The Engineering Way of Thinking: Adaptation

By William M. Bulleit, Ph.D., P.E.

In this, the fourth and final column of a series ("The Idea," December 2015; "The Future," January 2016; "An Analysis," February 2016), I ask you to consider the engineering way of thinking (EWT) as a relatively formal way of adapting to a constantly changing environment (in the broad sense) by enabling variation and selection as safely as possible under sometimes significant uncertainty. I will emphasize two sources: *Engineers and Ivory Towers*, by Hardy Cross (1952); and *Adapt: Why Success Always Starts with Failure*, by Tim Harford (2011). Cross is a well-known engineer (think moment distribution) from the mid-20th century, and Harford is an economist today.

Cross understood the EWT even in 1952: "They [engineers] use any fact or theory of science, whatever and however developed, that contributes to their art." He also understood that engineering goes beyond science: "Engineers are not, however, primarily scientists. If they must be classified, they may be considered more humanists than scientists. Those who devote their life to engineering are likely to find themselves in contact with almost every phase of human activity." 21st century engineers need to think more like Cross, recognizing that no matter how specialized our day-to-day engineering becomes, we use heuristics that – when generalized – can be useful in a wide range of endeavors.

The EWT is broad enough to allow engineers to design prototypical systems with relatively low uncertainty, such as engines; non-prototypical systems with high uncertainty, such as buildings subjected to seismic effects; and even vast systems with extreme uncertainty, such as the economic system of the United States. The way we go about implementing the EWT is to enable variation and selection – e.g., developing new designs, and then choosing the best based on failures, which can range from simply not meeting a particular criterion to complete system collapse.

Harford has something to say about this. He describes three principles of adapting, which sound like techniques that engineers have used for decades: first, "try new things, expecting that some will fail"; second, "make failures survivable: create safe spaces for failure or move forward in small steps"; and third, "make sure you know when you've failed, or you will never learn."

From a bird's eye view, these two authors, separated by about 60 years, have both given a fair description of the EWT. Be interested in and learn as much as you can about anything that might improve your day-to-day engineering, but have wide horizons about what you learn, because you never know what you might need. Your practice will present you with problems that require you to enter areas where you have never designed before, and possibly areas where no one has ever designed. The results will be a form of variation.

When structural engineers engage in this kind of variation, they usually become more conservative and try to vary what they have done in the past as little as possible; i.e., "move forward in small steps." We generally have little trouble knowing when our designs have failed due to the nature of our systems – if it deflects too much, it failed; if it collapses, it failed – however, recognizing failure is not so easy for all systems, particularly social systems. Is the "War on Drugs" a failure? Is the Affordable Care Act (ACA) failing? If we pick on the ACA, we can see that it attempts something new, yet does not expect any failures. There is no safe space for failures, and it certainly is not a small step. How can we even tell if it fails? Those who developed it will never admit to any failure. The ACA does not follow any of Harford's three principles of adapting.

It would have been (at least arguably) more consistent with those principles to allow the states to develop healthcare plans of their own, as was already happening. Then there would have been 50 experiments, leading to a range of variation. The steps of change would have been smaller, failures would have been smaller, and comparisons among the states would have better shown which approaches failed, thus allowing selection. Certainly this is not the only alternative, but it would have better followed the EWT for large-scale social systems. Of course, if we were really to follow the EWT, we would use models to choose the paths of variation and other heuristics to help with those decisions. The full EWT has not yet been used for these types of scenarios.

My intention with these four columns is to get more engineers to think more broadly about how their knowledge can and should be used to enhance not only the technological aspects of our world, but also the natural and social aspects. The techniques that engineers use every day can be generalized. Admittedly, some will *not* work for social systems, but then we will just need to develop more techniques. Who in 1950 would have visualized nonlinear finite element analyses that can be used to examine the behavior of a steel building subjected to a suite of ground motions scaled to whatever magnitude the designer needed?

Where can the EWT go if we all choose to put our minds to it? Furthermore, what could we accomplish if we were to start training all individuals to some extent in engineering, much like we already do in areas like English, mathematics, history, and science? In our technological society, the EWT may actually be the most important way of thinking that there is. How else will we properly adapt to a rapidly changing natural and social environment?▪

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