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Framework Development for Disaster Risk Dynamics and Resilience Analytics in Complex Socio-Technical Systems (STS)

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1. A New Perspective on Disasters

In most cases, disasters are assessed at an event-level, by focusing on quantitative surveys of casualties, physical damages, and qualitative root-cause analyses of individual events. However, disasters are usually not confined by spatial and temporal boundaries, with prolonged impacts that root back to social and organizational problems, which further complicate within the nexus of urban systems (Boin, 2005).

We argue that disasters are best understood as evolving processes of pathological changes in systems. The evolving process of a disaster starts from problematic inter-linkages within the considered systems, including critical resource and service flows, leading to internal functional disorder, or dynamic pressures; that in turn manifests as symptoms or warning signs and jointly determine the systems' conditions at the time. **The conceptual deconstruction of disaster events into a set of perturbations** that affect the functionality of involved systems, is an important step to further analyze disaster events and learn from them. We argue that the fundamental purpose of disaster risk reduction and resilience building, extends beyond the protection of physical structures and system components, **to remain in control** of the overall circulation of the critical resources and services, which sustain the systems.

2. Proposed Research Plan

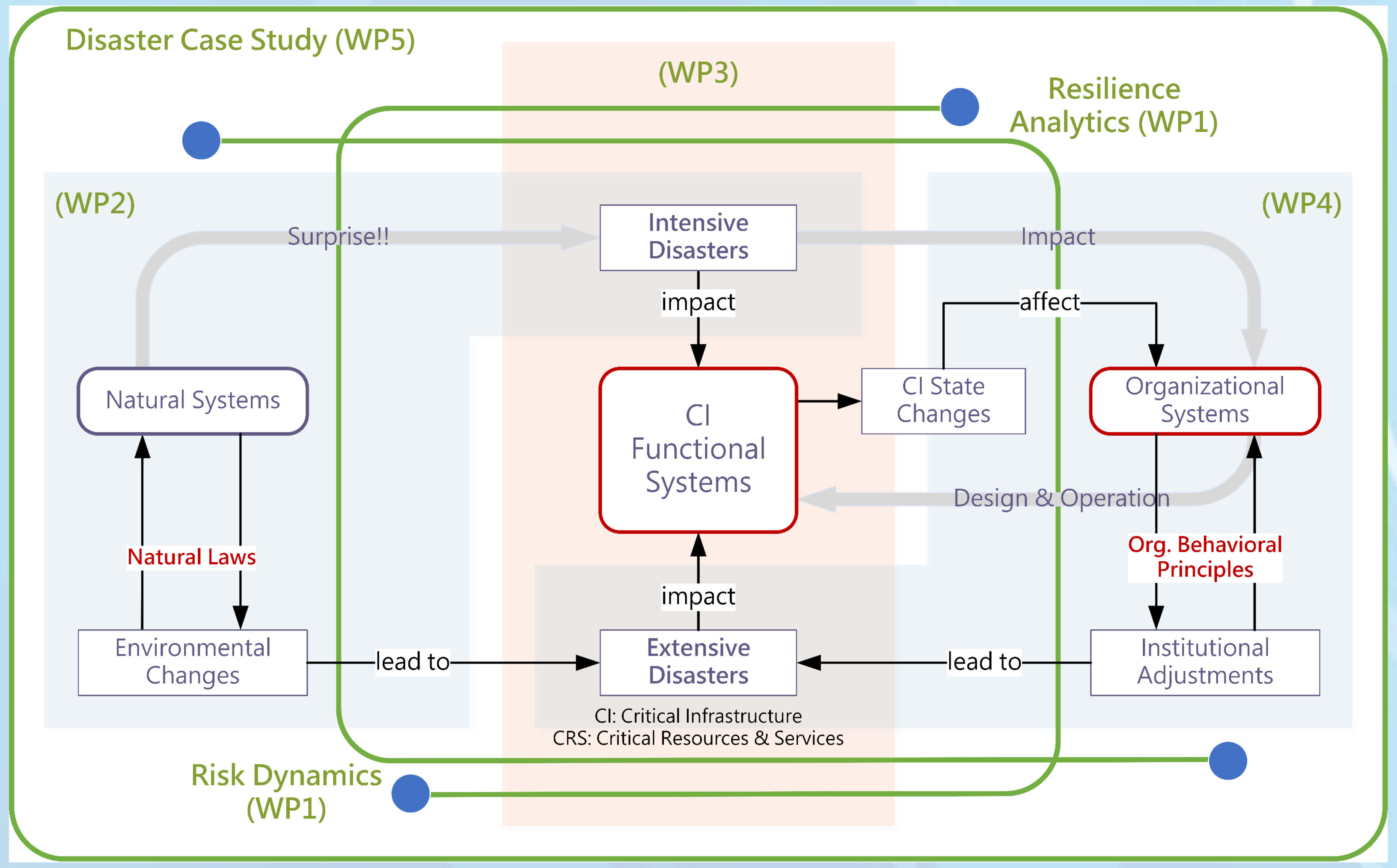

Figure 01. Proposed Research Framework

We propose a novel approach for modeling and analyzing disaster risk – the risk of change – in a coupled nature and complex socio-technical systems (STS) by evaluating the systems' state changes and our ability to control them. Consortium partners will focus on unique, but complementary cases, at involved countries, including Taiwan, the US, Japan, and the UK, and test the underlying hypotheses from multiple perspectives. Stakeholders from government agencies and infrastructure service providers will be engaged through continuous and direct involvement in dialogues and activities, supporting the development of novel DR3 solutions. The proposed three-year research project promotes four key objectives below:

- O1) Analyzing disasters and their risks within the context of a changing environment. (Cf. Section 15.2 WP1, WP4)
- O2) Tracking the progression of disasters and their impacts on complex STS in the absence of reliable data. (Cf. Section 15.2 WP2, WP1)
- O3) Modeling the coupled nature and complex STS through nexus approaches (Cf. Section 15.2 WP3, WP2)
- O4) Enhancing complex STS robustness and stakeholder organizational resilience building. (Cf. Section 15.2 WP4, WP3)

3. Disasters in STS

As argued by Leveson (2003) and Dulac's (2007), complex STS are largely designed and operated by human organizations and exhibit both technical and social complexity. For the disaster management purpose of this research, we propose to define disasters as functional problems at the intersection of the natural and societal systems, which manifest themselves as functional perturbations of **critical infrastructure (CI) functional systems** over time. In other words, we select to approach disasters as inseparable parts of the societal operation and critical resource and service circulation (CRS), deviating from the well-established concept that a disaster is simply the tragic outcome of human casualties and property damages. In this ground-breaking formulation, disaster management is not deemed as the management of the disaster itself, but rather as the analysis of the complex STS as a whole. In this context, disaster events are decomposed into functional perturbations from both the natural and societal systems, which affect the CRS, allowing for more efficient analyses of disaster events through learning algorithms. The proposed research framework include components of the STS that are susceptible to disaster-induced functional perturbations. In this research, focus is on macro-scale impacts from the environment, and meso-scale impacts originating from organizational interactions, processes and factors that influence the states and performance of STS. The latter integrate into the so-called **disaster dynamics associated with state, controllability and performance changes**.

4. Analyzing Disaster Risk under Change

Complex STS and their environments are constantly changing, maximizing the uncertainty aspects of the problem at hand. Change fraught with uncertainty may pose additional risks. More precisely, although risk can be portrayed as a "set of triples" (Kaplan and Garrick, 1981), the continuing uncertainty of change poses a challenge to current disaster risk analysis approaches with a chain-of-event paradigm of accident causation, e.g., failure modes and effects analysis, fault tree analysis, event tree analysis, and probabilistic risk assessment (Aven 2012; 2015, Gargoni, et. al. 2015, Dulac 2007). We argue that risk is a reflection of how systems and their states react to changes. Besides intensive changes, systems also evolve through small but persistent changes that accumulate over time and become a surprise at some point in time. Wimmer and Kössler (2006) believe that "change involves risk since it contains uncertainty". We argue that compromised organizational decisions made in the absence of complete information regarding complex system-state interactions may accumulate to socio-technical defects over time. For example, even a perfectly designed system at some point in time, may evolve to a flawed and obsolete state of operation, if significant changes occur to its environment. Hence, to what concerns complex engineering systems, disasters are fraught with additional risk aspects associated with the possibility of system states to fluctuate beyond control. Contrary to the current paradigm of risk, which indicates the expected consequence of an uncertain event (usually referred to as risk of chance), in DIRECTIONS we propose to portray a new concept of risk--the risk of change (Huang 2010)--as the potential of losing control under change, and develop an analytical framework for the assessment of disaster risk dynamics and system resilience building.

5. The Unfolding Process of Disaster(s)

Lastly, we argues that disasters are not independent events that can be clearly distinguished one from another. Disasters are best understood as the unfolding of the systemic pathological changes, as illustrated in the black loop in Figure 03. The unfolding process of disaster starts from problematic structures of the system leading to internal functional disorder, or dynamic pressures; that in turn manifest as symptoms or warning signs, which jointly determine the system's conditions at the time. Hazards, by definition, are things that can cause risk or danger; in critical realist term, hazards are the "other mechanisms" that triggers the escalation of the already unsafe conditions into a state of crisis or emergency. Hazards are not necessarily extrinsic. Depends on the coping actions, the outcomes of the crisis and emergency events eventually impact on the structures creating further underlying causes of the disaster. That, in turn, deteriorates the system structure and starts another disaster cycle.

6. Project Organization

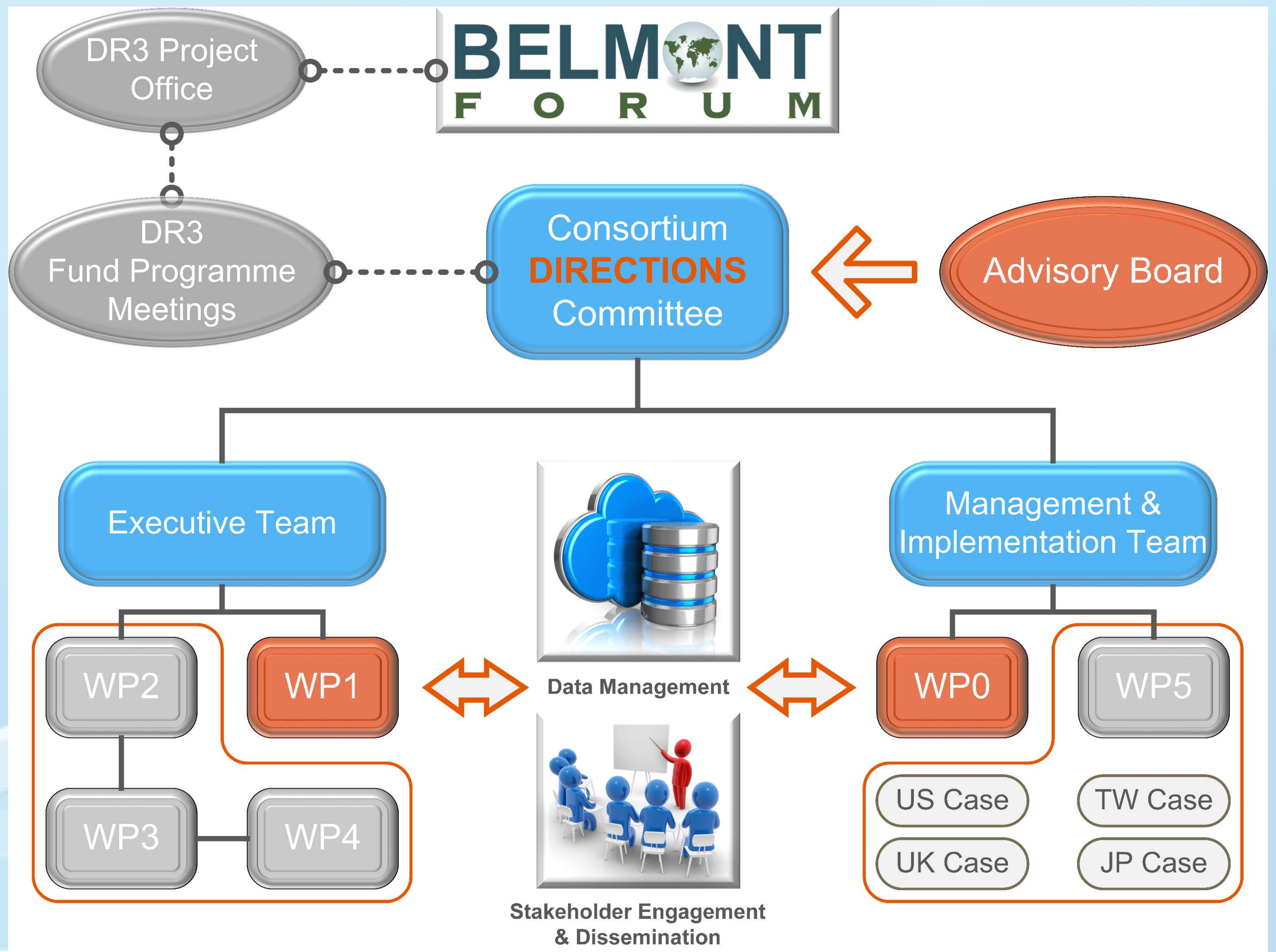

Figure 02. Proposed Project Organization

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