

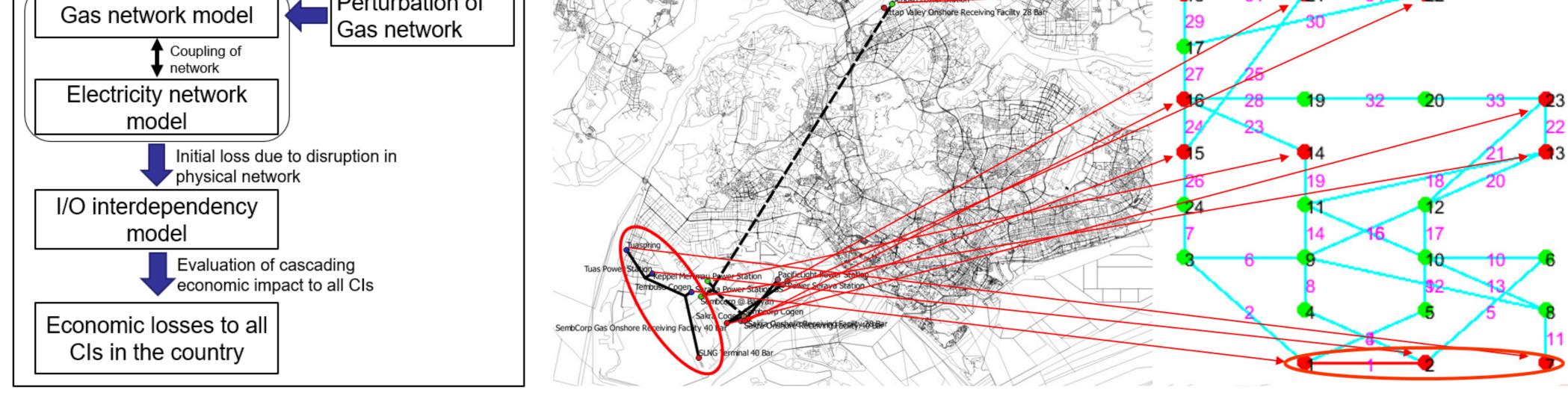
Institute of Catastrophe **Risk Management**

Modelling of Multi-Sectoral Critical Infrastructure Interdependencies for Vulnerability Analysis

- Critical infrastructures (CIs) are increasingly closely linked and interdependent on one another.
- With increasing investment and coupling complexity, limitations and vulnerabilities of coupled networks are becoming increasingly vital in their operational planning, with a prime example being that of coupled gas and electricity networks.

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• The objectives of this work are (1) model the coupling of realistic multi-sectoral physical infrastructures, specifically gas and electricity physical infrastructure networks with open-source data, and (2) simulate the cascading failure of the two infrastructure networks with a further evaluation of cascading national economic impact using a recently developed CI interdependency input-output (I/O) model based on national-level I/O tables[1,2].



Flow of cascading failure analysis

Simulating disruption on Singapore gas network with IEEE 24 bus network (as model of Singapore's electricity grid)

Methodology:

- An integrated formulation for the steady-state analysis of the gas (general flow model) and electricity (DC power flow model) infrastructure systems, coupled as based on a power rating ranking of the power stations is developed towards the quantifying the effect of disruptions (e.g. gas source failure in the gas network) to both networks.
- The CI I/O interdependency model evaluates the overall economic losses to all CIs based on the initial loss due to disruption in the coupled infrastructure systems.

Results and Summary:

• This developed framework allows the evaluation of the cascading impact of the known multiple critical infrastructure sectors in a country.

Perturbation of

• The I/O interdependency model provides insight on the economic

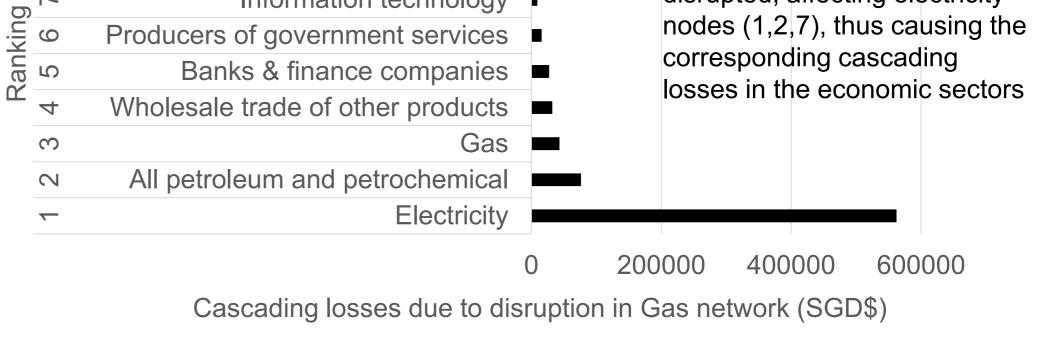
Top 10 sectors with highest cascading losses ($\Delta X - \Delta F$)

General & other insurance	10
Real estate	0
Other business & technical services	\odot
Information technology	\sim
Producers of government services	(0

Gas nodes (8,9,10) are being disrupted, affecting electricity nodes (1,2,7), thus causing the

impact on a country when a disruption on CI(s) happens, taking into account the interdependency of CIs as based on data from national I/O tables.

• Right figure show typical results from the I/O interdependency model, providing stakeholders with the amount of cascading losses (SGD) and ranking of the economic sectors due to a prescribed disruption in the gas network.



Modelled economic impacts due to gas network disruption in Singapore

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References:

[1] Lin, J., Tai, K., Tiong, R.L.K. and Sim, M.S. (2017) "Analysing Impact on Critical Infrastructure Using Input-Output Interdependency Model : Case Studies", ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering, Vol.3, No.4, Article Number 04017016 [2] Lin, J , Tai, K., Tiong, R.L.K. and Sim, M.S. (2018). "Modelling critical infrastructure network interdependencies and failure". International Journal of Critical Infrastructures. (Accepted)

