Professor Aminah Robinson Fayek uses fuzzy logic and fuzzy hybrid techniques to capture and model uncertainty in construction, thereby improving workforce and project management.

Why did you choose construction engineering and management as your research area?

I went into engineering as a field of study because I loved mathematics. However, my real passion became evident once I was introduced to the field of construction engineering and management, largely because it is a very dynamic and ever-changing discipline. Additionally, in construction engineering and management we are not only dealing with engineering systems and processes, but also with a significant element of uncertainty arising from the fact that human beings execute projects. The actions, behaviours and decisions of humans are affected by numerous and complex variables, which makes for a very attractive research area.

Could you provide some background information on the fuzzy logic technique you use in your research?

Fuzzy logic has many useful and practical applications in construction, and I have been using it in my research over the past 25 years. The technique can effectively capture expert knowledge and engineering judgement and combine these subjective elements with project data, enabling us to develop approaches to improve construction decision making, performance and productivity.

In construction, fuzzy logic allows us to capture and model uncertainty related to subjectivity and imprecision that we previously could not model. We can effectively model both quantitative and qualitative factors and capitalise on expert knowledge to develop better systems and solutions for construction.

Which key industry challenges are you hoping to address and how?

My team is enabling industry partners to better address issues related to workforce and project management. To facilitate this, we are analysing and modelling construction labour productivity, developing more effective risk assessment and management techniques, and modelling organisational competencies and project performance. We are also looking into optimising fabrication and module yard productivity and scheduling; conducting process improvement studies for power plant shutdowns; exploring how to best structure construction projects and teams; and investigating the career paths of tradespeople.

What do you enjoy most about your work?

One joy of being a researcher is seeing your work put into practice. We are fortunate to have strong industry and federal government support of our research programme that enables us to do so.

Additionally, working with talented graduate students and industry partners is a privilege, both personally and professionally, and is a critical component of our success. The University of Alberta, Canada, fosters and encourages industrial collaboration, making it an ideal place to carry out research in construction engineering and management.

With whom are you collaborating, both nationally and internationally, to ensure your work is diverse and multidisciplinary?

Collaborating directly with partner organisations in the construction industry has been central to the advancement of my research. I work closely with a number of diverse construction organisations, including owners, contractors and labour groups, thereby integrating a multidimensional, holistic perspective that I can apply to issues facing the construction industry as a whole. Because of the multidisciplinary nature of my work, I also collaborate with other academics within construction engineering and management, and in disciplines such as business that complement and add new dimensions to my research. In particular, I collaborate with simulation experts to develop fuzzy hybrid simulation methods and with experts in motivation theory to address motivation in the construction context.

Training future construction leaders is a key objective of your work. How are you passing on your wealth of knowledge in this sector?

I work closely with my students to train them in fuzzy logic modelling techniques, quantitative and qualitative data collection, statistical methods, validation methods, research ethics, project management practices and strategic issues that affect construction performance. The graduate students gain valuable experience by presenting their work at international conferences and to our industry partners, as well as by publishing their work in leading academic and industry journals.

My research has built an important bridge between industry and academia by producing direct, practical, innovative and academically sound applications. These relationships have created opportunities for my students to learn from industry and develop professionalism.

Upon graduation, my students are often hired by collaborating companies, not only because they are now trained in company-specific practices but also because, through their research, they bring innovation to help improve company performance. These students are contributing significantly to the Canadian economy by bringing advanced techniques based on their research to their employers and professional practices.
Building better decision making

At the University of Alberta, Canada, researchers are working alongside diverse organisations in the construction industry and creating hybrid intelligent decision support systems to solve real-world problems.

THE VALUE OF the construction industry in terms of its contribution to society is remarkable. It makes real the places where people live and work, and the transport infrastructure that allows them to reach their destinations.

Because of its inescapable presence, it is not surprising that the construction sector is also a major contributor to economic growth. In Canada, this industry is critical to the national economy, contributing significantly to GDP. According to the United Nations Statistical Division (UNSD’s) national accounts database, Canada has the eighth greatest construction output in 2012, totalling US $131 billion. Building activity impacts all areas of society, and Statistics Canada estimates that for every job that the construction industry creates, three jobs in the general economy will be generated.

The sector, however, faces major challenges to its future growth; economic uncertainty, lower than expected productivity, high project costs and a shortage of skilled workers are all points of concern. These obstacles stem from the inherent high risk and uncertainty—construction relies on humans to make decisions related to project planning, execution and investment, and the expert knowledge required to assess these areas often goes undocumented.

FILLING THE GAP

Dr Aminah Robinson Fayek, Professor in the Department of Civil and Environmental Engineering at the University of Alberta, is researching the use of fuzzy logic and fuzzy hybrid modelling techniques to facilitate intelligent decision making within the construction industry. She is well-positioned to make significant strides in this area and is an expert in the field. In January 2012, she became the Natural Sciences and Engineering Research Council of Canada (NSERC) Senior Industrial Research Chair (IRC) in Strategic Construction Modeling and Delivery.

In her role as chair, Robinson Fayek is creating hybrid intelligent decision-support systems combining fuzzy logic and other modelling techniques, such as, artificial neural networks, genetic algorithms and simulation. “The research has significant potential to change the way in which we model operations and decisions for the construction industry, leading to more accurate and realistic representations of the expert reasoning process and uncertainty involved,” Robinson Fayek explains.

A JOINT EFFORT

The IRC is unique in the way it places collaboration at the heart of its research, bringing together a wide range of stakeholders—owners, contractors, associations and labour unions—to carry out studies that develop solutions for key industry problems. “Many of these parties are direct competitors or have opposing interests in the construction industry,” Robinson Fayek comments. “The multiple and diverse perspectives of our partners enable us to carry out truly innovative research, important to all parties, with the potential to make a significant impact on the industry as a whole.”

By introducing the latest advancements in artificial intelligence and mathematical modelling techniques, the team hopes to provide its partners with real-time decision support to improve labour productivity and efficiency, reduce risks, create greater certainty in project execution, and develop industry best practices to increase their international competitiveness.

FUZZY LOGIC

Robinson Fayek has been using a mathematical modelling approach known as fuzzy logic in her research for over 25 years. The technique complements the construction industry because it is able to mimic the human decision-making process, as she points out: “Since many processes in construction rely on expert judgment and reasoning, often made in linguistic terms, fuzzy logic is ideally placed to model and solve construction-related problems.”

The techniques employed help overcome two of the biggest challenges for the industry: labour productivity, and risk assessment and management.

REAL-WORLD RELEVANCE

The fuzzy logic technique is especially useful for improving the accuracy of construction models because it takes into account those parts of a project that cannot be measured in certain terms, are subjective, or may not have exact or complete values. For example, worker skill and motivation, the quality of project teams and the quality and comprehensiveness of project practices are intangible and difficult to measure, and therefore are often not taken into consideration. “Models based on fuzzy logic also make the decision-making process more transparent, and allow experts to express themselves in linguistic terms rather than strictly numerically, which better suits their thought processes,” Robinson Fayek adds.

All the models are thoroughly tested and validated. In order for the models to be used as strategic decision-support tools by construction industry professionals, they are translated into user-friendly software forms. For example, one of Robinson Fayek’s fuzzy logic models has been turned into a commercial software product known as SuretyAssist™. The tool helps organisations looking to purchase construction services to evaluate the commercial and corporate capabilities of contractors.
The techniques Robinson Fayek employs also help industry overcome two of its biggest challenges: labour productivity, and risk assessment and management. The former is being addressed by looking at factors that have not been taken into account in the past because of their sheer complexity, such as cooperation between crews and different management styles. “We are currently working on models that can ‘connect the dots’ between these subjectively-assessed factors and productivity,” she states.

In another project, the researchers are studying the second challenge – risk assessment and management – to develop a systematic methodology, model and software tool for analysing risks and opportunities faced by different construction projects. To achieve this, the team is incorporating fuzzy and random variables in a Monte Carlo simulation to model and analyse risks in cases where insufficient data are available to develop probabilistic distributions. They are also using fuzzy logic to enable experts to express risk probability and impact using linguistic terms, and fuzzy arithmetic to calculate risk severity and overall project cost contingency.

**A TOOL FOR ALL**

As Robinson Fayek looks to further her research, she is now exploring two techniques that hold great promise: system dynamics and agent-based modelling. Indeed, she is confident that these techniques make for a powerful combination with fuzzy logic: “The ability to model both the subjective aspects of uncertainty in systems, and the nonlinear nature of the interaction of variables and elements in the systems, can be effectively achieved by combining fuzzy logic with these two approaches”.

Whatever path Robinson Fayek chooses to pursue for the next steps of her research, it is clear that her work will continue to have a far-reaching and influential impact on the construction industry.

**Construction industry applications of fuzzy logic developed by Robinson Fayek and her research group:**

- Assessing contractor commercial and corporate capabilities for prequalification and bonding
- Determining mark-ups for competitive bids
- Detecting performance deviations during construction and identifying appropriate corrective actions
- Analysing the impact of delays on construction projects and updating the schedule
- Determining the magnitude of design cost overruns
- Improving the processes involved in industrial fabrication and modularisation
- Analysing and quantifying risks on major capital projects
- Defining the roles and responsibilities of owners versus contractors on major capital projects
- Evaluating the skills of construction supervisors
- Modelling the factors affecting construction labour productivity to predict and optimise performance on projects
- Modelling both the technical and behavioural competencies of organisations and assessing their impacts on the performance and success of projects