Chemeca2026
Innovate. Integrate. Impact.
28 – 30 September 2026
Melbourne, Australia

Hazards
Australasia 2026

Chemeca 2026 and Hazards Australasia
28 – 30 September, Melbourne, Australia

Modelling Spatiotemporal Risk Evolution in Complex Systems: A Physics-Inspired Perspective

Md Tanjin Amin [a], Rouzbeh Abbassi [b], Vikram Garaniya [a], Nitish Verma [c,d], and Faisal Khan [c]

[a]Department of Chemical and Environmental Engineering, RMIT University, Melbourne, VIC 3000, Australia

[b]School of Engineering, Faculty of Science and Engineering, Macquarie University, Sydney, NSW 2109, Australia

[c]Mary Kay O'Connor Process Safety Center, Artie McFerrin Department of Chemical Engineering Texas A&M University, College Station, Texas 77843-3122, USA

[d]Department of Chemical Engineering, Indian Institute of Technology Kanpur, Kanpur, UP, India

Preseneter email id: md.tanjin.amin@rmit.edu.au

ABSTRACT

Conventional risk analysis (RA) approaches commonly represent risk through discrete scenarios and event chains. While these methods provide structured insights into potential failure pathways, they have limited capability to represent how risk evolves simultaneously across space and time within complex engineered systems. In practice, risk assessment has long been recognized as combining analytical rigor with expert judgment, reflecting its dual character as both a science and an art. Motivated by this perspective and by the limitations of existing static or scenario-based approaches, this study proposes a physics-inspired conceptual framework to model the spatiotemporal evolution of risk in complex systems.

The framework treats risk as a distributed system-level state variable and describes its evolution using a balance-law formulation analogous to transport phenomena in chemical engineering. Within this formulation, risk density evolves through mechanisms conceptually similar to advection, diffusion, and source-sink processes. These mechanisms are governed by a risk velocity field and a risk potential that aggregates key drivers of risk, including hazard intensity, exposure, vulnerability, and system connectivity. The resulting formulation enables the representation of how risk is generated, transported, accumulated, and mitigated across interconnected system components over time.

To demonstrate the conceptual behavior of the framework, an illustrative corridor case study is presented in which a hazardous release propagates toward an occupied control room. The example evaluates several response scenarios involving different combinations of detection, isolation, and evacuation actions. The results show how the proposed model captures the propagation of risk density from the source to downstream locations and highlights the critical influence of intervention timing and mitigation effectiveness. Early detection and source isolation significantly reduce the spatial extent and duration of elevated risk, whereas evacuation primarily reduces exposure without altering the underlying propagation of risk

through the system.

The proposed framework provides a unified mathematical structure capable of simultaneously representing temporal evolution, spatial propagation, event-driven changes, and uncertainty within a single modeling approach. Unlike traditional logic-based risk assessment methods that integrate risk properties separately through analyst interpretation, this formulation governs their interaction through a continuous spatiotemporal model. Although further work is needed to address parameter estimation and practical implementation challenges, the framework offers a promising foundation for next-generation dynamic risk analysis. Such approaches may support real-time, spatially aware risk management in complex industrial systems, including emerging energy infrastructures such as hydrogen facilities and battery energy storage systems.

KEY WORDS

Dynamic risk analysis, physics-inspired modeling, risk evolution, spatiotemporal risk analysis.

BIOGRAPHY

Include a short biographical (100 words) for the presenting author

Dr. Tanjin Amin is a Lecturer in Chemical and Environmental Engineering at RMIT University. His research focuses on process systems engineering and system safety, developing advanced methods for safety analysis, monitoring, and risk management in complex industrial and emerging energy systems, including hydrogen, ammonia, battery technologies, and carbon capture systems. Prior to joining RMIT, he served as a Postdoctoral Researcher and Visiting Lecturer at Texas A&M University. Dr. Amin has co-authored more than 30 peer-reviewed publications and has collaborated with industry and regulatory organisations such as ABS, API, and CCPS to translate research into practical safety solutions.

CONFERENCE PROGRAM

Please indicate which conference program your abstract relates to:

☑ Hazards Australasia

☑ Chemeca