Closure to "new resilience index for urban water distribution networks"

Closure to Discussion of "New Resilience Index for Urban Water Distribution Networks" by G. P. Cimellaro, A. Tinebra, C. Renschler, and M. Fragiadakis.

DOI: 10.1061/(ASCE)ST.1943-541X.0001433

G.P. Cimellaro[1], A. Tinebra[2], C. Renschler[3], M. Fragiadakis[4]

The authors are thankful for the in-depth comments provided by the discussers. The following summarizes the authors' opinions on the issues brought up in the discussion of the original paper:

- The use of T_{LC} in equation (6) and (9) instead of T_R allows to compare different scenarios of the same network as well as different networks, by maintaining the control time T_{LC} constant in all cases. The recovery time T_R is not suitable because it will change when different scenarios are compared as shown in Figure 13 of the original paper. This change will affect the values of the resilience indicators R_1 and R_2. The ranges T_{LC}, T_{NF-I} and T_{NF-II} are dependent each other and are not provided because they are selected by the user based on the problem at hand.

[1] Visiting Professor, Department of Civil and Environmental Engineering, University of California Berkeley, Davis Hall, Berkeley, CA 94720-1710, USA (gianpaolo.cimellaro@polito.it)
[2] Graduate Research Assistant, Department of Structural and Geotechnical Engineering (DISEG), Politecnico di Torino, 10129 Turin, Italy (gianpaolo.cimellaro@polito.it)
[3] Associate Professor, Department of Geography, University at Buffalo (SUNY), 116 Wilkeson Quad, Buffalo, NY 14261, U.S.A. email: rensch@buffalo.edu
[4] Lecturer, School of Civil Engineering, National Technical University of Athens, email: mfrag@mail.ntua.gr

- The definition of Resilience that is adopted in this paper is the one provided in Cimellaro et al., (2009), which in similar forms is commonly accepted in the civil engineering community. The proposed index is able to capture the capacity to recover from failure because the higher is the indicator, the faster is the recovery. Furthermore the index proposed in equation (6), which is related to the service availability, is similar to the index proposed by Shinozuka and Chang (2004) to measure resilience in power distribution networks.
- As clearly stated in the paper both indicators R_1 and R_2 should be considered in the analysis, because the first is related to the *service demand* and the second to the *capacity*. We will show two examples that explain why both are important. Right after the extreme event, if the authorities do not shutdown the system and are not able to identify the pipe breakage on time, there will be a large water loss in the network, while the service is still maintained, even if with lower pressure. In this case R_1 will remain constant while R_2 will capture the loss of resilience in the network. On the other hand, if the service is shutdown to allow repair operations for example for several hours, then R_2, that is related to the water level in the tank, will remain constant while the index R_1 will drop because there will be different users without service.
- Although the authors are fully aware of the problem of infrastructure interdependencies as shown in several papers from the same authors (Cimellaro et al. 2014a-b), the problem of infrastructure interdependencies has not been considered in this paper. Authors are already developing further research in that direction.
- The authors fully agree that the three indicators are dependent each other, because they are monitoring different properties of the same event. However, the indicators are

dimensionless quantities defined as ratios, so they are not probabilities. Different options has been compared such as the mean, the weight average, but finally we have decided to use the product because there is no need to define additional weight coefficients. Furthermore, observing the results, we have noticed that when combining different indicators associated to different properties of the network, we obtain a meaningful “average”. In fact a given percentage change in any of the indicators has the same effect on the final global indicator.

- The authors thank the discussers for identifying the misprint. The parameter Δt should be dimensionless, while Q_e in equation 19 is expressed in m^3/s.

Acknowledgements

- The research leading to these results has received funding from the European Research Council under the Grant Agreement n° ERC_IDEAL RESCUE_637842 of the project IDEAL RESCUE-Integrated Design and Control of Sustainable Communities during Emergencies.

REFERENCES

Cimellaro G. P., Reinhorn A. M., Bruneau M. (2010 a). "Framework for analytical quantification of disaster resilience." *Engineering Structures, 32: 11, 3639–3649.*

Cimellaro, G. P., and Solari, D. (2014a). "Considerations about the optimal period range to evaluate the weight coefficient of coupled resilience index." *Engineering Structures*, 69(2014), 12-24.

Cimellaro, G. P., Solari, D., and Bruneau, M. (2014b). "Physical infrastructure Interdependency and regional resilience index after the 2011 Tohoku earthquake in Japan." *Earthquake Engineering & Structural Dynamics*, 43(12), 1763-1784.

Shinozuka, M., and Chang, S. (2004). "Evaluating the Disaster Resilience of Power Networks and Grids." *Modeling Spatial and Economic Impacts of Disasters,* Y. Okuyama, and S. Chang, eds., Springer Berlin Heidelberg, 289-310.