

The evolution of fragility and vulnerability: the origin story of a preface

In the primordial soup of engineering creation something was a-churning. The elementary particles of structural life were combining and breaking apart, seeking equilibrium: stresses, forces, and moments; strains, displacements, and rotations; all mixing and matching until the two fundamental letters of safety emerged: C for capacity and D for demand. Let D be lower than C, said the Civil Engineer, and you will experience zero failures. But if D exceeds C, a failure will occur. Build structures from these verification zeros, and the world will be stable and safe. And, the Civil Engineer was happy.

For countless years it was all zeros and ones. Buildings and towers, bridges and domes were built and valiantly stood their ground, yet once in a while the earth shook and more than a few came down. “Maybe I forgot a 1 somewhere in those buildings,” tried to reason the Civil Engineer. But the seed of doubt had now been planted, and it kept digging its roots into the masonry/steel/concrete/wooden shell of the 0 and 1 creations. Through the cracks the little devil of uncertainty snuck in. He had been banging on that shell for a while, shouting to get in, but he was never heard. Now he found the way, and his voice was heard. First as a whisper, then as loud as the howling wind, and the message was as simple and as devious as it gets: there is infinite space between 0 and 1. And, the Civil Engineer was not that happy anymore.

Henceforth, all cannot be black and white, but only different shades of grey, said the Engineer. One needs to pick a light enough shade of grey to call it a white, a zero, perfectly knowing that it is imperfectly so. And one needs to map this for multiple levels of a seismic intensity measure, or IM, seeing the darkness grow as the IM increases. You mean $P(D > C | IM)$, said the little devil of uncertainty. Why not call this fragility, to always remind you of the futility of perfect safety in your 0 and 1 creation? And, the Civil Engineer was positively miffed.

And so it went for many years. The Civil Engineer building structures with zeros and ones, and the little devil keeping him on his toes with unholy fragilities, safety factors, reliability indices and other hellish concepts of probabilistic safety. Every time the Engineer tried to think hard about these, he became dizzy, but he grudgingly acknowledged that his creations no longer failed as frequently as before whenever the earth shook. Yet the Engineer’s troubles were not even close to being finished. The little devil of actuarial capitalism was soon heard banging on the door. He did not care about zeroes, ones or the more than fifty shades of grey between them. What about balance sheets? Losses? Insurance? “Show me the money!” he shouted through his business handset. Tell me how much I stand to lose if the earthquake happens. “You mean $P(\text{Loss} | IM)$,” quipped the ever-present uncertainty devil. Let’s call it vulnerability to make sure that non-Latin languages will struggle to find a term to distinguish it from fragility. And, the Civil Engineer was downright miserable.

Yet, this only brings us to 2021 and it is not the end of this story-- not by far. Little devils come in droves, and every time new seams pop open in the fabric of civil engineering--a few will always try to slip in. We actually seem to have attracted sixteen teams of such little devils in this Special Issue, each one with its own set of ideas on how to increase the Engineer’s woes. Global risk considerations, collapses, aging buildings and bridges, new metrics, soil effects, incidence and directionality, sequences of events, computational limitations, and new models or model mixtures are some of the issues raised. Take a look at them, Dear Reader, and decide for yourself which one is destined to become the next thorn in our Engineer’s side.