USE OF QUANTITATIVE RESILIENCE IN MANAGING URBAN INFRASTRUCTURE RESPONSE TO NATURAL HAZARDS

RESILIENCE
-Imperative of the society under global change-

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CONCLUSIONS

- There are **practical links** between adaptation to global change and sustainable development leading to:
  - re-enforcing **resilience** as a new development paradigm
- **Systems approach** to quantification of resilience allows:
  - capturing temporal and spatial dynamics of disaster management
  - 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
- To mitigate damages, **resilience to disasters** should be **integrated** into various planning, design and operational policies.
3 | PRESENTATION OUTLINE

- Introductory remarks
- From risk to resilience
  - Limitations of risk management
  - Definition of resilience
  - Quantification of resilience
  - Implementation of quantitative resilience measure
    - Systems approach (simulation, time and space)
- Example
  - ResilSIMt decision support system
- Conclusions
**INTRODUCTION**

4 | Research support

**Principal investigator**

- Systems Engineering Approach to the Reliability of Complex Hydropower Infrastructure

- Linking Hazard, Exposure and Risk Across Multiple Hazards
  - NSERC CRD with Chaucer Synd.: 2015-2019 $1,375,600

**Co-investigator**

- Coastal Cities at Risk (CCaR): Building Adaptive Capacity for Managing Climate Change in Coastal Megacities
  - IDRC - International Research Initiative on adaptation to Climate Change: 2011 – 2016 $2,500,000

- Advanced Disaster, Emergency and Rapid Response Simulation
  - NSERC CREATE: 2015-2021 $1,650,000
INTRODUCTION
Global change

- Global change
  - Population growth
  - Land use change
  - Climate change
  - **Complexity and uncertainty**

- Infrastructure systems (hard)
  - Water
  - Energy
  - Transport
  - Communications

- Infrastructure (soft)
  - Institutional
  - Social
  - Cultural
INTRODUCTION
Red River flood of the Century (USA and Canada) 1997
RISK TO RESILIENCE
Need for paradigm change

Risk = Hazard x Consequence

Legend:
- Risk Index
  - 0.00
  - 0.01 - 0.05
  - 0.05 - 0.10
  - 0.10 - 0.25
  - 0.25 - 0.50
  - 0.50 - 1.00

Arterial Roads
River

Kilometers
0 1 2 4 6 8
RISK TO RESILIENCE
Need for paradigm change

- Risk management framework
  - Static (in time and space)
  - Difficulties in assessing probability of extreme events
  - Difficult integration of physical, social, economic and ecological concerns

- Resilience framework
  - Dynamic (in time and space)
  - Not only assessment of direct and indirect losses – broader framework
RESILIENCE
Definitions

• Latin origin *resilire, resilio* – bounce
• Mechanics – strength and ductility of steel beams (Rankin, 1867)
• Systems theory - ecology (Von Bertalanffy, 1950; Holling, 1973)
  • ...measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variable...
• Hazard – based
  • ...capacity for collective action in response to extreme events...
  • ...the capacity to absorb shocks while maintaining function...
  • ...the capacity to adapt existing resources and skills to new situations and operating conditions...
• Used in this research –after UNISDR (2009)
  • ...the ability of a system and its component parts to absorb, accommodate or recover from the effects of a system disruption in a timely and efficient manner, including through the preservation, restoration or improvement of its essential basic structures and functions...
RESILIENCE

Quantification

- System performance and system adaptive capacity
- Transformation of system performance into resilience

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

\[ r(t) = 1 - \left[ \frac{\rho(t)}{P_0 \times (t - t_0)} \right] \]

\( t \in [t_0, t_r] \)
Implementation – temporal and spatial dynamics

\[ \frac{dr(t)}{dt} = AC(t) - P(t) \]
INFRASTRUCTURE RESILIENCE

Web based tool

...and all that implemented........
WEB BASED TOOL

- www.resilsim-uwo.ca (prototype)
- www.resilsimt-uwo.ca (new version)
  - Decision support system (DSS)
WEB-BASED TOOL

Project: Toronto Pilot (Pilot project for the city of Toronto)
WEB-BASED TOOL

Project: Toronto Pilot (Pilot project for the city of Toronto)
Project: Toronto Pilot (Pilot project for the city of Toronto)

Adaptation Measures
- Maintenance of drainage infrastructure
  - Reduced flood extent (Roads (DSM))
  - Invest in resilience building projects
  - Installation of backwater valves and other protection measures (Buildings (DSM))
- Improving evacuation
  - Improved training for faster evacuation and relocation (Critical Facilities (DSM))

Transformers Protected
- Transformers Protected (Toronto Hydro)
- Surface drainage
  - Improving surface drainage (Roads (DSM))
20 | WEB-BASED TOOL
There are practical links between adaptation to global change and sustainable development leading to:
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  - 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
- To mitigate damages, resilience to disasters should be integrated into various planning, design and operational policies.
REFERENCES

www.slobodansimonovic.com
Research -> FIDS -> Research projects


Slobodan P. Simonović
Research facility

• Computer-based research laboratory
• Research:
  • *Subject Matter* - Systems modeling; Risk and reliability; Water resources and environmental systems analysis; Computer-based decision support systems development.
  • *Topical Area* - Reservoirs; Flood control; Hydropower energy; Operational hydrology; Climatic Change; Integrated water resources management.
• > 70 research projects; ~ $11.5 M
• Completed: 8 visiting fellows, 18 PosDoc, 21 PhD and 43 MESc
• Current: 1 PosDoc (+1), 3 PhD, 1 MESc and 1 visiting (+2)
Slobodan P. Simonović
Research results

- > 540 professional publications
- > 230 in peer reviewed journals
- 3 major textbooks

- Water Resources Research Reports
  105 volumes
- > 73,000 downloads since 2011
• Water Resources Management Capacity Building in the Context of Global Change
• **Systems Engineering Approach to the Reliability of Complex Hydropower Infrastructure**
• Advanced Disaster, Emergency and Rapid Response Simulation
• Linking Hazard, Exposure and Risk Across Multiple Hazards