Università di Genova
DICCA DIPARTIMENTO DI INGEGNERIA CIVILE, CHIMICA E AMBIENTALE

A resilience-based methodology for the multi-risk assessment of urban settlements to be implemented in sustainable planning and management tools

A PhD project at Genoa University cycle XXXVII

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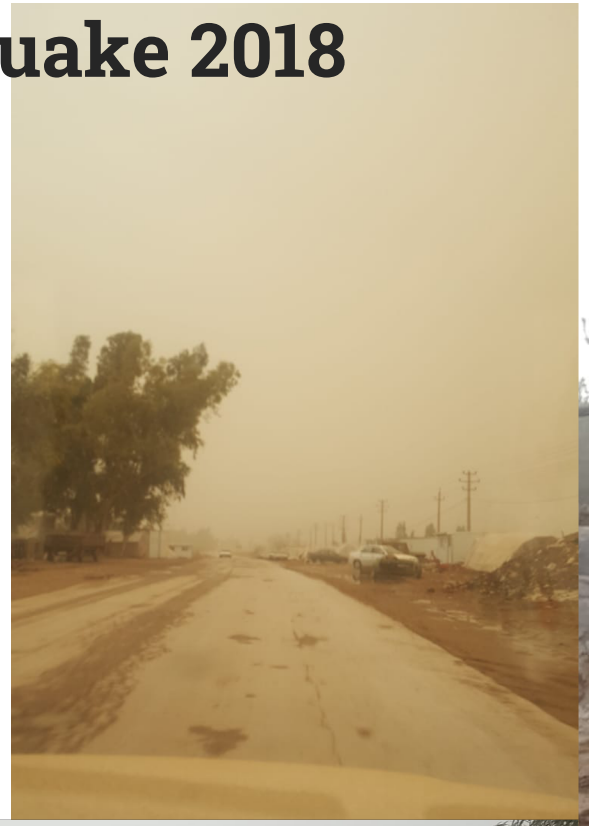
Some experiences

Sarpol-e Zahab earthquake 2018



magnitude 6.3

western Iran near its border with Iraq

Dust storm

Multi-Risk

Sarpol-e Zahab earthquake 2018

Life line infratructure access

Estimated time of the reconstruction

Sarpol-e Zahab earthquake 2018

Still 42 administrative buildings remained destructed

Confusion amongst the population

Sarpol-e Zahab flood 2019

Temporary houses by the river

Flood is a frequent hazard in Sarpol-e Zahab

Multi-hazard

Multi-risk

Flood in impacted community by earthquake

Sarpol-e Zahab flood 2019

Multi-risk neglected in recovery phase

Urban fabric, it collapsed with an earthquake, it washed away with a flood

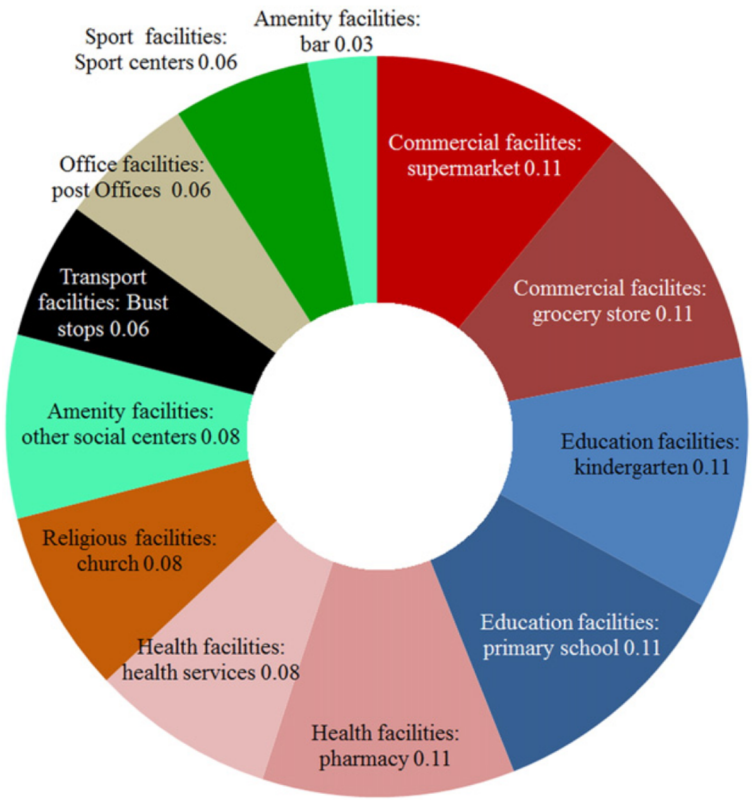
L'Aquila earthquake 2009

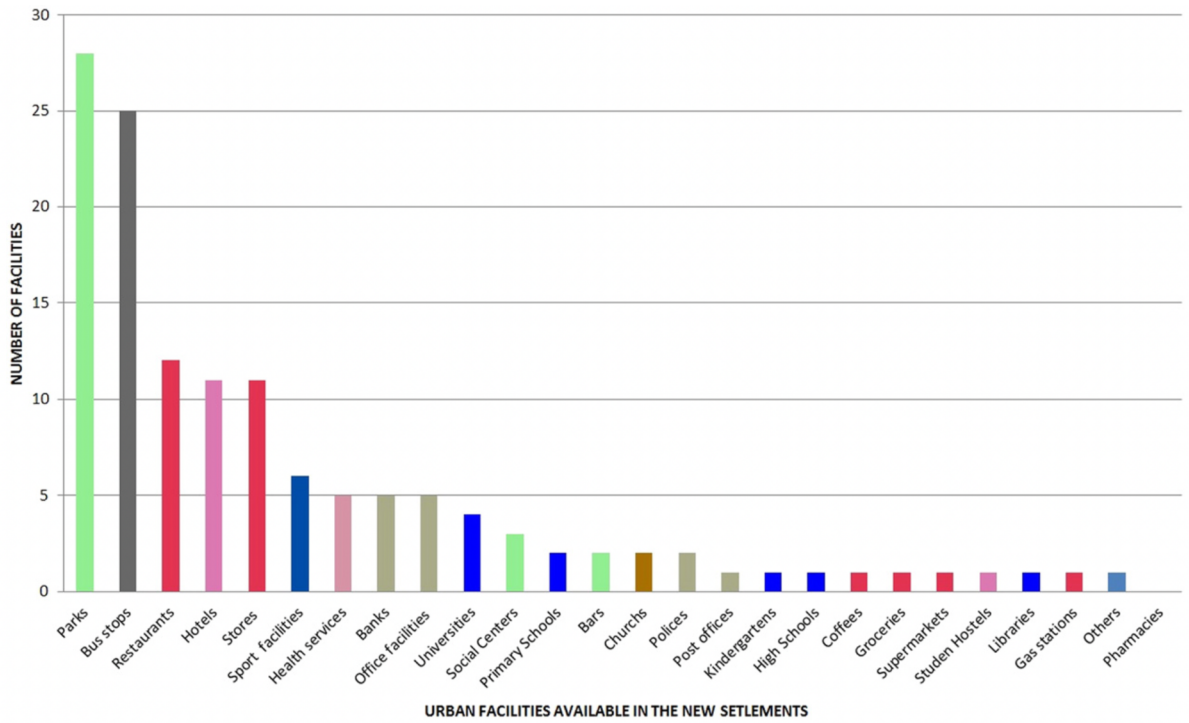
Cultural heritage and it’s role in citizen’s identity

L'Aquila earthquake 2009

Relative weights allocated to each category of urban facilities by adults with families (with larger values indicate a greater importance).

Source: Contreras, D., Blaschke, T., Kienberger, S., Zeil, P., 2014. Myths and realities about the re- covery of L'Aquila after the earthquake. Int. J. Disaster Risk Reduct.



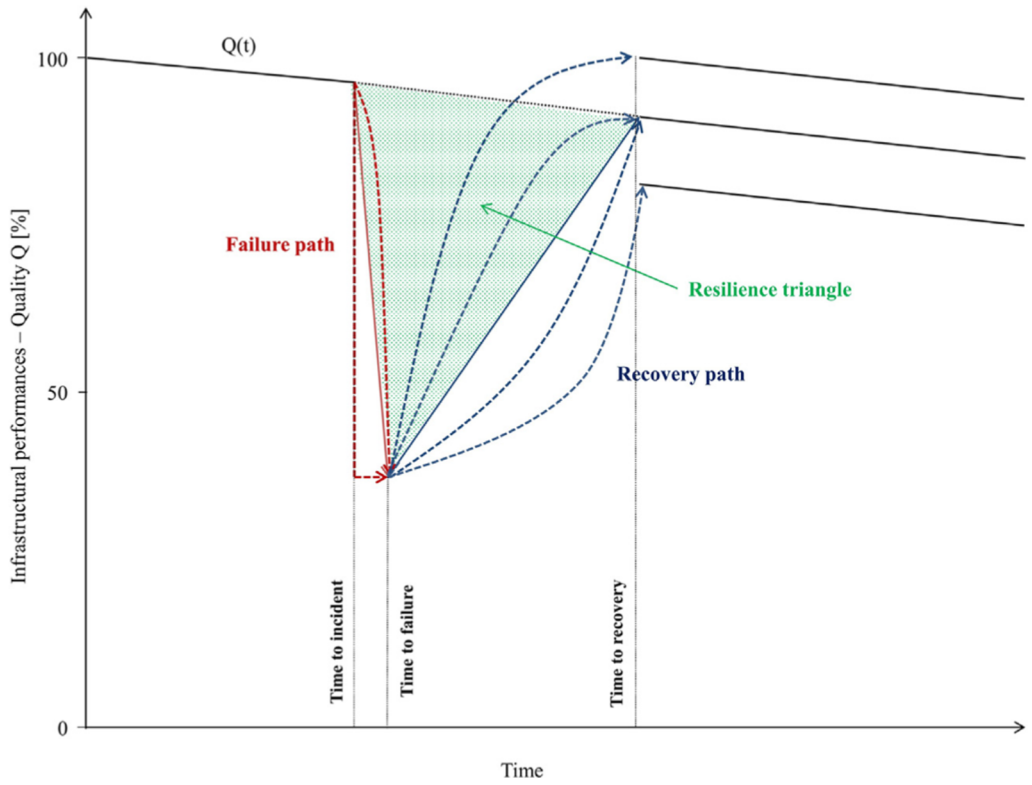


Urban facilities available in the new settlements built to accommodate the displaced population from the earthquake in 2009

Source: Contreras, D., Blaschke, T.,, 2016. Lack of spatial resilience in a recovery process: Case L'Aquila, Italy ,Technological Forecasting & Social Change

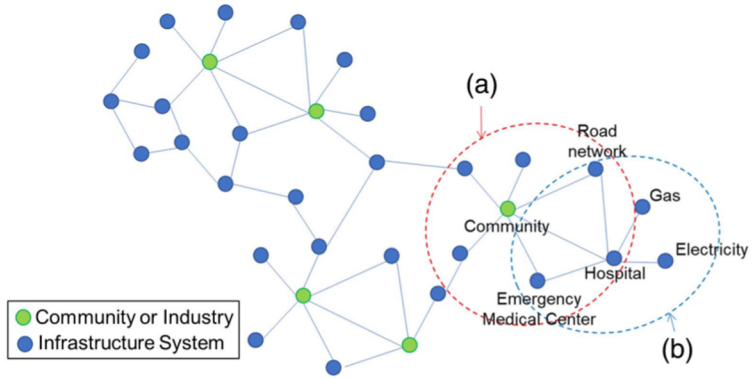
Some theory

Resilience triangle & interdependencies



Graphical representation of resilience and of the 'resilience triangle'

Source: Ayyub, Bilal M. "Systems resilience for multi-hazard environments: Definition, metrics, and valuation for decision making." Risk analysis



Community and infrastructure systems in a multi-infrastructure network: (a) community as a primary node and its associated infrastructure nodes in pursuing public health function; and (b) hospital as a primary node and its associated infrastructure nodes in maintaining the hospital's building facilities.

Source: Choi, J., Deshmukh, A., & Hastak, M. (2019). Seven-layer classification of infrastructure to improve community resilience to disasters. Journal of infrastructure systems

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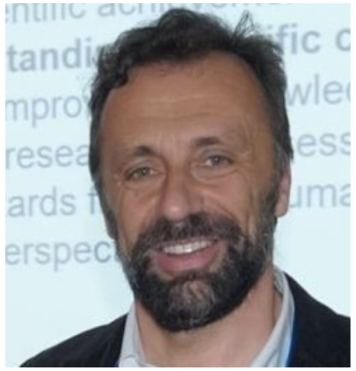
My Ph.D. research

Research title

A resilience-based methodology for the multi-risk assessment of urban settlements to be implemented in sustainable planning and management tools.

The University of Genoa (DICCA) research team



Giorgio Boni
Full professor,
Hydrometeorology, Flood Forecast, Flood Risk Assessment, Hydrology, Remote Sensing

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Earthquake Engineering, seismic vulnerability and damage assessment, Performance-based assessment of existing buildings and masonry cultural heritage

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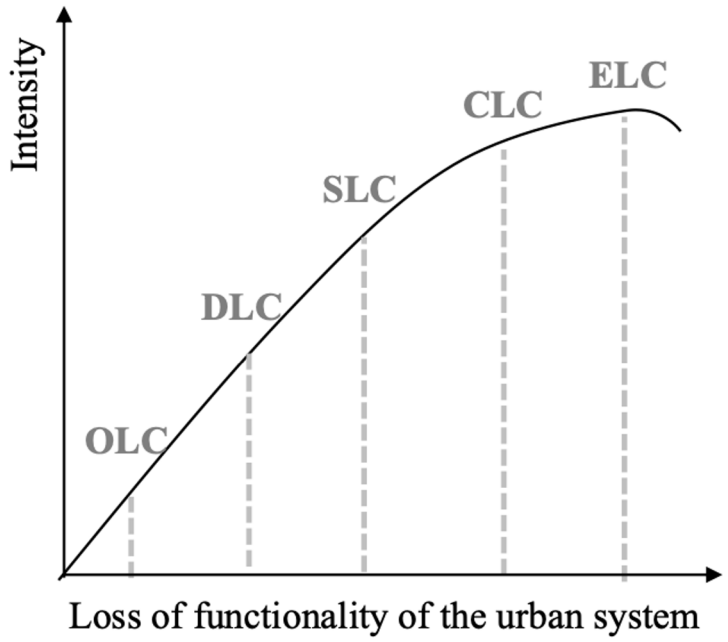
sustainable water management, climate change mitigation and adaptation, disaster risk reduction, single and multi-hazards risk assessment

Research Goal

develop a resilience-based methodology applicable to multiple hazards for **identifying the set of urban structures (i.e. the "minimum urban system")** to which act to **strengthen the robustness and ensure a fast recovery of the urban settlement**, preserving as much as possible its **essential attributes**

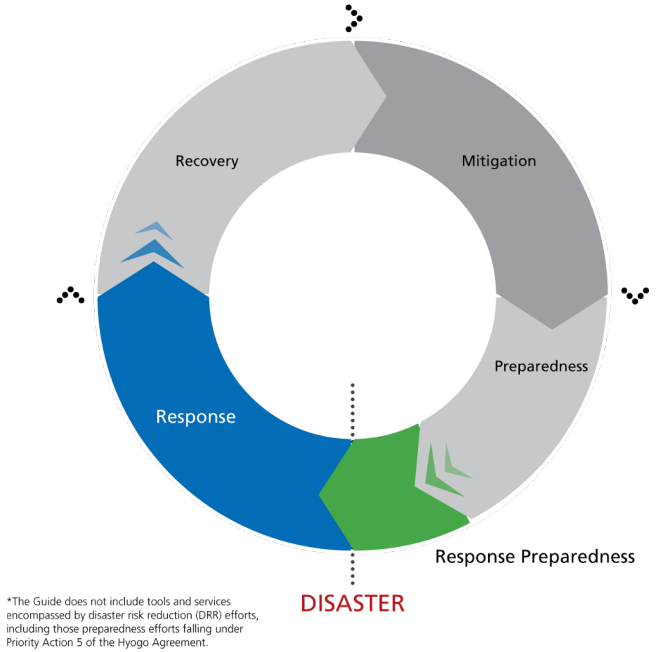
implement the methodology into **urban planning tools** to be really **applicable** by the relevant stakeholders.



ELC - The Emergency Limit Condition, when the **entire urban settlement** suffers physical and functional damage enough to produce the **interruption of almost all its urban function, except for** most of its strategic functions for an **emergency and their connection and accessibility with its surroundings.**

CLC - The Limit Condition of Collapse, when only a **few primary urban functions resist**

SLC - The Limit Condition for Safeguarding the existence of the settlement,
when the **damage is significant or prolonged in time,** though **not enough to compromise the general characteristics of the settlement.**
Main urban function are interrupted.



Conceptual graphical representation of the Limit Conditions proposed by the Italian CPD

Research aims & steps

1. Recognize and scoring vital functional system elements in the city, taking into account their role in the response and recovery process and also other features on which the livelihood of citizens and the sustainable development of the city depend.
2. Determining the overall functionality of the system (city) after a disaster, evaluating the impact on the system (and minimum urban system) of a given set of hazard scenarios, including flood, earthquake and multi hazard scenarios.
3. Optimization investments on basic urban structures before disaster based on the predetermined criteria with the aim of meeting SLC and increasing the resilience of the system with the perspective of increasing recoverability

First step

	Layer 1			Layer 2			Layer 2		
ID	L1			L2.S			L2.E		
Name	Lifelines and transports layer			Community services layer (social services)			Community services layer (economic and production services)		
Description	This layer includes infra functions that provide lifeline services for other layers and functions in the system. without this layer the other functions even if their buildings would remain intact after the disaster, are not capable to provide service to inhabitants. the reason behind the separation of this layer from the others and considering it as a lower layer is that the functions in this layer may not provide direct service to the users but more like cover the required service for other basic structures that are the final service providers. It should be mentioned that the pipelines in case of water sanitation services and energy and the grid network in case of electricity and telecommunications are not going to be examined and considered because they bring a high level of complexity and it is out of the scope of this study. Instead, the attention has been paid to the building and other basic structures that are involved in these subsystems			This layer includes functions that are providing services more directly in comparison with lifeline infrastructure. Also, they are all dependent on most of the lifelines for their functionality. Normally they don't have grids or pipelines and their buildings are the places where people get benefited from the service. In this section, we have more social-oriented services and functions. Although these functions may have economic aspects what is make them critical in the recovery phase after the disaster is more their social-oriented characteristics than economics. other important point about them is the fact that maybe there wouldnt be essential interdepedency amongst the asset in this specific layes. it means that for example L2SF1 is not depended to any L2SFs (except human resource subject)			This layer includes functions that are providing services more directly in comparison with lifeline infrastructure. Also, they are all dependent on most of the lifelines for their functionality. Normally they don't have grids or pipelines and their buildings are the places where people get benefited from the service. In this section, in this section we have basic structur that ensuring the economic aspect of the livlihood of inhabitants after disaster . also some of them are essential to produce consuming goods for the community		
Functionalities	ID	Name	Description	ID	Name	Description	ID	Name	Description
	L1.F1	Electricity		L2.SF1	health		L2.EF1	comerce	
	L1.F2	water and sanitation		L2.SF2	education		L2.EF2	tourism	
	L1.F3	tlecommunication		L2.SF3	housing		L2.EF3	agriculture	
	L1.F4	energy		L2.SF4	recreation and religion		L2.EF4	construction	
	L1.F5	trnasportation		L2.SF5	cultural heritge		L2.EF5	industry	

First step

functionality	water and sanitation			Health		
ID	L1.F2			L2.SF1		
Description						
assets	ID	Name	Description	ID	Name	Description
	L1.F2.A1	urban and small town swage systems		L2.SF1.A1	hospitals	
	L1.F2.A2	storm and runoff collection		L2.SF1.A2	long terms rehabiliation centres for injured people	
	L1.F2.A3	waste water ans swage treatment facilities i.e setting ponds		L2.SF1.A3	health centres	
	L1.F2.A4	pumping system		L2.SF1.A4	chronic diseas special shelters like dyaliseas	
	L1.F2.A5	latrines		L2.SF1.A5	psycological and mental health service centres	
	L1.F2.A6	septic tanks		L2.SF1.A6	health clinics	
	L1.F2.A7	french drains		L2.SF1.A7	accomodation for epidemics seek poeopl quarantine	
	L1.F2.A8	shared collection points I.e. large waste an rubish containers		L2.SF1.A8	diseas survelinace centre	
	L1.F2.A9	collection transport garages		L2.SF1.A9	land for burying dead peoples	
	L1.F2.A10	wate manegement site for dumping sorting compacting or burning		L2.SF1.A10	pharmacies ans dispensary	
	L1.F2.A11	hazard's waste facilities		L2.SF1.A11	vaccination centres	
	L1.F2.A12	reserviors water towers rain water tanks		L2.SF1.A12	tele medicine centres	
	L1.F2.A13	pipe distribution system		L2.SF1.A13	womens needs of privacy health infrastructures	
	L1.F2.A14	pumping stations		L2.SF1.A14	warehouse and refrigrators of medecines	
	L1.F2.A15	filteration systems		L2.SF1.A15	hygine shops	
	L1.F2.A16	chloride plants		L2.SF1.A16	land for interim health sectors	
	L1.F2.A17	rain water harvesting housholds and surfaces		L2.SF1.A17	laburatories	
	L1.F2.A18	ground water boreholes and dug wells		L2.SF1.A18	self protection equipments (i.e mask) workhouses	
	L1.F2.A19	surface water sources I.e river, lakes		L2.SF1.A19	blood banks	
				L2.SF1.A20	health care waste centres	

First step

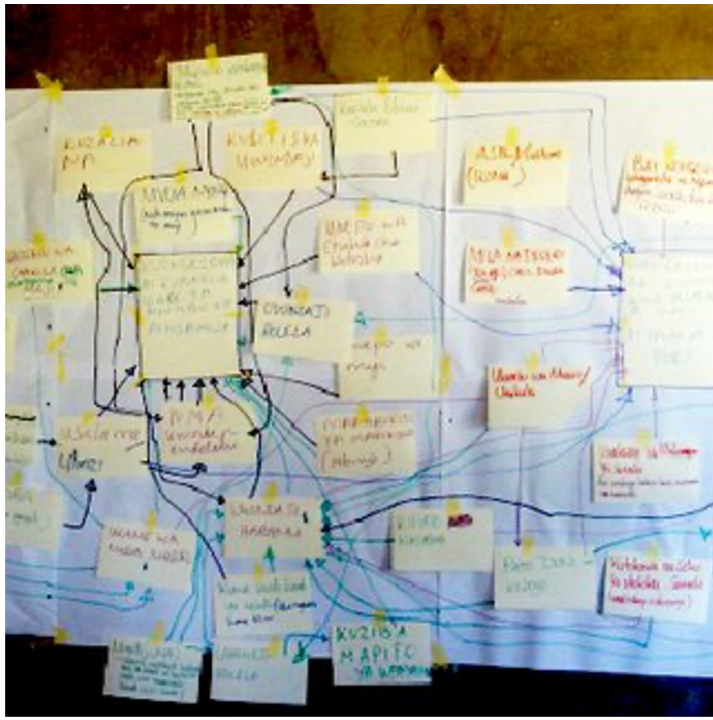
Model criteria

- number of the asset in case study
- estimated reconstruction time
- number of employees, age and education distribution
- covid lockdown closure status(open/close)
- the main threatening hazard (earthquake or flood) (controlling hazard)
- service provision/ buffer zone

we have defined more than 30 different criteria for our model, including stakeholders' opinion and dependencies between function and assets, which we will evaluate using fuzzy cognitive maps (FCM)

Fuzzy cognitive maps

- A combination of fuzzy logic and cognitive mapping, is widely used in environmental management and Social Ecological System studies to represent knowledge of systems under conditions of data scarcity and data uncertainty
- Structurally, it consists of a set of nodes (representing various variables) and fuzzy signed directed edges
- FCM models are usually developed with a participatory approach
- Stakeholders who are familiar with the operation and behavior of a system or specific problem of a system are asked to mention the most important variables, their causal relations, and the weights of the connections (i.e., how much a change of one variable causes a change in another variable).



Thank you for your attention

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