LEHIGH UNIVERSITY

Civil and Environmental Engineering

# Frangopol Takes the Long View on Civil and Marine Infrastructure

The philosophy behind life-cycle engineering holds that the best decisions are those that maximize the benefits of investments over the entire life of a structure or infrastructure system while adequately serving the needs of our society. This is accomplished by selecting the optimum balance among multiple requirements including safety, serviceability, economy, resiliency, and sustainability despite imperfect information and knowledge.

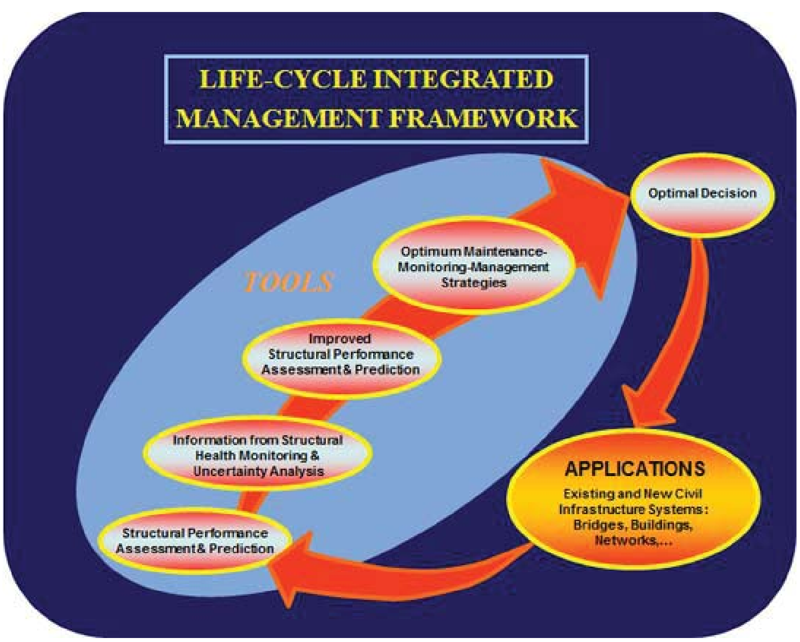
In other words, "How do we encourage policy makers and the engineering community to take the long view rather than focus on the upfront sticker price?"

Last fall, Dan M. Frangopol, the Fazlur R. Khan Endowed Chair of Structural Engineering and Architecture, posed this question to fellow educators and industry leaders in civil engineering at the American Society of Civil Engineers' (ASCE) annual convention in New York City, where he was asked to deal with this critically important area within civil engineering. That same question has propelled him to the forefront of life-cycle engineering and inspired more and more civil engineers to follow in his path.

Life-cycle engineering is a broad area of research that Frangopol started studying while writing the paper "Life-Cycle Cost Design of Deteriorating Structures." Published in 1997 in the ASCE's Journal of Structural Engineering, and co-authored by two of his former Ph.D. advisees, Kai-Yung Lin and Allen C. Estes, the paper addressed the issue of the civil engineering industry's short-sightedness when it came to weighing costs and benefits.

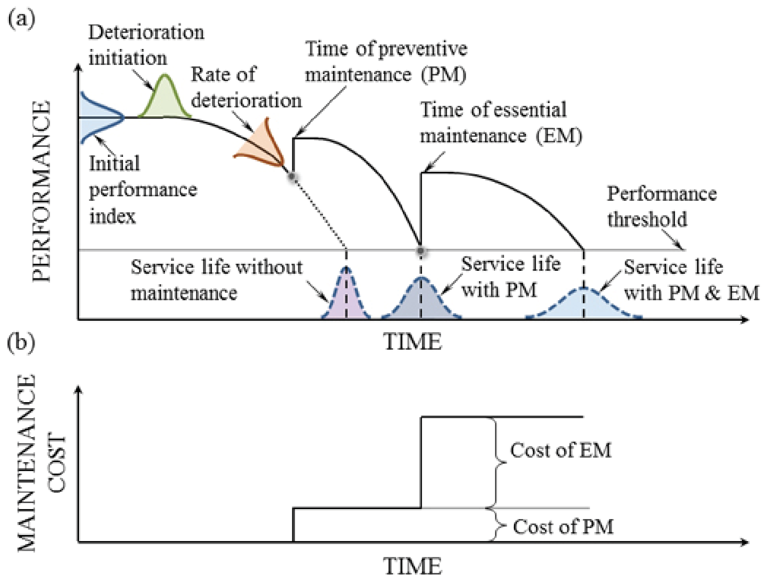
"People at the time weren't realizing that they could make investments and decisions that minimized the cost over the time horizon of a structure or infrastructure system," Frangopol says. Cost, in this sense, doesn't just include how much must be spent to create something, but also to inspect it, maintain it, repair it, replace it, and deal with factors like natural and man-made hazards and climate change, factors which themselves change over time and are highly uncertain. "The goal should be to minimize the price and maximize the performance over the entirety of that time horizon, and we as civil engineers have been moving in that direction."

A civil engineer following the models and methodologies developed by Frangopol must consider many factors before making the most informed decision regarding the life-cycle management of deteriorating structures under uncertainty. Environmental impact, social and political implications, recovery after disasters, time, and availability of resources are among them. Through probabilistic modeling and analysis, the engineer assesses uncertainties and, through computer simulation, finds the optimum solution. When successfully carried out, these optimum life-cycle management solutions can save money, time, and even lives.




*Lehigh Professor Dan Frangopol and two of his Ph.D. advisees have contributed to solve the Grand Challenge of the American Society of Civil Engineers, the nation's oldest engineering society, which represents more than 150,000 civil engineers.*

*Frangopol's life-cycle integrated management model for civil infrastructure systems*




*Deterioration and maintenance effects on performance and cost*

Additionally, civil engineers have to deal with risk concepts, which take into account both the probability and the consequences of failure. The decision-maker's risk attitude can have a great effect on the life-cycle optimization results. For bridges, decision-makers must decide how much material aging, traffic load increasing, and environmentally driven deteriorating they are willing to tolerate before it is time to dedicate financial resources for an improvement. In determining optimal intervention types and times, critical parameters include the effect of deterioration on bridge safety, bridge importance, traffic flow, cost of interventions, and failure consequences, among others.

Since Frangopol first published on the subject, he has witnessed a significant growth in the community studying life-cycle engineering of civil and marine infrastructure. "Ultimately, life-cycle engineering is about more than us," he says. "We're trying to optimize our world for future generations, too, and as a community, it's becoming more and more of a priority, especially in the last few years."

Last fall, the ASCE asked Frangopol to help lead efforts to solve its Grand Challenge: significantly enhance the performance and value of infrastructure projects over their life cycles, reducing the life-cycle cost of infrastructure by 50 percent by 2025, and fostering the optimization of infrastructure investments for society. This leading professional organization with more than 150,000 civil engineers also recently bestowed upon Frangopol its prestigious OPAL Award for Lifetime Achievement in Civil Engineering Education.

Frangopol has performed research and served as Principal Investigator (PI) in many projects sponsored by the National Science Foundation (NSF), Army (ARDEC), Navy (ONR), Department of Transportation (FHWA), and NASA, among others. His latest research funding as a sole PI came in the form of a three-year, $474K NSF grant for a proposal titled "Life-Cycle Management of Civil Infrastructure Considering Risk and Sustainability".

Because of climate change's effects on everything from Beijing's air quality problems to Venice's rising sea levels, the life-cycle design and management of structures and infrastructure systems, both new and old, must take into account rapidly changing, often irreversible environmental conditions. Frangopol's research for NSF will investigate coastal structures in three different American regions – the Northeast, the Gulf Coast, and the Pacific Coast. As air and water temperatures rise and hurricanes increase in both frequency and intensity, buildings and bridges in these areas will face more uncertainty than ever, and they are but one small segment of our country's and our world's civil infrastructure. Frangopol's research will create a risk- and sustainability-based framework capable of optimizing the performance and life-cycle of civil infrastructure systems under climate change and other threats, taking into account conflicting budgetary and safety constraints.

With more and more civil engineers following Frangopol's lead in thinking about these problems in their totality, the industry will continue to adapt and make the smartest, safest, and best decisions possible.

*—John Gilpatrick*
*May 26, 2016*

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