Measuring the Progress of a Recovery Process After an Earthquake: the case of L'Aquila-Italy

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ABSTRACT: After the earthquake in 2009, L'Aquila (Italy) started a torturous recovery process, characterized by a delay in the reconstruction of the city center, the political and legal intrigues, and the dissatisfaction of the population with the decisions made and actions taken by the government. Between 2010 and 2014 we formulated a recovery index based on spatial indicators, such as building condition and building use, to measure the progress of the recovery process in L'Aquila. Now, seven years after the earthquake, we are not only interested in measuring the progress of the recovery in L'Aquila, but also in validating the usefulness of the proposed recovery index. To achieve this objective, we are going to consider the same set of spatial indicators and expert criteria that we considered to determine the progress of the recovery in L'Aquila by 2010, 2012, and 2014. Over these years, the city center of L'Aquila was selected as the sampling area, to establish the progress of the recovery in the whole city. In 2016 we found that the number of reconstructed buildings and buildings under ongoing construction has significantly increased, followed by the number of inhabited buildings. The number of buildings classified as partially enabled, propped, reconstruction projected, and damaged had greatly decreased by 2016, while the number of demolished buildings and buildings with restricted use slightly increased. The number of buildings with residential and commercial use increased along the main roads by 2016. Paradoxically, while progress was observed in the overall building condition, there was no significant progress in the building use. This poses several questions about the dynamics of the returning process of the former habitants of the city center in L'Aquila. We can conclude that the proposed recovery index is useful for identifying the spatial pattern of the recovery process in an urban area affected by an earthquake. At the same time, this recovery index allows us to quantify the recovery progress based on indicators.

Keywords: Disaster recovery, spatial indicators, recovery index, earthquakes, GIS.

1. INTRODUCTION

On April 6th of 2009 an earthquake with a magnitude of 6.3 MW and a hypocentral depth of 10 km struck the Italian city of L'Aquila (population 72,800). The epicenter was located in Poggio del Roio, 3.4 km to the southwest of the L'Aquila city center. L'Aquila is the capital of the province by the same name, and the administrative capital of the Abruzzo region.

The historical city was badly damaged, 67,500 people were left homeless (Alexander, 2010), 1,500 people were injured (202 seriously), and 308 people lost their lives. About 10,000 buildings were damaged and between 1.5 and 3 million tons of waste were generated (Brown et al., 2011). The cost of the damage was estimated to be 16 billion Euros (UNIFI, 2009).

The recovery of L'Aquila has unfortunately been surrounded by political intrigues and scandals, not to mention several legal and administrative failures (Arens, 2014). The mayor of L'Aquila resigned several times (but then always withdrew his resignation). In 2014 he was under investigation. The person in charge of allocating funds was also accused and then acquitted of mismanagement of funds. The conflict between the financial manager of the reconstruction and the mayor of L'Aquila contributed to the delay of the reconstruction process. There were other debates going on simultaneously regarding the cost of the support scaffolding (Ciorra, 2014). Several discussions took place within the government with respect to the recovery of L'Aquila, which included the idea of relocating the whole city (Arens, 2014).

In our research, we select the historical city center as a sampling zone to test the progress of the recovery because it was the most affected area after the earthquake, and because there was an existing damage indication map of this zone, elaborated by Tiede (2010). An additional reason for selecting the historical city center as the sampling zone is that it is the most representative district of a city according to Kevin Lynch (1960). The location of the case study area is shown in Figure 1, together with a map showing the ground motion intensity during the earthquake.

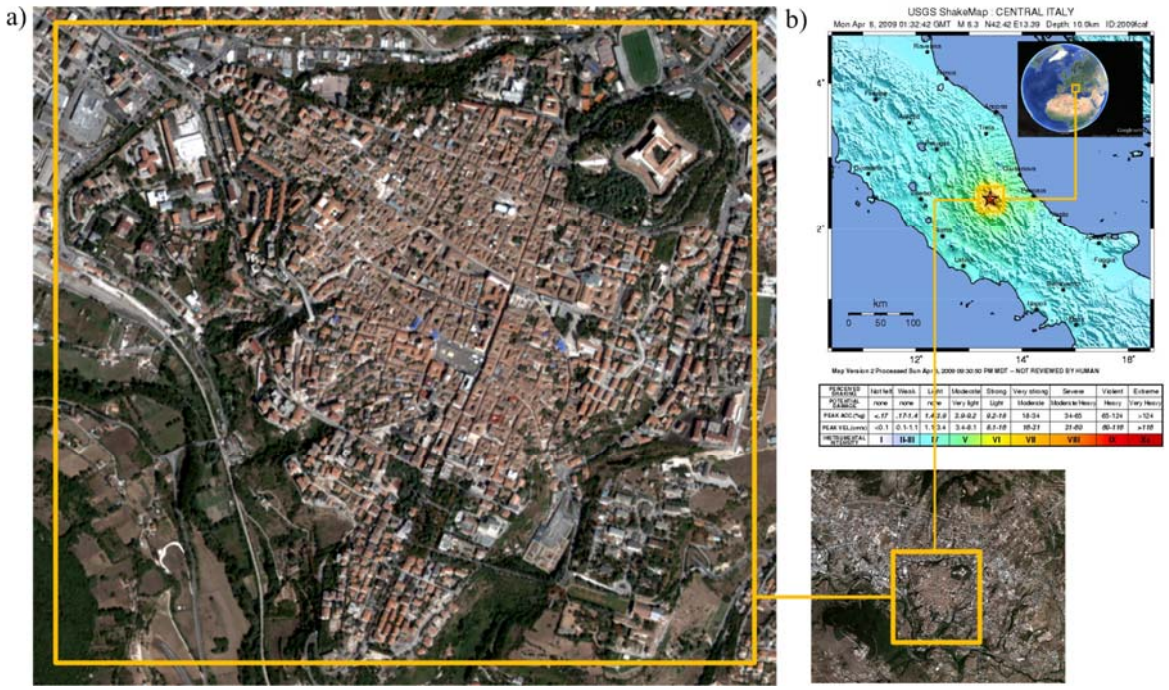

Fig. 1: a) Case study area: L'Aquila, Italy; b) Ground motion intensity during the L'Aquila earthquake.
Source a) Google Earth – QuickBird/DigitalGlobe, distributed by European Space Imaging on 11 September 2011; b) USGS (http://earthquake.usgs.gov/earthquakes/shakemap/global/shake/2009fcaf/).

2. METHODOLOGY

Between 2010 and 2014 we formulated a recovery index based on spatial indicators, such as building condition and building use, to measure the progress of the recovery process in L'Aquila. These recovery indicators were identified during the fieldwork visits to L'Aquila in 2010, 2012, and 2014, and validated in 2016.

Table 1. Monitoring schedule of the post-disaster recovery progress in L'Aquila (Italy). Adapted from (Contreras et al., 2016).

TIMELINE		REMOTE SENSING (RS)			GROUND OBSERVATIONS (GO)		GEOGRAPHIC INFORMATION SYSTEM (GIS)
N*	**YEAR**	**MONTH**	**SENSOR**	**Analysis**	**MONTH**	**TOOLS**	**SOFTWARE/APPLICATIONS**
1	2010				April	GPS Analogue maps interviews	Arc GIS 9.3-10 Google Earth Google Maps
	2011	September	Quickbird	OBIA GIS			
3	2012				September	GPS Analogue maps	Arc GIS 10.1 Google Earth Google Maps
	2013						
5	2014				April	GPS Analogue maps interviews	Arc GIS 10.3 Google Earth Google Maps
7 10	2016 2019**	April	Quickbird	OBIA GIS	June April	GPS Analogue maps interviews	Arc GIS 10.4 Google Earth Google Maps

*Number of years after the earthquake.
** Fieldwork planned.

Fourteen categories of building conditions were identified: *inhabited*, *new buildings*, *repaired*, *reconstructed*, *partially enabled*, *construction ongoing*, *reconstruction ongoing*, *reconstruction projected*, *propped*, *earthworks*, *debris removed*, *demolished*, *restricted use* and *damaged*. Thirteen categories of building use were recognized: *residential*, *commercial*, *transport*, *amenity*, *religious*, *hospitals*, *office*, *educational*, *industrial and sports facilities*, *hotels*, *monuments*, and *not inhabited*. These categories were later considered as variables. The methodology to assess the progress of the recovery is depicted in Figure 2.

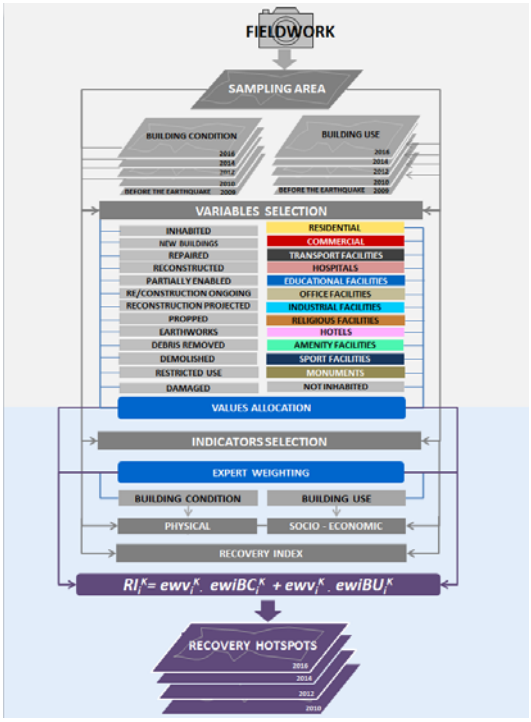

Fig. 2: Methodology to assess the progress of the recovery after an earthquake. Adapted from: (Contreras et al., 2014).

3. RESULTS

Figure 3 depicts the visualized results of applying the spatial recovery index to measure recovery in L'Aquila.

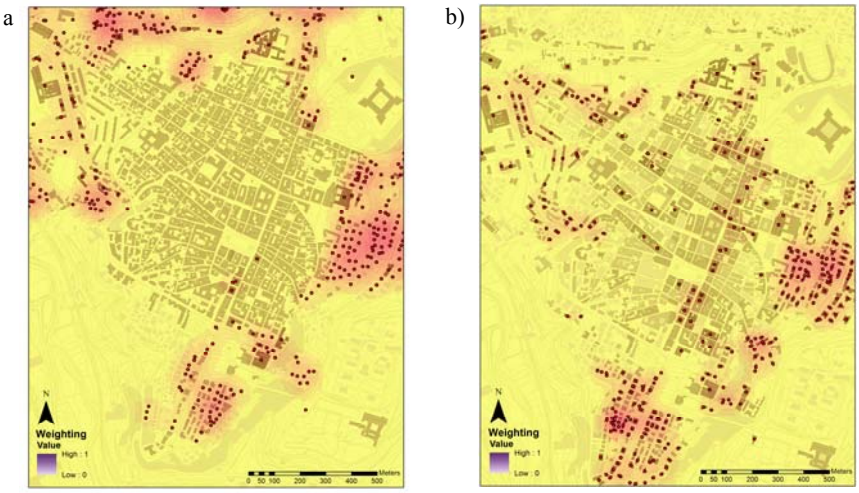

Fig. 3: Spatial recovery index applied to monitor the recovery of L'Aquila in a) 2010 and c) 2016. Note: 2012 and 2014 were not included because the changes were minimal compared to 2010 and 2016.

4. ADDED VALUE FOR INTEGRATIVE RISK MANAGEMENT AND URBAN RESILIENCE

A number of indices have been developed for measuring the vulnerability to disasters, but little attention has been paid to recovery indices, particularly with respect to earthquakes. The aim of this research is to provide a tool for monitoring and evaluating the progress of a recovery process, to avoid the emergent vulnerability, and therefore reduce the risk to an acceptable level. Identifying the drivers of a successful recovery process and learning from the lessons of other cases provides the opportunity of building resilience through the formulation of pre-impact recovery plans based on the known best practices of recovery.

5. CONCLUSIONS

Some damaged and propped buildings in L'Aquila have remained in the same stage for 7 years, because no owner or authority has made any decision regarding their future. This uncertainty has delayed the recovery of the city center. Some propped buildings were partially enabled, with some stores opened on the ground floor, while the above floors remained empty between 2010 and 2014. In 2016 we found that these buildings started to be reconstructed instead of being repaired, which represents a somewhat ambiguous step in the recovery process because it constitutes an advance in building condition, but a setback regarding building use. A similar scenario occurred with buildings that were found inhabited in the past fieldwork visits and are now in restoration. These facts demonstrate that spatial indicators are necessary to measure the progress of recovery, because the limits between post-disaster phases are always fuzzy (Contreras, 2016).

We found that the amount of reconstructed buildings and buildings with ongoing construction, as well as the number of inhabited buildings has significantly increased since the last fieldwork visit in 2014. The number of buildings classified as partially enabled, propped, reconstruction projected, and damaged had greatly decreased by 2016, while the number of the demolished buildings and buildings with restricted use slightly increased. The number of buildings with residential and commercial use increased along the main roads by 2016. Paradoxically, while progress was observed in the overall building condition, there was no significant progress in the building use because several reconstructed buildings are still inhabited. This poses several questions about the dynamics of the returning process of the former habitants of the city center in L'Aquila. This returning process will be interesting for further research. The reconstruction and returning process advances faster around the historical city center, perhaps because the larger road size makes it easy to locate and organize the requested machinery and materials for the reconstruction process

We can conclude that the proposed recovery index is useful to identify the spatial pattern of the recovery process in an urban area affected by an earthquake. At the same time, this recovery index allows us to quantify the progress in the recovery based on indicators.

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