improving process from 40% to 50% yield will take less effort than improving it from 50% to 60%; the change in Z-score shows the higher value corresponding to higher effort.

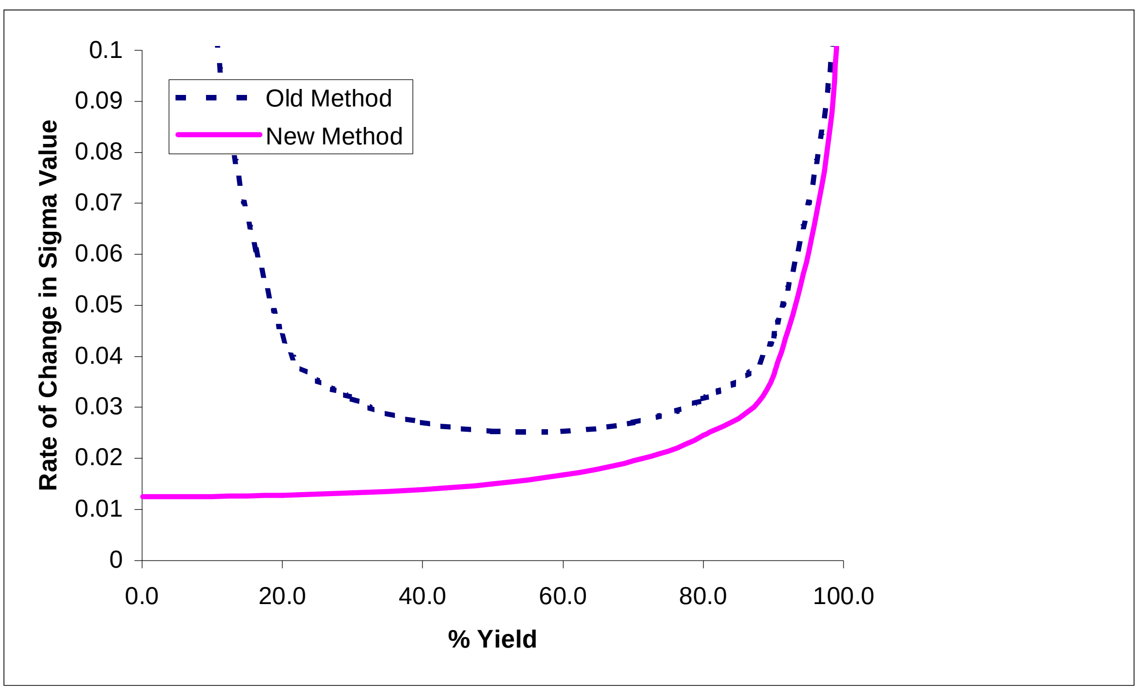

Figure 3: Change in Sigma Value as function of initial yield.

Conclusion:

Above illustrations and descriptions provide an alternate methodology for calculating process sigma that is more intuitive and hence useful for management. The method redefines the scale to be from zero to infinity as well as demonstrates the usefulness of using a multiplier to accommodate for the long versus short term variations. The effect of changed scale and method also helps address the topic of metric accounting for the relative effort required for improvement of a process at different level of yields. The method demonstrates that these objectives are aligned with Six Sigma philosophies and at the same time provide a more robust and useful performance reporting.

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