SIX SIGMA QUALITY: BEYOND HYPE

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SUMMARY
"Six-Sigma" quality is a buzzword in the quality community throughout the world. "Six Sigma" quality is defined as achieving reduction in the variation which allows for a ± 1.5 sigma shift (Harry Mikel 1997). It is also described as a philosophy, methodology, and a breakthrough strategy to solve problems. This paper presents an in-depth examination into the heads and tails of the "six-sigma quality" concept. The objective is to become better informed about the benefits of six-sigma quality. Actual examples and case studies illustrate its merits and warn against limitations and misuses. The ultimate objective is to understand six-sigma quality and place it in an appropriate context to reap the benefits.

KEY WORDS
Six-sigma quality, problem-solving, quality improvement

POINT/COUNTERPOINT

1

Point: We only hear about one side of the six-sigma coin.

Counterpoint: We should hear about both sides of the six-sigma coin.

Discussion: This paper is not a discussion about "for six-sigma" versus "against six-sigma." It is rather an exercise in striking a balance between "the much-talked-about side of the coin" versus "the other side of the coin". The corporate quality culture provides no acceptable channels to discuss both sides of the coin in an educational format. Even though quality achievement is preferred on a prevention basis, we do not subject new quality ideas, programs, or initiatives on the same basis. Treating a new quality idea such as six-sigma on a prevention basis would suggest that we examine the pluses and minuses of the idea with the intention of benefiting from the positives and guarding against the negatives. Historically, we let the new quality idea take its own course and examine why it did not work later. Titles such as, "Why does TQM fail?" or "Why don't Quality Circles work?" are not uncommon. Our purpose is to examine the "other side of the six-sigma coin."

Key Idea: Treat every new quality initiative including six-sigma as a two-sided coin. This enables us to examine points and counterpoints before we get too committed to a new quality initiative.

2

Point: Short-term PPM associated with six-sigma is 0.001.
Long-term PPM associated with six-sigma is 3.4 (Long-term is defined as a process experiencing a 1.5 sigma shift).

Counterpoint: There is nothing outside 3-sigma.

Discussion: There is evidence that there is nothing lying outside of ± 3-sigma on the normal distribution. There are several references that support this counterpoint (Gauss Photo on *Ten Deutsche Marks* bill, Shewhart 1931, Deming 1982, Neave 1990). Therefore, calculations outside ±3 sigma have no actual relevance. The Gauss model approximates actuality (100%) by a normal distribution where ±3 sigma limits match actuality 99.73% of the time. Table 1 compares the normal distribution model versus actual numbers for a one-sided specification. By examining the Reality PPM column in Table 1, we can say that reporting quality, at the *sigma level* is likely to create confusion rather than reflect the true progress. A better way to report progress on a breakthrough project is to exhibit the *before* and *after* picture.

Table 1 - Model versus actual: one-sided specification

No.	σ value	Model PPM	Reality PPM	Shifts
1	+1 or -1	158,500	158,500	
2	+2 or -2	23,000	23,000	
3	+3 or -3	1,350	0	
4	+4 or -4	31.5	0	
5	+4.5 or -4.5	3.4	0	PPM associated with ± 1.5 sigma shift.
6	+5 or -5	0.285	0	
7	+6 or -6	0.001	0	PPM associated with zero shifts.

Key Idea: The principal idea is to solve problems rather than becoming too concerned about reporting achievements in terms of process sigma level.

3

Point: ±1.5 sigma shift is assumed to arrive at 3.4 PPM.

Counterpoint: Amount of shift and type of shift are a matter of discovery and not a matter of assumption.

Discussion: In a certain class of problems, the shift is a major problem. For example, in a stamping process, the output variation is extremely narrow. However, the target keeps shifting with the changes in the steel coil. It is just as important to focus on the target as it is to focus on the variation (Tadikamalla 1994).

Key Idea: We should not desensitize the problem condition by allowing for target shifts.

4

Point: Six sigma performance is said to be achieved when the inherent process variation is half that of specification range (Cp = 2) and target shift is 1.5 sigma.

Counterpoint: To reference specification limits while seeking a breakthrough strategy, we undermine Taguchi teachings (Taguchi 1986).

Discussion: Taguchi teachings involve uniformity around a target with no reference to specifications. The definition of the Taguchi loss function clearly expresses this idea:

$$\text{Loss} = K\left[\sigma^2 + \left(\overline{X} - \mu\right)^2\right]$$

If we allow a 1.5 sigma shift, then the $\left(\overline{X} - \mu\right)^2$ portion of loss equals 1.5^2 equaling 2.5. Also if we allow specification as a part of the improvement conversation, then we begin to talk about what is acceptable rather than what is economically achievable.

Key Idea: Operational excellence efforts should be measured as uniformity around a target, independent of specification range.

5

Point: Calculations associated with six-sigma apply to attribute data as well as variable data (Harry Mikel, 1998).

Counterpoint: Calculations associated with six-sigma apply to variable data. They do not apply to attribute data.

Discussion: For variable data, target shift and variation are independent. That means, if we move the target, we do not necessarily affect variation and vice versa. For attribute data, target shift and variation are dependent. What this implies is that if we solve target as a primary problem, we might change variation as a side effect or vice versa. There are different tactics to solve target and variation problems. One has to choose the tactic before seeking a solution. The success in solving a problem largely depends on one's choice of the appropriate tactic. Converting attribute data into an equivalent sigma level forces us into solving variation as a problem condition.

Key Idea: The distinction between variable data and attribute data is crucial in selecting a problem-solving tactic.

6

Point: Main emphasis is on reducing variation.

Counterpoint: Main emphasis should be on reducing variability. Variability has three components: instability, variation, and off-target.

Discussion: Once we surpass the C_p of 1, instability and off-target problems become major contributors to output variability. The three problem conditions are shown in Figure 1. It is almost impossible to achieve $C_p = 2$ in the presence of instability (Shewhart 1931) and target problems.

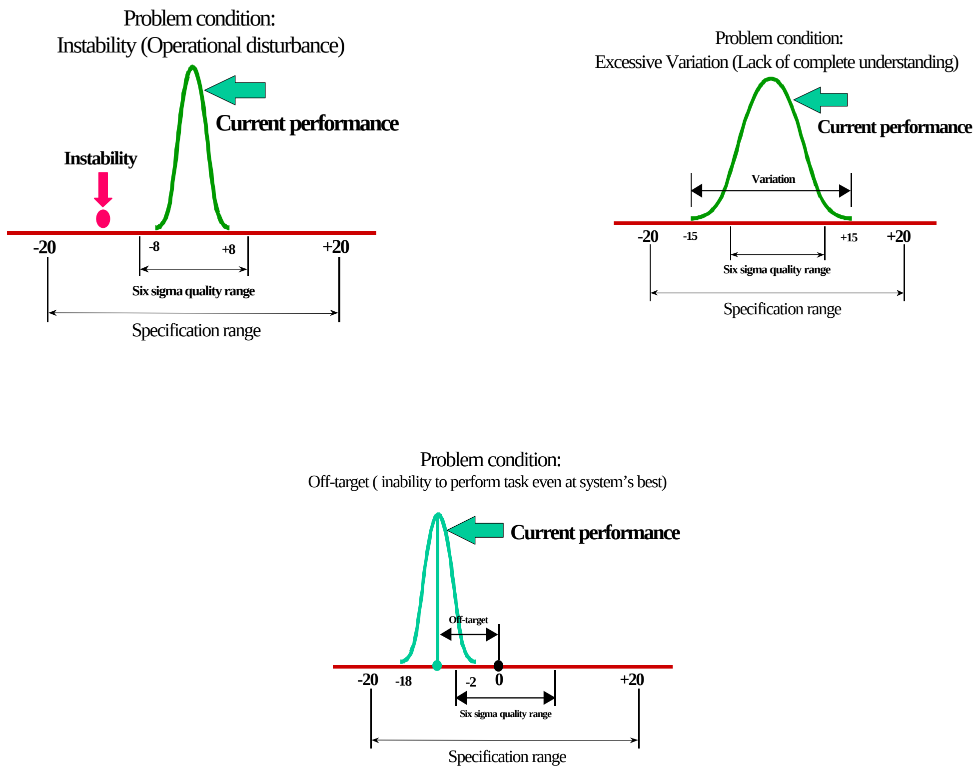

Figure 1 – Three Problem Conditions: Instability, Variation, and Off-target

Key Idea: If variation is the only component to be resolved, you could actually be working on the wrong problem condition. This will seriously undermine the problem-solving process.

7

Point: More attention is paid to reducing variation. Less attention is paid to developing robustness.

Counterpoint: Robustness can altogether eliminate the need for reducing variation.

Discussion: Let us look at an example where we are faced with a variation reduction problem. As shown in the Figure 2, Part A and Part B assembly must maintain a gap as per specification. For this to happen, appropriate tolerances are assigned to Part A and Part B. However, processes are incapable of producing parts A and B within the tolerance limits. We are faced with the problem of reducing variations for parts A and B. An alternate way to resolve this problem is an introduction of another part – a spring – as shown in Figure 3. The spring will forgive any lack of process capabilities for parts A and B. Therefore, no reduction in variation will be necessary.

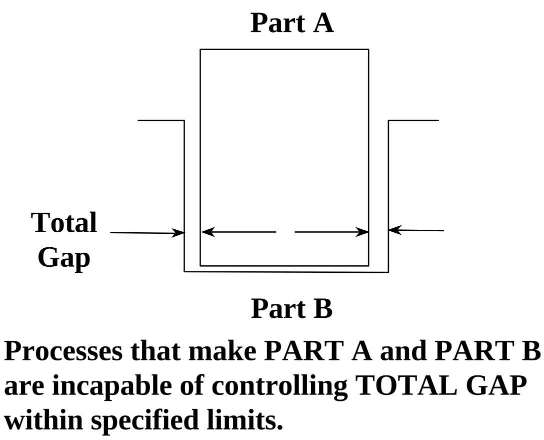

Figure 2 – Problem of Reducing Parts A and B Variations

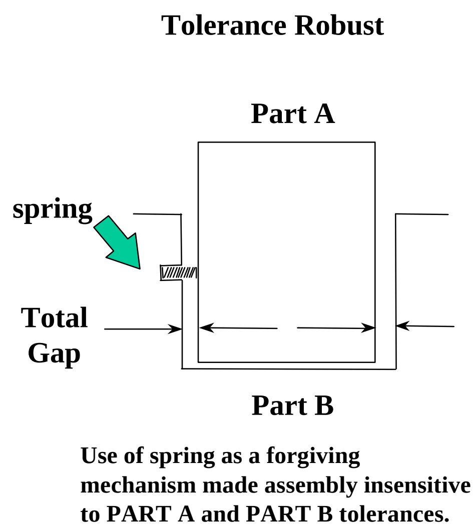

Figure 2 – Robustness as an Alternate Solution to Variation Reduction

Key Idea: Robustness is the first option. Variation reduction is the second option.

8

Point: Six-sigma teachings include a wide variety of methods that can handle any problem situation.

Counterpoint: The specific absence of reliability methods, multivariate methods, observational studies, and robustness methods are noticeable in six sigma teachings.

Discussion: Let us look at some examples.

- A clutch system supplier has a problem with leaky cylinders in the field. Internally, the cylinders meet all manufacturing specifications and design tests for shipment. Thus, it is a puzzling problem. Developing a solution to the leakage problem will require a reliability engineering discipline.
- A part is rejected by a functional gage. However, individual characteristics A and B that define the function of the part are within specifications. This contradiction is puzzling. To develop the solution to this problem will require a multivariate discipline.
- Parts A and B that make up an assembly are determined to be good. However, they fail to assemble properly. Occasionally, when parts A and B are determined to be bad, they still assemble well. This disparity is not easily resolvable. This problem can be investigated by an observational study.

Key Idea: The understanding of problems and development of effective solutions require a larger collection of strategies and methods. Six-sigma methods are only a subset.

9

Point: Six-sigma methods can tackle transactional problems.

Counterpoint: Transactional problems require statistical thinking more so than statistical methods.

Discussion: Manufacturing and design problems require that we investigate the influence of input variables on the output. Transactional problems, in many instances, require counteractions because investigations are either not possible or economical. For example, AutoWorld magazine reports “one of the Big 3 automotive companies is taking up to 120 days, and in some cases even longer, to pay for the work delivered.” Suppose, you are a supplier to the Big 3. You consider 120 days as problem for your cash flow situation. How would you go about investigating and thereafter correcting the situation? It is nearly impossible to investigate such a transactional problem. A proper option is to make list of possible actions to counter this problem. It will require statistical thinking to make a list of possible actions and ultimately determine the best course of action.

Key Idea: Transactional problems are resolved by statistical thinking more so than statistical methods. A large number of cases require that we counter the problem rather than determine the root cause.

10

Point: Six-sigma is a breakthrough strategy to solve a broader class of problems.

Counterpoint: Industry evils, which have been consuming large amounts of money, are not even considered.

Discussion: Here are some examples of industry evils:

- Industries spend millions to control key characteristics. However, the process of determining key characteristics are neither well defined nor properly executed. The most convincing evidence is that even when key characteristics are controlled at the level of Cp = 2, the performance level has a Cp of less than 1.
- Industry spends money on statistical control charting for monitoring processes instead of defining problems - a universal wasteful practice.
- The overwhelming preference in industry is to use Design of Experiment (DOE) instead of Observational Studies as competing strategies. Applying DOEs in certain problem situations is not even possible. In some other cases, even when DOEs are possible, they offer a more expensive route compared to observational studies. Companies spend large amounts of money in inefficient selection and execution of DOE methods.
- Companies spend heavily on so-called reliability tests. These tests, which fatigue-cycle the parts for thousands if not millions of cycles, are actually durability tests disguised as reliability tests. The real opportunity lies in converting long-period durability tests into short-period reliability tests.

Key Idea: The six-sigma strategy has not been directed at creating a breakthrough in the class of industry money gobblers. Any breakthrough strategy must include the attack on industry evils.

11

Point: Six-sigma methods emphasize the teachings of statistics as a science of confirmation.

Counterpoint: Problem solvers can effectively resolve problems by using statistics as a science of indication.

Discussion: No clear distinction is made between the use of statistics as a science of indication versus a science of confirmation while learning six sigma methods. When we use statistics to confirm the findings, it requires larger sample sizes for narrower confidence intervals. On the other hand, statistics, when used to indicate the direction of investigation, requires smaller sample sizes. That means, we can deal with point estimates in the investigative stage. Problem solvers need to evaluate a series of indications until they arrive at the final solution. Only then, can they confirm the final solution.

Key Idea: By using statistics, as a science of indication, investigation costs can be kept at minimum.

12

Point: Six-sigma is a philosophy, method, and strategy to create breakthroughs.

Counterpoint: Six sigma is only a statistical methodology. It must be combined with engineering strategies to successfully solve problems.

Discussion: Engineering elements in any problem resolution are:

- Investigation before action.
- Effective communication of the separation among instability, variation, and off-target conditions.
- Discussion of the four engineering tactics: control, optimize, modify, and recreate (Bajaria and Copp 1991).
- Use of the forgiving principle (Bajaria and Copp 1991).
- Emphasis of engineering efficiency over mathematical efficiency: (1) Randomization versus turf check, and (2) observational studies versus factorial experiments

Key Idea: Engineering strategies play a key role in ultimately deciding the success or failure of the problem-solving exercise. Statistical methods simply make engineering strategies more efficient.

13

Point: Six-sigma is a vertical system. It starts with a situation to be resolved and ends with a permanent solution. Simultaneously, it proves that the benefits of such an encounter far outweigh the resources expended.

Counterpoint: Creators of the six-sigma system have never discussed the difference between horizontal systems and vertical systems. Industries need a well-defined and well-managed balance between the two.

Discussion: In terms of strategy, this is the most positive contribution of six sigma. Even the originators of six sigma do not fully realize that what they have created is truly what industry needs. Historically, quality ideas are implemented with horizontal systems. A horizontal system takes a good idea and spreads it across the organization. Horizontal systems basically improve working efficiency; they do not necessarily solve problems. The horizontal systems have never proven the basic equation of quality: benefits must exceed the investments. For example, SPC applications are largely horizontal in nature. The SPC has become a monitoring tool rather than an element of vertical systems in defining the problems. By any measure, investments in horizontal application of SPC far exceed the benefits delivered.

Organizations see most issues from a horizontal system perspective. Organizations are devoid of vertical systems. As a result, inherent problems are neither visualized nor solved.

Key Idea: Organizations actually need both vertical and horizontal systems. Vertical systems act as drivers whereas horizontal systems are driven.

Vertical systems solve problems. Horizontal systems hold solutions in place.

14

Point: Documented case studies using the six-sigma methods are presented as the strongest evidence for six-sigma success.

Counterpoint: Six sigma case studies illustrated on websites are sketchy. There is no mention of any specific six-sigma methods that were used to resolve the problems.

Discussion: Are successful studies due to the Hawthorne effect or due to the use of statistical methods? By relying on the six sigma criteria, management is lulled into the idea that something is being done about quality, whereas any resulting improvement is accidental (Latzko 1995).

Some of the website case studies make problem solving seems like a one-shot proposition. To solve actual problems, it takes more than one shot. The improvement process is like a game of golf; there is no par one hole.

Key Idea: Are we making a true improvement with six sigma methods or just getting skilled at telling stories?

SUMMARY

Six-sigma has excellent potential to serve as a vertical system. However, six-sigma strategy as described in the popular literature needs to be modified. The fourteen counterpoints presented in this paper can be utilized to enhance the application of six-sigma. The counterpoints, if ignored, could actually nullify all the positives of six-sigma. These fourteen points are summarized below:

1 Treat every new quality initiative including six-sigma as a two-sided coin. This will enable an examination of points and counterpoints before we get too deeply committed.

2 Solve problems rather than becoming overly concerned about reporting sigma level of process. Use before and after pictures to demonstrate progress.

3 Do not desensitize the problem condition by allowing for target shifts.

4 Measure operational excellence efforts by measuring uniformity around a target, independent of specification range.

5 Make the distinction between variable and attribute data for selecting a problem-solving tactic.

6 Divide variability into three problem components to be resolved: instability, variation, and off-target.

7 Use robustness as the first option. Use variation reduction as the second option.

8 Develop a larger collection of strategies and methods than what the conventional six-sigma curriculum offers.

9 Develop and execute statistical thinking to resolve transactional problems.

Recognize that countering the problem condition may be a better option in some situations.

10 Create breakthroughs by attacking industry money gobbling evils.

11 Keep investigation costs to a minimum by using statistics as a science of indication.

12 Place primary emphasis on engineering strategies supported by statistical breakthrough strategies.

13 Use vertical systems to resolve the problems. Use horizontal systems to hold the gains.

14 Be aware of six-sigma success stories. Ask lots of questions to storytellers. Look for positive proofs.

Collectively, these counterpoints issue a warning to the potential users of six-sigma methods. The usefulness of the six-sigma philosophy, methods, and breakthrough strategy can be realized only if we are conscious of the counterpoints. There is no doubt that industries need a vertical system such as six-sigma strategy to solve complex problems. However, pursuing six-sigma strategies without the comprehension of counterpoints is a potential disaster in the making.

Whenever possible, leaders want to know in advance the positives and negatives of quality initiatives. For most other initiatives such as Statistical Process Control and ISO 9000, the leaders were not forewarned. In this case, they cannot complain since warnings have been presented and debated. It is available in a published format for their scrutiny. If we make the six-sigma strategy yet another fad, it will be a reflection on our culture rather than the quality science.

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