The Cost of Engineering to Society:
Risk to Life, Financial Loss, and/or (Un)intentional Exclusion

Organizer and Presenter:

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Description of Proposed Open Session:

If all goes well with each engineering artifact, its design, fabrication, manufacture/erection, and use contributes to the betterment of society. Ideally, it will perform safely, reliably, and predictably without failure. Also, ideally, it will impose no or minimal risk to life and safety, no financial loss, and no (un)intentional exclusion of competent designers, fabricators, manufacturers, erectors, operators, and maintainers.

Inevitably and sometimes invariably, a variety of failures has occurred. A few failures have been catastrophic. Many were minor. Some failures have recurred; others are chronic. Each failure has cost society lives, money, and/or social growth.

The types of failures have been technical, socio-technical, and/or socio-cultural.

The failure types may have had underlying causes that can be traced to the roots of engineering practice or to decisions made early on in conceptual design of the artifacts.

The underlying causes might have been due to a pervasive philosophy that projects must stay on the "drawing boards" regardless of budget, a lack of using available, pertinent knowledge in design decision making, a culture of exclusion in hiring to certain individuals or permitting certain individuals or companies to perform in leadership roles, etc.

An understanding of the underlying causes of these historical engineering failures will contribute to a better understanding of successes in the history of technology.

The papers for the proposed session will address most/all of the following:

- The type of historical failure related to engineering or a specific engineering field.
- The time period and geographic location and their significance.
- Any underlying causes of the failure.
- The "cost" of technical, socio-technical, and socio-cultural engineering failures to society.
- How and by whom lessons were learned or not.
- How (positive) change was initiated, affected, and reinforced, including how and by whom - or not.
- Whether or not these lessons have affected change, positive or perhaps negative.

Description of My Paper for Proposed Open Session:

Historically, engineers have gained a reputation for striving for economics in design. Sometimes, this is beneficial to society; oftentimes this is not.

In 1956[1], Ralph J. Smith, a professor of electrical engineering at Stanford University, listed ten definitions of engineering, the first dated 1828, the last dated 1941. Five definitions expressly mention the economics of design, two of which are as follows:

> "It would be well if engineering were less generally thought of, and even defined, as the art of constructing. In a certain important sense it is rather the art of not constructing; or, to define it rudely but not inaptly, it is the art of doing that well with one dollar which any bunglar can do with two after a fashion." A.M. Wellington, 1897.[2]

> "Engineering is the science and art of efficient dealing with materials and forces... it involves the most economic design and execution... assuring, when properly performed, the most advantageous combination of accuracy, safety, durability, speed, simplicity, efficiency, and economy possible for the conditions of design and service." J.A.L. Waddell, Frank W. Skinner, and H.B. Wesseman, 1933.[2]

My paper examines the cost of structural engineering on U.S. society from building design failures with a focus on the 1980s. The failures, mostly in high occupancy buildings, stem from the intersection of working under budget constraints and ill-informed design decisions made during conceptual and schematic design without using available, pertinent knowledge from related engineering fields. Many of these failures were catastrophic: disproportionate progressive collapses (i.e., a small, localized failure triggering a global, overall failure). Most of these failures have cost lives and imposed financial losses on society. The failures stem from a lack of understanding of 3-D framing systems with system attributes of continuity, redundancy, alternate load paths, size effects, etc. (from WWII systems definitions used in related fields in engineering). As a result of the catastrophic failures, building code requirements have been changed, but not by embracing 3-D framing systems. Building codes (which have always been minimum criteria) now require a limited number of semi-empirical quantitative assessments of only system properties, such as redundancy. Very few structural engineering textbooks and structural engineering courses address the design of 3-D framing systems. Instead, they continue to focus on 2-D subassemblages, structural members (beams, columns, diagonals), and connections between structural members. As such, in combination with low budgets, the changes in building codes are necessary, but not necessarily sufficient to preclude structural failures.

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1 Smith, Ralph J. (1956). *Engineering as a Career*, First Edition, McGraw-Hill Book Company, Inc., New York, NY, pp. 6-8.

2 See Smith (1956) for citations.