Understanding City Resilience through System Dynamics Simulation

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2 | CONCLUSIONS

- There are practical links between disaster risk management, climate change adaptation and sustainable development leading to:
  - reduction of disaster risk and re-enforcing resilience as a new development paradigm
- Systems approach to quantification of resilience allows:
  - better understanding of factors contributing to resilience
  - more systematic assessment of various measures to increase resilience
- Understanding of local context of vulnerability and exposure is fundamental for increasing resilience

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3 | CONCLUSIONS

- Introduction
- Resilience modeling effort
  - Systems approach
  - Resilience measure
  - System dynamics modelling
  - City model
- Coastal Cities at Risk (CCaR) project – Generic City Model
- Conclusions

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4 | INTRODUCTION
Needs

- Hazards from natural disasters
  - No procedures to quantify resilience
  - No procedures for comparison of communities in terms of resilience
- Resilience framework
  - Not only assessment of direct and indirect losses
  - Broader framework
- Need to move beyond qualitative conceptualizations to more quantitative measures
  - To better understand factors contributing to resilience
  - To provide for more systematic assessment of various measures to increase resilience

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5 | MODELING RESILIENCE
Basics

- Definitions
  - General
    - …the ability to recover quickly from illness, change or misfortune…
    - …buoyancy…
    - …the property of material to assume its original shape after deformation…
    - …elasticity…
  - Ecology – based (Holling, 2001)
    - …the ability of a system to withstand stresses of 'environmental loading'…
  - Hazard – based
    - …capacity for collective action in response to extreme events…
    - …the capacity of a system, community, or society potentially exposed to hazards to adapt, by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure…
    - …the capacity to absorb shocks while maintaining function…
    - …the capacity to adapt existing resources and skills to new situations and operating conditions…

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6 | MODELING RESILIENCE
Basics

- Commonalities
  - …the ability to adjust to 'normal' or anticipated levels of stress
  - …the ability to adapt to shocks and extraordinary demands
  - …spanning pre-event measures and post-event strategies

- Community resilience
  - In a resilient system, change has the potential to create opportunity for development, novelty and innovation.
  - A resilient city is a sustainable network of physical (constructed and natural) systems and human communities (social and institutional) .

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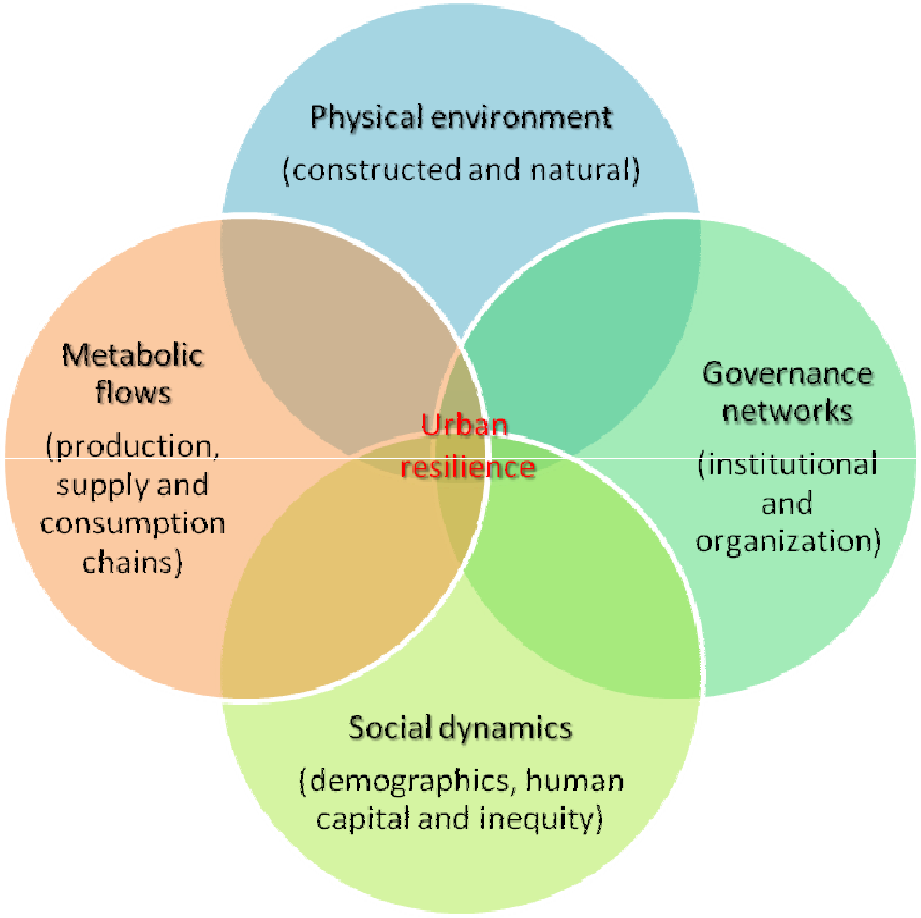
7 | MODELING RESILIENCE
Basics



Modified after Resilience Alliance, 2012 (www.resalliance.org)

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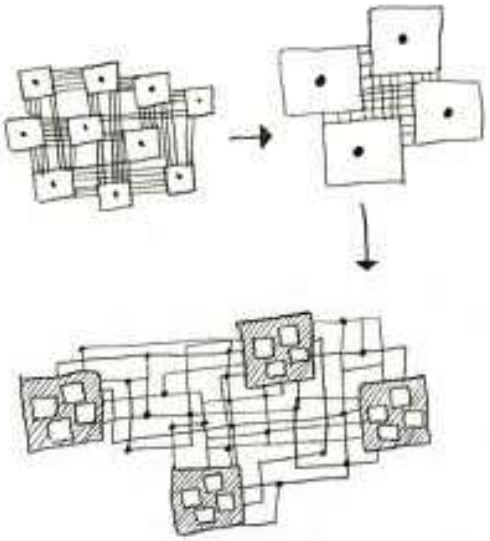
8 | MODELING RESILIENCE
Basics

- City – system of systems
  - Use of systems thinking to understand the behaviour of complex city systems!
  - Can we couple existing models of various aspects of the urban system to better understand resilience?
- Essential sub-systems
  - Water lifelines
  - Power lifelines
  - Acute-care hospitals
  - Emergency management organizations (firefighters, police,…)
  - Transportation lines
  - …..



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9 | MODELING RESILIENCE
Measure of resilience

- Quantifying the concept of resilience
  - Performance of any system can be measured as a point in a multidimensional space of performance measures (Bruneau et al, 2003)
  - The performance of a system over time can be characterized as a path through the multidimensional space of performance measures
- Broader concept of resilience
  - The ability of the system to reduce the chance of shock, to absorb a shock if it occurs and to recover quickly after a shock
  - Resilient system is one that:
    - Reduces failure probability
    - Reduces consequences from failures in terms of live lost, damage, and negative economic and social consequences
    - Reduces time to recovery (restoration of a specific system or set of systems to their 'normal' level of performance)

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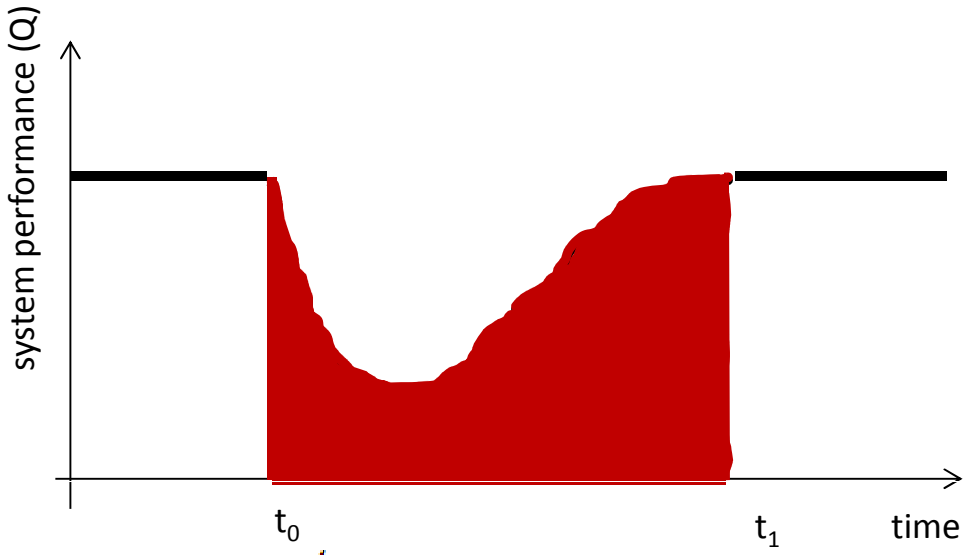
MODELING RESILIENCE

Measure of resilience



$$\rho^i = \int_{t_0}^{t_1} [Q_0^i - Q^i(t)]dt$$

Resilience - the ability of physical and social urban systems to withstand impacts of 'shock' through situation assessment, rapid response, and effective recovery strategies (measured in terms of reduced failure probabilities, reduced consequences, and reduced time to recovery)

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11 | MODELING RESILIENCE
Measure of resilience

- Dimensions of resilience (t, s)
  - Time
  - Space
- Properties of resilience (physical and social systems) – AC
  - Robustness
  - Redundancy
  - Resourcefulness
  - Rapidity
- Units of city resilience analysis - PHEOS
  - Physical
  - Health
  - Economic
  - Organizational
  - Social
  - .....

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MODELING RESILIENCE

Measure of resilience

General definition

$$\rho^i = \int_{t_0}^{t_1} [Q_0^i - Q^i(t)]dt$$

Integration of resiliency units (PHEOS)

$$R(t,s) = \{\prod_{i=1}^{M} \rho^i(t,s)\}^{1/M}$$

Representation of dimensions and properties

$$R(t,s) = f(E(t,s), V(t,s), AC(t,s))$$

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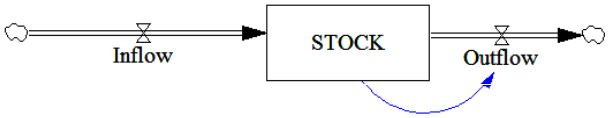
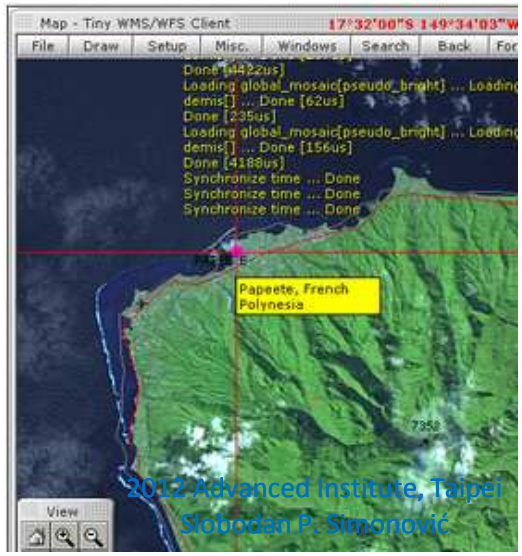
13 | MODELING RESILIENCE
Implementation

- Implementation
  - Temporal dynamics – System dynamics simulation
  - Spatial dynamics - GIS
- System dynamic simulation
  - A rigorous method of system description, which facilitates feedback analysis via a simulation model of the effects of alternative system structure and control policies on system behavior
- GIS
  - An information system that integrates, stores, edits, analyzes, shares, and displays spatial information for informing decision making.





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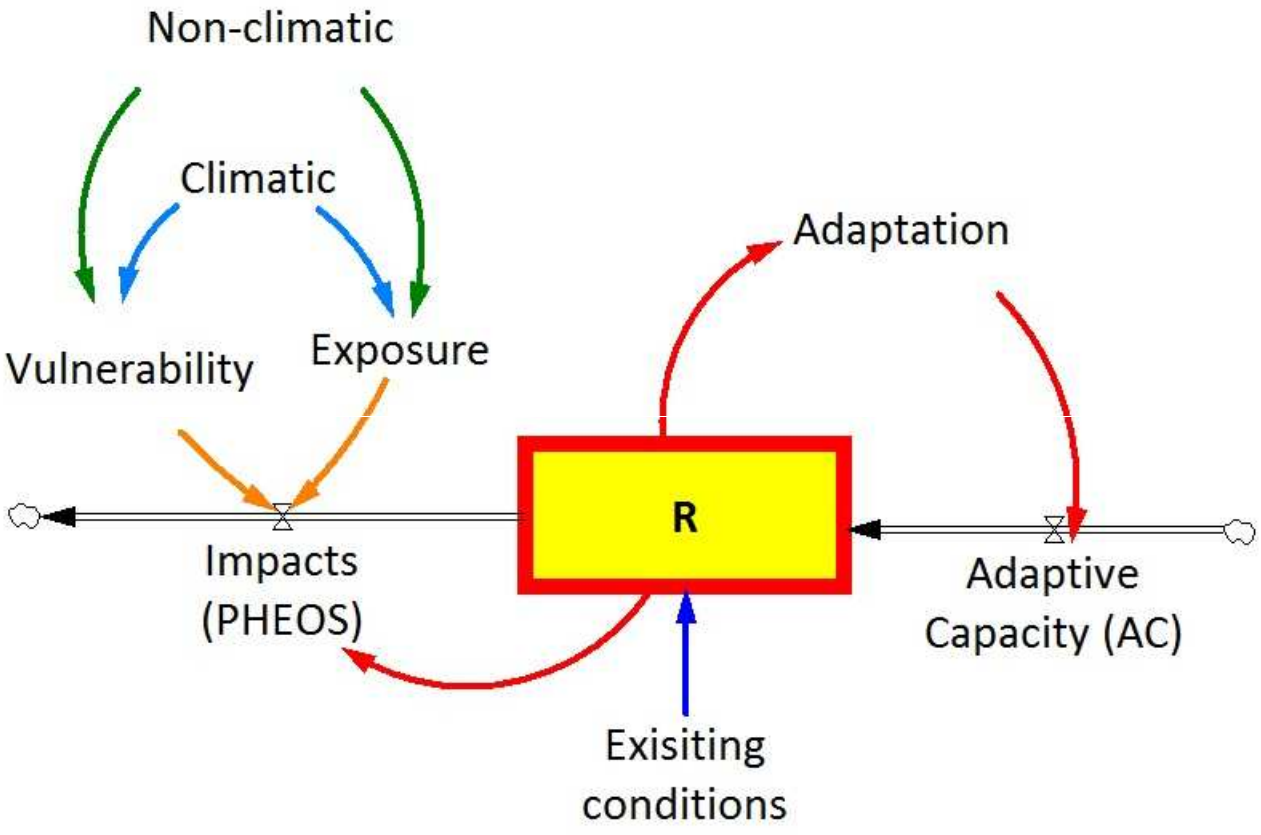
MODELING RESILIENCE

City resilience simulator



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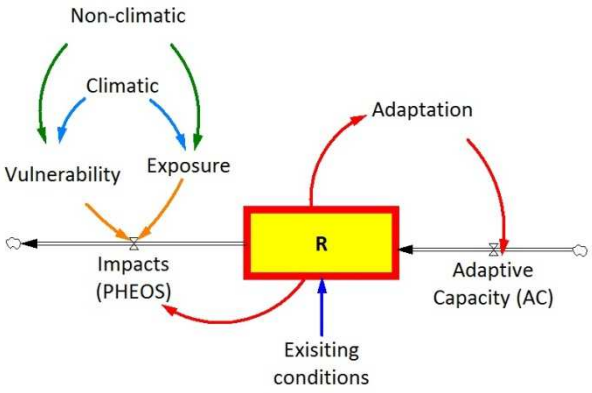
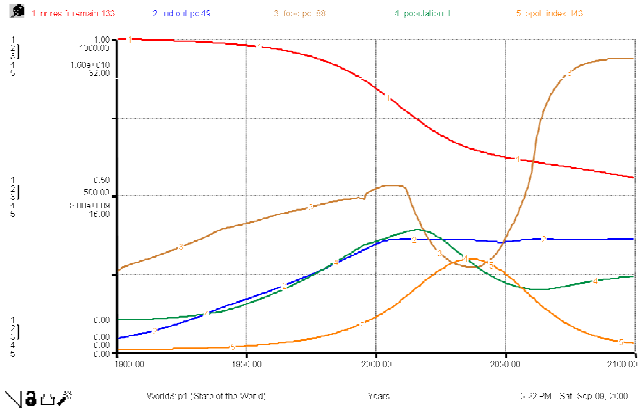
City resilience simulator





Temporal dynamics

SD ⟺ GIS

dynamic data exchange

Spatial dynamics

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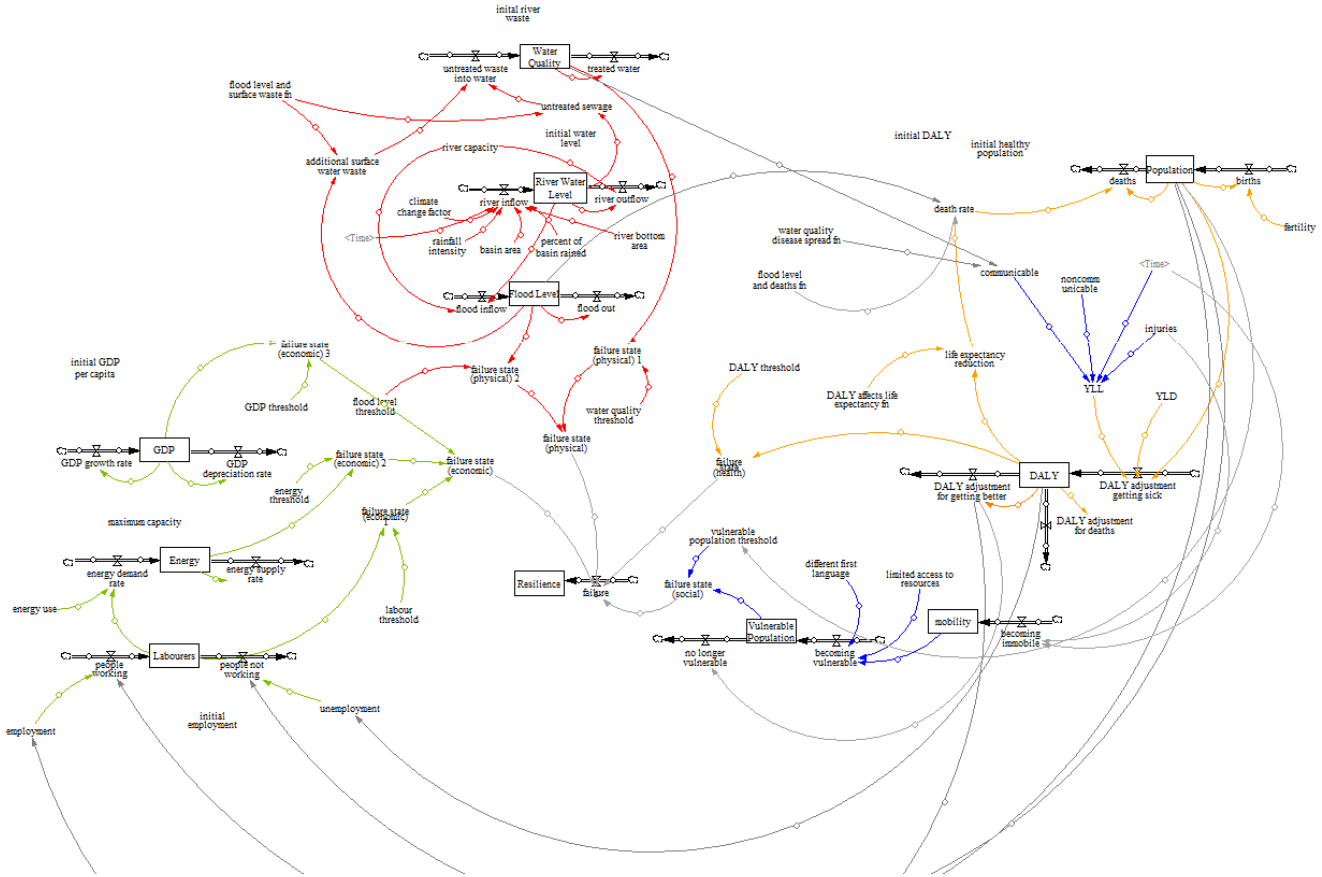
City resilience simulator – ver 1



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2012 Advanced Institute, Taipei
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MODELING RESILIENCE
Model data needs

- Data needs – time series

Other

Details related to water infrastructure, coastal infrastructure types, properties and maintenance
Disaster response plans and emergency management provisions
Details pertaining to expected disaster aid

Physical

Local climate patterns
Hazard data (historical and predicted)
Damage data

Economic

City-wide economic data including: imports and exports of goods, provision of services, production
Gross Domestic Product (GDP)
Work and labour data – employment statistics; jobs data
Energy production, consumption and distribution data

Social

Population statistics
Behavioural data (culture, religion, etc) related to disaster preparedness, response, recovery and adaptation

Health

Local disease data and statistics
DALY values
Mobility data (impact of local diseases on mobility)
Infection data (onset time, rate , duration of infection
Vaccination availability for communicable diseases

MODELING RESILIENCE
Model data needs

- Data needs – spatial information

Other
Digital Elevation Models (DEMs)
Digital boundary files; define geographic area of interest
Water features (rivers, lakes, oceans, ponds etc.)
Land cover data (trees, grass, sand, etc.)
Land use data (agricultural, industrial, commercial, residential, etc.)
Hydrological surveys of coast and rivers
Physical
Spatial distribution of hazards (area affected)
Economic
Fine resolution economic data (focus on locations)
Distribution of wealth
Energy distribution system
Social
Population characteristics;
Age (population under 19; population aged 65 and over; etc)
Gender (female population; ethnicity, etc)
Social status (average dwelling value; household income; incidence of low income; population who rent; etc)
Education (population with high school education; population with university education; etc)
Household arrangement (single-parent families; female-headed single-parent families; etc)
First language

19 | CONCLUSIONS

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20 | RESOURCES

www.slobodansimonovic.com

Research -> FIDS -> Research projects

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