PROFILE

# "Big picture" engineering

By Michael Mastromatteo

To uphold their commitment to public safety and protection, engineers might do well to ensure that their best problem-solving efforts come to the attention of policymakers at all levels. By providing a new way of assessing a multi-faceted and complex set of questions, the engineering educator featured here could be moving to the head of the class.

A desire to link policymaking with the engineering profession's emphasis on the greater public good seems to inform the lion's share of Heather MacLean's work at the University of Toronto.

An assistant professor at the university's department of civil engineering, MacLean combines teaching, industry experience, in-depth research and an eclectic approach to problem solving to practise what might be best described as "big picture" engineering.

Since coming to the University of Toronto in 2000, MacLean's work has concentrated on life cycle assessment of today's light-duty vehicles to measure their overall impact on the environment, economy and society at large. It's considered leading-edge research that is designed to assist policymakers and industry leaders in considering automobile design enhancements and regulatory changes that will make best use of existing fuel resources, while paying some heed to greenhouse gas emissions and urban air quality. As well, life-cycle-based analysis is seen as a boon to industry by providing methods to measure the environmental and sustainability worthiness of technology options before millions of research and development dollars are committed to their implementation.

In one sense, MacLean's work helps put a "dollar figure" on new technical processes so that their viability and their true impact on the environment can more accurately be considered.

MacLean is also involved in studies of alternative fuel/propulsion systems to gauge their potential for gaining a share of the market dominated by today's traditional gasoline-powered internal combustion engines.

In addition to research work, MacLean teaches three semester-long courses at the U of T's engineering faculty–Engineering Economics and Decision-making (third year), Engineering Project Management and Financing (fourth year), and a graduate-level course, Evaluating the Sustainability Implications of Engineering Activities.

To suggest that MacLean's research activities are limited to the auto sector would do little justice to the multi-disciplinary approach she takes to engineering, and that she endeavours to impart to her students. Her work in life cycle assessment is aimed at measuring the overall impact of the raw materials extraction, manufacture, use, maintenance and final disposal of today's and potential light-duty vehicles. It considers all the disparate factors that might abet or hinder the development of new technologies, and evaluates them against the environmental, regulatory, health, social and economic ingredients that increasingly compete for space on the public policy platform. And, as a further indicator of her real-world approach, MacLean ensures that consumer habits and preferences always inform her analysis of what will "sell" in the automobile marketplace.

## Systems approach

"My research focuses on developing, applying and evaluating methods and software tools for assessing the environmental, economic and social implications of engineering activities," MacLean says. "This work takes a systems approach and emphasizes the necessity of considering the entire product or project life cycle. Only through an evaluation of the net implications of potential changes, such as the introduction of new technologies to a sector of the economy, can appropriate decisions be made regarding the long-term feasibility and research and development priorities."

MacLean's emphasis on "net implications" speaks well of the engineer's role in assessing the existing environmental, economic and social landscape and making research-based extrapolations on how best to expend limited natural and capital resources. But it also suggests an additional challenge for engineers and educators to ensure that the net implications they project are fully and properly understood. To that end, MacLean's work supports the dynamic, but under-appreciated connection between engineering and more effective public policy and regulation.

A native of Halifax, MacLean graduated from Dalhousie University with a bachelor of (civil) engineering, and followed up with an MBA from St. Mary's University. She obtained her P.Eng. in 1990 from the Association of Professional Engineers of Nova Scotia (APENS).

She initially worked as a project/environmental engineer with the Shaw Group in Halifax, before opting to pursue graduate studies at Carnegie Mellon University in Pittsburgh. There, she earned a joint doctorate from the departments of engineering and public policy, and civil and environmental engineering.

MacLean admits that her interest in linking engineering and public policy was a key factor in her decision to pursue grad-

Heather MacLean, P.Eng., of the civil engineering department of the University of Toronto in a typical "transit" setting. MacLean's work focuses on strategies that will best address the needs of consumers, the auto industry, the economy and the environment.

uate work at Carnegie Mellon University. The school is renowned for its work in such areas as risk management and the environmental impact of products and technological process. To someone with an engineering bent and an appreciation for private industry's particular priorities, MacLean was keen on ensuring that future research work would have practical implications in the policymaking area.

"It's fair to say I've long had an interest in the interaction between technical enhancement and information as it informs public policy and the development of regulations and standards," she says. "Sometimes, the academic world doesn't appreciate business, manufacturing or commercial considerations, and so I try to make my findings relevant and not just an academic concern. I also look to analyze and deliver information on what consumers are looking for."

Her work in life cycle assessment and alternative fuel system research gains additional immediacy given the expectations of sustainability and building a "greener" environment for future generations. Although some progress toward the "greening" of vehicles has been made in the auto sector, more time is required to further improve sustainability issues in this area.

## Weighing the options

As MacLean notes in her research, "None of the currently available or likely available future fuel/technology options for light-duty vehicles dominates in the full range of social or driver concerns. Society will have to evaluate the tradeoffs in attributes among the competing fuel/technology options. Since social and driver goals, and available technology, have changed markedly during the past half-century, we expect that they will change in the next 20 to 30 years, making it difficult to predict the winning fuel/technology in 2030."

Despite this uncertainty, however, MacLean and her research partners do not see the staying power of traditional gasoline and diesel engines in the auto sector as reason for undue environmental angst. She points to ongoing improvements in the performance of traditional engines, coupled with incentives to continue developments of alternative, more environmentally friendly fuel sources, to account for the immediate perseverance of the status quo in the auto sector. "The fact that the current fuel and technology is so hard to displace means that society is getting what it wants at low cost," she says.

It was almost automatic that MacLean's work on life cycle assessment would come to the attention of the AUTO21 Network of Centres of Excellence, a national research initiative supported by the federal government, industry and universities. MacLean recently received a $315,000 grant from AUTO21 to expand life cycle assessment research. She now serves as project leader for the Evolution of Life Cycle Assessments component of AUTO21's societal issues section. The project is aimed at assessing how life cycle assessments are used in the auto industry and how economic, environmental and energy factors impact on the design, use and disposal of today's vehicles.

Peter Frise, P.Eng., chief executive officer of the AUTO21 research network and a former lieutenant-governor appointee to PEO Council, is well aware of MacLean's work in life cycle assessment. He believes MacLean and her AUTO21 partner Edwin Tam, EIT, embody some of the best qualities of the engineering profession by virtue of their "big picture" approach to product and process design.

"Heather's involvement with life cycle analysis, in itself, puts the engineering community in a positive light because of its broad focus," Frise told *Engineering Dimensions*. "Her analysis measures not just the economic cost of an activity, but also the design, manufacturing, environmental, disposal and social implications. It really is a valuable research tool that should benefit the manufacturing industry greatly over the coming years."

Others who have worked with MacLean over the years are quick to point out her practical application of engineering ideals. Professor Lester Lave of the graduate school of industrial administration at Carnegie Mellon University, was MacLean's PhD advisor during her pursuit of the joint doctorate in engineering and public policy. Lave says that in an era of heightened awareness about the overall impact of technology on society, MacLean combines ethical and practical considerations.

## Mindful of social dimension

"Narrow engineers solve the problems posed to them without thinking about the social dimensions," Lave said. "As a result, we can get horrible products or processes that are efficient in a narrow sense, but harm society. Engineers have looked at ethical issues, and many have an iron ring to remind themselves about competence and social commitment. Environment and sustainability go beyond ethics in a narrow sense. When Professor MacLean brings in these additional dimensions, she helps engineers serve society better, putting the profession in a more positive light. Good engineering is looking at the consequences of design and production, not just making something."

Lave said that while the goal of MacLean's research isn't revolutionary, her methods are breaking ground by providing more effective tools for analysis. "This is what Heather is providing, as well as important examples of how to improve the environmental and sustainability implications of important products," Lave added. "Many young people want to serve society. If they see engineering as building monster vehicles that guzzle gasoline or make products that are far from sustainable, they will go into law or some other profession that they think will help society. Her work should get more young people to choose engineering since they can see that it will help make our economy more environmentally friendly and sustainable."

And do MacLean's students feel the same way? Jon Norman, P.Eng., a policy analyst with the Ontario Ministry of Energy, worked under MacLean during his pursuit of a master's degree in civil engineering at the University of Toronto.

"Having worked as a consulting engineer for a number of years, I was quite keen on finding a supervisor who thought outside of a traditional engineering box, which frankly pervades much of engineering practice and its schooling," Norman said. "The research that Heather is spearheading at the U of T embodies a cutting-edge interdisciplinarity that drew my attention immediately. My first meeting with Heather confirmed her commitment to moving away from the traditional, to root out creative solutions to engineering problems." Norman also suggested that MacLean takes pains to keep engineering students focused on "real-world relevance" and social context.

Similarly Don Duval, also studying for a master's degree in civil engineering at the U of T, said the leading-edge component of MacLean's research pervades her approach to mentoring. "Heather's background and continued research interests in life cycle assessment are easily identifiable in her teaching style," Duval said. "She consistently engages her students to look at problems from different perspectives and, in doing so demonstrates the importance of not making decisions until all relevant variables have been considered."

Duval's impressions point back to the "net implications" analogy that MacLean herself uses to describe her work. It's a virtue that MacLean hopes will inspire industry leaders and those with influence in policymaking circles to at least avail themselves of her research.

"It may be true that not all engineering activities improve society, but I've always looked at engineering as a profession that should address society's issues," MacLean said. "And if I hope to emphasize the broader side of engineering, I want to make sure that the results of this work we're doing are as relevant and transparent as possible."