TQM AND STATISTICAL THINKING

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1. ABSTRACT

TQM has gained popularity because it has found funding. Consequently, it has allowed all concerned to put forward their own agenda. After a decade of substantial investment in TQM efforts, both social and monetary, very few intended inherent changes have taken place. A few positive inherent changes that did take place are mostly technology-induced and not quality-induced.

Quality, statistical thinking, and their potential for impact on inherent changes are still not well understood. As a result, statistical thinking is not effectively utilized. In this paper, we explore TQM and statistical thinking with a focus on achieving inherent changes in the ways we approach product, process, and administrative designs and solve related problems.

2. INTRODUCTION

To improve quality we must increase our understanding of physical, social, and statistical sciences. This in turn allows us to engineer the systems for increasing the quality of goods and services. The systems can include all activities performed toward production of goods and delivery of services. It is commonly expressed that the systems must be engineered. That means, we must integrate knowledge of all sciences for achieving successful performance.

Statistical thinking assists in the tasks of generating, improving, and maintaining engineered systems. Such an assistance can achieve completeness and speed. That is, statistical thinking allows us to gain a complete knowledge of all variables at the fastest speed possible. Why is then statistical thinking not so widely utilized in creating and perfecting engineered systems?

Several obstacles need to be understood and cleared before statistical thinking ever becomes a habit. From an academic viewpoint, there are several inherent deficiencies in engineering education. For example, engineers are educated to think real variables not random variables, they are trained to act upon rather than investigate suspect variables, their preference is forensic analysis (learn from bad situation) rather than statistical analysis (learn from good and bad situations), etc. From statistical expertise side, there are many difficulties, as well. First and foremost concern is the need to understand that the people creating systems are customers and people encouraging statistical thinking are providers. Therefore, the statisticians must understand the accepted behavior when a customer and a provider are interacting. Secondly, the statistical thinking elements are much broader in scope than simply serving a need to plan and analyze the data.[7] The real engineering needs are: 1) using data as an indication rather than confirmation, 2) determining strategy in choosing variables for investigation, and 3) being able to execute data collection smoothly in the operational environment. The first item is at odds with teaching of statistics. An indication requires point estimates, on the other hand, confirmation requires confidence intervals. The statistics is taught with emphasis on confirmation. The second item relating to strategy requires an ability to ask questions to the team members possessing the knowledge of physical and social sciences. The answers to these questions facilitate the grouping of variables reducing the total investigative space. As much as we like engineers to learn and apply statistical thinking, we must develop attitude toward understanding the underlying physical phenomena. The third item is a business need which dictates whether or not a statistically efficient scheme can be executed in the operational environment. This item requires that we test our statistical expertise on real-life problems rather than limiting it to classroom learning alone. The additional concern engineers have is an acute need for simplicity with which statistical ideas must be conveyed and applied. To the extent that engineering terminology is understood by a common person, statistical terminology has not achieved similar status. How can statistical thinking be effective for masses when powerful ideas contained within cannot be stated with simplicity at the level of application?

The Table 1 illustrates the difference between engineering thinking and statistical thinking as they relate to creation of successful systems. We must recognize and act on these differences to make statistical thinking integral to TQM.

Table 1 Differences Between Engineering Thinking and Statistical Thinking

Engineering thinking	Statistical thinking
Two categories of variables: Innocent, guilty	Three categories of variables: Innocent, suspect, guilty
Problem-solving is a one-shot proposition.	Problem-solving is a multi-shot proposition.
Intuitive search for solutions	Orthogonal search for solutions
Prefer irreversible changes	Prefer reversible changes
Acts on a symptom - Forensic approach	Acts on a variation
Repeat samples plus confirmation is a preference	Replicate is a preference
Talks about specification range and disregards anything within a specification range as not being a potential problem	Talks about desired target and actual part conditions with no reference to specification range
Wants to use statistics for indication	Wants to use statistics for confirmation
Preference is to control upstream	Preference is to forgive downstream
No use of strategies in listing variables	No use of strategies in listing variables
Observational studies are preferred	Factorial experiments are preferred

3. MEANING OF TQM

TQM could have many conceptual as well as operational definitions. However, we need to have a working definition of TQM in order to focus on establishing clearer relationships between statistical thinking and TQM. Total means all people, all sciences, all engineering and administrative disciplines, all activities, and all encounters. Quality means either anticipated or existing output conditions. Management means output conditions must be defined, the resources must be assigned for their improvement, the undesirable conditions must be acted upon, their progress must be reviewed, and their performance levels must be improved.

Meaning of TOTAL proposed here cannot be argued because it is all encompassing. The word QUALITY could be argued because its definition involves a distinct departure from other definitions of quality having rigid, fuzzy, or philosophical tones.[4, 6,10] Meaning of MANAGEMENT should be less argumentative because the word has been around and its meaning is well understood and well accepted.

4. ELEMENTS OF STATISTICAL THINKING

- Collect data and make inference about underlying phenomena.
- Show the truth envelope (confidence interval) so that we make sure that the meaningful sample size was collected.
- Be aware of two phenomena: 1) the truth may be accepted when it should not [β error] and 2) the truth may be rejected when it should not [α error].
- Cover complete investigative space while searching for cause and effect relationships.
- Be aware of covariables while investigating a problem. They tend to occupy some portion of error variation or they may make you think that certain variable was important but, in fact, it was not.
- System initiation requires subject matter expertise (forward thinking), on the other hand, system perfection requires statistical expertise (backward thinking).
- The underlying physical and social science phenomena cannot be understood when operational disturbances interfere with investigation. That is, instability problems inhibit understanding of variation problems.
- A large investigative space (20 variables requiring 1.048,576 tests) can be systematically reduced to a manageable space (4 variables requiring 16 tests).

5. SYNTHESIS OF TQM AND STATISTICAL THINKING

We are interested in communicating to **all people** that every activity has an output that must be satisfactory to recipient as defined by the recipient. To realize this goal, we use two complementary approaches: 1) Forward approach which is based on physical and social sciences and 2) backward approach which is based on statistical science. The forward approach allows system to be initiated and the backward approach allows system to be perfected. This fundamental idea applies to creation and perfection of **all activities** whether they are designs, processes or administration. **All disciplines** including physics, chemistry, biology, and sociology can benefit from the backward approach. Furthermore, we want to communicate that 100% continuous success needs system maintenance. That means, we must be conscious of instabilities **all the time**, which may degrade the output performance or may nullify corrective actions.

TQM and statistical thinking must be synthesized in a way that is reflected in every encounter made toward creating, improving, or maintaining the systems.

6. A MODEL TO INTEGRATE STATISTICAL THINKING INTO TQM

The model we build to integrate statistical thinking into TQM must be consistent with meaning of TQM and statistical thinking elements that were identified earlier. The model must be responsive to a synthesis need as well as to the obstacles that have existed in the past and still continue to exist.

Having worked with 300-400 real-life problems, I wanted to consolidate the problem-solving encounters into a practical problem-solving model that can be universally applied and will be long lasting. After considerable scrutiny, I decided to label it as *Statistical Problem Solving -- A Team Process for Identifying and Resolving Problems*.[3] The model has been extensively and successfully tested in actual applications. It has been published as a book[3] consisting of nine chapters. The book title itself integrates the principal ideas of statistical thinking. A *team process* indicates that we are synthesizing several disciplines to improve quality. *Identifying* suggests that without statistical thinking it is difficult to label certain phenomena as quality phenomena and therefore, many problems simply go unrecognized. The word *statistical* suggests that we learn from differences between good and bad situations as opposed to forensic analysis -- a conventional choice of investigators.

A powerful way to integrate TQM and statistical thinking is to think in terms of problems. All actions being taken to create, improve, and maintain systems are either to prevent or to solve problems. The word "problem ' immediately creates a focus and keeps us close to real-life situation. Even though the book title includes the word problem solving, the SPS applies equally well to problem prevention. SPS has well documented teamwork principles as well as advice on how to execute problem-solving without incurring excessive investigation expenses in real-life environment. The statistical thinking in SPS is focused on problem resolution and not on discussion of statistical methods. The model is structured clearly to separate three-stages of any investigation: 1) talk to results, 2) talk to process, and 3) act on discovery. Talking to results narrows the field of investigation, talking to process reduces the list of suspect variables to be evaluated, and acting on discovery brings permanency to the solution.

The Table 2 lists the chapter by chapter account of the SPS model and a sequence in which it integrates different elements of statistical thinking.

Table 2 SPS Model and Sequence of Statistical Thinking Elements

Chapter	Title	Statistical Thinking
1	Meeting a need	• Reversible attempts • Backward thinking
2	Dealing with complexity	• Statistical output conditions • Interactions • Tactics • Signal + Noise variables needing a team
3	Selecting a Problem	• Shewhart + Pareto principles • Problem of correlated outputs
4	Defining the Problem	• Separating Instability, Variation, and Off-target
5	Listing Variable	• Listing tunable variables • Grouping variables • Use of Forgiving Principle
6	Prioritizing Variables	• Strategies of Systematically Reducing Number of Variables
7	Evaluating the top Few Variables	• Problem-solving in more than one attempts – rough cut + fine cut • Factorial Experiments and Observational Studies as competing tools • Answering four relevant questions
8	Optimizing Variable Settings	• Planned experimentation and computer simulations
9	Implementing SPS Solutions	• Distinction between SPC of Product Variables versus SPC of Process Variables

7. SUMMARY

Total Quality Management as a concept is a powerful way to approach creation, improvement, and maintenance of systems to achieve desired levels of performance. The systems can address product designs, process designs or administrative activities. To be competitive, we must execute the required tasks with the fastest speed possible. Statistical thinking can play a role of catalyst in actualizing the power of TQM.

Central players in systems are designers using physical sciences. Source of statistical thinking is statistical science. The wide gap between the practitioners of these two scientific disciplines slows effectiveness of TQM. We identified and listed fundamental differences and voids responsible for this gap both from system engineering and statistical perspective.

Based on my numerous real-life experiences in solving problems, emerged a practical model that would act on the gap. The model is labeled *Statistical Problem Solving - A Team Process for Identifying and Resolving Problems*. The SPS model is robust to tackle variety of situations and withstand a test of time. I hope TQM practitioners as well as statisticians will find the SPS model useful in integrating statistical thinking in actualizing TQM promises.

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