Resilience - concept and strategy to cope with unexpected and ambiguous disruptions

Hans R Heinimann, Programme Director
Future Resilient Systems @ CREATE
Singapore
Key Messages

1. Resilience: framework and strategy to cope with **ambiguity** and **unexpectedness**

2. Building resilience: (1) making systems **more robust**, (2) **recoverable**, and (3) **reconfigurable**

3. **Interconnectedness**: driver for ambiguity and unexpectedness (emergence)

4. **Regime shifts** cannot be predicted with historic data
Urbanisation – The Main Driver

Percentage urban
- 80 or over
- 60 to 80
- 40 to 60
- 20 to 40
- Less than 20

Megacities >10M
Large Cities 5-10M

The Asian Challenge

Interdependencies of Infrastructure Systems

1. How robust and resilient against a set of multi-hazard disruptions
2. How do system topology, interconnections and feedback loops affect robustness and resilience
3. How to detect / anticipate critical regime shifts
Cyber-Physical Systems

Cyber-Physical-Human Systems

Focus on
- Algorithms
- Physical components
- Human agents

Capabilities
- Shared perception
- Shared decision-making
- Shared learning and adaptation
  - Machine learning
  - Sensing from sensors, networks, people
Cyber-Part Trends | Lines of Software Code

- Google
- Car Software
- Facebook
- F35 Fighter
- Space Shuttle
- Mac OS X 10.4
- Windows 7
- Windows 2000
- Linux V2.2

Lines of Code (millions)
Artificial Intelligence

Artificial / Augmented
• Perception
• Sensemaking
• Action design
• Choice
• Action release
• Action control
Socio-Technical Perspective

Engineered Resilient Systems
[DoD, since 2012]
Regime Shifts (Osorio et al. 2010)

“Even if it is of low likelihood, SINGAPORE will do something about it if the consequence is very high”

Joo Koon train collision, Nov-15-2017

Outliers

Dragon Kings

Not predictable from historic data

Self-organized Criticality (Power-Law Regimes)
Increasing Ambiguity and Unexpectedness

Traditional Management
Risk-Based Management
Resilience-Based Management

Resilience – Building Blocks

1. resist within acceptable limits of degradation,
2. restabilize critical functions,
3. rebuild functions, and
4. reconfigure the flow of substances, energy and services.

COUPLED with
5. staying aware,
6. sensemake and anticipate,
7. respond,
8. update and adapt.
Building Resilience

Robustness

Recovery

Power Supply (10^6 customers)

28.10  01.11  05.11  09.11  13.11  17.11

Time (Date)

2.5
2.0
1.5
1.0
0.5

FUTURE RESILIENT SYSTEMS
Robust Design

- Traditional Engineering Design & Optimization
- Robust Engineering Design & Optimization

Objectives
- Certain
- Uncertain

Design Variables
- Certain
- Uncertain

Flexible
Engineering
Design &
Optimization
Robust Design – Key to Resilience IEEE-30

Traditional Optimization

Robust Optimization
Influence of Repair Tactics on Recovery

MIN(proximity + repair time)

System Performance

Proximity

Time (d)

Flight Operations Recovery After 9/11

Sensing, anticipating, sensemaking and the identification of purposeful action options are crucial to cope with ambiguous, unexpected events.

Resilience-building actions comprise of resistance, re-stabilizing critical social functions, recovery of social functions and reconfiguration of social interactions.
Pitfalls...

Sooo complex, we have to model it

Really nice model!
Key Messages

1. Resilience: framework and strategy to cope with ambiguity and unexpectedness

2. Building resilience: (1) making systems more robust, (2) recoverable, and (3) reconfigurable

3. Interconnectedness: driver for ambiguity and unexpectedness (emergence)

4. Regime shifts cannot be predicted with historic data

5. Resilience - change to no to be changed [B Walker 2018]
High Reliability Organisations (HRO)
[Weick, Hollnagel, Woods]

Focus on Operations
No simple interpretations
Preoccupation with Failure

Sense
Signals
Cues

Appraise
Sense-Making
Meaning

Retrieve
Useful response patterns

Recombine
Response patterns to actions

Act
Operate
Implement

Commitment to Response / Recovery

Remember (Store)
Past disruptions – Action repertoires

Flexible Organizational Structures