Flexible engineering design for infrastructure projects

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For nearly 50 years, Richard de Neufville has been working on ways to plan, analyze and design complex engineering systems. A civil engineer by background, de Neufville's latest research focuses on a major paradigm shift in engineering in general.

To be successful, today's engineering projects require intentionally designing systems for a range of possibilities. "It is a major change from the way people think of the standard way of engineering design," says de Neufville of the traditional manner of designing a project to service a prescribed set of specifications.

In contrast, the "flexibility in engineering design" (FIED) mindset requires that the system be designed to needs and opportunities that exist over time. "You want to create a system that can adapt to the actual demands occurring at different points of time over its lifetime," Neufville says. Regardless of its application, FIED is an engineering design concept that can—and is—applied to a wide range of fields and problems.

"Flexibility in Engineering Design" is also the title of the textbook co-authored by de Neufville and Stefan Scholtes of the Cambridge University. In it, the authors describe and apply FIED concepts to all sorts of engineering systems, i.e. any complex physical arrangement of different parts performing different functions that have to perform reliably, effectively, and efficiently over time. Examples range from automobiles, highway networks, and aircraft systems to communication satellites and petroleum drilling and refinement.

Three-pronged approach to creating value

De Neufville explains that the FIED concept increases the value of an engineering project in three ways. First, it reduces the possibility of a loss by not creating an over-sized system in the first place. Secondly, by adding to it or changing the capabilities, the design can take advantage of new opportunities. Third, the initial cost is typically smaller. Together, de Neufville suggests that these benefits can lead to a 25-30 percent improvement in a project's expected value.

A real-life industrial application of FIED involves de Neufville's recent partnership with a company to design a major set of oil platforms. Typically, de Neufville's group collaborates with industry domain experts tasked with a particular problem or engineering need. The usual engineering approach would be to build to the midpoint of a range of capacity possibilities, the "most-likely" scenario. "This means that the actual design is almost always too large or small for the actual situation," de Neufville explains. Instead, de Neufville and his students engineered a modular system, bringing together smaller platforms, often separated by many miles.

"These platforms are tied in with connections that allow them to be operated very flexibly in terms of what goes where and how," he adds. "The company we worked with estimated this type of design would improve expected lifetime values by almost 80 percent."

Over the course of his long career, de Neufville has worked with a number of major innovative projects. The development of the Sydney, Australia, airport system is one example. There, the team transformed the design concept from one of simply building a large new airport to a strategy of acquiring a site for a possible large airport for if, and when, it might be needed. This approach saved the government from a large, premature expense while enabling future construction of a facility suited to what the future might actually bring. As of 2014, the government decided to exercise this option and take advantage of this flexible system design.

Whatever the project, de Neufville's goal is to work with industry partners to provide a holistic, complete approach to the engineering need. Each unique experience provides insight into the next project that by extension can be useful for other companies and other activities in that field.

Major infrastructure challenges

With his background in civil engineering, de Neufville is particularly drawn to projects involving major public infrastructure developments. He refers to the many major public/private industrially-led developments of ports, highways, and water resource systems as key examples. Working with other MIT colleagues, de Neufville has been involved with developers in India, Portugal, Morocco, China, and Singapore to engineer some of these projects.

As a professor both of engineering systems and civil and environmental engineering, de Neufville has a particular interest in airport systems planning and design. He has been associated with major airport projects "on every continent except Antarctica."

Going forward, de Neufville sees enormous potential for FIED concepts to improve global engineering projects, such as developing subway systems in Brazil, water resources desalination plants in the Persian Gulf, or defense systems because technologies and threats change rapidly.

Keeping it real and in context

For 25 years, de Neufville chaired MIT's Technology and Policy Program, a program that focuses on understanding the embedded policy context, legal environment, and economics surrounding any technological product and project. "We can benefit enormously from having a strategic view of what we are doing, not just thinking about what the problems are today but what they may be in future and how we should position ourselves for it," says de Neufville, who also considers the larger societal need or requirement when working on a project. "The proper design of engineering systems has to consciously involve the social, environmental, and economic context of the situation. Absent that we can design wonderful artifacts that may be in fact great failures."

Ultimately, the role of engineering design, in de Neufville's perspective, is to provide good value for money. "We need to understand that value is not something intrinsic in the artifact, in the cleverness of the design. Value resides in the context of the users as individuals, groups, as societies."

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