The Nature of Performance Beyond Six Sigma

by Bob Rhyder

Gavin observed the high-speed manufacturing process. After a few moments, he stepped away from the stamping press and walked toward the SPC data collection station. He stopped briefly to examine the gaging system, then turned his attention to the control chart and process performance indices on the computer display. In disbelief, he staggered backward a step, looked at me, and stuttered, "Th-the SPC system indicates the P_{pk} is over 20!"

I was pleased because Gavin had just established himself as the first supplier who understood the numbers that frequented our computer displays. While anyone involved in manufacturing should know that a P_{pk} of 20 represents process performance at a 60σ level, Gavin was the first, and the only supplier, who actually recognized it. This indicated that he was observant, that he understood control charts and SPC theory, and that he had at least some level of appreciation for the difficulties associated with variation reduction in manufacturing operations.

Although tempted to take full advantage of the situation and tell him that we expected all of our suppliers to do the same, I simply agreed with him and said, "Wow, you're right! That is a high P_{pk}!"

As I started turning away, however, I couldn't resist teasing him a little and I added, "We don't generally get P_{pk}'s much above 15…"

In the past, I often said that I specialized in "process optimization." Over time, I learned that this phrase means different things to different people. To me it means the *best* attainable combination of process targeting, minimal variation, and minimal cost – a critical process trinity needed for all highly successful operations.

Optimization leads to a singular condition. The word "best" makes it so, by definition.

Six Sigma and 6σ

I am reluctant to claim specialization in Six Sigma, because many people, including quality practitioners (and *more than a few* Six Sigma instructors!), actually confuse Six Sigma and 6σ. So, let's get it straight:

1) Six Sigma is a PROGRAM
    a) Six Sigma advocates the use of many different (and very beneficial) tools
    b) Six Sigma performance is accepted as 3.4 parts-per-million defective[1]

2) 6σ is a measure of dispersion
    a) 6σ has nothing to do with any quality improvement tools
    b) 6σ performance is 2 parts-per-billion

Is the difference clear yet? If not, multiply 2 parts-per-billion by 1,700 and the product will be 3.4 parts-per-million. These two levels of performance are not similar. The difference between them is a multiplication factor of seventeen hundred!

Six Sigma (the PROGRAM) was originally conceived at Motorola as a methodology to pursue 6σ quality. In its infancy, the program was often written about as a bold, new initiative that promised huge returns and unheard of manufacturing consistency. Ultimately, the program fell far short of its published goals. The concept of a 1½ σ shift was introduced and the levels of expectation were toned down dramatically.

In the beginning, descendants of Motorola's program were simply known as Six Sigma. Later, after its popularity had ballooned and then started to level off, monikers like Transactional Six Sigma, Lean Six Sigma, and Six Sigma for Healthcare followed. With the addition of techniques such as value-stream analysis and adjectives like "global," "Six Sigma" has increasingly moved toward becoming a catchall phrase for many

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[1] Stated as equivalent to 6σ dispersion with ± 1½ σ shift

programs that seem to offer great financial rewards to its practitioners.

Of course, let us not forget that each new variation of Six Sigma also offers great financial rewards to trainers and consultants, so there are strong motivations to continue the expansion of Six Sigma.

What Happened to 6σ?

So, what happened to the original pursuit of 6σ? Many companies and individuals have either ignored it or dropped it. They do so because Six Sigma and 6σ sound like the same level of performance, or because they think 6σ is not practical and it is too expensive to pursue. After all, if originators of Six Sigma could not achieve 6σ performance, it must be unachievable. Right?

Wrong! Performance at and beyond 6σ is achievable in many, many applications. And when properly done, it is often neither too difficult nor too expensive. Performance at 6σ levels and beyond is, in fact, frequently the very least expensive way to run a process! Many may have missed the mark early on, but that doesn't mean that everyone has.

Process optimization frequently leads to a state that is best described as "**$d^2\sigma$**" quality. The **$d^2\sigma$** stands for *double-digit σ* as a measure of process capability. It signifies variation so insignificant that the process mean is more than 10 standard deviations from the nearest specification limit. I wouldn't refer to the state as 10σ, or 20σ, or even 30σ, because someone would surely write it as Ten Sigma, Twenty Sigma, or Thirty Sigma and the confusion between "Sigma" and σ would continue. Besides, those levels of performance have all been exceeded years ago, at least in some applications.

Process optimization includes cost considerations and does not always lead to end states that exhibit double-digit levels of σ, but it very often does reveal the possibility, even if those states are not ultimately selected. Remember that an "optimized" process is one with the best *combination* of targeting, reduced dispersion, and minimum overall costs.

The Pursuit of CPK (It's not what you think)

There are no tricks or expanded specification limits involved in achieving **$d^2\sigma$**. Dramatic performance levels are often realized by pursuing a state that I refer to as CPK or Complete Process Knowledge. Not "complete" in an omnipotent sense, but certainly a state far, far more comprehensive than companies typically possess. For example, if you experience a process that shifts $\pm 1.5\sigma$ there truly is nothing "normal" or "natural" about it. The process shifts because causal factors have not been identified and are not properly controlled.

To achieve Complete Process Knowledge you must understand which inputs control targeting for all of the measured outputs of your process. You must also understand which inputs control the dispersion of all your process outputs. And, of course, you must understand the cost ramifications of the process input selections. (Figure 1)

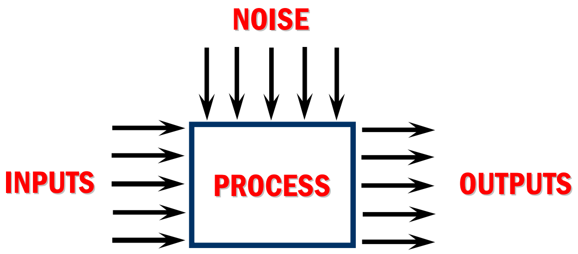

Figure 1: Process Model

Note that "outputs" in this discussion does not refer to multiple units of production. It refers instead to the unique quality characteristics identified for individual units of production. Outputs are measurable characteristics such as length, width, height, hardness, color, surface roughness, etc.

Think you understand your processes? If they produce scrap, it's a sure sign that you have an inadequate amount of process knowledge. The same applies for processes with uncompetitive costs, rework, customer returns, and warranty failures. If you did have enough process knowledge, you would not allow these conditions to persist. (Those who do possess adequate process knowledge and tolerate these conditions anyway have a problem of another sort entirely.)

Don't confuse CPK with re-engineering. It is the antithesis of re-engineering. CPK is learning how to make the best possible product with the equipment you already have. It actually eliminates the need for costly re-engineering efforts and allows emphasis to be placed where it belongs – on the development of the next new product and the next new process.

Achieving $d^2\sigma$ Performance

$d^2\sigma$ quality is not only possible in many applications, it's <u>practical</u>. It can also be very inexpensive and very simple once it is achieved. And it just makes sense. Good, sound, engineering sense. It's also likely that it will place you solidly in "world class" status (by my definition that means the very best in the world).

Not surprisingly, attaining **$d^2\sigma$** requires use of many well-known techniques, but some of them are employed in fashions that are slightly different from what you may be accustomed to. It also requires focus on some of the little-used, and often confused, techniques – this is where many Six Sigma practitioners fall short in the formulation and application of their improvement efforts.

What is required? Techniques such as TOPS, DoE, SPC, Cost Systems, and MSA form the core of the program. In addition to these, however, knowledge of Process Paths, Taguchi's Signal-to-Noise Ratio analysis, and MRATs (multiple response analysis tables) are crucial to success.

The following list summarizes the manner of usage for the techniques referenced above.

1. **TOPS (Team Oriented Problem Solving)**: A core requirement for problem solving and process improvement efforts. It is adopted for usage in the ***$d^2\sigma$*** process without significant changes, but operator involvement is a must.

2. **Cost Systems**: Cost of Quality (prevention, appraisal, internal failures, external failures) with additional input from standard cost accounting systems, emphasizing Juran's Language of Money. Also adopted without significant changes.

3. **MSA (Measurement System Analysis)**: The standard calculations are applicable to the ***$d^2\sigma$*** process, but interpretation of acceptability ranges is more stringent than normal. Ultimately, for a ***$d^2\sigma$*** process, the GR&R of the measurement system will be the primary limiting factor of the process optimization effort. For instance, a measurement system with a 10% of tolerance total GR&R will not be able to report a $P_{pk} > 10$, even thought the actual process dispersion could be far less than 10% of the tolerance. (A P_{pk} of 10 is a 30σ process.) Process improvements beyond this level would not be visible due to the variation of the gaging system.

   Do you want P_{pk}'s of 20 like the one in beginning of this article? You will need to start with measurement systems whose total GR&R's consume no more than 5% of their respective engineering tolerances.

4. **SPC (Statistical Process Control)**: SPC remains critical for process monitoring, but ***$d^2\sigma$*** processes will typically not be able to demonstrate a state of statistical control. This is a result of the gaging system's inability to discern variation in ***$d^2\sigma$*** manufactured product.

   It's not unusual to observe range charts that may have only one value plot below the upper control limit for R-bar. All of the other values are either zero or above the control limit.

   I've also witnessed many X-bar charts that exhibit almost no variation at all. Such "flatline" conditions, even in health care environments, are not a sign that your processes are in dire trouble. These conditions are signs that your measurement systems are no longer able to discern variation in the manufactured product that you are producing.

5. **Process Paths**: Determination of process paths, and knowledge of the inherent variation that they can introduce into a process is required. More than process mapping or flow charting, the path concept examines the process in detail.

   For example, consider a single machine as one node, or step, in a series of activities necessary to make a product. Suppose supervision provides the setup personnel with 7 unique OD tools, 5 unique ID tools, 10 shim stock sizes, and 10 input material thicknesses so that adjustments can be made to properly target the manufactured product. Supervision has unwittingly provided the setup person with 3500 different ways to run this manufacturing process ($7 \times 5 \times 10 \times 10 = 3500$). Each of the "paths" the product could follow is meant to create a unique result. While management intent may have been to give setup personnel the ability to adjust the process, they instead ended up presenting the employee with an overwhelming number of choices, and the setup person was expected to choose the correct combination every time the product was manufactured.

6. **DoE (Design of Experiments) and SNR (Signal to Noise Ratio Analysis)**: Taguchi Methods with SNR analysis are used in the pursuit of ***$d^2\sigma$*** processes. The application of SNR techniques is critical to identify the causal factors of dispersion in manufacturing processes.

7. **MRATs (Multiple Response Analysis Tables)**: The practical use of this technique enables the selection of process inputs at levels that will improve targeting, minimize dispersion, and minimize overall manufacturing costs for the greatest number of output characteristics concurrently.

Nature of *$d^2\sigma$* Performance

What can you expect from processes that perform at *$d^2\sigma$* levels?

Process paths are minimized, so setup times are dramatically reduced and the potential of wrong choices is minimized. You will almost certainly realize savings from reductions in tooling inventory.

Designed experimentation with signal-to-noise ratio analysis and multiple response analysis is widely used in the process development process, and in problem-solving activities. The use of sequential experimentation is the norm, not the exception. Properly executed, this type of experimentation may reveal the opportunity to run processes at higher speeds without adverse consequences. It is not unusual to see 2, 5, or even 10-fold improvements in processes that are subjected to this type of analysis for the first time. (Figure 2)

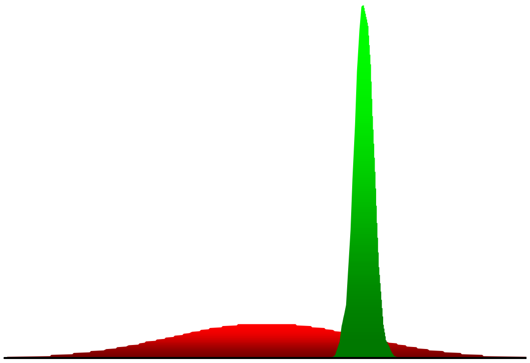

Figure 2: Before and After Experimentation

Measurement system analysis is integrated into the process development process and gaging systems tend to be the best commercially available. The resulting processes often demonstrate so little dispersion that the only detectable variation for monitoring comes from the gaging system.

SPC is used to ensure run-to-run consistency and monitor process P_{pk}'s, but the normal rules of control chart interpretation no longer apply and calculations which depend upon control chart values and estimators, such as C_{pk}, are no longer valid.

Ultimately, if the settings necessary to achieve “optimum” solutions are chosen properly, *$d^2\sigma$* processes exhibit precise targeting, a minimum amount of discernable variation and minimum overall manufacturing costs. Under these conditions, it is often possible to virtually eliminate scrap, rework, returns, and warranty issues.

Moving Beyond Six Sigma

If you have already implemented a Six Sigma program, congratulations – you obviously care about performance and your bottom line. You should be realizing significant financial gains from Six Sigma implementation. You are also already versed in many problem-solving and process improvement tools.

To go beyond Six Sigma (and even beyond 6σ) you need only a few more tools and a different approach to engineering and managing your processes. You need an approach that will expose the interrelationships of your process variables and enable you to optimize your systems, increase your profitability, and satisfy your customers all at the same time.

Real understanding of a process is an enlightening event. I can’t tell you how many times I have been with engineers and manufacturing personnel who witness the actual interrelationships between process inputs and outputs for the very first time. It is a true epiphany when they realize how a process actually works and compare that to how they *thought* the process worked.

With this level of understanding comes immense power. The power to target a process. The power to minimize variation. The power to minimize overall costs. The power to actually control processes, production schedules, and profitability - instead of allowing them to control you.

About the author:

Bob Rhyder *is the president of Rhyder Associates, Inc., a Jacksonville, FL based firm that specializes in problem solving and process optimization. An ASQ Certified Quality Engineer and an ASQ Certified Six Sigma Black Belt, he is the author of “Manufacturing Process Design and Optimization” ©1997, Marcel Dekker, and has a bachelor’s degree in mechanical engineering from Lehigh University in Bethlehem, Pennsylvania. Additional information about $d^2\sigma$ is available at www.d2sigma.com.*