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Proper Blending

The right mix between statistical engineering, applied statistics

SINCE WE PROPOSED the idea and theory behind statistical engineering, we're often asked: "Is it just another term for traditional applied statistics?" That's a legitimate question.

To answer that, the relationship between statistical engineering and applied statistics—as it has been traditionally practiced—must be addressed. We believe statistical engineering can make greater use of strategic thinking and systems thinking. In fact, a blend of statistical engineering and traditional applied statistics is what's needed.

New way of thinking

Statistical engineering is defined as "the study of how to best utilize statistical concepts, methods and tools, and integrate them with information technology and other relevant sciences to generate improved results."[1] This definition provides a new way of thinking about the use of statistical thinking and methods. It is consistent with dictionary definitions of engineering, which emphasize the study of using existing science for the betterment of humankind.

In general, the statistics profession has primarily focused on advancing statistical science—the development and application of new methods—while not recognizing that statistical engineering is the "other side of the coin" that could enable statistics to have greater societal impact.[2-8]

This sentiment became obvious during a presentation in January 2010 by Susan Hockfield, president of the Massachusetts Institute of Technology.

To paraphrase, Hockfield explained that about the dawn of the 20th century, physicists discovered the basic building blocks of the universe—a parts list. Engineers said: "We can build something from this list." They produced the electronics revolution and, subsequently, the computer revolution.

More recently, biologists have discovered and mapped the basic parts list of life—the human genome. Engineers have said: "We can build something from this list," and are producing a revolution in personalized medicine.

Relating this to statisticians, while there seems to be great emphasis within the profession on advancing the parts list of statistical methods, there is considerably less emphasis on building something of importance to society from this parts list.

For example, we speak of building overall approaches to problem solving or process improvement that involve multiple methods, such as Six Sigma, which we suggest as a positive counterexample.

Statistics as a system

Figure 1 shows how statistical engineering, traditional applied statistics and statistical theory fit together.[9] Consider statistical thinking as the strategic aspect of the discipline, providing a philosophy of thinking about statistics and its application. Statistical methods and tools are, of course, critical and where the "rubber hits the road" in terms of delivering value to society.

Statistical engineering can be viewed as the tactical element that provides overall approaches to attack big, unsolved problems that are consistent with the principles of statistical thinking. Statistical engineering links methods and tools with philosophy, and guides the use of the tools.

We noted Six Sigma as an example of statistical engineering as we have defined it. The philosophy of Six Sigma is based on statistical thinking: At a high level, it is used to improve processes, typically by reducing variation, thereby improving internal costs and customer satisfaction. The define, measure, analyze, improve and control method provides the tactics

for integrating and using specific tools to implement the philosophy.

Taking on tradition

Statistical engineering and traditional applied statistics are closely related concepts and shouldn't be viewed as competing approaches. There are important, unique aspects of both, but we fear that greater emphasis on applied statistics will not, in itself, develop the field of statistical engineering to the degree needed.

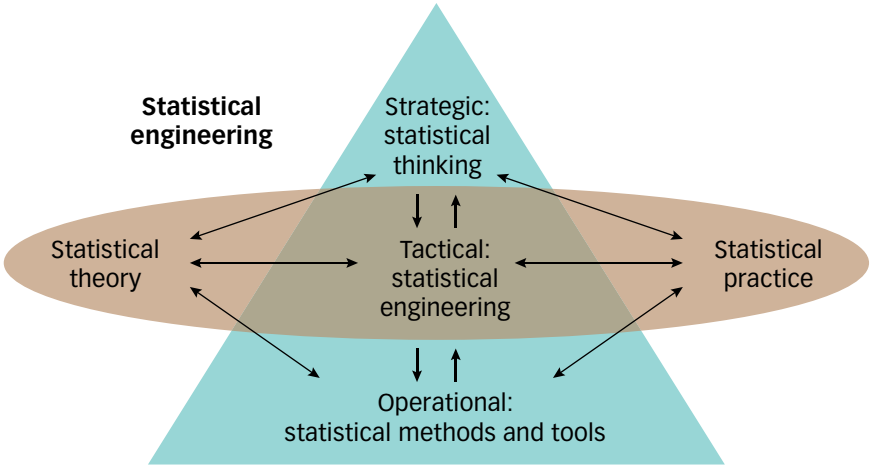
There are many applications of applied statistics that involve presenting a real problem, questioning to clarify the problem, determining the appropriate methods to be used, and competently applying design or analysis tools, including checking assumptions, analysis of residuals and clear communication to nonstatistical clients.

In other cases, there is no known solution to a problem, nor is the development of a new statistical technique the right approach. The problem might be too big and complex for any one technique.

Rather, there is a need to create something new from the existing parts list of tools—a totally new approach, typically one that integrates several statistical and nonstatistical tools in a novel way. "Experience in Applied Statistics and Statistical Engineering," a sidebar found on this column's webpage at www.qualityprogress.com, provides a personal example of this thinking.

Returning to Figure 1, statistical engineering is a horizontal slice of this model, which integrates statistical theory with statistical practice. Statistical engineering needs to be based on a solid theoretical foundation to help determine what works, what doesn't work and why. It then needs to provide overall approaches or tactics for how the theory can be used for maximum impact. In this sense, it will and has directly led to more impactful statistical applications.

The statistics discipline as a system: statistical engineering / FIGURE 1



Statistical engineering is a discipline that studies how to drive greater impact from the existing science or theory of statistics. It is therefore a "horizontal slice," connecting statistical theory with statistical practice.

Dimensions of traditional applied statistics and statistical engineering problems / TABLE 1

Problem dimension	Traditional applied statistics	Statistical engineering
Criticality to the organization	Low - medium	High
Impact—financial, process performance, customer, social and environmental	Low - medium	High
Number of departments, groups or functions involved	Few	Several
Complexity—technical, political	Low	High
Sources of information	Few	Many
Number of tools involved	Few	Many
Use of IT	Some	Essential
Need for sustainability	May be needed	Essential

Table 1 elaborates on the uniqueness of statistical engineering relative to traditional applied statistics. Traditionally, applied statistics includes applying individual tools to relatively well-defined technical problems.

In many situations, however, problems are complex and not well defined. There are significant political and social challenges, in addition to the technical challenges. Data may come from multiple sources that are inconsistent or even conflicting with one another. There is no single correct statistical method that can address the totality of the problem.

Rather, a novel approach to solution needs to be crafted using various methods in the statistical tool kit, as well

as methods from other disciplines such as computer science or organizational effectiveness. We do not see such examples included in statistics textbooks, nor are they seriously discussed at statistical conferences.

Deepen your understanding

The reason many consider traditional applied statistics more art than science becomes clearer when you consider what it takes to have an effective system:

- **Strategy:** This is where we are going.
- **Tactics:** These are the roadmaps and principles to guide us.
- **Operations:** This is how we will do the work needed to accomplish our objective.

Without all three components, the resulting system is less effective. Up until the late 1980s and early 1990s, traditional applied statistics focused only on the operational component of the system. The strategic and tactical components were developed informally and specific to each problem. As such, it was too often an art form learned from experience with no supporting body of knowledge (BoK) or theory.

In the late 1980s and early 1990s, the strategic piece of the system started to develop in the form of statistical thinking with its critical elements of process, variation and data.[10] This provided a strategy and vision to guide us.

First, understand the process that generated the data and the context for the problem being investigated. Next, identify the sources of variation to understand the process, with the reduction of unwanted variation as the overriding goal.

The limiting aspect of working with only strategic and operational components comes into focus when you encounter large, unstructured complex problems. The goals and objectives are usually clear (strategy), and you have the tools and methods available (operations). But how do you:

- Provide structure to the problem so it can be effectively addressed?
- Create a strategy for how the problem will be addressed? What parts of the problem will be addressed in what order? What is the game plan for attacking each one?

Imagine you're serving in a war. You're ordered to take a certain objective, perhaps a city or island. You have enough well-trained troops, air support, ammunition, material, vehicles and tanks. How will you weave these components into an effective battle plan?

With little or no formal plan (tactics), you charge into the battle. You fight hard, and heroics abound. You stick together, and after some time and great loss of personnel and materials, you prevail and take the objective.

You did so well that you get the chance to do it again. You take the same approach, but you have little systematic evaluation of what you did in the first battle—only faint memories. This time, you lose at a great cost. Is this the way to fight a war?

You should have used the available theory to guide you in the construction and implementation of the tactical plan. You should have implemented the plan and evaluated the results to better develop and execute the plan for the next time and revise the theory as needed.

In traditional applied statistics, there must be a better way to develop tactical plans and methods to connect strategy and operational tools so you increase the effectiveness of your work and continually improve your approaches. Statistical engineering provides this tactical component. The system is thus complete, containing all three components.

Strategic and systems thinking

As problems being addressed become larger and more complex, the need to use strategic thinking and systems thinking becomes greater. Strategic thinking is needed to properly define the goals and objectives of the project and decide how the project will be conducted. Systems thinking is needed to understand how to:

- Fit the processes, people and functions together.
- Improve the processes so that the goals and objectives are attained.
- Fit the tools together to create the desired solution.

In general, the statistics and quality professions have not given adequate attention to each of these items. The term "systems thinking" is paid lip service—sometimes mentioned but rarely used. Strategy is given even less attention.

This isn't surprising. The quality profession has been focused on operational work—the creation and use of tools and methods—with little attention given to strategic and tactical components. This operational view and outlook has served the profession well in the past. But a number of important problems have been overlooked or poorly solved, hurting organizations and reflecting poorly on those involved, as well as the overall profession.

An exclusive focus on the operational view can put the profession at a disadvantage in today's environment of large, unstructured and complex problems that need to be solved with competition from other professionals who want to provide the needed solutions. Strategic and systems thinking can no longer be brushed to the side. It must be addressed today.

Training and BoK

Many say applied statisticians are already solving large, unstructured and complex problems. This is happening to some extent, but questions remain:

Statistical engineering becomes impotent if you do not have **solid statistical methods and people** who can apply them.

1. What theory is used to guide the attack on such problems?
2. What textbooks, chapters or journal articles are used to develop approaches?
3. How are those entering the professions that attack such problems being trained?
4. Are the approaches indeed the best ones to use and pass along?

Usually, people say they rely on their experience, and they mentor those new to the field using past experiences to guide them. Such an approach is inefficient in time and resources, fails to codify and enhance what has been learned, and is difficult to learn and pass on.

What's needed is a BoK with a solid theoretical basis that is continuously refined and improved. Statistical engineering provides a theory to guide the analyst and, over time, develops better strategies, methods and approaches, resulting in a BoK that advances the field and helps others learn the field.

Blend as necessary

Some have incorrectly suggested we want to abandon traditional applied statistics for statistical engineering. As an integral part of statistical practice, applied statistics will always be needed. Not all problems have the breadth and scope of those requiring a statistical engineering approach. Also, statistical engineering becomes impotent if you do not have solid statistical methods and people who can apply them as part of the game plan.

A blend of traditional applied statistics and statistical engineering is appropriate. What the exact mix should be depends on the issue, organization and individuals involved.

The opportunity to work on issues that require statistical engineering often starts with a solution to a problem using the traditional applied statistics approach. Good work provides the license to take on more important problems—those most likely needing statistical engineering to solve. It seems prudent to work toward statistical engineering making up as much of one's work program as possible.

Increasing the effect

Many experienced statisticians have been crafting novel approaches from the parts list of tools for a long time. We have neither invented nor discovered this phenomenon. But there has not been sufficient theory to guide practitioners to apply statistical engineering to these complex challenges, nor has an appropriate BoK been developed via books, journal articles or conferences.

Traditional applied statistics is alive and well; however, it is not sufficient to address big, complex and unsolved problems. Higher-level approaches founded on statistical thinking concepts are required to craft novel solutions. Remember, one size does not fit all, and each problem must be addressed on its own merits—although a well-developed theory and literature on statistical engineering will help practitioners significantly.

Those who use statistical engineering will make a greater positive impact on their organizations. The statistical profession, too, will benefit. Attacking the associated problems that are more important to the organization can help advance the reputation of the individuals involved. QP

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