NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

College of Engineering
School of Civil and Environmental Engineering
Risk and Infrastructure Systems Lab

PhD Positions in Structural Reliability and Safety under Climate and Societal Change

About us

We study how buildings and infrastructure behave under uncertainty, how they age, and how society should invest in their safety in light of climate change. Our motivation is to support equitable, robust, and sustainable decision-making for the built environment by linking engineering models, socioeconomic trajectories, and risk-based assessments to guide intergenerational infrastructure management policies. The research is organized into three streams:

1. **Reliability and robustness**. We investigate how structures respond when damaged, how failures spread, and how we can design systems that continue to function under extreme loading.
2. **Risk acceptance and safety**. We study how societal values, demographics, and climate change influence acceptable levels of safety, and how these insights can inform future design standards.
3. **Risk-informed decision-making**. We analyse how individuals, organisations, and policymakers make safety-related decisions under uncertainty, and how we can incentivise favourable behaviour.

The Risk and Infrastructure Systems Lab will be established at the School of Civil and Environmental Engineering at Nanyang Technological University (NTU) in July 2026. The lab will be led by Dr. Alex Sixie Cao, who will join NTU as an Assistant Professor from his current position as a Postdoctoral Researcher at Empa and ETH Zurich in Switzerland. We offer an ambitious, supportive, and intellectually stimulating international research environment at the intersection of structural mechanics, probabilistic modelling, and societal decision-making with a global network of collaborators.

Position details

The positions are fully funded full-time PhD scholarships with a typical duration of four years, starting in August 2026 at the NTU in Singapore. All candidates must meet the Admission Requirements and will be supervised by Dr. Alex Sixie Cao. Good written and spoken English proficiency is required.

How to apply

Send your application to rislab@alexcao.org with the subject line: *PhD application* | *Your Name* | *Topic*. The topics are described on the following pages. Your application should include:

1. Motivation letter (1 page) explaining:
   (a) Why you are interested in this specific topic.
   (b) How your current knowledge and experience are relevant to the topic and to a PhD.
   (c) What methods or concepts you hope to use or learn during the PhD.
   (d) Why you are interested in this position at NTU and in this research environment.

   Please avoid generic phrases and AI-generated content. We are interested in your personal ideas, experiences, motivations, and your potential to conduct impact- and meaningful research.
2. Curriculum Vitae.
3. Academic transcripts (from all university degrees).
4. Contact information of two referees (letters may be requested at a later stage).

1 PhD in Reliability and Robustness of Structural and Infrastructure Systems

1.1 Topic description

Buildings and infrastructure networks are complex systems whose safety depends not only on the reliability of individual components, but on how the individual components interact and propagate failure that emerges in the global system behaviour. This project aims to advance the understanding of system reliability and robustness in buildings and infrastructure networks and how they respond to perturbations. Using hierarchical probabilistic models, network and graph theory, and computational methods inspired by percolation and contagion processes, the project will investigate how initial damage, redundancy, segmentation, and spatial organisation influence the likelihood and extent of progressive collapse and how robustness can be measured in ways that remain meaningful across scales and different types of infrastructure.

The PhD student will develop and analyse probabilistic models for structural and infrastructure systems under uncertainty, leveraging concepts such as entropy-based robustness indices, conditional failure propagation, and multi-scale system representations. The work will involve computational modelling, numerical simulation, and the development of efficient algorithms to quantify global reliability and identify tipping points between local and systemic failure regimes. Applications will range from building structures to generic networked systems, providing broad methodological training and contributing to the development of rational, performance-based strategies for robustness in the built environment.

1.2 Candidate profile

Candidates should be motivated to understand how complex structural and infrastructure systems behave under uncertainty and how damage and failures propagate across scales.

Essential qualifications:

1. Background in structural engineering, civil engineering, or another related quantitative field.
2. Proficiency in Python or a similar programming language for numerical and probabilistic modelling.
3. Good understanding of structural behaviour and mechanics.

Additional strengths:

1. Basic knowledge in uncertainty quantification, reliability, or probabilistic modelling.
2. Interest in network or graph theory, system level modelling, or progressive collapse.
3. Experience with numerical simulation or algorithmic modelling in Python.

2 PhD in Structural Safety in Light of Climate Change, Societal Changes, and Geopolitical Developments

2.1 Topic description

Climate change, societal changes, and geopolitical developments introduce significant uncertainties that challenge how structural safety should be defined, justified, and allocated in an equitable and resource-efficient manner. Current practice often relies on a break-even condition between marginal benefits and marginal costs, which serves only as a lower bound on acceptable safety and implicitly assumes idealised market behaviour rather than an actual optimum. This project will investigate how safety and management strategies can instead be formulated as an optimisation problem of an expected utility, where costs, benefits, climate impacts, resource consumption, and societal welfare are expressed in a consistent way that remains meaningful across future climate and socioeconomic pathways.

The PhD student will extend and investigate decision-theoretic and utility-based approaches to determine an optimality criterion for the safety and management of infrastructure under uncertain future conditions. This includes combining structural safety with management strategies and scenario-based representations of demographics, economic development, equity considerations, and the spatio-temporal allocation of resources, while allowing for different assumptions about discounting, design lifetimes, management options, and societal preferences. The objective is to identify safety and management policies that are rational, equitable, and responsible across a wide range of plausible futures, and to examine how these optima change with evolving climate, societal priorities, and policy choices. The resulting framework will support long-term safety targets and management policies and inform future decision-making for the built environment.

2.2 Candidate profile

Candidates should be motivated to explore how climate change, demographics, economics, and resource use shape rational and equitable safety and management strategies of the built environment.

Essential qualifications:

1. Background in structural or civil engineering or another quantitative field, such as applied mathematics, economics, operations research, or data science.
2. Proficiency in Python or a similar programming language for modelling, data analysis, or numerical calculations.
3. Ability to interpret probabilistic concepts and engage with simple optimisation problems.

Additional strengths:

1. Interest in structural safety, climate change, resource allocation, or decision analysis.
2. Familiarity with concepts such as discounting, utility theory, or risk-related concepts.
3. Curiosity about integrating engineering models with societal, economic, or ethical considerations.

3 PhD in Decision-Making and Emergent Behaviour for Structural Safety

3.1 Topic description

Conventional approaches to structural safety often assume a representative and perfectly rational decision maker. In reality, safety-related decisions are made by many different actors who vary in resources, objectives, information, and risk perceptions. Individuals respond to uncertainty in diverse ways and may rely on simplified rules, incomplete information, or heuristics that are neither fully rational nor irrational. This project will investigate how such heterogeneity shapes safety outcomes in the built environment and how local decisions can accumulate into emergent, system-wide patterns as climate and societal conditions evolve.

The PhD student will explore and extend decision-theoretic, behavioural, and agent-based approaches to model how different stakeholders form beliefs, learn from experience, and respond to incentives and uncertainty. This includes representing diverse preferences and constraints, incorporating adaptive and exploratory behaviour, and analysing how interactions among individuals lead to collective outcomes that cannot be understood through representative-agent models alone. The objective is to identify when certain behaviours emerge, how they influence long-term safety and investment patterns, and which policy or regulatory strategies can steer the system towards desirable outcomes. The resulting framework will support virtual policy testing and inform decision-making for structural safety in complex and dynamic societal settings.

3.2 Candidate profile

Candidates should be motivated to study how diverse stakeholders make decisions under uncertainty and how their interactions give rise to emergent behaviour affecting outcomes in the built environment.

Essential qualifications:

1. Background in engineering, applied mathematics, computer science, economics, or another quantitative discipline.
2. Proficiency in Python or a similar programming language and interest in computational or simulation-based modelling.
3. Openness to work with behavioural, decision-making, and uncertainty-related concepts.

Additional strengths:

1. Interest in agent-based modelling, game theory, complexity science, or behavioural decision-making.
2. Familiarity with utility-based models, incentives, or adaptive and heterogenous agents.
3. Curiosity about how individual decisions emerge into collective outcomes.