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**DEVELOPMENT OF A RESILIENCE MODEL AND
TOOL FOR RESILIENCE OPTIMIZATION FOR
INTERDEPENDENT CRITICAL INFRASTRUCTURE**

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Doctor of Philosophy (PhD)

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Thesis submitted in partial fulfillment of the requirements for the degree

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March 2025

DECLARATION

I declare that this is my own work, and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

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The above candidate has carried out research for the PhD thesis under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Dr. Varuna Adikariwattage

Signature of the Supervisor:

Date: 29/09/2025

DEDICATION

This thesis is dedicated to the resilient and hardworking people of Sri Lanka at every level, from those who clean our streets to the highest-level professionals, whose relentless efforts and sacrifices form the backbone of our society. To the people, whose sweat drives our economy, your contributions are invaluable. Despite the many hardships you face, your unwavering commitment to paying taxes sustains the free education system that has empowered countless individuals, including myself, to pursue our dreams. I am deeply indebted to the system of free education, a beacon of hope and opportunity that reflects the power of collective investment in our nation's future. It stands as a testament to the belief that every child, regardless of their background, deserves the chance to learn, grow, and succeed.

To the dedicated teachers who have guided and nurtured me since grade one, your unwavering dedication, wisdom, and encouragement have been instrumental in shaping my journey. Your impact extends far beyond the classroom, and for this, I am profoundly grateful.

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ABSTRACT

Critical Infrastructures (CIs) are highly interdependent systems making them vulnerable to cascading failures during disruptions. The resilience assessment of CIs has become a crucial aspect at present yet challenging due to the interdependencies that drive their systematic behaviour, compounded by their dynamic nature. This thesis aims to bridge this gap by developing a comprehensive resilience assessment model for CIs, which incorporates the complexities of interdependencies through the application of Dynamic Bayesian Networks (DBN) and Machine Learning (ML) techniques. The study begins with a systematic review of CI resilience literature, including definitions, interdependencies, climate change impacts, modelling techniques, and resilience frameworks. The study also identifies eight governance measures to enhance the resilience of CIs. Moreover, Climate Change Adaptation (CCA) measures for enhancing resilience of CIs are prioritised based on different stages of infrastructure cycle, using the Analytical Hierarchical Process (AHP), with an expert survey. Then, a systematic literature review and expert survey were conducted to identify and validate the resilience assessment parameters. Then, a novel methodology to quantify the resilience of the CI system, accounting for both the interdependencies of CIs and the dynamic nature of their capacities, is proposed utilising the DBN. A case study from Sri Lanka demonstrated the DBN model's practical applicability, showing strong agreement with expert assessments. Simulation data generated from the DBN model was used to train and validate six ML algorithms, resulting in a robust resilience prediction tool. SHAP analysis was used to interpret ML outcomes and highlight key drivers of resilience. It further validates the research output identified in the early stages of the present study. The outcomes of this study can be used as a foundation for developing a resilience optimisation tool. It provides actionable insights for policymakers and infrastructure managers, offering a validated, transferable tool to strengthen CI resilience across diverse contexts.

Keywords: Machine Learning; Climate Change Adaptation; Resilience assessment; Critical Infrastructure; Disaster Risk Reduction; Disasters; Climate Change; Dynamic Bayesian Network

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ABBREVIATIONS

- CI : Critical Infrastructure
- CCA : Climate Change Adaptation
- DRR : Disaster Risk Reduction
- GHG : Green House Gas
- IPCC : Intergovernmental Panel on Climate Change
- PACC : Paris Agreement on Climate Change
- SFDRR: Sendai Framework for Disaster Risk Reduction
- SDGs : Sustainable Development Goals
- CIN : Consistency Index
- RI : Random Consistency Index
- CR : Consensus Ratio
- CPT : Conditional Probability Tables
- BN : Bayesian Network
- DBN: Dynamic Bayesian Network