INTERNATIONAL AFFAIRS

The Structural Network

By Amalia Safran '13 and Chris Larkin

Professor Dan Frangopol (left) with Professor Konrad Bergmeister, of the University of Natural Resources and Life Sciences in Austria, at the IALCCE conference that they co-chaired in 2012.

When it comes to building and maintaining bridges and other infrastructure with inherent resilience and long-term societal value, Professor Dan Frangopol (http://www.lehigh.edu/~dmf206/index.html) is a leader in more than one sense.

The first holder of Lehigh University's Fazlur Rahman Khan Endowed Chair of Structural Engineering and Architecture (http://www.lehigh.edu/~infrk/chair.html), Frangopol is a recognized international researcher in structural systems and networks, specifically in life-cycle performance, maintenance, reliability and multi-criteria optimization. With more than 40 years in the field, his contributions, according to the American Society of Civil Engineers (ASCE) "have defined much of the practice around design specifications, management methods, and optimization approaches." Moreover, his work "has not only saved time and money, but very likely also saved lives."

Among his most important contributions, however, is a different type of infrastructure—intellectual networks that link the brightest structural engineering minds from all over the world and help guide the development of more sustainable, resilient structural systems.

Frangopol has played a leading role in building an interconnected set of professional networks that drive collaboration around some of his field's most vexing issues. These networks, formalized through international associations that regularly meet and publish cutting-edge research, support the sharing of crucial information across the global structural research community.

"Over time, new concepts introduced into our field profoundly reshape our thinking and approaches," Frangopol explains. "As a research community, we've been moving in the direction of 'sustainability' before the term entered the popular lexicon. At each step, it is critical to support these conceptual shifts with professional networks that integrate expertise and form the basis of wider-scale understanding and application."

The evolving themes of these professional networks follow the development of the field. In 1999 Frangopol helped create the International Association for Bridge Maintenance and Safety (IABMAS (http://www.iabmas.org/)) and became its founding president. IABMAS encompasses all aspects of bridge maintenance, safety and management—from bridge repair, rehabilitation and safety to issues of cost, risk and other economic implications. Its 1,100 individual members and 90 collective members from 55 countries meet regularly, with international conferences occurring every two years. Thus far, Spain, Japan, Portugal, South Korea, the U.S. and Italy have hosted the event, with the next two conferences slated for China in 2014 (http://www.iabmas2014.org/) and Brazil in 2016.

Over the last decade, the field had advanced further, evidenced by the birth of the International Association for Life-Cycle Civil Engineering (IALCCE (http://www.ialcce.org/)), with about 350 members from 50 countries and the ASCE's Technical Council on Life-Cycle Performance, Safety, Reliability and Risk of Structural Systems (http://content.seinstitute.org/committees/strucsafety.html). As their names imply, these groups—both of which came together with Frangopol's guidance—seek to incorporate an even more complex set of variables into structural design and decision making. IALCCE has held previous symposia in Italy, Taiwan, and Austria, with the 2014 event to be held in Japan (http://www.ialcce2014.org/).

Frangopol is quick to note that the ongoing vitality of these global organizations is heavily influenced by their in-country working groups. While the worldwide events and publications help set a broad global agenda, active in-country groups, such as those in Portugal (http://www.ascp.pt/) and China (http://iabmas-cg.org/), leverage this knowledge to solve pressing issues "on the ground" in their home communities and provide valuable feedback.

Life-cycle and sustainability of infrastructure

Life-cycle engineering is a relatively new pursuit—one that Frangopol and his students have helped to pioneer. The idea is fairly easy to understand: designers must incorporate all the variables that impact a given structure's viability over time. But in practice, over the average lifespan of structures intended to last for centuries, how can informed decision-making be based upon unknowable changes in demographics and population growth, structure usage levels and environmental impacts, as well as politics and taxation?

"In the most simplistic approach, decision making about the design of a structure is based solely on its initial cost," explains Frangopol. "Yet over time, the total cost of keeping the structure maintained and safe may be much larger than the initial cost. Especially in emerging economies throughout the world, this has posed a problem. If minimum initial cost is the sole consideration, what happens when these structures start to deteriorate, all at once and in a relatively short timeframe?

"The design, maintenance and repair costs have to be considered together, using life-cycle engineering," he continues. "Decisions regarding all requirements have to be based on what we call 'multi-criteria optimization under uncertainty. In this way, we can balance conflicting objectives such as structural performance and cost."

According to Frangopol, life-cycle engineering is inextricably linked to sustainability. "Along with the physical properties of a given structure and the intensity of the activity it supports, there are economic issues, political issues and social issues that impact its long-term viability. Our goal is to integrate these

into a cohesive picture and allow for the best possible decisions to be made at the outset—long before unsatisfactory conditions occur."

Frangopol's research team and students simulate various conditions and quantify the probabilities of various outcomes in Lehigh's Computational Laboratory for Life-Cycle Structural Engineering (http://www.atlss.lehigh.edu/index.php/facilities/life-cycle-engineering). They can accurately optimize, predict and assess the performance of a given structural system or network of structures over their service life.

At Lehigh, Frangopol leverages this broad network of structural engineering expertise via the annual Fazlur Rahman Khan Distinguished Lecture Series (http://www.lehigh.edu/~infrk/). The series invites renowned researchers, engineers and architects to campus to discuss state-of-the-art approaches to structural engineering and architecture.

"I'd imagine any professor hopes that their research and the ongoing success of their students can contribute to society's well-being over the long run," Dan concludes. "Integrating and elevating the work of talented minds across the globe has the potential to contribute more than any one project or researcher ever could."

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