ADAPTING ENGINEERING FOR CLIMATE CHANGE

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FOR THE PAST several decades, major investments have been made to reduce carbon emissions from infrastructure systems. Examples include implementing water efficiency programs, diversifying the energy portfolio with renewable energy technologies and constructing LEED-certified buildings, to name a few. However, despite our efforts, scientific evidence demonstrates that the carbon emissions released to date are enough to cause significant climate changes–changes our current systems are not designed to withstand (IPCC).

Currently, Canada's infrastructure sectors, including buildings, transportation, water, energy, and information communication technologies (ICT), are inadequate to meet changing environmental conditions (Birch and Wudrich). These shortfalls have been observed during several extreme weather events across Canada in 2013 alone. As the frequency of climate-related events worsens, engineers must act now to reduce climate risks.

Engineers must design sustainable infrastructure systems that integrate decarbonization alongside adaptive capacity against a spectrum of climate events (Birch & Wudrich). These events include severe, short-term issues such as flash flooding or long-term, gradual changes, including temperature increases and sea-level rise. However, traditional engineering methods rely on historical data to extrapolate future climate information. Due to the potential magnitude and severity of climate change, historical values may no longer be relevant for designing secure and reliable infrastructure. Therefore, to manage the uncertainties of future conditions while balancing socio-economic needs, engineers will need to shift to new ways of approaching infrastructure design.

OPPORTUNITIES AND RISKS OF CLIMATE CHANGE FOR ENGINEERING

Developing sustainable infrastructure presents numerous business opportunities involving the development of a green economy (Royal Academy of Engineering). This is beneficial for engineers and skilled trades whose roles include planning, designing, constructing and maintaining new and existing infrastructure over its life cycle.

On the other side of the coin, failure to adapt may result in a host of professional liabilities. By legislation and tradition, professional engineers are expected to protect the health and safety of the public. Our duties include eliminating risks that can result in the endangerment of the public from myriad hazards, including loss of heat and power, lack of clean water, and destruction of property. Failure to mitigate climate risks could conceivably lead to the revocation of one's professional designation, but also cause legal issues due to negligence. This is evidenced by the increase in climate change litigation cases against owners (and subsequently engineers) (Koval).

However, in a 2012 survey conducted by the Canadian Standards Association, greater than 70 per cent of engineers reported the lack of adequate information and support to address climate change (CSA Group). Failure to integrate future conditions in infrastructure designs due to uncertainties, or "not knowing," is becoming a risky fallback, in particular from a law and ethics perspective. While the scientific community slowly develops complex climate models to populate future climate data, the engineering profession must move forward and attempt to create certainty out of uncertainty. Engineering education and professional development is key to furthering this agenda.

ENGINEERING EDUCATION AND PROFESSIONAL DEVELOPMENT

Typical engineering education revolves around discussing, processing and analyzing information, i.e. facts, theorems and formulas. However, in reality, modern engineering practice is often guided by heuristics. What should be taught when there is a lack of information to disseminate? Technical competence is important; however, engineering employers are more frequently seeking graduates with an arsenal of sought-after *skills*, including analytical thinking, problem solving, self-directed learning and communication.

In the workplace, these skills support problem solving through experience-based learning, guided by senior engineers and industry heuristics. And yet, the intricacy of engineering problems has evolved and, under this current model, we are slated to fall short of our duty and accountability as a profession. We think analytically, but within defined parameters. We are quick to understand and solve a problem of inputs and outputs, but cross-discipline, cross-culture and cross-continent problems do not fit within our often linear approach.

Formal undergraduate education provides the foundational knowledge and exposure to engineering practices, but does not explore the complexities of evolving information, the spaces between black and white, and decision making in changing contexts. Climate change is a problem of this very nature. So, while it may be wildly popular, this is not a question of introducing course content on climate change; this is a matter of equipping engineers with an enhanced engineering skill set—to respond to the epic problems of this century—and those yet-to-be discovered problems of the future. Responding to climate change demands infrastructure and systems that are not only adaptable, but also resilient. The same can be demanded of an engineer's skill set.

SKILLS DEVELOPMENT

First and foremost, engineers must be trained to analyze infrastructure systems holistically through the use of systems thinking. The established paradigm of using a linear, reductionist approach is insufficient to address the systemic risks resulting from climate change. Building systems resilience is paramount compared to sector resilience, as municipal infrastructure rarely operates in isolation. For instance, water distribution systems rely on energy to run pumps and ICT to continuously monitor operational functionality. Therefore, a failure in one sector during an extreme weather event can result in cascading failures causing rapid increases in economic costs and reducing the productivity of society.

It is clear from the above example that all sectors must be resilient to an equal degree to be a resilient system. Engineers should, therefore, also be skilled in consultation and design integration with multiple disciplines to better understand interdependencies between infrastructure sectors. This will assist in identifying pinch points within systems requiring further analysis.

Once critical infrastructure risks are identified, a vulnerability assessment should be undertaken to understand the impacts of various climate events. Engineers Canada has developed the PIEVC (Public Infrastructure Engineering Vulnerability Committee) protocol (www.pievc.ca/e/doc_list.cfm?dsid=48) to assist in this regard. However, engineers need to be comfortable with ambiguity and the lack of sufficient climate data. Probabilistic modeling and sensitivity studies of complex risk scenarios are examples of how one can alleviate uncertainties. By understanding the potential magnitude and severity of risks, problem areas can then be prioritized.

Understanding tolerance levels for risk will need to be considered to moderate the potential of over-investing in adaptation actions. Engineers will need to be innovative and maximize opportunities to develop all-inclusive solutions to increase adaptation capacity across multiple sectors. This can be through the use of multi-functional infrastructure systems. One such example is a tunnel in Malaysia used as a road under normal conditions, but having a dual-function as a stormwater reservoir under extreme flooding events (Mott MacDonald).

TEACHING METHODS

When it comes to integrating the development of these skills into our undergraduate and professional curricula, there is no need to reinvent the wheel. There are a growing number of programs exploring these concepts in the engineering context (see: University of Cambridge—Engineering for sustainable development, MIT—Systems design and management). Further, we can look to peers in other professions; law and business curricula rely heavily on case-based learning:

"Using a case-based approach engages students in discussion of specific scenarios that resemble or typically are real-world examples. This method is learner-centred with intense interaction between participants as they build their knowledge and work together as a group to examine the case. The instructor's role is that of a facilitator while the students collaboratively analyze and address problems and resolve questions that have no single right answer." (Queen's University)

Case-based learning can be an effective tool in facilitating cross-discipline work efforts and communication, and introduces ambiguity to the problem-solving process.

In the professional development realm, our current approach is relatively unstructured and informal. In other professions, such as dentistry, one can confidently say a dentist is most up to date and informed in state-of-the-art dental practices and technologies. Can a member of the public necessarily say the same about the engineering teams behind our current infrastructure? Implementing more formalized and frequent professional development would be a valuable first step in regularly engaging practising engineers, and in developing and enhancing the broader skill set outlined above.

Open forum, group learning and discussion, much like the nature of the January 13, 2014 panel and group discussion hosted by the Ontario Centre for Engineering and Public Policy (OCEPP), should be recognized as an effective way to promote and develop these skills. Expert guest speakers and case-based learning also support this intent. Conducted outside of the workplace, this approach offers junior and senior professionals an opportunity to collaborate, influence and realign their practising norms–the heuristics–that guide their day-to-day decision making.

Designing a professional development curriculum that encourages continued learning and action is also crucial to effect a transition in engineering professional practice, for example, concluding seminar or workshop sessions with not just a new perspective, but a set of questions or considerations for participants to share with colleagues and reflect upon. This process of reflection and further consideration of concrete actions in the workplace would build the foundation for subsequent professional development sessions and learning. As a whole, this professional development model creates a forum for defining a new normal–one that better reflects the scope and scale of the problems we are facing. Σ

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