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Young CRITIS Award

Role of Urban Interactions and Damage in Seismic Resilience of Historical Centers

Anna Bozza, Domenico Asprone, Fulvio Parisi and Gaetano Manfredi

University of Naples Federico II Department of Structures for Engineering and Architecture Via Claudio 21, 80125, Naples, Italy

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INSTITUTE FOR ADVANCED STUDIES LUCCA

Why Resilience?



"Resilience is the capability of a system to withstand an external stress and bounce back to the equilibrium, i.e. its ability to have a positive response."



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Why historical centers? A specific application

Historical centers are places where local identity principles and contemporary dynamics of urbanization coexist. They conserve cultural heritage, hence the presence of many historical assets makes these places highly vulnerable and exposed.

2018 is the year of cultural heritage conservation and protection also according to the EU Horizon 2020 strategy.

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The scale of resilience

The city can be understood as a complex system



Strogatz, S.H., Nature 410.6825 (2001): 268-276.







Ecosystems

Milo, Ron, et al., Science 298.5594 (2002): 824-827.



M. E. J. Newman and M. Girvin, Physical Review Letters E, 69, 026113, 2004.

Cavallaro, M., et al., Computer-Aided Civil and Infrastructure Engineering 29.8 (2014): 608-625.

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Modelling urban ecosystems: the hybrid social-physical network (hspn)

The modelled HSPNs consist of two set of nodes and two set of edges:



- Ni, the set of street crossings nodes
- Nb, the set of building nodes
- Usb, the set of street-to-building links;
- Uss, the set of street-to-street links





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Quantifying disaster resilience



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615 door-links

547 street links

1,009 nodes (617 buildings and 395 street junctions

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- ✤ 3.57 km perimeter
- ✤ 0.569 km² wide in-plane geometry
- 614 masonry residential buildings estimated
- I7 schools
- ✤ 30,000 inhabitants estimated
- ✤ I citizen each 30sqm (ISTAT 2011)
- ✤ I to 5-storeys buildings

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Return period, T _r	PGA [g]	d [%]
2475	0.51	85
975	0.39	60
475	0.30	30
201	0.22	15
104	0.18	3

Two different recovery strategy simulated

 $y_1(c) = \frac{E(c) - E^{post}}{E^{pre} - E^{post}}$

$$R = \int_0^1 y(c) \cdot dc$$

$$y_2(c) = \frac{E(c)}{E^{pre}}$$

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Damage dependent resilience, RDD against 5 diverse damage levels in the

case of citizen-citizen recovery strategy

Damage independent resilience, RDI, against 5 diverse damage levels in the case of citizen-citizen recovery strategy

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9-11 October 2017 Damage dependent resilience, RDD against 5 diverse damage levels in the case of citizen-school recovery strategy

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Damage independent resilience, RDI, against 5 diverse damage levels in the case of citizen-school recovery strategy

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Conclusions

The novelty of the experimental framework proposed lays in the chance to merge civil engineering and ecosystem theory approaches.

The correlation between urban resilience and the damage level observed after a

This approach enables for a **systemic damage assessment**, which allows to observe

Results highlight these two resilience metrics to be collateral: the damage-

independent being more objective and proper for comparing urban HSPNs having diverse features; the damage-dependent specifically accounting for recovery efforts, hence can be useful for assessing resilience of the same HSPN subjected to diverse

event typology. Finally, they can be used paralleling to verify the assessment of any

addition, to contextually account for **anthropocentric issues**.

the urban behaviour as a whole, instead of focusing on each single structure and, in

seismic event is investigated towards the development of an experimental relationship

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between the two

urban response in case of disaster.

Conclusions

- Experimental results shown a decreasing trend of the resilience indices with respect to the increasing damage level.
- The observed drop of such indices results to be higher in the case damage dependent resilience and citizen-school recovery strategy. This is because of the higher variability of this index caused by its direct dependence on the initial level of damage. In fact, being RDD highly influenced by the network damage, causes also a higher standard deviation of the observed results.
- Despite results in terms of the damage dependent and the damage independent resilience indices being very similar against the seismic magnitude simulated, RDI seems to be unbiased. Hence, higher reliability is observed for the RDI index.
- The proposed approach can be valuable to be integrated within current traditional practices for **disaster management**. Developing preliminarily resilience curves against the damage level with respect to a certain event, can support local institutions in forecasting the urban capability to recover.

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Future and ongoing research activities

- Damage-dependent and damage-independent resilience metrics are currently being investigated focusing on **diverse event typologies** (landslides) with diverse intensities and impact.
- The computational model (matlab routine) that has been developed for implementing the framework is going to be re-elaborated to obtain a user-friendly interface.
- Further real and synthetic case studies are currently being developed to further prove the effectiveness of the framework.
- Urban networks will be also developed according to further complex networks models (compartmental network), enabling to embed non-linear relationships for considering decision-making and economics dynamics.
- New and different recovery strategies will be implemented to simulate specific urban behaviours and verify the framework results.

... further Case Studies

- * RC regular frame buildings
- Typical 70s-80s European constructions
- ✤ N° of storeys taken fixed: 10% as 2-storey, 40% 3-storey, 30% 4-storey and 20% 5-storey
- I citizen each 30sqm (ISTAT 2011)
- ✤ 2% 5-storeys school buildings
- Scaling in size and shape according to the starting topology

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... further Case Studies

Histograms of damage-independent resilience (left) and damage-dependent resilience (right), in the case of 15% collapsed buildings

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... further Case Studies

Histograms of damage-independent resilience (left) and damage-dependent resilience (right), in the case of 30% collapsed buildings

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Dr. Eng. Anna Bozza

University of Naples Federico II Department of Structures for Engineering and Architecture <u>anna.bozza@unina.com</u>

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Innovation Management Consultant | Ciaotech s.r.l. a socio unico (PNO Innovation B.V.) | +39 06 33 268 972 (T)| +39 344 2653937 (M) | skype: <u>aanna.bozza</u>

a.bozza@ciaotech.com www.ciaotech.com www.innovationplace.eu