



## The Role of Critical Infrastructures' Interdependencies on the Impacts caused by Natural Disasters

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### The Role of Critical Infrastructures' Interdependencies on the Impacts caused by Natural Disasters



- Context
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  - A Simulation Model
- Conclusion
- Further research

## Context



- What makes people remember the occurrence of a natural disaster years later?
- Why have disasters such as Sandy, Katrina, Haitian and Japanese earthquakes and Eyjafjallajökull volcano had such a great impact on society?



### Significant effect on Critical Infrastructures (CIs)

- Society is highly dependent on their correct functioning
- If a CI is damaged consequences may affect whole society

## Objective

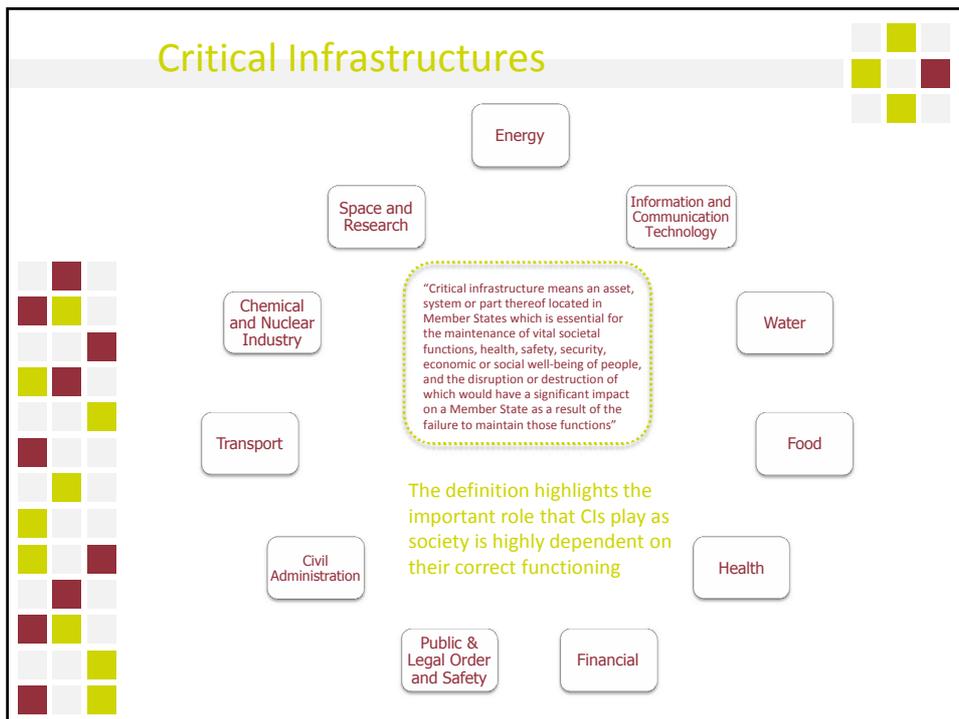
- Emphasise the important role of CIs and their interdependencies
- Include evolution over time on impact analysis



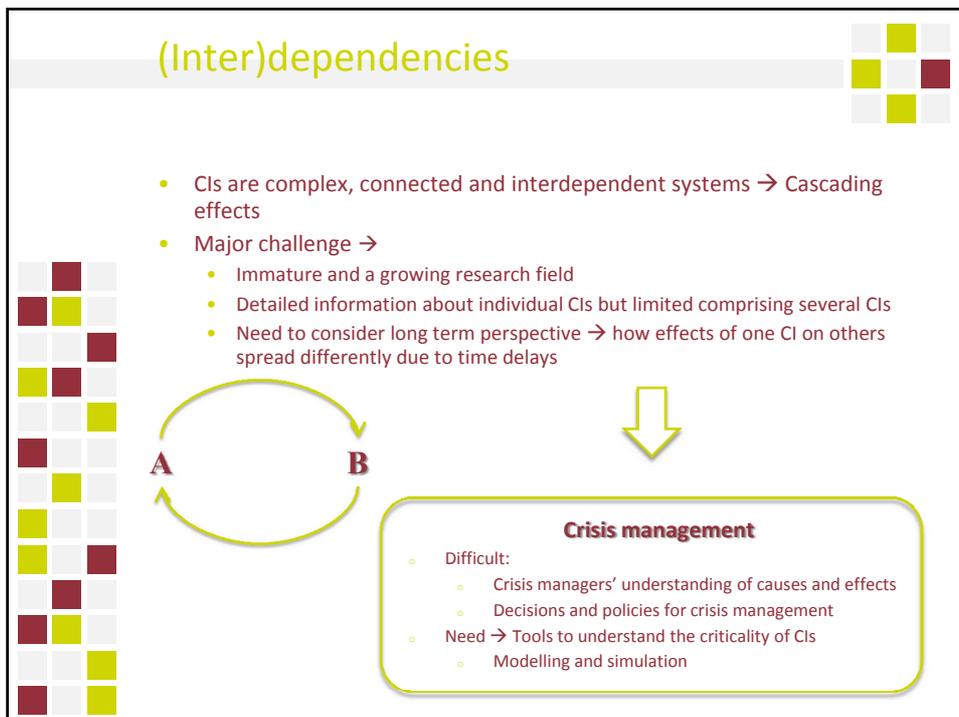
### Simulation model

- Based on →
  - Effect of a natural disaster on CIs
  - Consequences of CIs interdependencies
  - Effect of policies related to disaster management
- Allows →
  - Analysis of how the presence of interdependencies between different CIs aggravates and prolongs disaster consequences

## Critical Infrastructures



## (Inter)dependencies



## Modelling and simulation



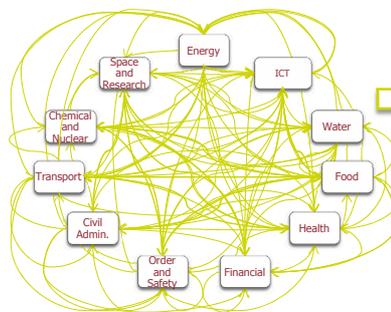
- Several authors highlighted the importance of modelling and simulation of CIs and their interdependencies for national and international security
  - To include system's dynamics through variables' evolution
  - To help crisis management in prevention, preparation, response and recovery phases
  - Their criticality makes analysis of system behaviour a very relevant task
- CIs interdependencies modelling difficulties:
  - Data gathering → Information not easily available
  - Level of abstraction → Very detailed level (too much information) vs. too aggregated level (might not give significant results)
  - Multidisciplinary agents → Agents with different expertise have different points of view and information about the same CIs
  - CIs owners "limited" knowledge → Good idea about the CIs they directly depend upon but not about higher order dependencies
  - Unforeseen effects → Systems complexity can produce unforeseen effects
  - Standard for CIs modelling → Not one standard methodology



## Modelling and simulation



- Modelling methodologies used for CIs:
  - Agent based models
  - Input-Output models
  - Dynamic simulation → Includes long term perspectives and evolution over time. Based on feedback interactions (analogous to CIs interdependencies)



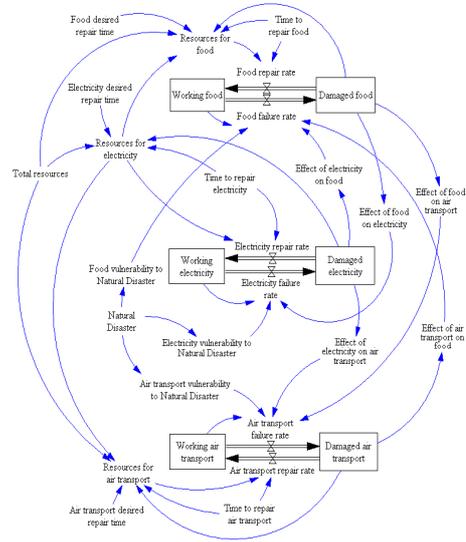
Including interdependencies among all CIs could lead to an improvement in crisis management

Therefore, there is still work to do in this research field

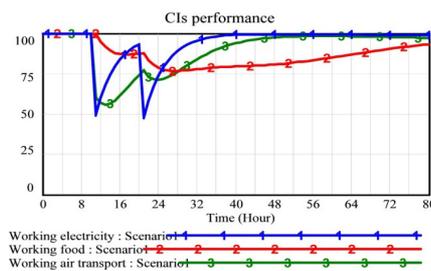


## A Simulation Model

- Dynamic analysis of impacts illustrates
  - Crucial role of in subsequent impact generation
  - Higher the level of interdependencies, more prolonged and aggravated impacts
- System Dynamics simulation models
  - Not focus on the isolated events but rather on behavior patterns that these events lead to
  - Allows handling “soft” variables and not only technical but also human and organizational aspects
  - Enables visualizing unintended side-effects
- The simulation model
  - Non linear look up tables have been included to calibrate the relation among variables
  - Quite high aggregation but still allows including enough detail about CIs performance, their interdependencies and the effects of carrying out policies



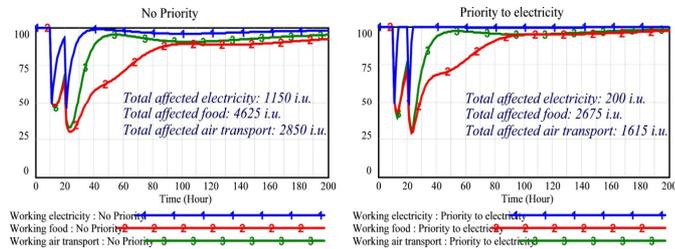
## A Simulation Model



Hour 10 → 3 CIs damaged by winds  
 Hour 20 → Electricity damaged by floods

- At hour 20 air transport and food performance also goes down due to their dependency on electricity
- Air transport and food do not fail as rapidly as electricity (power generators)
- Food’s performance needs longer time to recover due to high dependency on others:
  - Time is needed to recover usual level of food supply after recovering air transport
  - Raw materials lost without electricity to refrigerate them
  - Firstly other CIs have to be restored and then could food improve its performance

## A Simulation Model



Hour 10 → 3 CIs damaged by winds  
Hour 20 → 3 CIs damaged by floods

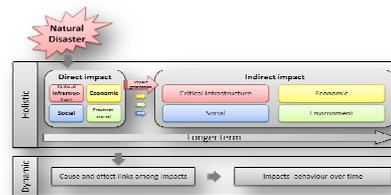
- Crisis managers have to make decisions about resources deployment policies.
- “No priority” and “Priority to electricity” scenarios
- Giving priority to electricity shows better results as electricity is the most influential CI
- The higher the time electricity is down, the higher its impact on CIs will be
- Complete recovery of CIs:
  - “Priority to electricity” → < 2 weeks
  - “No priority” → 1 month

## Conclusion

- This research highlights the important role that CIs and their interdependencies play in the impacts a natural disaster generates
- It is necessary to improve natural disasters management by paying more attention to CIs and their interdependencies system
- Simulation model:
  - Allows holistic perspective (social, environmental, economic...) to help crisis managers having a complete view of the system they are managing
  - Allows managers to simulate different scenarios with short or long term perspectives
  - Can help analyzing the effects of carrying out several policies to develop new policies, preparation and legal and regulatory issues
  - Allows gaining a better understanding of how the impacts, that natural disasters or interdependencies lead to, evolve over time
  - Valuable training tool

## Further research

- Simulation model with pedagogical purpose →
  - Calibrate it more accurately with real data for different scenarios
  - Include most important interdependencies among all CIs
  - Include more policies (from prevention to response phases)
- Develop a natural disaster impact dynamic framework in order to assist natural disasters management
- Properly evaluating the impacts following a crisis helps managers to efficiently manage them through the development of preventive and response programs
- By analysing crisis evolution over time and how consequences spread, managers can learn how decision making and the carrying out of different policies affect the final crisis impact



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Thank you!

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