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Overview

This paper identifies literature and other resources for resilience analytics, in particular when the emphasis is the disruption of preferences by alternative system perspectives. It recognizes that multiple, possibly conflicting, perspectives of politics, economics, demographics, technology, environment, etc., are an inherent part of decision-making and plans and processes need to be resilient to emergent and future conditions that might bring one or more perspectives closer to the front.

The literature of resilience reflects an interest in the separation of a system from its as-planned or as-expected functionality over time (Connelly & Lambert, 2016; Ganin et al., 2016; Hamilton et al., 2016; Thorisson et al., 2016; Linkov et al., 2014). The National Academy of Science describes the resilience of a system as its ability “to plan and prepare for, absorb, respond to, and recover from disasters and adapt to new conditions” (National Research Council, 2012). A quantification of this definition is proposed by Ganin et al. (2016) by evaluating temporal recovery of the critical functionality of the system when subjected to stressors.

Connelly & Lambert (2016), Hamilton et al. (2016) and Thorisson et al. (2016) describe an approach where resilience of systems of systems, such as hierarchical and interconnected arrangements of infrastructure, health care, manufacturing, economics and environment, can be characterized by separations of time-based priorities or proposed schedules, in particular when a single system comes to the front. Each system has an associated set of factors and conditions, also known as scenarios, which might prompt a reevaluation of priorities (Karvetski et al., 2011a; Karvetski et al., 2011b; Martinez, 2011). The priorities of an agency are for projects, existing assets, policies, geographic locations, organizational units, and other entities, known as initiatives. A prioritization of initiatives can be viewed as a timeline of implementation or execution, and thus resilience can be characterized in terms of separation of the timeline or milestones of plans from an ideal.

A conceptual illustration of the timeline view is given in Figures 1a-c. Figure 1a shows the as-planned system in the space of a timeline or milestones. Figure 1b-c then illustrate separations from the as-planned system when subjected to various factors, alone or in combination. In Figure 1b the system recovers and achieves the originally planned end state while in the Figure 1c it adjusts to a new end state. Interpreting Figures 1b-c, the resilience of the system of systems to stress on particular systems is the closeness of the disrupted trajectories to the as-planned trajectory.

![Figure 1](image.png)

**Figure 1: Resilience as the disruption of a timeline of priorities. The resilience of the system is characterized by the separation of the timeline from an as-planned timeline when systems (alternatively recognized as scenarios) influence the higher level system.**

Resilience analytics as described below focuses on methods for identifying the systems (or particular scenarios related to the systems), that, alone and in combination, are most in need of investigation, including risk analysis, simulation, experimentation, data collection and analysis, etc. (Karvetski et al., 2009; Teng et al., 2012). Risk analysis often relies on being able to assess likelihood and consequences of scenarios, while resilience analytics can proceed without that assessment (Thorisson et al., 2016).

Resilience analytics identifies the systems that have the greatest potential to separate the schedule or priorities from an ideal. This allows system owners and operators to focus on mitigating the separative influence of identified systems or build flexibility of milestones into strategic plans.

Resilience analytics should be considered in the context of negotiations (Thekdi & Lambert, 2014) or development of terms for design and operations of systems of systems (Lambert et al., 2012), as follows. By quantifying how various stressors might affect a timeline of priorities the analysis quantifies which systems have the most potential to cause a change of mind about the priorities of a strategic plan within organizations and among stakeholders, which can also be interpreted as scenarios that might prompt renegotiations. Thus, resilience is achieved by anticipating and accounting for these vulnerabilities by including elements that specifically address the systems that
are identified to have the greatest potential to have cascading effects on the overall timeline of implementation.

The resilience of the design and operation of a system of systems can be quantified, in part, as the separation of a disrupted timeline of implementation from the as-planned timeline, by attention to a system within the system of systems. The closer the timelines, the more resilient is the system of systems to the scenario of any particular system within it. In the case where elements of the system are ordered in terms of their relative priority or time of implementation, a precondition for quantifying resilience is establishing this order for the as-planned system as well as alternative orders that account for different circumstances (scenarios) where emergent and future conditions bring one or another system to the front.

In the cited references, resilience (as a separation from an initial set of priorities for a system of systems) is represented graphically (Lambert et al., 2013), or quantified as the absolute value of change in prioritization (Connelly et al., 2016; Parlak et al., 2012)), the sum of squares of ordering change (Connelly et al., 2015; Hamilton et al., 2012), Spearman rank correlation coefficient (Thorisson et al., 2016), Kendall tau rank correlation (Hamilton et al., 2015; You et al., 2014a; You et al., 2014b).

Annotated Bibliography


**System Safety.**

Introduces resilience analytics with scenario-based preferences as compilations of instantaneous framings of initiatives, objectives, stakeholder preferences, and uncertainties. The paper presents a case study with application to a micro grid investment plan.


Assesses the resilience of a timeline of research and development priorities for energy islanding.


Assesses the resilience of research and development programs within an agency and highlights the role of stakeholder elicitation in the process.


Applies methodology introduced by Karvetski et al. (2009) to investments in infrastructure in Afghanistan and emphasizes the role of stakeholder engagement in the evaluation process.


Describes how resilience analytics can be achieved by integrating scenario planning with multicriteria decision analysis.


Assesses the resilience of different alternative energy sources for military and industrial installations.


Introduces methodology for prioritizing initiatives and evaluating their resilience to various scenarios incorporating elements from multicriteria analysis and scenario analysis.


Applies methodology introduced by Karvetski et al. (2009) to investments in infrastructure in Afghanistan and emphasizes the role of stakeholder engagement in the evaluation process.

Assesses resilience of transportation infrastructure assets in a coastal region to scenarios involving the combination of climate change and other factors.


Describes requirements for resilience management and the differences between risk management as a tool to react to known quantifiable threats and resilience management which deals with unknown and unforeseeable threats.


Assesses resilience of investments in electricity capacity expansion to emergent conditions of electricity consumption rates, price volatility of oil and gas, anti-pollution policies and pressure to move towards green technologies.


Provides a definition of resilience as the ability to plan and prepare for, absorb, respond to, and recover from disasters and adapt to new conditions.


Assesses the resilience of emergency preparedness initiatives to a dirty bomb attack.


Demonstrates a systemic approach to achieve compliance of a risk program with administrative and organizational principles and guidelines for risk analysis. Assesses the resilience of policy initiatives to emergent and future conditions.


Describes a form of resilience analytics as a means to achieve stakeholder consensus in negotiations.


Describes resilience analytics as a complement to risk analysis characterized by likelihood and consequences and demonstrates on a power grid capacity building plan in Afghanistan.

Compares perspectives of several management systems to evaluate the vulnerability of agency priorities to combinations of climate change and other risk scenarios.


Introduces a modification of the Kendall Tau rank correlation coefficient as a measure of the resilience of project portfolios.