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Public space planning in minor historic centres exposed to seismic risk: lessons learnt from the experience in Navelli (AQ)

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Highlights

- Vulnerability reduction in small historic centres subject to seismic risk requires the implementation of specific surveys and detailed urban planning tools.
- Approaches to seismic risk management in small historic centres generally prioritise the securing and enhancement of the built heritage over public spaces.
- Post-earthquake planning tools can play a crucial role in guiding sensitive vulnerability mitigation and improving accessibility to public space.
- The gap between rigorous risk management decision support methodologies and ordinary urban planning practice in smaller urban centres is still quite evident.

Abstract

Risk reduction in minor historic centres exposed to seismic hazards is essential for the protection of life and cultural heritage but also for social and economic development and requires appropriate strategies. The current state of knowledge and technology suggests that intervention on sensitive mitigation of urban systems vulnerability is the most desirable solution to prevent the devastating earthquake's effects. This requires a careful planning of both built and public spaces. Within this framework, the contribution illustrates an integrated methodology that accompanied the drafting of the Reconstruction plan of Navelli (AQ) and Civitaretenga, drawn up in response to the earthquake that struck the Abruzzo Region in 2009. Although dated, this methodology can be considered a best practice due to the innovative systematic assessment of both built heritage and open space in the two historical centres, supported by an Integrated Information System (IIS). An innovative approach to the assessment of vulnerability and accessibility of public spaces is also introduced. Monitoring the first outcomes of the Plan implementation provides a pretext for a critical reflection, about 10 years later, on the role of post-earthquake planning tools and on the evident relations or gaps between the scientific and technical contribution of the university and ordinary reconstruction processes in minor urban centres, generally prioritising interventions on the built heritage over the public space.

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1. Introduction

Smaller historic centres are highly exposed to seismic risk due to their urban morphology and fabric features, typological structures, and materials. The Italy earthquakes in 1997 (Assisi), 2009 (Aquila), 2012 (Emilia) and 2016 (Amatrice)are just few examples of severe damages inflicted to historic centres (and cities). During earthquakes, these dense, highly stratified, and worth urban systems can generate cascading or systemic effects, i.e., can induce sequences of events governed by cause-and-effect relationships: from buildings elements to open spaces accessibility, to human behaviour. This stresses a need for developing and implementing measures to reduce risks in seismic zones through risk management strategies. Despite earthquake hazards cannot be completely removed, disaster risks can be decreased by risk management techniques and planning (see, i.a., (Tira, 1997; Menoni, 2013; Pescaroli & Alexander, 2016).

However, the lack of suitable plans and techniques, and the integration of measures into national, regional, or local strategies is still a reality (Tira, 2016). The gaps in this regard concern pre-event and post-event actions (Romao & Bertolin, 2022). Pre-event actions focus on developing risk assessment methodologies, related to the collection, and recording of priority information layers according to shared tools and protocols. The "inventory" approach focuses on devising global knowledge frameworks, developing methods and protocols, using standardized tools in cataloguing heritages, comparing data from previous disasters, and validating models. The vulnerability analysis follows, deepened through defining sets of criteria and indexes derived from the inventory phase. Therefore, it identifies the vulnerability of elements. Next, "mitigation" planning establishes appropriate emergency response measures, estimates resources required and/or assesses their cost-effectiveness. It acts by intervention priorities, often simulated, which are associated with multi-stakeholder training processes on actions to be taken in real emergencies. Post-event actions concern the definition of recovery management plans according to multi-stakeholder cooperation procedures and protocols. Therefore, they focus on recovery and safeguarding actions following the earthquake period (e.g., removal and disposal of rubble, cataloguing and classification of the structural stability of buildings), development of plans and programs of the post-earthquake material heritages for public and private interventions (Mazzoleni & Sepe, 2005).

Practice and research results showed a primary interest in post-event (the first) and pre-event (the second) approaches. However, both are often segregated to a specific feature - e.g., the vulnerability of buildings - forgetting that an integrated approach is needed in these "cascading" events. Moreover, the resulting issues, such as mitigation techniques and planning, are often deferred to subsequent developments (Sgobbo, 2016).

Consequently, this research focuses on an integrated methodology in support of urban and earthquake risk planning. It can be considered a best practice that includes an integrated assessment of damage to the built heritage and an innovative vulnerability assessment of public space. It is presented through the Reconstruction Plan of the Municipality of Navelli (AQ) case, drawn up in response to the 2009 earthquake of Aquila. From the integrated methodology, the Navelli case becomes a pretext for a critical reflection, approximately ten years later, on the results that this methodology has brought in the structuring phases of the Reconstruction plan of Navelli and on how it has influenced the administration's choices and modes of action in the implementation phases still underway.

The paper is structured as follows. Section 2 shows the current state-of-art in scientific literature. Section 3 provides the methodology description to support the formation and management of Reconstruction Plans and deepens the integrated vulnerability assessment of public spaces. Finally, Section 4 provides a first discussion of the results and further research directions.

2. Literature review

Research on risk management has generally focused on emergency response, impact analysis, and post-earthquake recovery. However, studies showed a shared awareness of developing appropriate tools for a high comprehension of risks and identifying solutions to mitigate their effects.

Different approaches have been developed. A first approach focused on the building component through computational methods related to materials and structural aspects or empirical methods on an *ex-ante* or *ex-post* urban scale for homogeneous factors. For instance, Brando, Cianchino, Rapone, & Spacone (2021) proposed a quick seismic assessment of buildings vulnerability at the urban scale applying a predictive model of eight seismic parameters derivable from the CARTIS form, i.e., building inventories tools of Italian Civil Protection generated through quick inspections. The predicting damage scenarios are carried out on an urban scale and build fragility curves under different earthquake intensities. Anglade et al. (2019) applied a large-scale vulnerability assessment of façade walls as its primary role in developing damage scenarios. Data are collected and elaborated in a Geographical Information System (GIS) environment. Ravankhah, Schmidt, & Will (2021) applied a disaster risk assessment for cultural heritage sites and examined direct and indirect impacts of earthquake and non-structural vulnerability factors, i.e., human-induced threats and heritage significance. Differently, Juliá, Ferreira, & Rodrigues (2021) focused on fire ignition risk triggered by earthquakes in dense urban areas, such as historic centres, which can start chain fires. Therefore, the authors developed a risk matrix to identify the buildings most subject to fire risk.

A second approach focused on human behaviour according to probabilistic simulation models of population behaviour and their interactions with debris or generalised macroscopic or microscopic models associated with each individual affected by the earthquake. Studies differ by critical factors considered, computational models (e.g., Agent-based Model), simulation platforms, and key performance indicators. For instance, Bernardini, D'Orazio, & Quagliarini (2016) focused on pedestrians' evacuation, considering human behaviour and environmental changes due to the earthquake; finally, the authors proposed a behavioural design for seismic safety. Lu, Yang, Cimellaro, & Xu (2019) simulated pedestrian evacuation with earthquake-induced falling debris. Zlateski, Lucesoli, Bernardini, & Ferreira (2020) based simulated human behaviour in post-earthquake scenarios applying risk indexes from seismic vulnerability index of masonry façade walls and damage assessment correlations.

Finally, recent contributions highlighted the relevance of the "mesoscale" of the built environment elements, i.e., public spaces (streets, squares, green areas), capable of effectively influencing the urban capacity to withstand the seismic event and preserve its functions and services. Russo, et al. (2022) highlighted how a few studies considered vulnerability factors related to open spaces and identified them through literature review. Results showed five-factor categories of morpho-typology, physical, construction, use and users, and context. Bernardini, Lucesoli, & Quagliarini (2020) analysed six predictive methods of path availability in the immediate aftermath and compared them to real-world cases. Data showed the best prediction results on approaches that combine street-building geometries, building vulnerability, and earthquake severity. Similarly, the correlation of street-building geometries was the main factor considered in several methods (Santarelli, Bernardini, & Quagliarini, 2018; Singh Golla, Bhattacharya, & Gupta, 2020).

Despite of its primary role in seismic evacuation, the public space system is subject to different degrees of vulnerability involving intrinsic and extrinsic-endogenous factors. However, the vulnerability study still seems focused on the building component (especially on buildings of historical and architectural value), and the "urban" dimension integrated into the definition of scenarios is still little considered, often related to the geometric correlation alone. For instance, a few reflections concerned pre- and post-event accessibility. Probably, this is due to a prevalence of studies related to engineering construction science rather than urban planning. Furthermore, many authors highlighted the role of technologies that can help develop adequate heritage data inventories and monitoring solutions as fundamental tools for risk assessment and forecasting as emergency recovery strategies. Therefore, in a complex and compact urban context, such as the Italian one greatly characterised by smaller historic centres in high seismic risk areas, vulnerability analysis of public spaces seems particularly urgent.

In this regard, the contribution presents reflections on the integrated methodology using GIS systems to support the Reconstruction Plan (PdR) of the minor historic centres of Navelli and Civitaretenga, which assesses vulnerabilities and opportunities for intervention in public spaces for disaster and ordinary features period.

3. The Reconstruction Plan of Navelli and Civitaretenga: from drafting to implementation

After the earthquake that hit the Abruzzo Region in April 2009, involving L'Aquila and other 56 municipalities (Manella, Genitti, Corsi, & Frezzini, 2016), the University of Parma developed technical-scientific activities supporting the Municipality of Navelli, in the ex-ante phase of the reconstruction plan formation for the small historical centres of Navelli and Civitaretenga (1). The results of this applied research activity were delivered to the Technical Office in charge of drafting the plan, in December 2013. The final conference open to the public was held in Navelli in 2014, and a second conference followed ten years after the earthquake in 2019.

The objectives of the activity can be summarised as follows: (a) setting-up an updatable cognitive and analytical framework of the built heritage and open spaces; (b) selecting intervention priorities; (c) optimising the resources for the reconstruction process, speeding up the timetable and controlling the funds management. Another general, underlying objective was to reactivate the social and economic sphere around the reconstruction debate, as a fundamental action to support the plan implementation, especially regarding the private reconstruction processes. For this purpose, dissemination and participation activities were carried out to engage private stakeholders and share with local communities the work progress and the ongoing public initiatives.

Navelli and Civitaretenga are two small historic villages (5.38 ha and 1.60 ha respectively) belonging to the municipality of Navelli (42 km^2 and 560 inhabitants) located about 34 km away from the city of L'Aquila. The villages are located at an altitude of about 700 metres and undergo a continuous and steady depopulation since 1921, when the municipality had about 3,000 inhabitants concentrated in its two historic centres (2). Between 2001 and 2018 the municipality of Navelli recorded a population decrease of 14%. The village of Navelli has about twice as many inhabitants as Civitaretenga, nevertheless, the percentage of abandoned buildings is higher.

3.1 *An Integrated Information System (IIS) to support the recostruction plan and its management*

The recostruction plan is based on a detailed survey of the built heritage, street network, open space structure and landscape features in the two historic centres of Navelli and Civitaretenga, with a strongly interdisciplinary approach. An Integrated Information System (IIS) was designed and populated to store and manage a great amount of data collected through topographical, photogrammetric, and direct survey campaigns. The IIS was meant as an easily searchable and updatable tool capable of supporting the entire plan process, from the analytical phase to the planning proposal to implementation and management (Ventura, Zazzi, Carra, & Caselli, 2019). The IIS, designed as a relational database, was first of all used to store and catalogue information from the various survey campaigns: cartography; identification data; geometric data; typological, formal and architectural characteristics of the buildings; static information on the load-bearing structures of the buildings (extent of damage and usability); layout and construction features of the public and private open space. Proposals for Aggregate Minimum Units (AMUs) (3) were also collected from both citizens and the public administration and then implemented in the IIS.

The spatial and statistical processing phase followed data acquisition and returned output maps providing an overall knowledge of the urban system: (public and private) AMUs, property regimes, historical and architectural values, earthquake damages, degree of transformability of buildings and public space. In addition, the IIS supported the vulnerability and accessibility assessment of public space, as described in the following paragraph.

The cognitive and analytical framework led to the elaboration of guidelines and temporal planning of interventions that the Plan subsequently incorporated. The Plan makes a specific distinction between areas in which direct building transformations are permitted, identifying specific classes of compatible uses and intervention methods, and private or public AMUs in which reconstruction processes can only be implemented through specific preliminary urban plans (i.e., Coordinated Intervention Programmes or Integrated Intervention Programmes). Different intervention time frames and methods on the public space were also identified according to different degrees of priority derived from the severity of earthquake damages and accessibility/vulnerability assessment.

3.2 *Analysis of vulnerability and accessibility of public space*

Among the various possible operational applications of the implemented IIS, an analysis of the vulnerability and accessibility of public space was carried out with the aim of identifying actions

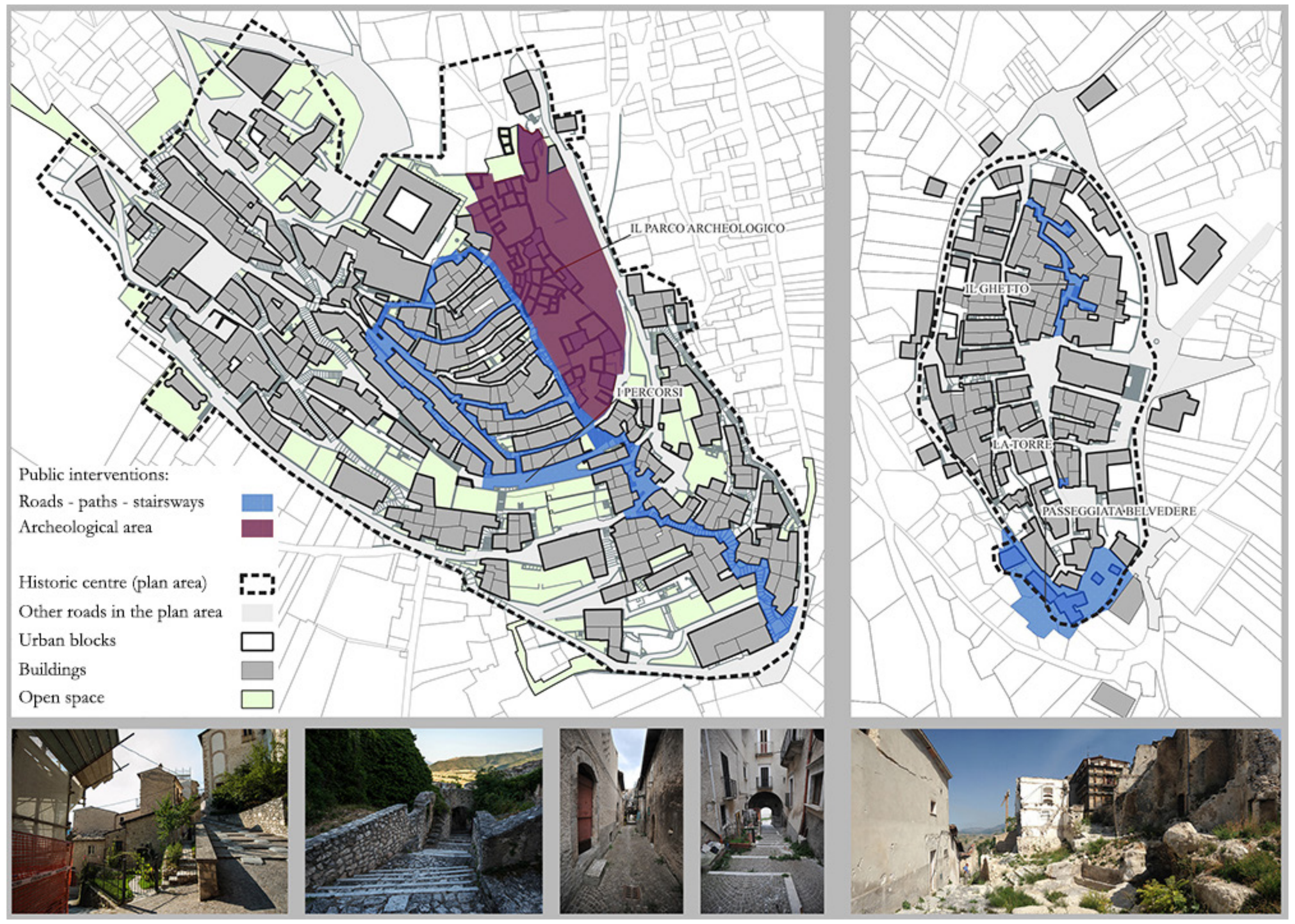

Figure 1: Main intervention areas in the public space identified by the Reconstruction plan of the Municipality of Navelli: clearing rubble and/or restoring road surfaces (paths and stairways); securing the archaeological area and planning the archaeological park. The photographs below show the status of the mapped sites in 2019. *Source: authors' elaboration.*

to improve the safety of pedestrian routes in the event of an earthquake.

The methodology based on direct urban survey aimed at collecting data on routes considering both indicators of vulnerability to the seismic event and indicators of accessibility in ordinary time (4). Data collected were implemented in the IIS, thus developing a synthetic indicator of accessibility/vulnerability that highlighted an overall criticality level associated to each route link (or arc).

The IIS's data model defines the extent of route links based on the homogeneity of their physical configuration, surrounding elements or other significant features such as surface type and slope. The informative layer of route links within the IIS was populated thanks to the information gathered during in-field inspections, through the filling out of survey forms. The survey form (Table I) included a list of attributes to be detected, some by simply choosing one or more solutions from the suggested options, others by entering quantitative data in the specified measurement unit. The survey form was divided into six sections including the identification and location of the route links, descriptive elements of the route link and urban context, morphological indicators, indicators of continuity and access and, finally, quality indicators with references to functional characteristics.

The form was meant as quick to be filled in, to be compatible with the staff resources commonly available in small public administrations.

This tool can integrate different levels of detail into a single analysis to formulate qualitative and quantitative assessments on the level of criticality of the observed routes. This provides information on the characteristics of route links continuity and conformation, but also supports the identification of the safer travel systems between strategic buildings and potential escape routes. Going beyond the classical definition of a route link, the

Table I: Path analysis form with highlighted vulnerability indicators (in dark grey) and accessibility indicators (in light grey).

Denomination:		...	ID GIS:	...	Reference code:	...	Survey date:	...
Cartographic and photographic documentation								
Location: cartographic extract to locate the area under investigation in the context of the city					Aerial photogrammetric shred: Detailed cartographic extract of the aerial photogrammetric survey (scale 1:5.000) with the radius of influence of 200 m			
Photograph					Photograph			
Typology	Vehicle accessible	o	Suitable for cycling	o	Pedestrian	o	Mix	o
Configuration	Closed/open on one side	...	Open on two sides	o	Open on three sides	o	Open on four sides	o
	H average surrounding buildings [m]	...	Path length [m]	...	Average H and L ratio of the path (1)	...	Path width [m]	...
Usage characteristics	Paved public square	o	Equipped public garden	o	Public lawn garden	o	Public buildings area	o
	Buildings lots	o	Private green area	o	Vegetable garden	o	Agricultural area	o
	Public parking	o	Uncultivated area	o	Fill area	o	Transformation area	o
Conformation	Rectilinear	o	Curvilinear	o	Fragmentary	o	Steps	o
Continuity	Continuum	o	Cul de sac	o	With final widening	o	Interrupted	o
Slope	Longitudinal	o	Transversal	o	Frequent slope variations	o	Slopes in connected areas	o
Presence of adjacent prevalent critical artefacts	A	o	B	o	C	o	E	o
Hierarchy	Non-strategic path	o	Strategic path as the main transport infrastructure	o	Strategic path for access to strategic functions	o	Strategic path as an escape path	o
Path	Sidewalk presence [n. sides]	...	Average width of the pedestrian path [m]	...	Average longitudinal slope [%]	...	Average transverse slope [%]	...
	Path interruptions [yes/no]	...	Level of promiscuity [n. of traffic components that disturb the pedestrian]	...	Bottlenecks and section discontinuities [n]	...	Average condition of the surrounding terrain	...
	Lateral elevation difference [H]	...	Lateral elevation difference [L]	...	Sudden changes in way [n. variations]	...	Sudden changes in slope [%]	...
Path pavement	Fallow	o	Rough stone paving	o	Stone slabs	o	Brick paver	o
	Asphalt	o	Dirt street	o	Other	o	Friction coefficient according to test B.C.R.A. [μ]	...
Stairway	Typology	o	Width scale [m]	...	Average height [H]	...	Average tread [L]	...
	Raise-tread ratio [n]	...	Presence of parapet [yes/no]	...	Presence of handrail [yes/no]	...	Presence of end-stair scale signal [yes/no]	...
Stairway pavement	Fallow	o	Rough stone paving	o	Stone slabs	o	Brick paver	o
	Asphalt	o	Dirt street	o	Other	o	Friction coefficient according to test B.C.R.A. [μ]	...

CONTINUITY AND ACCESS								
Number of intersection and accesses	Street intersection [n]	...	Vehicle access to building lots [n]	...	Pedestrian access to buildings or adjacent lot [n]	...	Driveway height difference [H]	...
Artefacts along the path	Bridges [L]	...	Viaducts [L]	...	Linear development of bridges and viaducts [L path / L tot bridge + viaducts]	...	Driveway ramp slope [%]	...
Obstacles or discontinuities along the path	Stairs and bleachers [n]	...	Stairs and bleachers [L]	...	Dissuaders [n]	...	Drainages [n.]	...
Fixed artefacts and structures	Influence of the building facades along the path [%]	...	Average physical vulnerability of buildings facades along the path (EMS)	...	Linear development of lateral structures (walls, enclosure, hedges)	...	Billboards / signs [n]	...
	Lampposts [n]	...	Trellis [n]	...	Trees [n]	...	Benches [n]	...
	Garbage bin [n]	...	Dumpster [n]	...	Other [n]	...	Lighting [L illuminated section]	...
Projecting elements and structures	Cornice, eaves [L]	...	Balconies [L]	...	Portico [L]	...	Flyover [L]	...
	Other [L]	...	Linear development of projecting elements [%]	...	Vaulted passages, arcs [%]	...	Height of projecting obstacles [H]	...
FUNCTIONAL CHARACTERS								
Temporary or mobile artefacts [yes/no]	Bar and restaurant tables [yes/no]	...	Facilities for fairs, open-air markets, etc. [yes/no]	...	Street furniture [yes/no]	...		
Presence of parking spaces along the path [yes/no]	On dedicated area [m2]	...	On improper area [m2]	...	Terminus and bus stops [yes/no]	...		
Underground technological networks	Power grids	o	Water	o	Gas	o	Other	o
Non-residential activities on the ground floors	Bar, restaurant	o	Craft activities	o	Office	o		
	Hotel	o	Public services	o	Other	o		

analysis can be extended to a larger section of the route, treating it as a whole. This approach allows consideration of interposed node elements such as intersections, squares, open spaces and urban access points with which route users interact.

Some of the surveyed factors (those highlighted in grey in table I) were then used to assess the overall vulnerability and accessibility levels of each path. Among the indicators of vulnerability to the seismic event of the routes, the analysis considered the ratio between the average height of the built fronts and the routes width, the presence of bottlenecks and discontinuities, the presence of potentially vulnerable streetside structures (e.g., skywalks/bridges between buildings), and the linear development of lateral structures with potential impediments for escape routes. For example, fig. 2 shows the distribution of the ratio among the height of the prospicient buildings and the paths width, highlighting in red the most critical paths, where buildings are particularly high above the street, or where there are covered passages under buildings. Parameters used for the construction of the accessibility indicator in ordinary time, instead, included the average width of the route, the slope, presence and type of stairs.

In the specific case of Navelli, the integrated analysis of the vulnerability and accessibility of the urban spaces based on the IIS showed that Navelli's

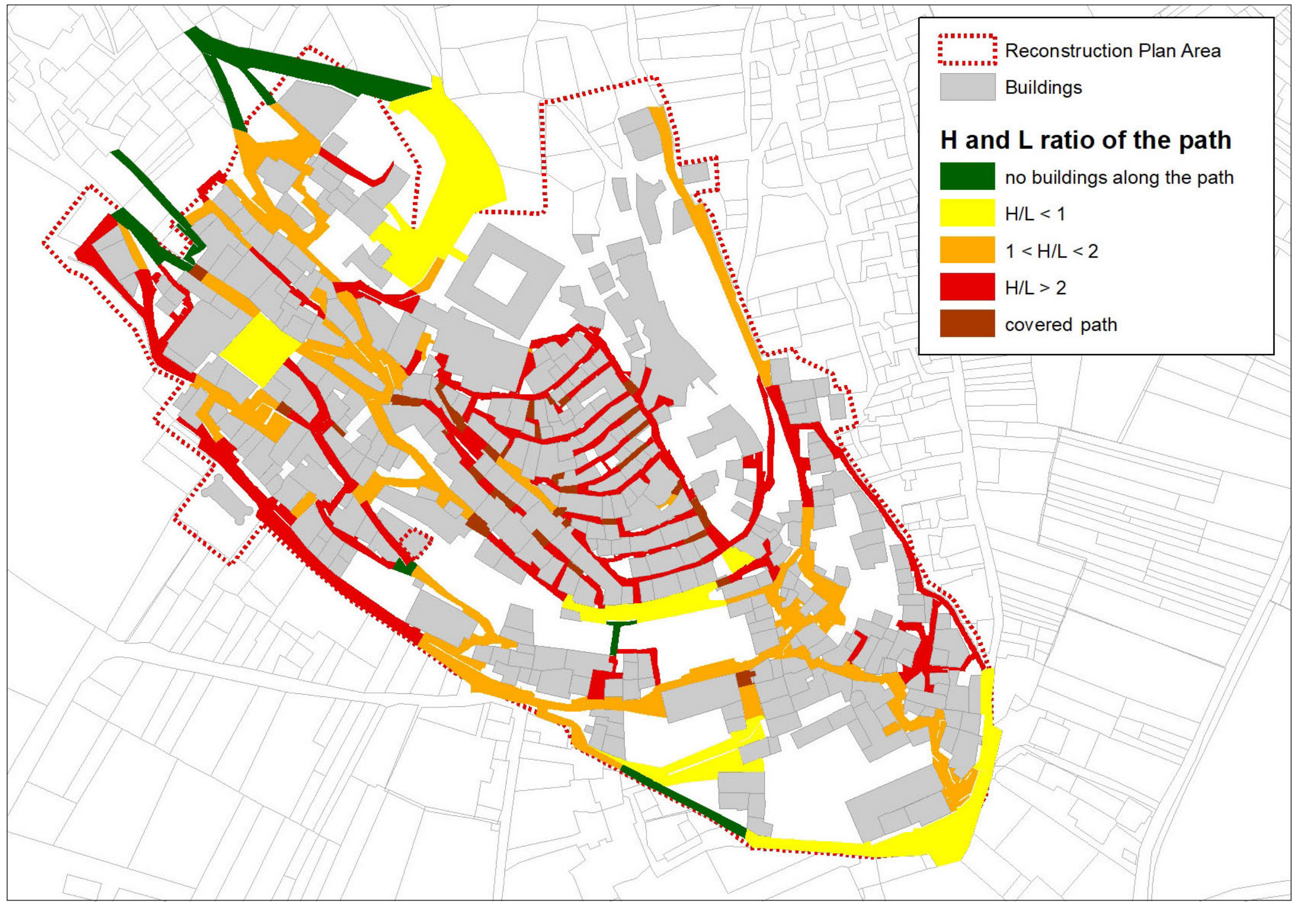

Figure 2: H and L ratio of the path within the Reconstruction Plan Area in the main historical centre of Navelli, an example of vulnerability feature of the street system in case of an earthquake. *Source: authors' elaboration.*

central core, i.e., the oldest area characterised by a compact morphology of the urban fabric, has the highest level of criticality.

This application followed the "Guidelines for Reconstruction" (DCD no. 3/2010), which attributed to reconstruction the meaning of securing and recovering damaged public spaces, understood not as a mere restoration of pre-earthquake conditions, but as general improvement of the overall safety conditions, in order to reduce risks (that are unavoidable in seismic areas), enhance accessibility and social inclusiveness and relaunch the economic and social sphere.

3.3. Main evidence from the Reconstruction Plan implementation, ten years after the earthquake

The Reconstruction Plan became effective in December 2013. Before this date, the reconstruction process within the historic centres of Navelli and Civitaretenga mainly involved minor repairs to usable buildings (A usability rating buildings), and light damage reconstruction for slightly damaged buildings (B or C usability rating buildings, temporarily/partially unusable) to enable a fast re-occupancy. The start of heavy reconstruction occurred only after the final approval of the Reconstruction Plan, with the presentation of the first projects. The first construction sites started in 2015, following the preliminary investigations. After that date, the reconstruction process accelerated rapidly.

In 2017 and, subsequently, in 2019, two monitoring activities of the Plan's implementation phase were carried out, through in situ visits and interviews with the mayor and technicians from both the public administration and the Special Office for Reconstruction of Crater Municipalities (5).

In 2019, ten years after the earthquake, projects for private reconstruction in the municipality of

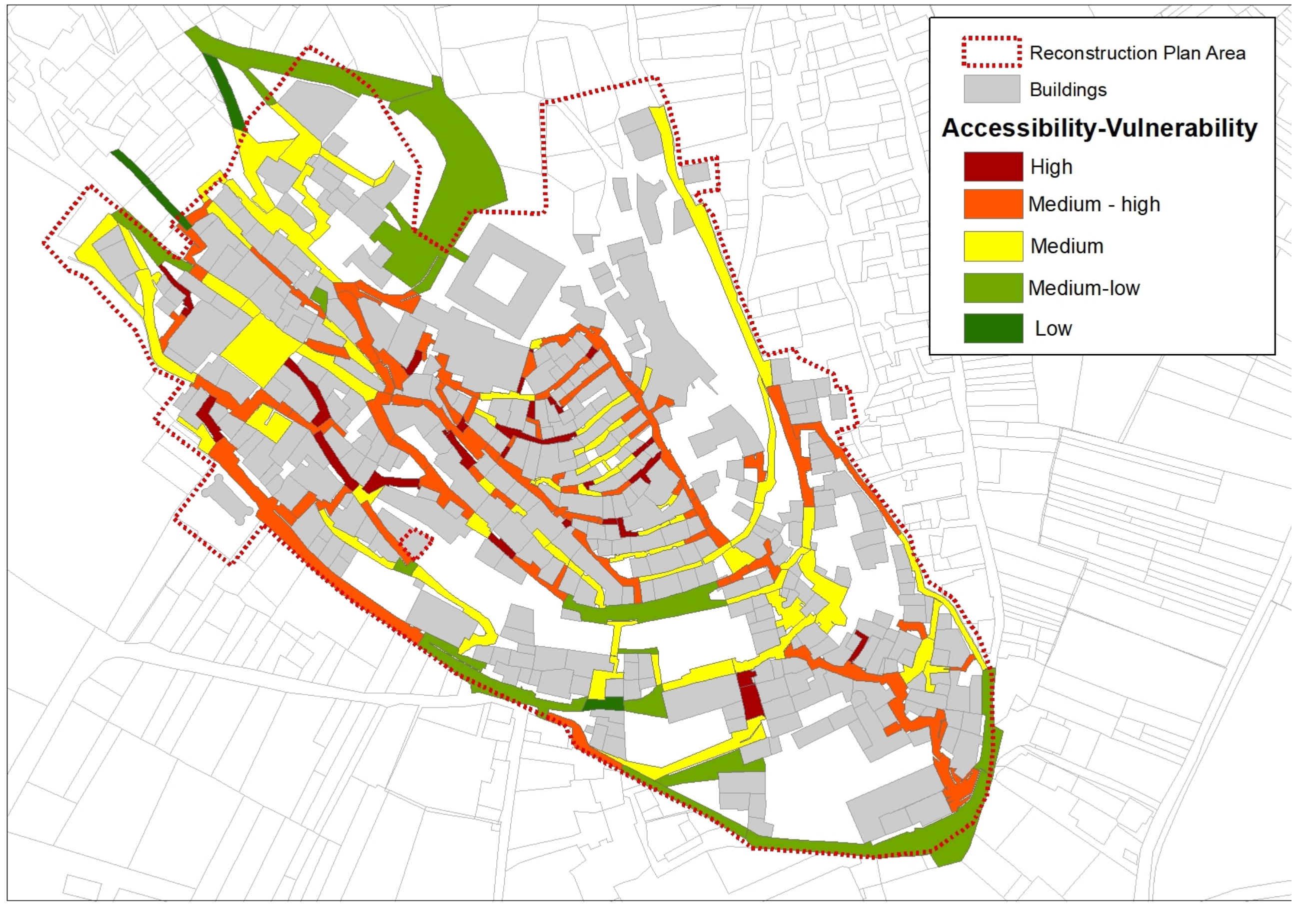

Figure 3: Integrated vulnerability-accessibility levels within the Reconstruction Plan Area in the main historical centre of Navelli. *Source: authors' elaboration.*

Navelli had been approved for a total of EUR 46.5 million, with works completed or in progress worth EUR 26.4 million. Several preliminary investigations on projects within both the historical centres of Navelli and Civitaretenga were ongoing. Moreover, as shown in figure 4, some construction sites were already completed, others were in progress or about to start.

As far as public reconstruction is concerned, much had already been done. One of the first interventions completed was the repair with seismic improvement of the primary school building. Public interventions also included the restoration of many places of worship within the two historic centres and the construction of the new municipal headquarters, inaugurated on 13 July 2017, an earthquake-proof building capable of serving as a reception centre for evacuees in the event of an emergency. Projects that had already been financed, such as the demolition and reconstruction of the nursery school, the repair with seismic improvement of other religious buildings, and the securing of the Civitaretenga's cemetery were also underway.

In addition to the damage caused by the 2009 earthquake, the public property of the municipality of Navelli was also seriously damaged by the earthquakes that struck central Italy between August 2016 and January 2017, making both the historical municipal palace (Palazzo Santucci), former seat of the municipal offices, and other places of worship unusable. Repair work or planning work were therefore also undertaken on these additional damaged assets.

Despite the great attention paid to the public built heritage, the resurfacing of the streets and underground utilities in the two historic centres (estimated cost of approximately EUR 14.6 million) was only planned as a corollary to the entire reconstruction process (both public and private). In addition, since the implementation phase of Navelli's Reconstruction plan began (as monitored in

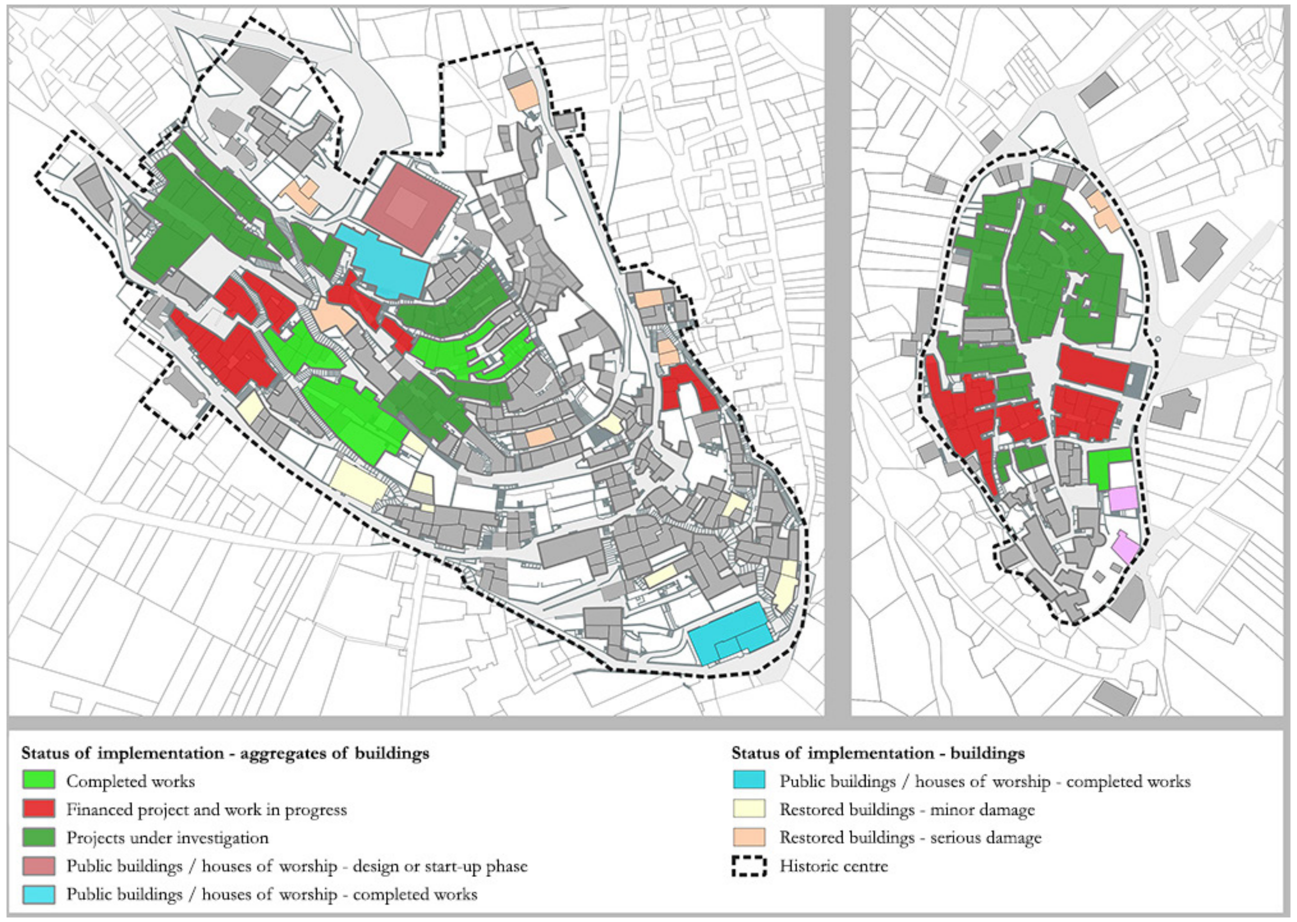

Figure 4: Implementation of the Navelli's Reconstruction plan in 2019. *Source: authors' elaboration based on data by the Municipality of Navelli.*

2019) there were no evidence of specific projects for the improvement and qualification of public spaces, even though these were foreseen in the Reconstruction Plan.

4. Discussion and concluding remarks: the role of planning tools for integrated seismic risk assessment

As highlighted in the literature review and as emerged from the case of Navelli, approaches to seismic risk management in small historic centres often privilege the securing and enhancement of the built heritage, sometimes neglecting the improvement of safe and universal accessibility to public spaces. The research activity around Navelli's Reconstruction plan intends to integrate seismic vulnerability assessment on a broader scale than the built heritage, allowing the identification of the most appropriate intervention methods and priorities for public open spaces. The pre-planning phases provided an efficient integrated cognitive and analytical framework supported by an integrated information system. The IIS is not intended as a simple information tool to summarise the results of studies conducted independently on various components of the urban space, but rather as a 'systemic' tool suitable for the analysis and evaluation of the built and public space aimed at defining the most suitable intervention methods and priorities. Furthermore, the system was set up to support all planning, coordination and implementation phases. It was therefore set up for continuous updating to support the management of public and private reconstruction processes, but also to introduce possible diagnostic insights, such as the vulnerability/accessibility assessment of the public space.

The analysis of public spaces considered two relevant factors: vulnerability to seismic events and accessibility in ordinary times. This approach was able to support the identification of intervention priorities in the public space most subject to seismic risk, but pursuing a high qualitative and functional standard of the accessibility system even under ordinary conditions, i.e., in the absence of exceptional events. This approach is in line with a vision of "prudent urban planning" (Tira, 1997).
Therefore, the IIS synthesised several features applied in the scientific literature concerning computational methods for building and cultural heritage in an urban scale perspective, human behaviour in pedestrian evacuations during earthquakes, and integrated methods in a mesoscale perspective (i.e., urban planning scale) for the vulnerability of "cascading" events. Consequently, due to these characteristics, it could serve as both a pre- and post-seismic event tool, capable of highlighting the relationship between elements of urban and social structure and between natural and anthropic events.
The experience of Navelli's Reconstruction plan was, recently presented as a good practice of post-earthquake planning for minor historic centres at the workshop of the Interreg project "Adriseismic", developed following the seismic event in Central Italy in 2016 (6). The workshop aimed at comparing different good practices of seismic risk management and, concerning urban planning, its outcomes highlighted the importance of integrating the extraordinariness of earthquake events into the ordinariness of planning strategies (Santangelo, Melandri, Marzani, & Tondelli, 2022). Indeed, actions to reduce urban systems vulnerabilities may increase safety against seismic risk, e.g., improving accessibility in historical centres, and removing architectural barriers within public space, may simultaneously contribute to the identification of alternative, safe, and accessible escape routes. The post-earthquake planning tool is conceived as an emergency tool capable of managing intervention priorities downstream of the seismic event, securing and restoring the functionality of compromised urban systems. Since the level of earthquake impact also depends on pre-existing vulnerability factors, vulnerability assessment is even more valuable in ordinary planning tools that should deal with limiting potential damage induced by seismic hazards.
Looking at Navelli's experience, post-earthquake planning has had undeniable positive effects at the local level and probably the Reconstruction plan acquired an additional role with respect to its function as an emergency tool. The prolongation of the reconstruction processes has in fact made the plan a pseudo-ordinary instrument, although its influence is limited to the historic centre areas where the risk problem is currently marginal. Indeed, the risk in Navelli's historical centres has objectively decreased as a result of careful structural consolidation of buildings over the last decade, the reduction in settlement density caused by the sharp decline in the resident population (which is currently of about fifty people), and economic activities.
However, while private reconstruction has been favoured, sometimes at the expense of architectural quality, many interventions in public spaces have been neglected due to a lack of resources and funds. An interesting case is the archaeological area in the northeast sector of Navelli, an area that is accessible but abandoned since ancient times, which has badly damaged and degraded structures and poses a risk to citizens and tourists. The intervention in this area would be strongly complementary to the ongoing restoration and reuse interventions and strongly synergic with the Reconstruction Plan. Unfortunately, such onerous but important interventions highly depend on funding opportunities. A short-time collaboration was provided by the University of Parma to the Municipality of Navelli regarding the public funding announcement "RESTART Abruzzo" for the redevelopment and museumisation of the archaeological park in 2019-2020.
Another positive note concerns the exceptional economic, technical, organisational, and intellectual/scientific response to the 2009 earthquake in Abruzzo: the involvement of two coordination centres (Special Offices for the Reconstruction of the Crater Municipalities / L'Aquila) for reconstruction in the earthquake crater municipalities, in particular the historic centres, the collaboration of several universities and the direct employment of hundreds of professors, researchers, and students. This dynamism becomes even more valuable when compared to the fragilities of public organisational and administrative systems attributed to minor communities located in remote areas (Damianakos, Ventura, & Zavrides, 2011) i.e., the gaps in knowledge of risk assessment, in the adoption of preventive or 'mitigation' measures, or in data collection, management, and processing. Some technological issues of data management and pro-

cessing were indeed encountered in Navelli, too. The monitoring of the implementation phase in 2019 revealed some of the previous gaps. E.g., the IIS tool developed to support decision-making and coordinating reconstruction processes has been 'forgotten' by the municipality in favour of common and additive management tools, incapable of correlating data or systemically updating the reconstruction process framework.

The absence of comprehensive planning tools results in deficiencies in the overall area assessment with consequent negative impacts on the decision-making process and mitigation measures (Anglade et al., 2019). This aspect recalls the need to promote capacity-building opportunities in the local public administrations of smaller municipalities, as well as a reflection on the transfer of scientific research into the urban planning practice.

Endnotes

1.Research agreement (2011-2013) between the Municipality of Navelli and the Department of Engineering and Architecture of the University of Parma, coordinated by Prof. Paolo Ventura (Ventura, Carra, Rossetti, Caselli, & Zazzi, 2020).

2.Statistics available at: http://www.comuni-italiani.it/066/058/statistiche/popolazione.html

3.These aggregations of buildings, called Aggregate Minimum Units (AMU), are non-homogeneous set of building-structural units, which are interconnected by a more or less structurally effective connection, and which may interact under seismic or dynamic action in general. The definition refers to O.P.C.M. no. 3820 and no. 3832. Another definition of AMU is reported by De Martino et al. (2023).

4.The methodology is reported in Bonotti, Rossetti, & Montepara (2019) based on R. Bonotti, L'incidenza delle trasformazioni urbane nella valutazione del rischio sismico. PhD thesis, University of Brescia, 2014; G. Ciampà, Il tema della sicurezza nella pianificazione per i centri storici: il caso di Civitaretenga (AQ), MSc Thesis, University of Parma, 2012; M. Inselvini, Il tema della sicurezza nella pianificazione per i centri storici: il caso di Navelli (AQ), MSc Thesis, University of Parma, 2013.

5.The Special Office for the Reconstruction of the Crater Municipalities (USRC), located in Fossa (AQ), was set up in December 2012 following the closure of the state of emergency, established after the earthquake in 2009. It provides technical assistance to public and private reconstruction processes and monitors the interventions implemented or underway in the 56 municipalities in the earthquake crater area (excluding the city of L'Aquila) and in the more than 100 municipalities outside the crater area. It is also responsible for the financial monitoring of the interventions and the transmission of related data to the Italian Ministry of Economy and Finance.

6.The workshop was held online on March 2, 2022. More information on the European Interreg project titled "Adriseismic. New approaches for seismic improvement and renovation of Adriatic and Ionian historic urban centres" can be found in the dedicated web page https://adriseismic.adrioninterreg.eu/

Attributions

The authors jointly designed and contributed to the paper conceptualization. All the parts of this paper have been discussed and approved by all the authors. However: §§ 1 and 2 are by M.C., §§ 3, 3.1 and 3.3 are by B.C., §§ 3.2 is by S.R. and §§ 4 is by M.C. and B.C. Corresponding author: B.C.

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