Formalizing Resilience Concepts for Critical Infrastructure[i]

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Introduction

In an era that has seen a multitude of high impact disasters ranging from natural events such as earthquakes, floods, tsunami's, volcanic disruptions to man-made acts of terrorism and cyberattacks, there is a pressing need to assess the resilience of modern societies to withstand and recover from unexpected adverse events, with a particular focus on critical infrastructure (CI) (as defined by Council Directive 2008/114/EC. Unsurprisingly, against the backdrop outlined above concepts of resilience which offer all-encompassing, integrated approaches to planning for, responding to and recovering from all manner of man-made and natural disasters have dominated recent discourse on disaster and crisis reduction and management. In this regard, the frequency and severity of impacts of disaster and crises events have channelled attention to vulnerable physical assets,). The removal or suspension of critical infrastructure assets from normal service would significantly affect public safety, security, economic activity or environmental quality (Clarke et al., 2015).

Resilience building in cities has grown in importance with a number of global programmes which have promoted the importance of urban resilience. A notable example is the Rockefeller Foundation's "100 Resilient Cities Campaign" (100RC), which provides economic grants for international cities to improve their resilience, as well as producing some more generic guidance on the topic. Interestingly, and in contrast to some of the more technical approaches seen elsewhere, 100RC identifies the enhancement of resilience as more of an organisational challenge. Following extensive academic, policy and practice literature reviews pertaining to the topic of resilience, three typologies or qualities of resilient systems have been identified by 100RC: asset-based characteristics (e.g., hazard proofed infrastructure); practices or process-based characteristics (e.g., community involvement in planning) and attributes (e.g., flexibility and adaptability); these are assessed against eight qualities that underpin these typologies across the urban system:

- Acceptance - of uncertainty with foresight incorporated in system design
- Reflective - evidence of learning from previous events
- Adaptive - tacit and corporate knowledge used
- Robust - systems can withstand loss of functionality

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- Resourceful - spare capacity is available when systems fail
- Integrated - information is shared across sectors
- Diverse - assets are distributed across the city to ensure that risk is not concentrated
- Inclusive - marginalised communities are included in resilience vulnerability measurements and plans.

The approach demonstrated above is indicative of the transition which is occurring in the understanding of resilience as the measure, metric and indicators that we employ to evaluate our CI systems become more nuanced and multifaceted. Vugrin et al. (2010) recognises the need for the expansion of resilience considerations to transcend the quantitative and there is now a concerted move within by practitioners to move toward more holistic means of CI resilience evaluation.

Objective

The greatest strength of the concept of resilience is its multidisciplinary origin, as outlined succinctly in Clarke et al. (2015). It is the origin of the concept of resilience that hints at the manner in which is best advanced as an important discipline in the management of adverse events which strike CI works, that is an adaptive synthesis of quantitative and qualitative understanding of the impacts of an adverse event on CI networks and the society that they serve. In terms of resilience vs. risk management as outlined in Clarke et al. (2015), the advantage of resilience as a concept and through its application in comparison of the narrow confines of risk management thought and theory is the scale at which resilience-focused methodologies can conceive of and react to adverse events. Clarke states;

> "*The widening of the resilience metaphor and its application within a broader policy arena fits with the complexity and interrelated nature of truly 'global' or 'globally significant' events that combined exogenous and endogenous forces (such as climate change/environmental disasters) and influence anthropogenic systems and infrastructures at a variety of spatial scales. Events during the early part of the 21st century such as Hurricane Katrina in 2005, the global economic recession and credit crunch between 2008 and 2013, and the 2011 Tohuku earthquake demonstrate a need for responses which are multi-agency (vertical and horizontal integration) and multi-scalar (global-national-regional-local) where the initial shock poses a threat to integrated 'systems', and often illuminate more persistent stresses at a local and regional scale*" [p 14].

The reasoning advanced above truly conceives of the need for an expansive concept of resilience which truly engages with the vast potential impact of adverse events on CI as opposed to quantitatively defined and narrowly focused risk management strategies.

Instruments for Resilience Management

Enhancing the rresilience of communities and infrastructures requires an understanding of how the activities of crisis planning and planning are carried out. Gaining this understanding is an aim of the Realising European ReSILiencE for Critical INfraStructure (RESILENS) project in order to create a user-friendly, citizen centric European Resilience Management Guideline which is founded in the principles of risk management and vulnerability reduction. To this end the research will include an analysis of the various activities involved in maintaining the safety and security of people and property, including the analysis of emergency response plans, systems and procedures in order to establish the nature of the various elements that go into the planning and organisation of crisis and emergency response, crisis prevention and resilience assurance. The research will result in the development of a detailed *'Concept of Operations'* (CONOPS) model (Future Analytics Consulting, 2015), which is a description of a system or system of systems based on a number of critical elements. These include:

- Actors: looking at the human factor in resilience including the role of individuals and organisations; citizens and planners, operational emergency response personnel and crisis managers; service providers and their operational and management staff;
- Roles: (defined in terms of the distinct activities involved in everyday resilience as well as crisis management, with their own distinct objectives);
- Interdependencies and relationships: in terms of the extent to which there is a division of labour between different actors, examining the points of intersection between actors in the various systems we will be examining;
- Organisation: referring to the structure, horizontal and vertical, within agencies and also between agencies;
- Resources: This is primarily concerned about information and human resources (but all resources that are relevant to crisis management are considered).
- Coordination and communication: mechanisms used primarily by civil protection, but also those used by citizens in response to major emergency and crisis events.
- Conflicts and contradictions: examining for areas where the activities of personnel and organisations may not be harmonious, where there are potential conflicts in terms of legal and regulatory issues, resources limitations, suitability of education and training, etc.

This type of analysis will facilitate the development of quantitative and qualitative metrics formed and influenced by the characteristics out the above, by which resilience-enhancing outputs can be measured and assessed in practice by expert practitioners maintaining and managing the upkeep of CI.

Assessing the performance of the deliverables against the needs identified by the above elements will be key in terms of ensuring that the approach to CI resilience is effective in safeguarding societal processes before during and after times of crisis. In addition, illustrating the expansiveness of resilience and the comparatively narrower remit of risk management, this section will review two different approaches to the protection of CI. It should be noted that ISO/TC 292 Security and resilience is in the process of examining international standards relating to the application of resilience through the lens of standardisation. The existence and work of this committee is a step toward the remediation of resilience centric gaps in existing ISO standards, such as *ISO31000-Risk Management-Principles and guidelines*".

"*ISO31000-Risk Management-Principles and guidelines*" illustrates effectively the rationale and approach of a risk management focused methodology which intersects with considerations relating to resilience. The principles and guidelines are flexible in terms of the manner in which it can be applied. The manner in which ISO31000 functions is succinctly described in Clarke et al. (2015) which states,

> *"ISO31000 begins by 'establishing the context', including factors such as local and national policy, and using this as a baseline for assessment and management. The next stage is 'risk assessment', which also includes 'risk identification', 'risk analysis' and 'risk evaluation', and often involves a variety of quantitative approaches. This can then be translated into physical or organisational methods through 'risk treatment', whilst the final stages of the approach are 'monitoring and overview' and 'communication and consultation"* [p 35].

For a particular piece of infrastructure, this approach is rational and effective. It determines a risk, assesses it, develops responses on the part of the CI operator which may contain or remediate that risk and monitors the results. The scalability of this approach and its predominantly quantitative nature, however, does constrain its ability to engage with qualitative markers at a higher spatial scale, where the complexities of the end users of CI intersect with the systems themselves.

Metrics

In terms of the optimal selection of indicators for the monitoring of resilience in practice, these can be defined in a variety of manners. One of the more effective and comprehensive approaches to deriving resilience indicators is the work that was undertaken by Argonne National Laboratory (ANL) in the US in 2013. This is just one mechanism for the quantification of resilience related metrics. There are others such as the UNISDR scorecard which are equally valid in terms of quantifying the characteristics of resilience associated with critical infrastructure. Figure 1 below illustrates the framework of the Resilience Measurement Index that ANL derived.

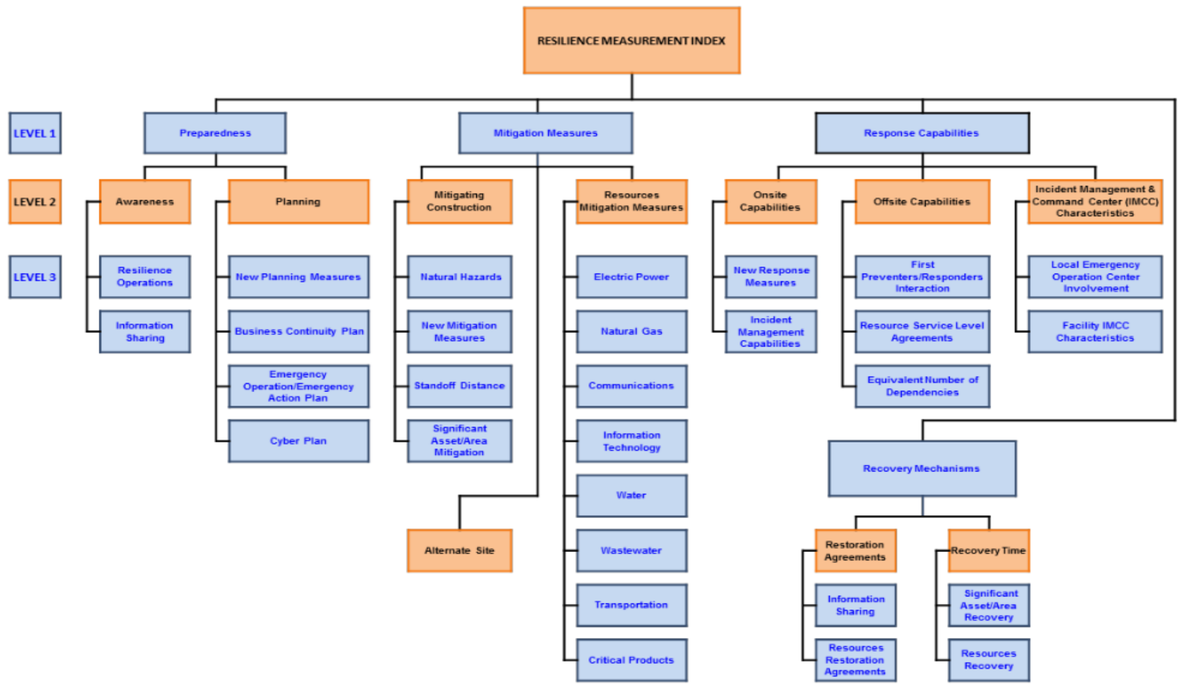

Figure 1: Resilience Management Index (Argonne, 2013)

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