Dynamic Resilience to Climate Change Caused Natural Disasters in Coastal Megacities – Quantification Framework

Slobodan P. Simonović
Department of Civil and Environmental Engineering
Western University

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

3 | LOCAL CONTEXT

- Record rainfall in Beijing – July 2012
  - heaviest rainfall in 60 years (460 mm in Fangshan district)
  - Beijing was like "standing under a waterfall "
  - 37 people dead, 65,000 evacuated, and 1.9 million people affected
  - 500 flights cancelled at the main airport
  - economic losses estimated to 10 bn yuan




4 | PRESENTATION OUTLINE

- Introduction
- Resilience modeling
  - Systems approach
  - Space-time dynamic resilience measure (ST-DRM)
  - City model
- Implementation – Generic City Model
- Conclusions

5 | INTRODUCTION
Project

- Project: Coastal Cities at Risk (CCaR) - Building Adaptive Capacity for Managing Climate Change in Coastal Megacities
  - International research initiative on adaptation to climate change
  - International Development Research Centre - NSERC, SSHRC, CIHR
  - Five years - $2.5 M
  - Vancouver – Canada
  - Manila – Philippines
  - Lagos – Nigeria
  - Bangkok - Thailand

6 | INTRODUCTION
Needs

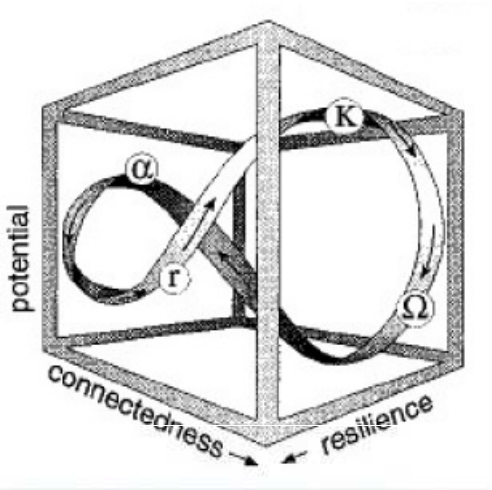
- Hazards from natural disasters
  - No procedures to quantify resilience
  - No procedures for comparison of communities in terms of resilience
- Resilience framework
  - Not only assessment of direct and indirect losses
  - Broader framework
- Need to move beyond qualitative conceptualizations to more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

Manila

Bangkok

Lagos

7 | MODELING RESILIENCE
Basics

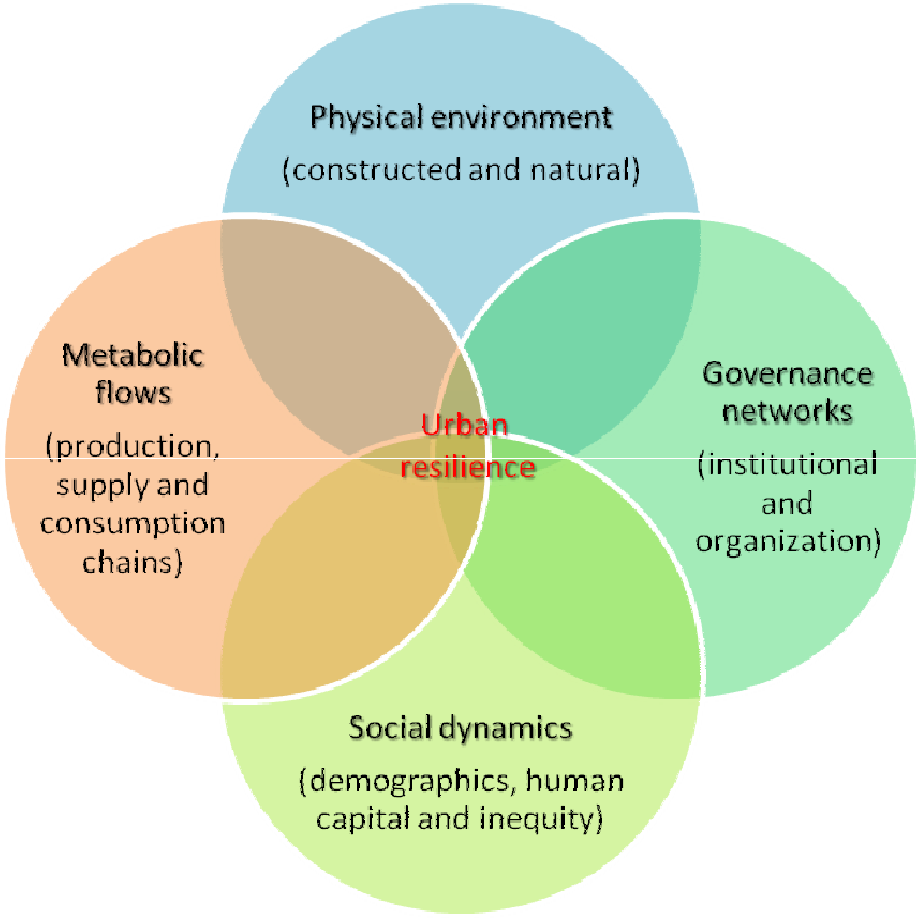


- Definitions
  - Initial ecology-based (Holling, 2001)
    - …the ability of a system to withstand stresses of 'environmental loading'…
  - Hazard – based
    - …capacity for collective action in response to extreme events…
    - …the capacity of a system, community, or society potentially exposed to 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…

8 | MODELING RESILIENCE
Basics

- 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) .
- 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)

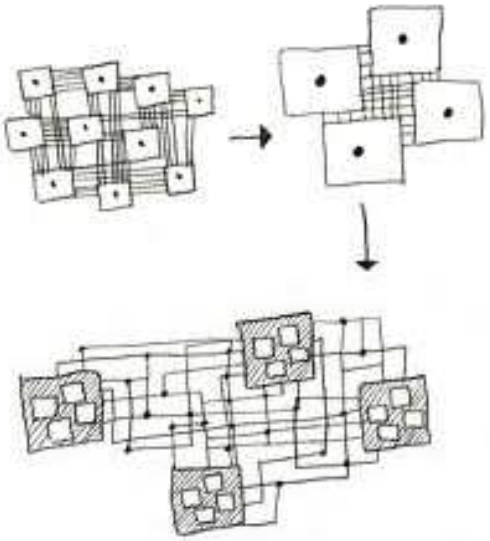
MODELING RESILIENCE
Basics



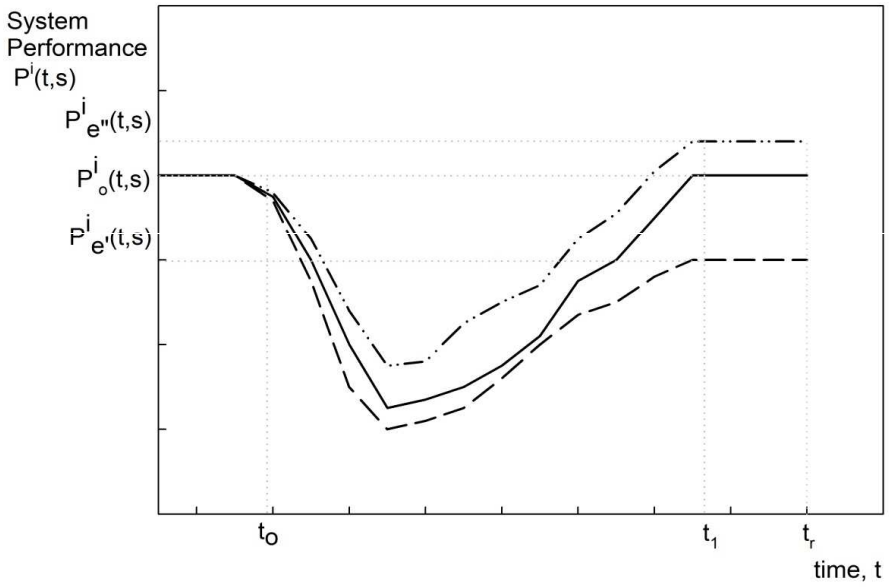
Modified after Resilience Alliance, 2012 (www.resalliance.org)

10 | 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
  - …..



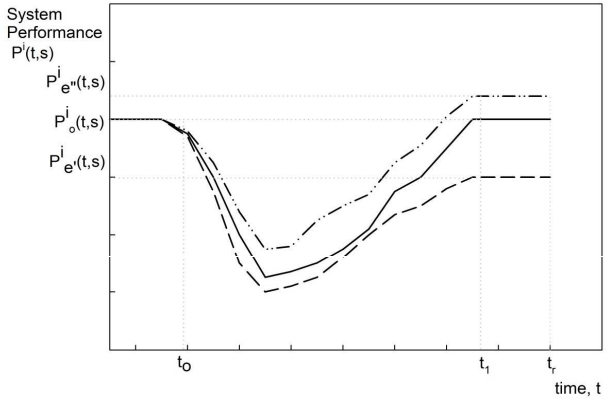
11 | MODELING RESILIENCE
Space-time dynamic resilience measure (ST-DRM)



- 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
  - …..

12 | MODELING RESILIENCE
Space-time dynamic resilience measure (ST-DRM)

- ST-DRM integrates various units that characterize impacts of disasters on urban community:
  - physical impacts (i=1) - length [*km*] of road being inundated by a flood, or the reduction in water supply [m^3/s] due to pipe break, and so on.
  - health impacts (i=2) - integral index like disability adjusted life year (DALY), or the number of hospital beds in emergency hospitals, and so on.
  - economic impacts (i=3) - aggregate like GDP, or much more sophisticated input-output modeling.
  - social impacts (i=4) - age, gender, ethnicity, social status, education and household arrangement.
  - organizational impacts (i=5) - number of disaster management services available to the population, or the time [*hr*] required under the current regulations to provide assistance or process a damage claim, or similar.

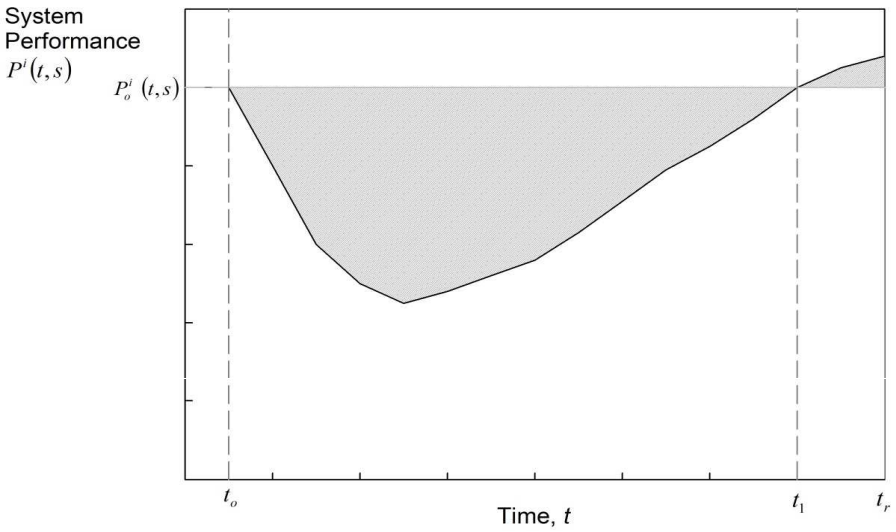


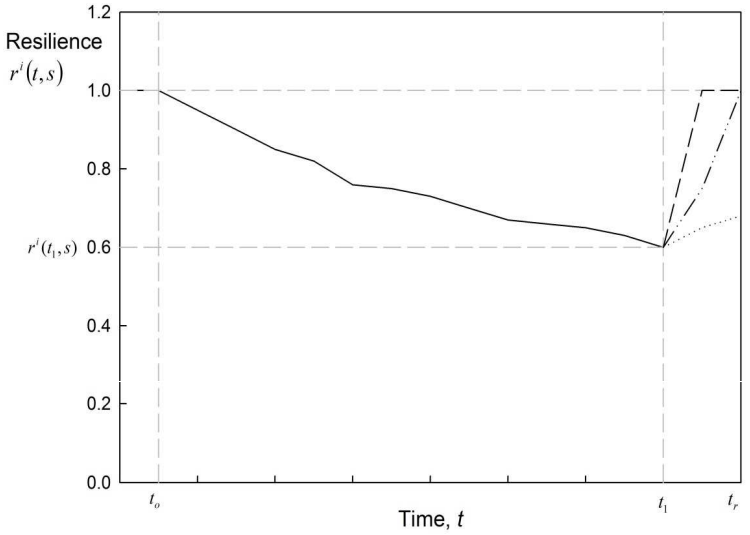
$$P^i(t,s), i = 1, \ldots, 5$$

13 | MODELING RESILIENCE
Space-time dynamic resilience measure (ST-DRM)

Critical system	Robustness	Redundancy	Resourcefulness	Rapidity
Water	% of residential buildings with safe drinking water service immediately following a flood event	Alternative and secondary drinking water sources	Water conservation programs, boil water advisories, bottled water initiatives implemented	Reestablish safe drinking water supplies in 1 day
Power	% of all residential buildings with power service immediately following a flood event	Alternative power supplies	Power conservation programs implemented	Reestablish power to residential buildings in 1 day
Hospital	% treatment of injured people and ability to provide patient care without transfers	Alternative hospitals and care clinics	Arrangements for temporary hospitals and treatments	Treat all injured persons in 2 days
Emergency Response Services	% of response vehicles that maintain service	Multiple response units with multiple emergency routes	Allocate additional voluntary emergency responders for disaster assistance	Maintain emergency response at all times, provide emergency shelters for displaced residents within 12 hours

14 | MODELING RESILIENCE
Measure of resilience





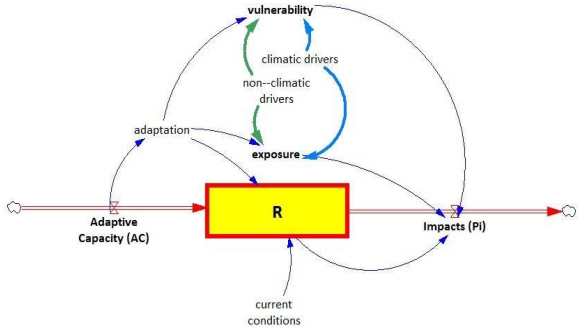
$$\rho^i(t,s) = \int_{t_0}^{t} [P_0^i - P^i(\tau,s)]d\tau$$

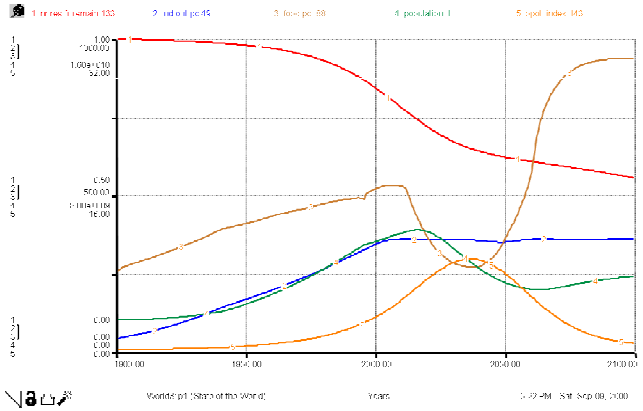
$$r^i(t,s) = 1 - \left(\frac{\rho^i(t,s)}{P_o^i \times (t - t_o)}\right)$$

$$where\ t \in [t_0, t_r]$$

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

15 | MODELING RESILIENCE
Implementation - city resilience simulator





Temporal dynamics

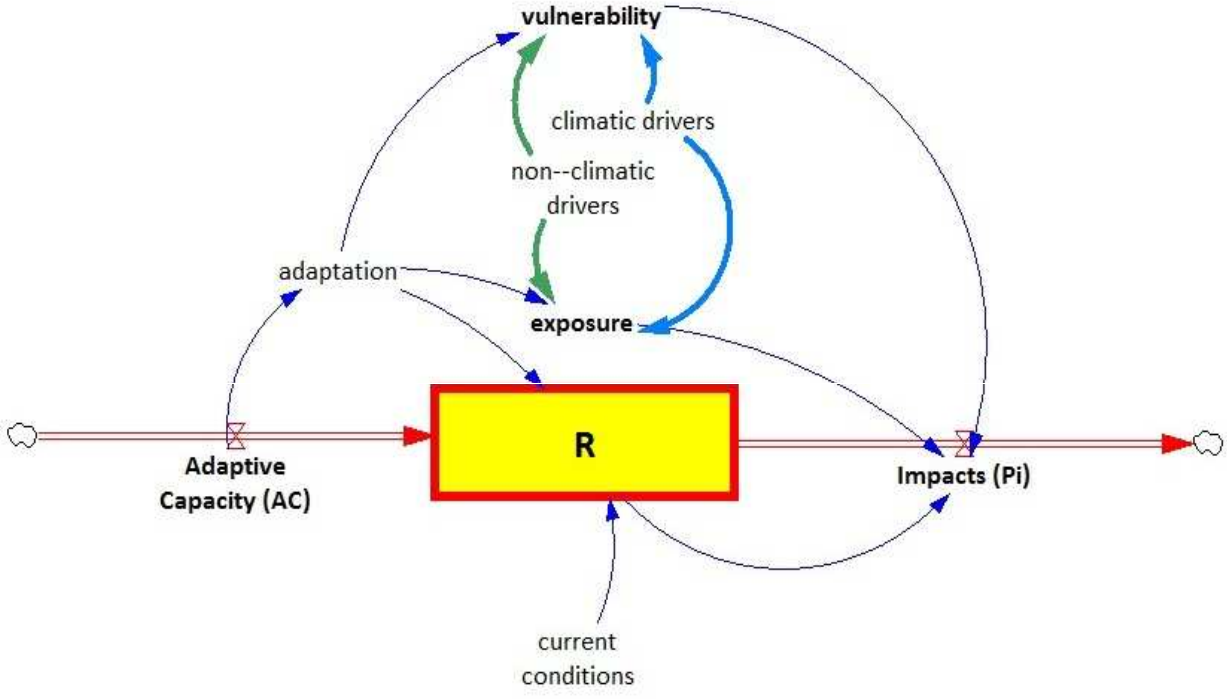
SD ⟺ GIS

dynamic data exchange

Spatial dynamics

MODELING RESILIENCE

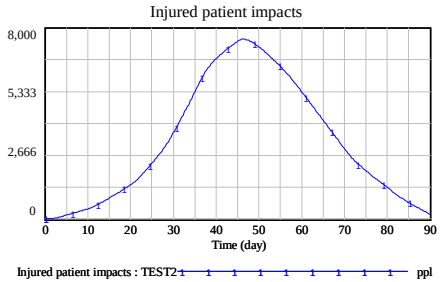
City resilience simulator

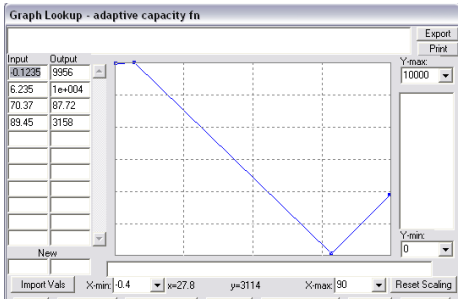


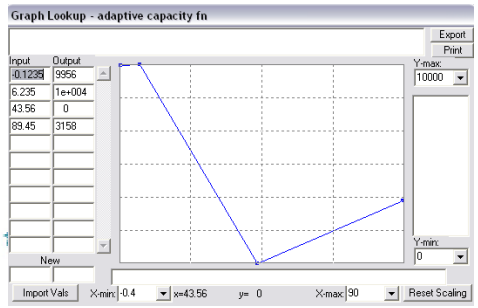
$$\frac{\partial \rho^i(t)}{\partial t} = AC^i(t) - P^i(t)$$

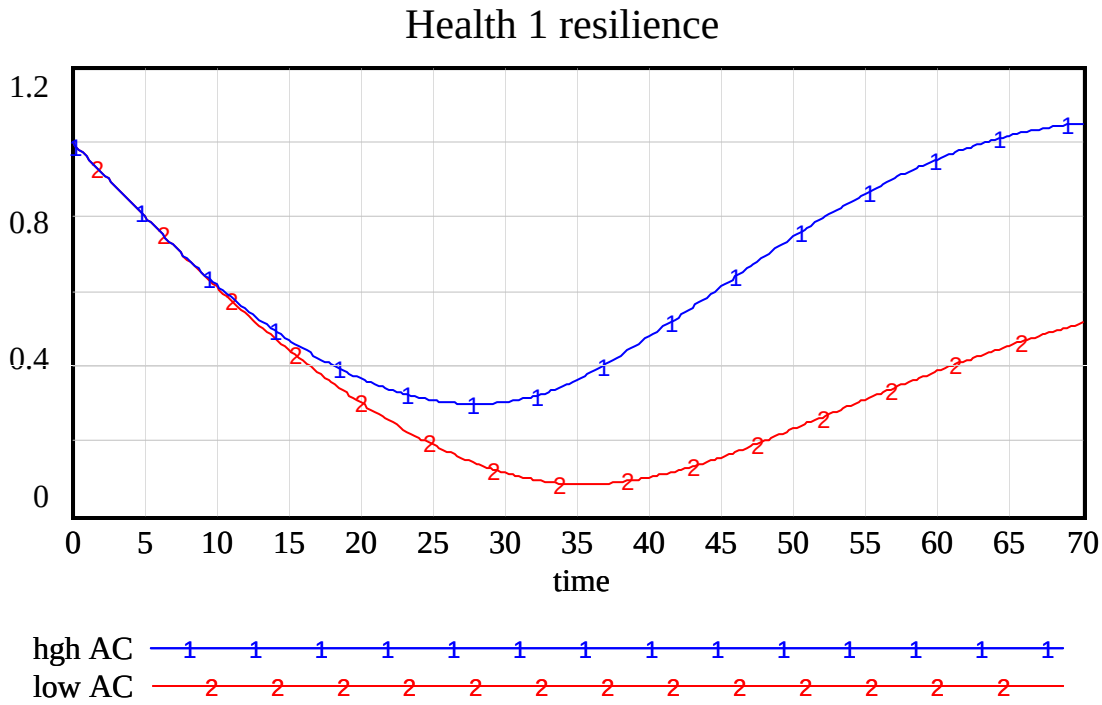
$$\frac{\partial R(t)}{\partial t} = AC(t) - \prod_i P^i(t)$$

17 | MODELING RESILIENCE
City resilience simulator – proof of concept

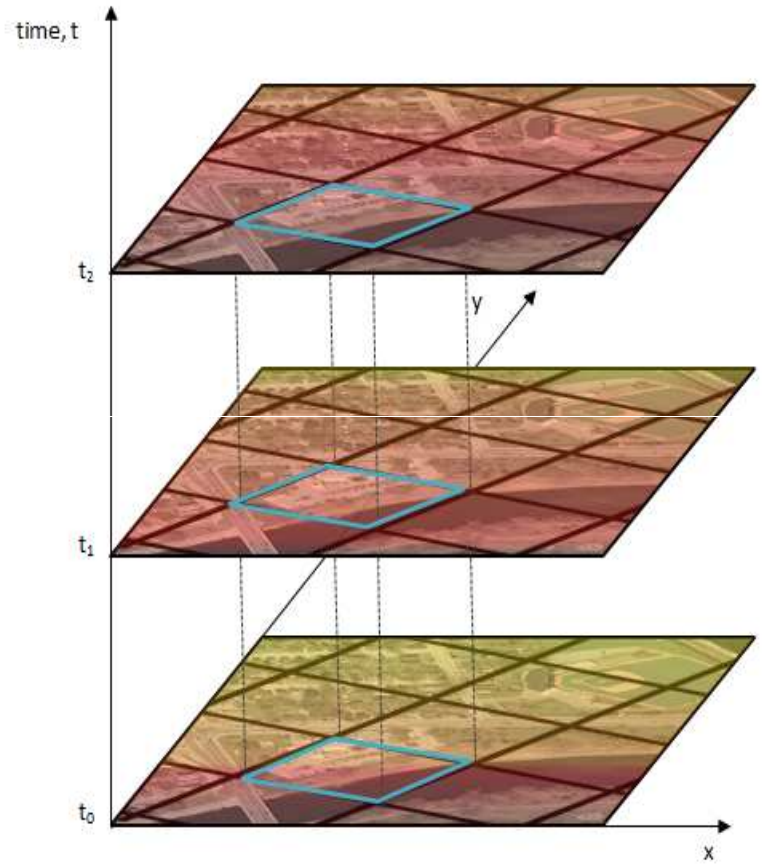








18 | MODELING RESILIENCE
City resilience simulator



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20 | RESOURCES

www.slobodansimonovic.com

Research -> FIDS -> Research projects