AI SUSTEIN

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Showcase #1

Model and solution method for mean-risk cost-based post-disruption restoration of interdependent critical infrastructure networks

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Background

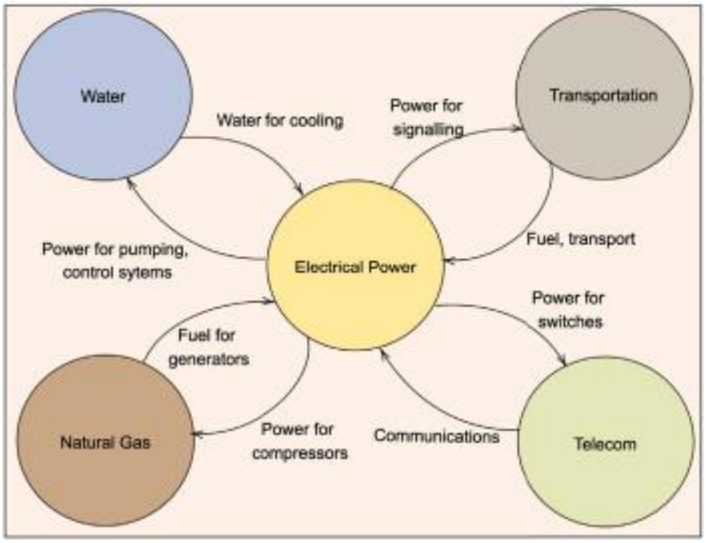


Figure 1 - The networks that we rely on are all interconnected. (Adapted from Rinaldi et al. (2001))

In this era, we rely on many different interconnected networks to go about our daily lives. If something were to happen to these critical infrastructure networks (CINs), we would not be able to function. This study focuses on speeding up recovery and linking risk factors and levels of importance by integrating a mean-risk two-stage stochastic model with the CINs. A mean-risk stochastic model adds uncertainty and risk as factors, which will significantly help in restoration when compared to other deterministic, or even general two-stage stochastic models. This model will provide a more problem specific solution with minimal impact compared to solutions provided by other models that may not have the best performance if the risk is too high.

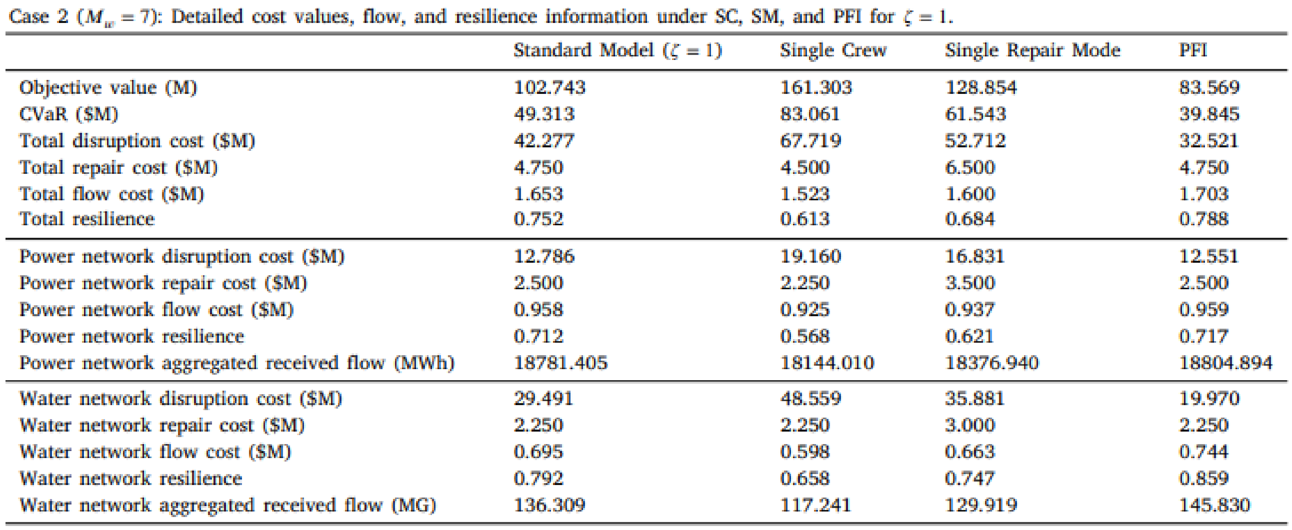
Methodology/Approach

This proposed model expands on recent resilience-based restoration models to bring added capabilities of multicrew assigning (as opposed to one crew per component), multimode repair (a minimal repair or complete one), fully or partial functioning and interdependency (PFI), and incorporates cost, repair, flow, and resilience loss to deal with issues in the previous models. The first stage of this model consists of identifying any failed components, and depending on the repair mode for the component, will schedule crews to either restore it to full capacity, or the capacity it needs to function. Depending on priority, crews can restore components individually or concurrently, contingent on the time and resources available. While the first stage determines the restoration cost of the failed component, the second stage computes the rest of the costs, which includes the flow costs and unmet demand costs. With this, it is expected that the results will provide reduced disruption and repair costs. To see if our stochastic model has added value against its deterministic counterpart, we compare a mean-risk value of stochastic solution (MRVSS). Higher values mean more added value to a mean-risk approach than a deterministic approach.

Results and Discussion

This model shows a high MRVSS, meaning this solution outweighs the deterministic ones. Our results show that the deterministic solutions will cost $2.285M more, and cause between 10%-20% more economic loss when compared to our mean-risk solution. When testing against two hypothetical real-life earthquake scenarios with the power and water networks in Shelby County, Tennessee of the United States, we found that overall, the conditional value at risk (CVaR), which is used to measure financial risk, is significantly lower than just single crews and mode, and even lower yet when considering PFI (shown in table below).

This data suggests that multimode and multicrew is the optimal way to go, with a reduction of repair costs by 27%, and disruption costs by 20%. When judging resilience of the system, the graphs in Figure 2 below show that overall, the system improves its resilience in both networks with the multimode and multicrew settings.



Case 2 ($M_w = 7$): Detailed cost values, flow, and resilience information under SC, SM, and PFI for $\zeta = 1$.

	Standard Model ($\zeta = 1$)	Single Crew	Single Repair Mode	PFI
Objective value (M)	102.743	161.303	128.854	83.569
CVaR ($M)	49.313	83.061	61.543	39.845
Total disruption cost ($M)	42.277	67.719	52.712	32.521
Total repair cost ($M)	4.750	4.500	6.500	4.750
Total flow cost ($M)	1.653	1.523	1.600	1.703
Total resilience	0.752	0.613	0.684	0.788
Power network disruption cost ($M)	12.786	19.160	16.831	12.551
Power network repair cost ($M)	2.500	2.250	3.500	2.500
Power network flow cost ($M)	0.958	0.925	0.937	0.959
Power network resilience	0.712	0.568	0.621	0.717
Power network aggregated received flow (MWh)	18781.405	18144.010	18376.940	18804.894
Water network disruption cost ($M)	29.491	48.559	35.881	19.970
Water network repair cost ($M)	2.250	2.250	3.000	2.250
Water network flow cost ($M)	0.695	0.598	0.663	0.744
Water network resilience	0.792	0.658	0.747	0.859
Water network aggregated received flow (MG)	136.309	117.241	129.919	145.830

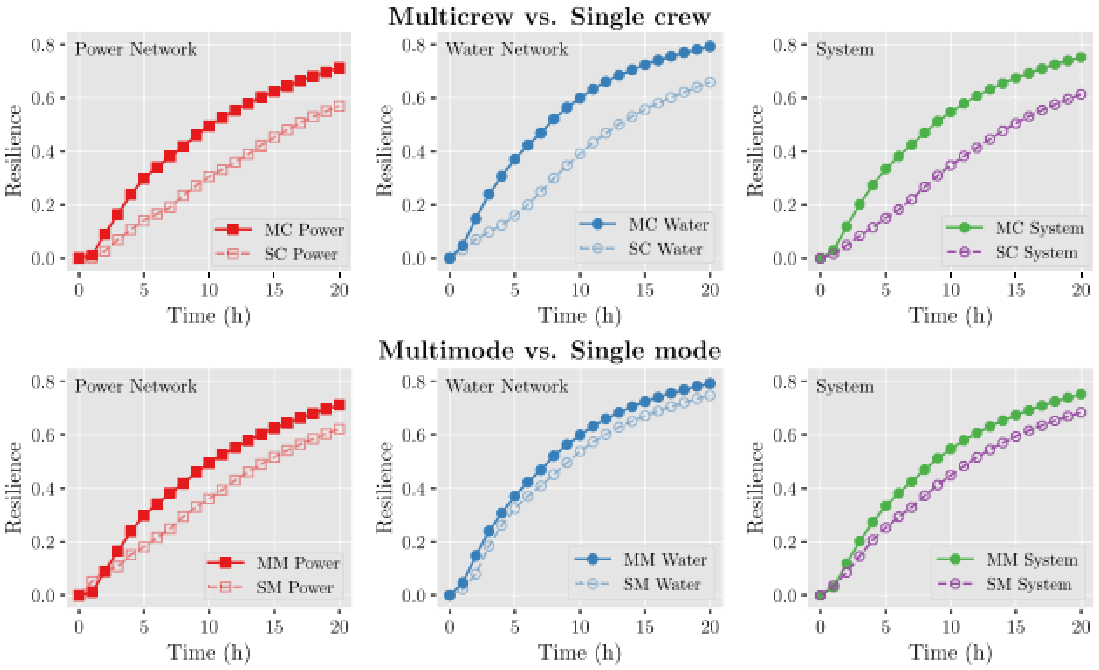


Figure 2 – Case 2 (Mu=7): Comparison of the resilience of the overall system and individual networks under SC vs MC, and SM vs MM settings

For more information, please refer to:
https://www.sciencedirect.com/science/article/abs/pii/S030505482200096X?via%3Dihub .