PROBABILISTIC METHODS AND 6σ

INTRODUCTION

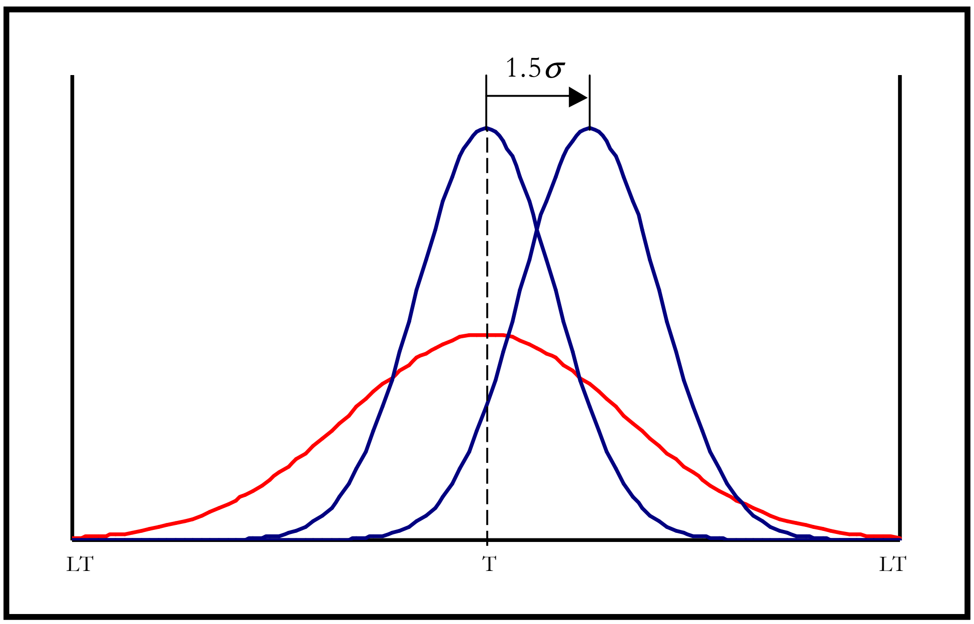
6σ is probably something that you have at least heard of, if you are in anyway involved with quality. Given that probabilistic methods make an ideal tool for quality improvement the question of the relationship between the two (6σ and probabilistic methods) is one that is likely to be raised. This article will first provide a brief overview of 6σ, which will highlight the underlying principles of the process. Second, the potential role of probabilistic methods within 6σ will be discussed. Third, this discussion will be used to reach conclusions about how one should view 6σ and probabilistic methods relative to each other and how they should be used in conjunction.

6σ

6σ started out in the late 1980's at the Motorola Company and was probably made well known mostly by Jack Welch when he was CEO of General Electric. When one considers what can be done with probabilistic methods, the basic principle of 6σ might not all that impressive. However, it has been found by many that the effects of its application are indeed impressive. The reason for its success does not seem to be a result solely of its goal, but also the culture that has developed with it. The success of 6σ in GE probably had more to do with Jack Welch than it did with the principles behind it. But what are the goals and principles of 6σ?

Typically, we say that the tolerance range is equal to six standard deviations; therefore, the distance from the mean to the upper or lower tolerance is three standard deviations or 3σ. The aim of 6σ is to make the distance between the mean and the upper or lower tolerance equal to 6σ.

The result of achieving this aim is that the effects upon quality from random variability or a mean shift are negligible. Consider the graph below. The distribution in red is what would be considered typical (or traditional) of a performance characteristic; the tolerance range is $\pm 3\sigma$. The distribution in blue with the same mean as the red distribution is respective the 6σ distribution. The same tolerance range is now $\pm 6\sigma$, and the value of σ is halved. Such a distribution corresponds to a significantly smaller proportion being out of tolerance, and the customer will probably be unaware of any random variability. This would potentially still be the case if there were a mean shift equal to 1.5σ, which is considered to be the average mean shift that can be expected in practice. It can be seen in the graph that a very small proportion of the shifted distribution (also in blue) would be out of tolerance. This is a much smaller proportion than that of the original distribution. In fact, only about 3.5 cases per million would be out of tolerance for the shifted 6σ distribution while about 13 per thousand would be out of tolerance for the original distribution (which has no mean shift!).



What should be noted here is that a Normal distribution has been assumed: this can be a questionable assumption. Nevertheless, if the variability of the output is significantly smaller than the tolerance range, any undetected anomalies in the manufacturing operation will be less likely to cause any quality problems. Thus, a preliminary consideration of the goal of 6σ shows us that the potential benefits are significant. However, as mentioned above much of the success comes from the way 6σ is implemented.

6σ has evolved considerably over the past decades to move from a basic goal to a process and culture. Even though the basic goal (halving the random variability so that it is not longer evident) has remained the same, the methods used have increased and an overarching process frequently referred to as DMAIC[1] has been developed. Further, the application has moved from the manufacturing of engineered products to various operations, including those that deliver services. Also, the culture associated with 6σ has expanded, and organizations that focus on the control/regulation of 6σ practice have developed. Adams, Gupta and Wilson have cited the need for the implementation of the appropriate culture and development in the leadership levels in an organisation in their book *Six Sigma Deployment*. They go on to argue that strategic alignment is the most critical factor for sustaining the initiative. This is not implicit in the probabilistic approach or other quality tools and methods that have been incorporated into 6σ. Therefore, while the actual tools and methods used might be very important, it is evident that the success of 6σ is most dependent upon the culture and attitude that comes with it.

Typically, the suite of tools and methods that have been incorporated into 6σ excited prior to its development: Does this suite include the concept and practice of robustification? According to *Six Sigma Mechanical Design Tolerancing* written in 1988 (one of the earliest publications on 6σ) by Mikel J. harry and Reigle Stewart the reduction in random variability is achieved by limiting random variability in one or more of the input variables. This practice is evident in the control phase of the DMAIC process covered in various, and more recent, 6σ books such as *The Six Sigma Way* by Pande, Neuman and Cavanagh. This suggests that many involved with 6σ have neglected the potential benefits of robustification. However, some of the more recent works on 6σ (which are often company publications, and not commonly available) do introduce this concept.

In summary, we can say that the underlying principle of 6σ is the significant reduction of the random variability so that the end user is unaware of the variability. Traditionally, it is the control the random variability of all the factors that influence the output of the respective system that is used to achieve this. This in turn relies on the use of various established methods and the development of a strong and accommodating culture. However, the established methods used do not typically include probabilistic methods. Thus, a question remains: How do 6σ

[1] Define, Measure, Analyze, Improve and Control

and probabilistic methods compare and should the latter be explicitly included in the former?

6σ AND PROBABILISTIC METHODS

To compare 6σ with robust design, we could say that whereas 6σ requires extra effort to decrease variability, robustification (see the article on robustification) looks for an easy way to increase the tolerance range allowed for each input. This focus on ease would suggest that robustification and probabilistic methods would be better than 6σ. Still, 6σ has proven very popular: what are its advantages?

While robustification might allow a company to achieve 6σ quality, there is no reason why it would introduce the culture that 6σ seems to be able to bring with it. Such a culture would be ideal for any company that needs to improve its quality. Further, such a culture would be more likely to promote an understanding and an appreciation of probabilistic methods; therefore, 6σ might also allow a company to take fullest advantage of robustification. It would seem that there is an advantage in combining the two concepts, and this is what some, such as some automotive companies, have done. How have they done this?

At times you might hear the terms ‘design for 6σ (DFSS)’ or ‘6σ design (SSD)’ being used to include, or instead of, robustification. This is an example of how some combine robustification with 6σ; robustification is used to design a system to help achieve 6σ quality. Probabilistic methods are also sometimes used in 6σ to identify major sources of variability. By doing this analytically, major sources of random variability are found earlier. Efforts are then directed toward the areas where the maximum benefit can be had; improvements are then both greater and evident sooner. Therefore, probabilistic methods in general can help increase the effectiveness of 6σ by optimizing the design first and quickly finding the areas where effort should be applied.

It has been found in practice, and it stands to reason, that robustification and probabilistic methods can increase the effectiveness of 6σ. It is also the case that 6σ is much more likely to bring the culture that is needed if quality is to be a part of a company’s operations, which is essential even with the application of robustification. Thus, it is clear that the two benefit from each other. Therefore, robustification and probabilistic methods should be viewed as tools that can be used either independently or as a very effective and important part of the 6σ process. A question remains: what is the best way to incorporate the two?

INTEGRATING PROBABILISTIC METHODS WITH 6σ

We have established that robustification and probabilistic methods are ideal tools to be used within the context of 6σ. This section will finish the article by putting forward recommendations on how the two should be combined.

6σ is a holistic process that optimizes a system to ensure the consistent provision of that system's output. Typically, this is done by following the DMAIC method mentioned earlier. The two first stages, Define and Measure, focus upon identifying what the system is meant to achieve, for whom and how well it has been doing this. These stages require either qualitative analysis or the collection of data. However, the next two stages require analysis that is quantitative in nature and also require that finding be made. Essentially, in the Analysis stage the causes of poor quality need to be identified and verified. Then in the Improve stage, the system under consideration is modified, redesigned or replaced. This will require an ability to predict the benefits of the proposed changes and to optimize those changes. Finally, the last stage, Control, is implemented to ensure that the improved system is applied so that all improvements are maintained. The Control stage relies more on data collection for feedback, and does not require the quantitative analytical skills that the Analyze and Improve stages do.

It is the Analyze and Improve stages that require the verification of the sources of quality issues and the optimization of the system to limit the effects of these sources respectively. Further, probabilistic methods in general and robustification specifically are ideal, respectively, for the determination of the sources of quality issues and the optimization of a system to limit quality issues. Therefore, it is recommended that probabilistic methods be used in the Analyze stage to verify the sources of each quality issue and that robustification be used in the Improve stage to make the system less sensitive to randomness in these sources. It might even be that you decide to have dedicated people (either external or internal) with advanced probabilistic skills involved in these stages and only these stages so that you can make the most economic use of their skills and your resources.