Theorizing the Resilient Systems Design Framework: From SETS Mapping to Action Pathways

Keywords: resilient design theory, complexity modeling, social-ecological-technological systems, multi-scale analysis, and implementation pathways

Extended Abstract

Infrastructure failures increasingly stem from cross-domain feedbacks linking social, ecological, and technological processes [1]. Prevailing governance and design frameworks remain siloed, undermining efforts to build policies and systems that are resilient to current or emerging risks across deeply uncertain futures [2] and equitable across communities and ecosystems [3]. This study therefore asks whether a Social-Ecological-Technological Systems (SETS) lens can be operationalized through a novel Resilient Systems Design Framework (RSDF) to identify hidden risks to and opportunities for enhancing system resilience; how such insights can be converted into practicable action pathways and adaptive governance architectures; and whether practitioners regard this approach as both feasible and valuable for real-world decision-making.

Methods
The RSDF was developed through a mixed-method, iterative design process. We began by synthesizing SETS, complex systems, decision making under uncertainty, engineering design, and adaptive-policy literature to draft a three phase resilient design framework (see Figure 1): Phase 1 maps current SETS goals, risks, and opportunities; Phase 2 assesses policy capacity and simulates present-state dynamics to co-create effective action pathways; and Phase 3 stress tests those pathways across scenario-based futures using adaptive policy techniques [4].

Ten virtual focus-group workshops (n = 60 experts from water, agriculture, forestry, built-environment, and natural-habitat domains) were embedded at each design stage to co-create and appraise the RSDF. During each session, participants supported the creation of RSDF definitions, metrics, cross-system linkages, policy constraints, and envisioned futures; these inputs were used to revise the framework. Subsequent system-dynamics sketches, and scenario planning exercises served to test whether the emergent RSDF could be used to reliably identify resilience options, for built or intentionally used natural systems, robust to deep uncertainty.

Implications
Focus group discussions surfaced three insights with direct theoretical and practical implications. *(1) Cross-domain dependencies:* more than 70 bidirectional linkages between infrastructure domains (e.g., lock-and-dam schedules shaping grain logistics, rooftop-solar targets interacting with urban-canopy goals) were identified by expert attendees, providing evidence to suggest the value in SETS mapping to identify unforeseen connections between domains, potentially reducing the likelihood for maladaptive single-domain fixes [5]. *(2) Policy-capacity gaps:* recurring gaps shared by attendees (e.g., misaligned hydrologic-political boundaries, subsidy regimes that entrench monocultures, and rigid building codes) supported the hypotheses that Phase 2's adaptive capacity audit, of the system of focus, can generate

novel action pathways for enhancing system resilience [6, 7]. *(3) Action pathways:* the more than 30 practitioner-derived interventions (e.g., watershed storage, resilience-hub retrofits, biomass markets) suggest that expert knowledge can support early development of scenario-testable action pathways for Phase 3. Collectively, these results suggest that coupling SETS theory with an adaptive resilient design practice might yield a replicable method for developing system resilience that bridges disciplinary silos [8] while embedding equity and justice considerations through actor co-production and behavioral insights throughout the design process [9].

Conclusions

The RSDF bridges complexity science and resilient design by iteratively linking system mapping, adaptive capacity assessment, and scenario testing within a SETS lens. Early expert appraisal shows the framework (1) has the capacity to capture cross-system dynamics, (2) surfaces feasible, equity and justice aware action pathways at the system level, and (3) provides a structured method to design more comprehensive system-of-systems adaptive governance architectures. Ongoing work seeks to (1) establish common SETS indicators and metrics, (2) refine the methodological toolkit required to operationalize the RSDF, and (3) apply the framework in a real-world case study.

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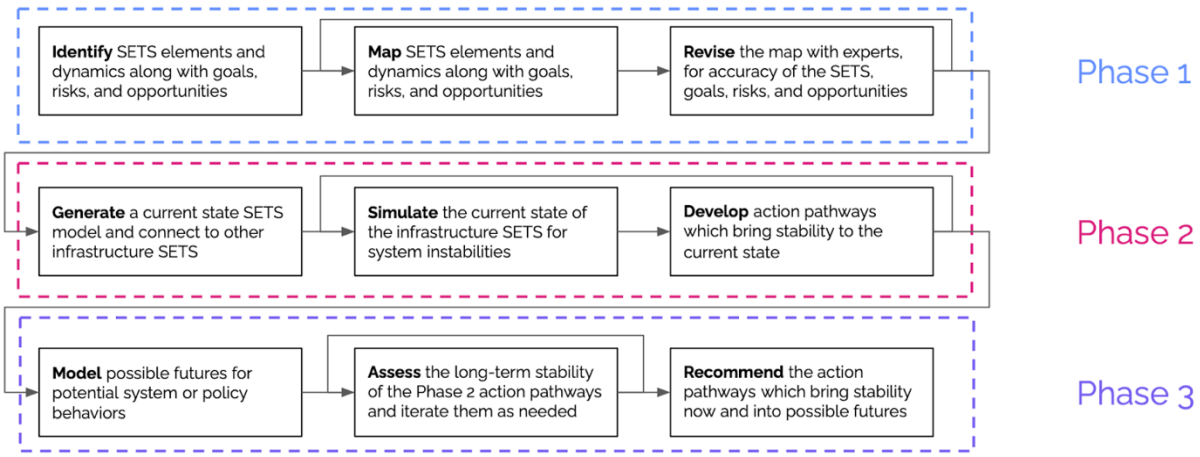

Figure 1. **Three-Phase Workflow of the Resilient Systems Design Framework.** Iterative three-phase RSDF: map SETS, assess existing capacity and develop action pathways, then stress-test scenario futures for resilience.