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**Pasquale Tunzi**
Professor of Architecture Drawing at the Department of Architecture, University of Study "G. D'Annunzio" in Chieti-Pescara. He is a academic of visual communication in Architecture and the Historic City, and produced numerous essays and publications addressing the issues of architectural-environmental survey and graphic representation on various scales. tunzi@unich.it

# Survey activities seeks recovery of an old town in Abruzzo hit by the earthquake of 2009

## *Una campagna di rilevamento finalizzata al recupero di un centro storico abruzzese colpito dal terremoto del 2009*

*After the earthquake of L'Aquila in 2009, the Pescara University "G. d'Annunzio" undertook a study about some of the fifty-seven urban centers affected by the earthquake in order to recover them. Real estate damages were huge and 47% of buildings were completely unusable. In order to cope with the urgencies, as indicated by the Region, campaigns have been organized of survey. Here is presented the survey related to the medieval town of Brittoli, located on the foothills of the Gran Sasso, led by a team of the Faculty of Architecture, using various methods. The produced material, along with the other six municipalities, provided support for the Reconstruction Plans of Municipalities in the Homogenous Area 5.*

*A seguito del terremoto dell'Aquila del 2009 l'Università degli Studi "G. d'Annunzio" di Pescara si è impegnata nello studio di alcuni dei cinquantasette centri urbani colpiti dal sisma, al fine di poterli recuperare. I danni al patrimonio immobiliare sono stati ingenti e il 47% degli edifici sono risultati totalmente inagibili. Per far fronte alle urgenze, secondo quanto indicato dalla Regione, sono state organizzate e svolte delle campagne di rilevamento. Qui si presenta quella relativa alla cittadina medioevale di Brittoli, situata alle falde del Gran Sasso, condotta da una équipe della Facoltà di Architettura, impiegando diversi metodi. Il materiale prodotto, insieme a quello relativo ad altri sei Comuni, ha costituito il supporto per i Piani di ricostruzione dei Comuni dell'Area Omogenea 5.*

**Keywords**: Integrated Surveying, historic center, earthquake, Abruzzo

***Parole chiave**: rilievo integrato, centro storico, terremoto, Abruzzo*

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## THE EARTHQUAKE OF 6 APRIL 2009

One of the first documents showing the effects of an earthquake is photographs. Their eloquence bears witness to the drastic changes to the town or city resulting from the loss of part of its history and distinctive characteristics. Whether printed on paper or projected onto a screen, these images attest to the absence of life, piles of rubble and the impossibility to conduct day-to-day life. Our thoughts turn immediately to how we can restore its previous state and address residents' needs. The reconstruction machine is set in motion in a multi-disciplinary approach that aims to preserve the area's historic memory and consider possible transformations.

Forty-two municipalities in the province of L'Aquila, eight in Teramo and seven in Pescara were hit hard by the earthquake on the night of 6 April 2009. All 57 of them were located in the "L'Aquila earthquake crater" [1] as established by Decree no. 3 of 16 April 2009, since they were struck by earthquakes of a magnitude of at least 6 on the Mercalli-Cancani-Sieberg (MCS) scale. The area has a radius of over 150 km with its epicentre in Roio (AQ), classified as level 2 in terms of earthquake risk.

After addressing the critical rescue phase immediately following the earthquake, the National Civil Defence Service inspected all of the affected buildings directly and classified them in six categories based on a usability scale according to the damage caused to the building and its type [2].

During the frenetic organisation stage after the event, the Abruzzo Region in collaboration with the Associazione Nazionale Costruttori Edili, asked Universities in the Region to contribute to a structured approach toward restoring the historic centers [3]. Eight interdisciplinary research groups from the Pescara architecture faculty of Università "Gabriele d'Annunzio" worked in various parts of the area [4].

This essay will examine the integrated assessment campaign conducted in seven towns in the province of Pescara, all part of so-called 'Homogeneous Area 5" [5]: Brittoli, Bussi sul Tirino, Civitella Casanova, Cugnoli, Montebello di Bertona, Ofena and Popoli. We will examine the work done in the historic centre of Brittoli as an example of the entire campaign supporting the post-earthquake reconstruction process. The assessment was conducted by a team of ten people from the Departments of Science, History of Architecture, Restoration and Representation, coordinated by Livio Sacchi [6], in order to document the state of the property heritage and direct possible recovery in a reasonably short time.

Fig. 1 View of the western slope of Brittoli

## BRIEF HISTORY OF THE BRITTOLI HISTORIC CENTRE

On the southeastern edge of Gran Sasso National Park and Monti della Laga (1995), in the Voltigno nature reserve, the village of Brittoli [7] is located 781 metres above sea level and is part of the province of Pescara. It is located in the heart of the region, just 63 km from L'Aquila, 49 km from Pescara and 98 km from Teramo. The upper part of the village enjoys a broad view: the narrow tributaries of the Nora river flow through the Piancialunga area to the north, the Casanova and Massone plains lay to the east with streams flowing south to the Cigno stream, while Monte Cappucciata (1801 m) rises to the west, with Monte Scarafano (1432 m) further south.

The "Aprutium" map frescoed in the Gallery of Maps in the Vatican by Ignazio Danti in 1580-1585 provides evidence of the existence of Brittoli during the Renaissance period. Another document from the same period, "L'Abruzzo Ulteriore" by Natale Bonifaci (1587), shows Britolli on the peaks of imposing hills, though its position with respect to neighbouring villages is significantly altered.

The *Atlante Geografico del Regno di Napoli* published by Rizzi-Zannoni in 1808 shows a narrow rough road from Capestrano on the western slope passing through the centre of Brittoli before continuing north to Carpineto della Nora and Civitaquana. Today, State Road 602 circumvents the built-up area to the west, connecting Ofena and Catignano, while a number of side roads to the south connect it with hamlets and villages on the Fonte Canale plain.

The village's ancient origins are poorly known. Lorenzo Giustiniani [8] left a few lines indicating the civil jurisdic-

Fig. 2 I. Danti, Aprutium, Gallery of Maps, Vatican, 1580-85

Fig. 3 A. Rizzi-Zannoni, Atlante Geografico del Regno di Napoli, 1808

tion of Santa Maria di Casanova in Villa Celiera (Pe), and criminal jurisdiction assigned to the Cantelmo family, Dukes of Popoli by King Frederick of Aragon in 1498. In the late 16th century, this family gave the village to the Princes of d'Afflitto, who, to pay off debts, sold it to Scipione de Curte in 1603, who kept it until 1811, when it passed to the Royal Household.

In the early 1800s, Joseph Bonaparte's administrative reorganisation assigned Brittoli to Abruzzo Ulteriore I, in the Città Sant'Angelo district, in the neighbourhood of Catignano, the dioceses of Penne and Atri [9]. Under National Unity, it was added to the province of Teramo, where it remained until 1927 when Pescara became the provincial capital.

The village has played an important role inspecting

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Fig. 4 Aerial photograph of Brittoli 2009 (SCUT)

goods for customs over the centuries, and there is a look-out tower on the Magno L'Aquila-Foggia drove road in Forca di Penne (4 km from the centre), near Capestrano.
Recent maps and aerial photographs show Brittoli's "teardrop" shape with its point facing south, a natural urban expansion along the state road. On the ground, its morphology can be seen from nearby roads, with a terrace on which the village rises surrounded by hillsides and plains covered with luxuriant vegetation.
The urban core lies along Via Umberto I, a route to the east of the built-up area that bends slightly westward towards the ancient San Carlo Borromeo parish church dating from 1126. The load-bearing structures of this church with three naves and rounded arches were seriously damaged by the earthquake, making it unsafe for use.
At the beginning of the main street is a square and look-out point bordered by Palazzo Pagliccia, with its noble chapel dedicated to Saint Anthony. The palazzo rises to the east, on the side opposite the inhabited area, bearing the austere architectural signs of the 16th century, with sandstone outer walls and white stone and brick finishes. The stone portal with its rhomboid motifs and emblems on the keystones opens onto a long vaulted hallway paved with cobblestones and brick, off of which opens the staircase to the salons upstairs. Part of the palazzo's facade and loadbearing structures collapsed, compromising the chapel. Part of the roof and side wall also collapsed. Some of the rooms upstairs lost their brick ceilings, and the stone walls to the east were seriously damaged.
The historic centre's early medieval origins are clearly visible in the narrow streets typical of the dense urban network running from the southeast to the northwest [10]. The lanes are grooved in places with underpasses perpendicular to the main street. The buildings suffered severe damage and collapses that render the entire historic centre uninhabitable. Most of the 15th-century tower in Forca di Penne collapsed.
It is important to remember that the most recent earthquake was much more violent and destructive than the previous fifteen seismic events that have struck the historic centre of Brittoli over the centuries.

## THE ASSESSMENT CAMPAIGN

In order to reach a full and deep understanding of each of the urban areas struck, we performed assessments to establish their measurements and materials, and special and architectural characteristics, with graphics an models. This is clearly the most essential step before re-planning can begin, while considering the needs expressed by the local mayors.
On 11 December 2010, the reconstruction commissioner's mission technical structure [11] supporting the work to be done in the various towns and villages provided guidelines for technical specifications for the "altimetric survey of the historic centres". In four points and with related specifications, it stipulated the base topographical survey, the altimetric survey via laser scanner, photographic documentation and critical processing of acquired data.
On 28 December 2010, the special specification established how to address the transformation and encourage the search for satisfactory responses from technical knowledge. This tool directed local authorities to seek assistance from external bodies and professionals like universities willing to survey the buildings. The Technical Specifications [12] which required the use of

Fig. 5 View to the southwest of Brittoli

Fig. 6 Entrance to Via Umberto I and view to the northeast

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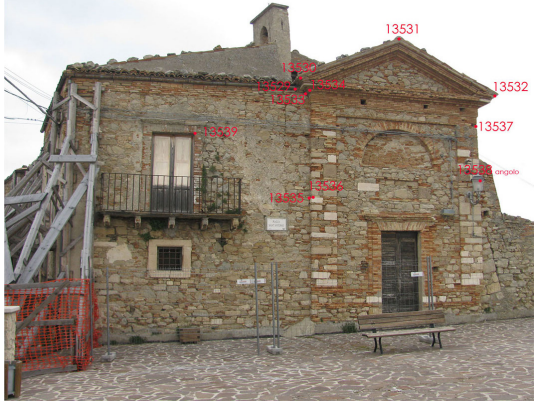
digital technologies to be adapted to the unique characteristics of each site in order to provide useful media for the creation of the reconstruction plans.
For Brittoli's historic centre, as for the other six centres to be surveyed [13], the working group's two coordinators drew up "integrated assessment projects" [14] that subdivided the area into interconnected spaces [15]. These projects were defined following surveys of the characteristics of the seven historic centres from physical and environment viewpoints, in terms of scope, perception and accessibility, distance and building quality. In this way, we were able to determine the activities most appropriate to meet the requests in terms of surface area and altimetric reports, bearing in mind the pre-established scales (1:500; 1:200; 1:50).
In the first phase, we established the outlines of the affected area. For Brittoli we established the reference system by identifying four orientation points identified using TST and GPS readings taken at the entrance to the village, at the beginning of the main street at a higher altitude, at its ending point in an almost straight line and at the northeast end of the urban outline [16]. We compared these points with the IGM95 network [17] coordinates G in the Abruzzo Region. Using them, we draw a closed topographic polygon surrounding the entire georeferenced inhabited area, using a simplified geometric scheme adapted to the site's morphological characteristics. Then we attached a second open polygon to it at a higher altitude, with ten bases, primarily along Via Umberto I, which, from Piazza Domenico Pugliese and the belvedere runs north to the mother church. Each station was clearly identified along the route in order to show the two adjacent bases through alignment and never exceeding a distance of 180 metres. Using these bases, we identified specific points, and in particular the vertices of each curtain facade and the openings. By enlarging the main polygon through the secondary ones within the inhabited area, we were able to obtain good topographic coverage.
At the same time, we conducted an intense photographic campaign to complement the measurements of all of the architectural and urban elements. Given the difficulty in moving around in the village, the photographs played an appropriate punctual documentation role of the village's current state. The orthophotos provided a useful framework for an initial assessment [18] and identification of the damage to be examined in

Fig. 7 Screenshot of graphic retur of survey (SCUT)

Fig. 8 Extracted from monograph relating to baron palace (SCUT)




greater depth.
An important element to be established in the surveying was the geometry of each building after the earthquake in order to determine its geometry prior to it. By comparing the two geometries, we were able to identify any structural shifts or deformations. This important element was affected by the materials with which the buildings were constructed and their framework with regard to implementation. If conducted properly, these two elements will be very useful in subsequently defining the actions on the entire structure and therefore on the three-dimensional geometric model that can then include opposing reactions by various parts of the buildings leading to their possible collapse.
Another important piece of data is the utilities network (gas, electricity, water, telephone) that was surveyed based on overhead lines, connections and manholes which were then included in a map as requested. Re-establishing primary infrastructure networks to reduce their vulnerability through appropriate drawings is one of the key aspects of restoring a place's functionality. In the reconstruction plan, one of the basic thematic tables contains overlapping sewerage, water, GPL, electricity and public lighting networks as a necessary support in relational spaces and for each individual building unit.
The next phase consisted in an elaborate laser scanning campaign of the many roadside facades including on Corso Umberto I, Via Palazzo, Via Garibaldi and Piazza S. Antonio. We positioned photogrammetric targets in order to establish three-dimensional shots for the main polygon. This operation was necessary for subsequent georeferencing of the cloud of points. Laser scanner acquisition [19] was made particularly complex by the narrowness of the streets, less than two metres wide at the beginnings, and by the great height of the elevation which was over ten metres in many cases. As usual, the level of detail is in full scale and includes a photographic scan of each elevation and by the models' georeference.
The final phase involved graphic processing, that is, drawing tables using the enormous amounts of data collected. We created layouts in 1:500 scale, such as an outline of the inhabited area, and in 1:200 for the roofs and attachment to the ground, with profiles and cross sections in 1:200 and 1:50. We used the same

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scales for the drawings and aerial photos of the building fronts along the streets. We were also required to carefully select those data able to guarantee many representations on different graphical scales depending on the topic (e.g. building volumes, open spaces, summary of damage, etc.), numerous drawings on various scales, as requested by the technical specifications and provided by the program document drafted by Università d'Annunzio.
These drawings became necessary for the subsequent study phases, and were delivered on time in two steps over four months. The laser scanner survey also allowed us to obtain three-dimensional digital models that can be explored using interactive browsers, useful for understanding the actions of the earthquake.
All of the collected material constitutes an important database for precisely defining the current state of each building, and for establishing and designing future developments according to the timeline of the central activity.
The earthquake's effects concern a highly precarious, temporary and unstable area, where surveying must be limited to rationally observing a fleeting state of a small area, while at the same it can serve as a basis for interpretation and especially for subsequent modifications and checks of a state that can still change. We often think that the aim of this type of modification is to return the place to its former state, a return to the past with a few improvements, depending on the survey results. However, the indications that the surveys provide actually serve as guidelines, as we stated earlier, even in cases where radical interventions have to be done. The results of the surveys offer reassurances on what can still be saved from total destruction and what has been irrevocably lost.

## DESCRIPTION OF THE BRITTOLI RECONSTRUCTION PLAN [20]

As stated in the goals of the entire urban operation, the reconstruction plan for Homogeneous Area 5 concerns a multi-level integrated platform with both a functional framework and an implementation program. Obviously, its main objective was to quickly restore the building heritage damaged by the earthquake, to make it safe and to quickly restore economic and social development. However it also has much broader aspirations. The Plan [21] comprised a combination of five different elements: a physical reconstruction programme for each town, a broad strategic sustainable development program, a pilot project to stimulate recovery

Fig. 9 Reconstruction Plan Sub-Services Network Map (SCUT)

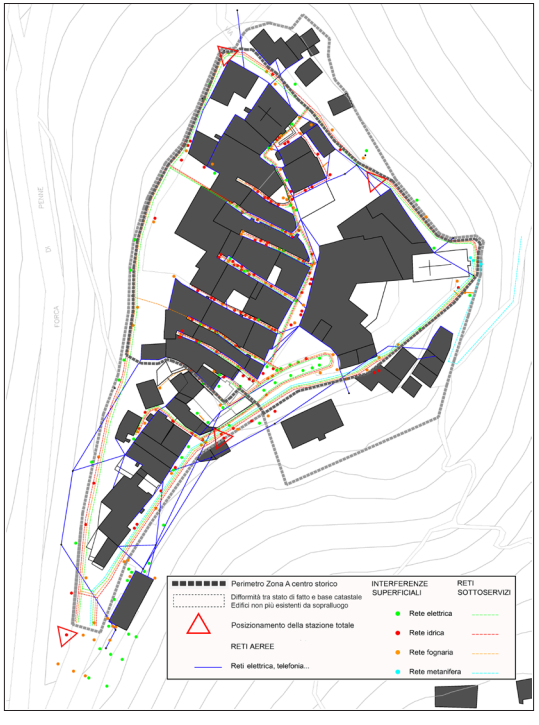


Fig. 10 Laser scanning of a part of Via Umberto I (SCUT)

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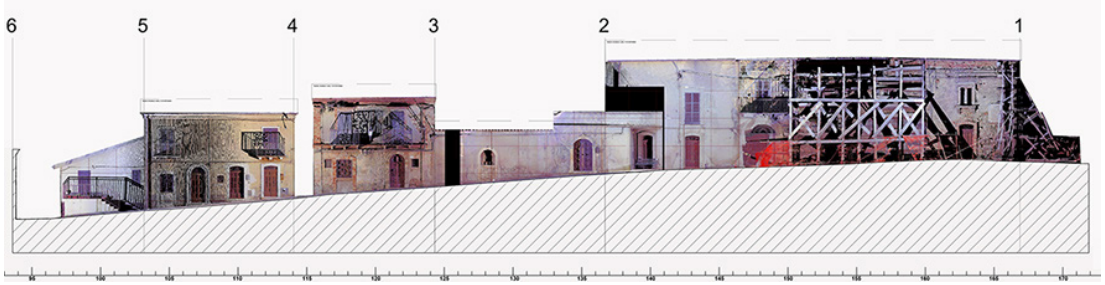

Fig. 11 Photoplane of the east face of Via Umberto I (SCUT)

in each town, and a technical and economic framework accompanied by implementation measures.
The work to be done on public and private buildings, underground utilities, infrastructures and areas at risk of landslide constitute the reconstruction plan. The strategies for the consolidation and promotion of local systems are he heart of the strategic programme. A limited set of works very important for recovering local identity values were included in the pilot project [22].
Then, the need for public and private investments for planned works identifies the technical and economic framework, while the set of rules, the timetable to be respected and the players to be involved were defined in the implementation measures.
The reconstructions plans, with the support of the towns, were structured in five logical and operative phases: Identification, Assessment and forecasting, Qualification, Definition of the actions, and Feasibility and implementation. In the first three phases, surveying contributed to identifying the context of the work, updated knowledge of the scope of the heritage, assessed the historic-architectural and landscape-environmental aspects, and oriented and defined quality objectives.
The reconstruction plan for Brittoli's historic centre aims to restore its role as access point for the Gran Sasso National Park and to become the hub for hiking in the Appenines, while natural tourism services will be established in the village itself.

## CONCLUSION

Currently, the growing awareness of the scope of the risk is creating a sense of insecurity, especially in those living or working in earthquake-prone areas. Working with the goal of offering reassurance and alternatives means applying intervention strategies for physical elements that we need to learn more about, with a wider variety of studies and experiences.
The frequent and devastating earthquakes over the past 20 years have been addressed through the application of surveying methods developed as a result of the widespread use of computing and digital technologies, which are then integrated with traditional ones.

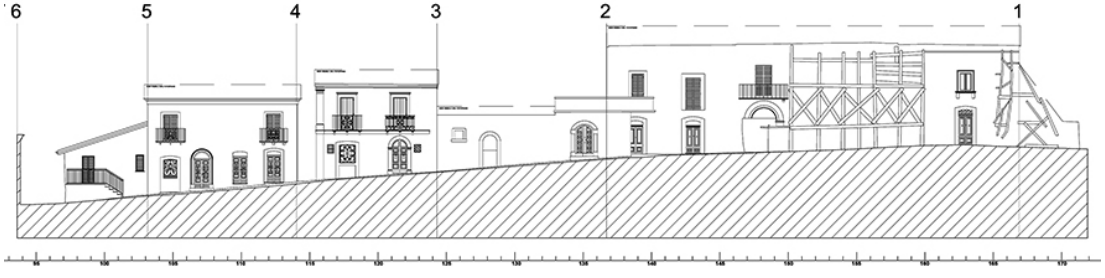

Fig. 12 Graphic Return on scale 1:100 of the east face via Umberto I (SCUT)

The results of certain research projects of national interest (PRIN) and various contributions to conventions reflect definite attention to the issue, since it is now easier to monitor operations and results with greater precision. And integrated methods are being used more and more frequently since they can shorten timelines and improve our knowledge and interpretation of the subjects we are studying.
In the post-earthquake context, measurements are considered an essential starting point for various forms of planning, obviously including a wide variety of surveying techniques in order to examine every aspect of the subject. In this sense, various surveys were taken of the crater areas, such as a census and classification of the buildings in their registered state of use using AeDES sheets, and a geological study of the seismic micro-zone to identify areas considered safe (or at less risk) to be used for new temporary or permanent settlements. Surveyors capture the area in its actual state, but are unable to document modifications that today are faster, on various scales and indecipherable with respect to their trajectories. Earthquakes raise this question.
Integrated surveying seeks to examine a complex subject, to be a set of relational and intermediation practices between many underwriting and completion processes, extended, to a great part, to include geomatics. In Brittoli, for example, it could not be otherwise given the presence of scaffolding and braces that often limited instrumental surveying operations which were then completed through partial direct measurements at salient points. We must also remember the aforementioned requests made by the Mission Technical Structure, to which were added the creation of thematic maps with the historic centre as a centrepiece and component of a broader system.
The architectural and urban surveying procedure prepared by the STM, based on specific urgent programming needs, was observed to the letter, in order to obtain exactly the same documentation for each historic centre and more quickly provide a single base for the recovery of damaged homes. So, we produced only geometric documents with forms and figures showing

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Fig.13 Some photopianes placed on the 3D model in wareframes of the historic nucleus: Via Umberto I and piazzetta Sant'Antonio (SCUT)

the entire area as a single unit. The possible support analyses developed using these documents were delegated to specific disciplines such as restoration, construction techniques, structure mechanics and urban planning, to mention just a few, in order to propose theories and solutions. In this way, surveying becomes an activity providing open results that can be interpreted in many ways and lead to more action.

Moreover, the STM programme's points were pre-established, not permitting any other kind of data that might have been produced by experimenting with or using other acquisition techniques, or from individual buildings. While this was done in certain cases outside the programme, it was useful to test the effectiveness of alternative techniques and procedures, such as photo modelling. Still, this experience provided an opportunity to test a synergic working method, combining service to the local area, research and (limited) experimentation with commissarial direction. We can therefore consider this a possible innovation of intervention strategies for the reorganisation of areas struck by natural disasters, for integrated urban restoration. And given the short times of execution and individual specifics, it necessarily requires compatibility between immediate and strategic actions, a high level of integration and flexibility among various disciplinary fields, and timely and constant relations with policy areas.


Fig.14 Extract from the Reconstruction Plan: Proposed external arrangement of the Baron's palace (SCUT): 1) stone or stucco frames, 2) re-opening the walled portal, 3) apricot basement socket, 4) best of iron corten and body Integrated light fixture, 5) traditional colored plaster paste, 6) wooden fixtures, 7) copper plummet, 8) baronial palace gallery.

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NOTES

[1] Following the macro-seismic surveys conducted by the National Civil Defence Service in collaboration with the Istituto Nazionale di Geofisica e Vulcanologia (INGV), a list of 37 towns and villages in L'Aquila, five in Teramo and seven in Pescara was drawn up. On 21 July 2009, following a broader investigation, five more towns and villages were added in L'Aquila and three in Teramo.

[2] Class A: safe building; class B: temporarily unsafe building (in whole or in part) but usable with emergency response measures; class C: partially unsafe building; class D: temporarily unsafe building to be re-examined in greater depth; class E: unsafe building for structural, non-structural or geotechnical risk; class F: unsafe building for serious external risk. Cfr. National Civil Defence Service, order 3753/2009. There were 73 484 inspections conducted on public and private buildings, of which 23 403 were declared uninhabitable.

[3] The first national agreement was signed in 1976 between the Friuli Region and Università di Trieste following a severe earthquake on 6 May of that year. Under the agreement, the university was to draft study criteria and methods for earthquake geological and technical surveys in the areas of Friuli struck by the earthquake (1977) and conduct a study of various towns and villages in order to orient reconstruction. For the first time, seismic micro-zoning (MZS) was used for areas less subject to seismic risk.

[4] The national seminar entitled "Idee per la ricostruzione delle città. Imprese e Università a confronto" was held in L'Aquila on 5 May 2009. It recommended an intervention platform backed by synergies among the municipalities struck by the earthquake, universities and local operators to draft quick systematic measures. On 12 May 2009, a memorandum of understanding was signed by the Abruzzo Region with the mayors of interested towns and Università de L'Aquila and Università di Chieti-Pescara.

[5] This area extends from the Pescara River valley and the areas on the eastern slopes of the provinces of Teramo and L'Aquila. The earthquake crater was divided into nine homogeneous areas covering a total of 2965 $km^2$, representing approximately 20% of the region.

[6] The surveying working group of the Architecture Faculty of Università di Pescara included Caterina Palestini (operations coordinator), Giovanni Mataloni, Giovanni Caffio, Carmela Casulli, Luigi Losciale, Alessandro Luigini, Alessia Maiolatesi, Massimiliano Mazzetta and Roberto Potenza. This group belonged to the international centre for competitive urban and regional research (SCUT), along with the designers of the reconstruction plan backed by many collaborators. The SCUT was formed following the experience at the Abruzzo InterLab, reconstruction workshops promoted by Università di Chieti-Pescara and Università dell'Aquila in collaboration with the Region in early May 2009.

[7] "Brittulis" is mentioned on page 970 of Chronicon Casauriense, a collection of chronicles about San Clemente Abbey in Casauria written between 866 and 1182. Catalogus Baronum Napolitano (by E. Jamison) contains a list of fiefdoms compiled by the Normans in the mid $12^{Th}$ century. "Brictolum" is mentioned on page 1072.

[8] Dizionario geografico ragionato del Regno di Napoli di Lorenzo Giustiniani, vol. II, Naples, 1797, p. 380.

[9] G.B. Carta, Dizionario Geografico Universale, Naples, 1843.

[10] Il Piano territoriale di coordinamento del 1987-96, by Bernardo Secchi, lists mountain towns and villages like Brittoli "with an old residential heritage, composed of small privately owned homes, often lacking utilities, with significant percentages of uninhabited or underused buildings", often related to tourism.

[11] The cohesion and support work for the small centres was done for the first time by the STM by speeding up the various procedures required by law, approving the procedure for access to authorisations and resources, and constant information via internet regarding guidelines and procedural approaches for the various specifications and actions.

[12] We should explain that these specifications add nothing to the guidelines of 11 December.

[13] In March 2011, an agreement was signed by the seven towns of Homogeneous Area 5 and the faculty of architecture of Università d'Annunzio for the provision of support activities for study, analysis and the reconstruction project. The integrated surveying campaign began immediately.

[14] The organisation was based on the goals and timelines. As a result, the various phases and levels of investigation were established in line with the first interventions and subsequent reconstruction stages through pilot projects, reconstruction plans and strategic plans.

[15] Material provided by the towns was also examined. Brittoli's technical office provided the location and environmental resources on a 1:25000 scale, the general zoning plan section at 1:5000, the map of public areas and meeting places, and the infrastructure system at 1:1000.

[16] The points were detected using a Leica TCR 1101 plus SR total station and collected in coordinate tables and monographs archived digitally.

[17] For the past several years, the IGM has organised the so-called National Dynamic Network (Rete Dinamica Nazionale) in order to precisely monitor the entire country. This system allows users to update the coordinates of IGM95 geodetic points in the new ETRF2000 platform.

[18] We straightened angles that were not too sharp in the photos, when this would not compromise the appearance of the image and the data it contained.

[19] We used a Faro Focus 3D 120 laser scanner with GPS receiver.

[20] Alberto Clementi was responsible for the entire reconstruction plan with the assistance of Pepe Barbieri and Paolo Fusero, and backed by the technical and scientific team composed of Matteo Di Venosa and Aldo Casciana. There were also 16 consultants and numerous collaborators for each disciplinary sector.

[21] Sixteen experts from the disciplinary sectors contributed to the reconstruction plan for the seven towns in Homogeneous Area 5.

[22] The Brittoli pilot project was drafted by the "d'Annunzio" team composed of Carlo Pozzi (leader), Alessandro Buongiovanni, Michela Palermo, Luigi Colonna, Michele A. Demaio and Anne-Sophie Risch. Cfr. Pianificare la ricostruzione, 2012, p. 124.

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