The RISPOSTA procedure for the collection, storage and analysis of high quality, consistent and reliable damage data in the aftermath of floods

F. Ballio[1], D. Molinari[1], G. Minucci[2], M. Mazuran[3], C. Arias Munoz[1], S. Menoni[2], F. Atun[2], D. Ardagna[3], N. Berni[4] and C. Pandolfo[4]

1 Department of Civil and Environmental Engineering, Politecnico di Milano, Milano, Italy
2 Department of Architecture and Urban Studies, Politecnico di Milano, Milano, Italy
3 Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milano, Italy
4 Centro Funzionale Decentrato – Regione Umbria, Foligno, Italy

Correspondence
Daniela Molinari, Department of Civil and Environmental Engineering, Politecnico di Milano, Piazza Leonardo da Vinci 32, Milano 20133, Italy

Introduction

High quality data collected in the aftermath of flood events are the basis for understanding flood damage mechanisms and the root causes, the purpose being to define more tailored risk mitigation strategies. Such data are essential for risk mitigation soon after an event (e.g. identifying needs for recovery and reconstruction) and for better calibrated risk assessment before an event so as to support preventive measures. In the aftermath of floods, reliable information on damage is the basis of any compensation mechanism, be it conducted by public or private organisations (see e.g. Elmer *et al.*, 2010).

Despite the perceived abundance of data collected by government agencies, insurance companies and others (typically nongovernment organisations and research centres) after a disaster, the current information is not good enough to provide full and reliable understanding of flood impacts. The main limitations of existing disaster data in general are summarised in two recent reports by the European Joint Research Centre (JRC; De Groeve *et al.*, 2013, 2014), and they are discussed in detail in the following section. Put briefly, problems arise from the diversity of purposes for which data are collected and the variety of stakeholders involved in data collection and management. As a consequence, existing data often regard only certain categories of damage or exposed sectors; they refer to different spatial and temporal scales; and they do not take account of fundamental damage explicative variables, such as vulnerability features and/or relevant flood parameters. These are some of the reasons why available data often cannot be compared across geographical areas and are of limited usefulness in improving currently used flood damage models (see e.g. Merz *et al.*, 2010; Meyer *et al.*, 2013).

The standardising of flood damage data collection has been constantly advocated (see e.g. Cammerer *et al.*, 2013; Handmer, 2003; Rose, 2004; Downton and Pielke, 2005) so that consistent and reliable data can be provided to public administration officials, scientists and practitioners. Promoting improvements in the knowledge base for disaster loss management including disaster loss databases (DBs) is a key priority at both international and European level (see e.g. the Hyogo Framework for Action, the EU Disaster Prevention Framework, the European Union Solidarity Fund, the Green Paper on Insurance of Natural and Man-Made Disasters, the Floods Directive). In the reports by JRC cited above, EU Member States are encouraged to build a process for loss data collection and recording.

Given the huge amounts of economic and human resources required by data collection, the multi-usability of the data collected should be pursued. Recent efforts by both national and international organisations go exactly in this direction: in particular, the Post Disaster Needs Assessments (PDNA) methodology (GFDRR, 2013), developed with the leading role of the United Nations, the methodology developed by Australian authorities (EMA, 2002) and the Guidelines supplied by the World Meteorological Organisation specifically for post-flood losses assessment (APFM, 2013). Those methods have in common the objective of reaching agreed and feasible solutions to coordinate data collection and damage analysis (1) at different times given the evolution of the disaster, (2) across different sectors and (3) with the active involvement of all relevant stakeholders (i.e. data owners and data users). The successful accomplishment of these goals yields the 'integrated interpretation' of the event recommended by Pielke (2000).

This paper proposes a new procedure for the collection, storage and analysis of data in the aftermath of floods, which is called RISPOSTA (Reliable Instruments for Post-Event Damage Assessment). The procedure is an attempt to overcome the limitations of the existing disaster data repositories available in Europe by adapting and tailoring the above-mentioned methods for losses data collection to the Italian context. In order to achieve the multi-usability of collected data, the key principles implied by recent data collection methods have been followed. Accordingly, in the RISPOSTA procedure, data are collected at relevant time intervals to capture both direct and indirect damage, regarding both observed damage and its explicative variables, in the finest possible detail. Moreover, such data collection is embedded in the administrative procedures for emergency and recovery management and damage compensation in place at the national and the European level. This latter point is of paramount importance for guaranteeing the procedure's feasibility and its real implementation by practitioners.

In what follows, RISPOSTA is first described in general terms as far as challenges and approaches adopted in the procedure are concerned. Then a detailed description is provided of three of its main distinctive aspects: the collection of data on the physical event, the collection of data on damage to the residential sector, and the IT tools developed for the collection, storage and analysis of data. The description is supported by discussion of several stress tests performed to verify the applicability of the tools proposed.

Challenges

The challenges to be faced by RISPOSTA derive from the need to collect information for several purposes, so that data must fulfil a variety of requirements.

A first problem relates to the huge amount and heterogeneity of the data to be managed (Molinari *et al.*, 2014b). An integrated picture of flood impacts requires information not only on the damage, but also on its explicative variables; knowledge about the physical effects of the forcing event (such as flooded areas, water depth and velocity, etc.), about the vulnerability of exposed items and, finally, yet importantly, about data on mitigation actions implemented by emergency services and members of the public before and during the flood because they influence both physical effects and damages. Such information must be mapped across the variety of exposed sectors: people, economic and human activities, infrastructures, public and cultural heritage and so on. As regard damage, this is primarily represented in terms of physical units (sometimes only by qualitative descriptions, as for psychological effects or impacts on the cultural heritage). Corresponding monetary values, for tangible damage, are required for loss accounting. The translation of physical damage into monetary values is still a matter of concern (see e.g. Handmer, 2003; Downton and Pielke, 2005); as a consequence, both physical and monetary data should be recorded.

A second problem concerns the temporal and spatial scales of the assessment. The spatial scale changes according to the phenomenon under investigation and to the objective of the assessment (Molinari *et al.*, 2014c) so that data can refer to individual objects (e.g. damage to a building, a bridge, an industry), the local scale (e.g. number of evacuees in a municipality), the large scale (e.g. traffic disruption in the province, flood-prone zones in the river basin) or to the regional/national/international scale (e.g. indirect damage to ecosystems). Ideally, data must be collected at the smallest possible scale to be subsequently aggregated. The data collection procedure must also consider that information is made available at different times according to its nature: data on exposure and vulnerability are available before an event occurs; the extension of the flooded area must be surveyed immediately after the event; indirect damage (e.g. disruption of economic activities, of basic services to the population, the loss of rental income) becomes manifest some months later.

Third, data come from different sources. Most of them (e.g. exposure and vulnerability assessment, damage to infrastructures) can be acquired from subjects that generate or collect such information to undertake practices related to risk assessment or compensation (e.g. local authorities, utility companies). Other data are typically not recorded after the event and must be collected by means of field surveys (e.g. direct damage to buildings, water depth within the flooded area).

As a consequence, the data collected inevitably have different formats: paper based or digital (e.g. texts, spreadsheets, images or multimedia). When possible they should also be georeferenced.

Approach of the RISPOSTA procedure

To address the above-described challenges, an interdisciplinary approach was adopted to develop RISPOSTA. The need to analyse both the physical features of the event as well as its consequences entailed expertise from engineering, urban planning, sociology, economy, etc. Moreover, the development of proper IT tools was necessary to ease as much as possible the collection, storage and (spatial) analysis of data. Accordingly, expertise from Information and Communications Technology (ICT) and geomatics was embedded in the procedure.

The variety of competences is certainly an important condition for achieving the goals set for improved damage data collection; another, equally if not more important one, is the coproduction of procedures and tools for data collection and analysis with the stakeholders responsible for intervening after a disaster and for conducting the subsequent damage assessment. This is the main reason why RISPOSTA has been designed jointly with the Civil Protection Authority of the Umbria Region. Civil Protection agencies are well positioned not only to manage the overall process (De Groeve *et al.*, 2013), but also to act as data coordinators as suggested by the recently produced Guidance at the EU level (EU Expert Working Group, 2015) given their preferential links with most data owners.

The involvement of stakeholders, in fact, has extended beyond the development of the tools and methods, because also their application and testing have been conducted jointly (see next section). As a consequence, all the actors are aware of the practical conditions in which data collection and analysis takes place, including the constraints due to operational intervention in the field and legislative and administrative requirements.

In fact, in order to implement the procedure and the various tools associated with it, several training sessions were carried out with public administration officials and with the technical volunteers asked by the Regional Civil Protection Authority to help with data collection. After each training session an evaluation of the quality of gathered data was carried out jointly, and problems were addressed in joint meetings.

The overall structure of the procedure, in line with the guidelines provided by De Groeve *et al.* (2014), consists of two macroactivities: (1) data collection and (2) data storage and analysis (Figure 1).

RISPOSTA enables the collection and management of data related to: the physical event, costs required to take preventative and mitigation measures (before and during the event), observed damage and its explicative variables (i.e. exposure and vulnerability). Sector-based data management is applied, the sectors being: (a) residential buildings, (b) industrial and commercial buildings, (c) agriculture, (d) infrastructures, (e) public items, (f) emergency costs, (g) people, (h) environmental and cultural heritage.

As regards data collection, the procedure specifies, for each sector, the set of actions to be performed, data to be collected by means of each action, the most appropriate time for each action to be carried out and who is responsible for collecting the data.

Sectors were chosen first so that they cover the entire range of damage/costs arising from a disaster. From this perspective, on the one hand, the classifications adopted by existing methodologies were considered (e.g. World Meteorological Organization and PDNA); on the other, sectors reflect what is recommended by the Floods Directive in terms of principal targets of the risk assessment and the flood risk management plans. At the same time, sectors were defined according to the possibility of adopting homogeneous actions for data collection within each sector.

Indeed, the experience gained in analysing current practices in the Umbria Region suggests that different strategies must be adopted for data collection.

Where damage data are already collected by responsible authorities, after every flood event and with a satisfactory level of detail and accuracy (sectors c, d, e, f, g, h), actions basically consist in the acquisition and organisation of available knowledge. In this case, the definition of shared protocols and agreements with data owners are crucial for acquiring all significant data, at the right time, and in a consistent format. For example, in the case of critical infrastructures, owners or managers of the latter already carry out their own assessment because recovery must be rapid and effective also because of legislative and contractual obligations. In these cases, the procedure foresees that information on damage is shared with the Civil Protection, which acts as the coordinator of losses data.

Nevertheless, it may happen that data are systematically collected, but some important information is missing. In these cases, besides sharing protocols, agreement on data integration must be reached with data owners (e.g. in Italy this is the case of the road system).

By contrast, when data are not systematically collected in the event of a flood (so that the availability and quality of data depend on specific circumstances like the existence of a

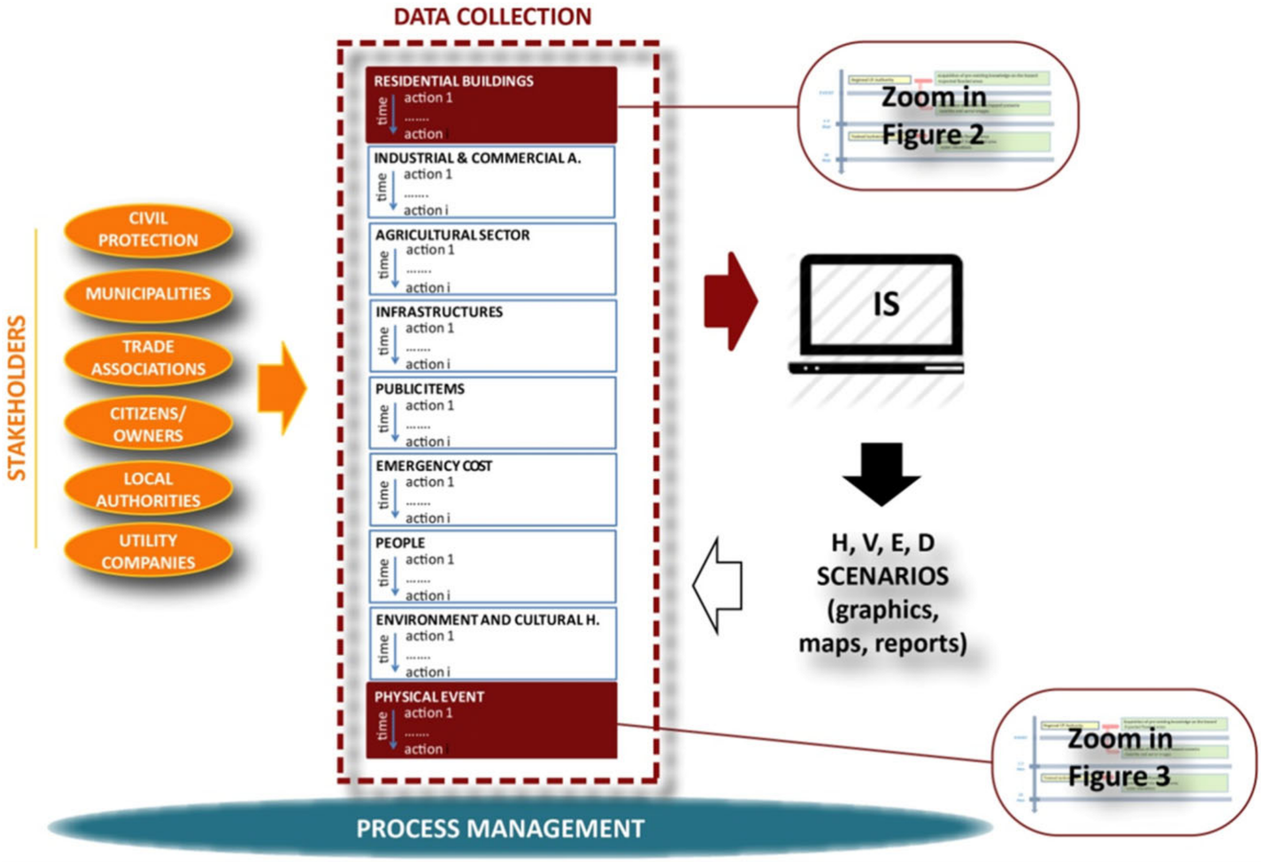

Figure 1 General scheme of the RISPOSTA procedure: links among data collection, storage and analysis.

compensation fund, or a subject – e.g. a trade association or an insurance company – collecting data for a specific purpose), a field survey is introduced (sectors a,b). Accordingly, specific procedures and methods were developed within RISPOSTA.

A distinction can then be drawn within the procedure between actions that can be performed remotely (basically consisting in the acquisition and organisation of existing knowledge) and actions that have to be performed locally (e.g. field surveys). Whereas the former set of actions can be easily transferred to different contexts and to the analysis of several risks, the latter set is typically hazard and context specific.

The time for the collection of data depends on their nature, so that actions can be performed before, soon after or some months after the event. Moreover, the procedure has been designed to fulfil deadlines defined by law for public compensation.

All RISPOSTA activities (i.e. data collection, storage and analysis) are supported by an information system (IS) developed *ad hoc* (Figure 1) whose functionalities are described in detail in following sections.

The RISPOSTA procedure in detail

In this section, the procedure is described in detail with respect to three main distinctive aspects: collection of data on the physical event; damage data collection for residential buildings; and collection, storage and analysis of data by means of the IS. For each aspect, the present status of the procedure is discussed, as well as results from stress tests performed to verify the feasibility of the tools proposed.

Data collection on the physical event

The collection of data on the physical event is not directly linked with *ex-post* damage assessments; however, it is embedded in the procedure for two main reasons. First, it is important to define the extension of the flooded area as a basis for the collection of flood damage data. The usual practice is to derive the extension of the flooded area from satellite or aerial images collected soon after the event. However, such tools may not be applicable and furnish unreliable results for events with relatively short time scales (e.g. flash floods) because areas wetted at the time when the images are acquired may be a significant underestimation of

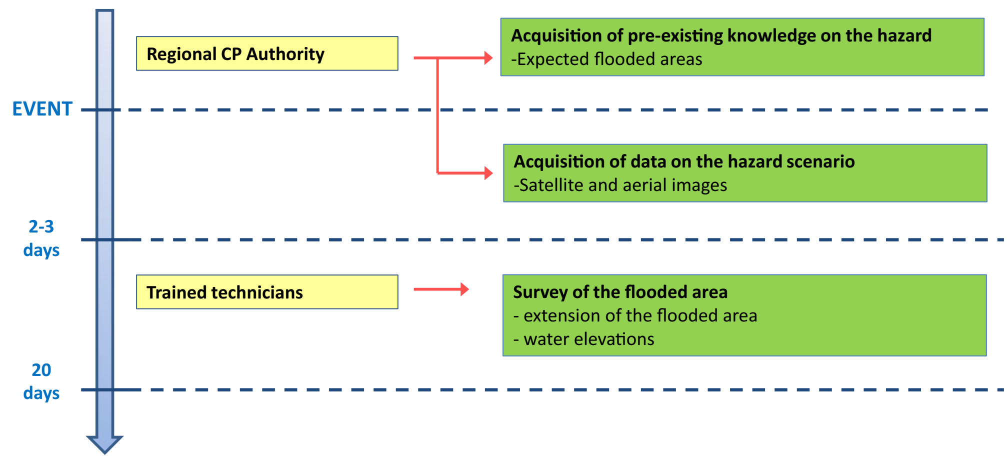

Figure 2 Scheme of the RISPOSTA procedure for data collection on the physical event: actions to be performed, times of actions, collected data and responsible actors.

the maximum flood extension. In such cases, typical of mountain areas, a field survey is required. Second, explicative damage variables related to the hazard features (like water depth and velocity at building locations) are usually not recorded during post-event assessments or are difficult to measure. Such information, however, can be reconstructed by means of numerical modelling of the flood event. Given the huge efforts required by data collection, it is reasonable that also the knowledge base for the validation of hydraulic modelling should be acquired during the field survey.

Other hydraulic data that are relevant for modelling validation (like hydrograph, pre-existing flood frequency estimates, etc.) are instead acquired from authorities/agencies in charge of hazard assessment and management, both before or soon after the flood. Accordingly, data collection has a twofold aim: defining the flooding area and acquiring useful information for the validation of hydraulic modelling (including measuring water elevation at significant points).

In the following, actions related to the first objective are described in detail as measurement of water elevation is still at an experimental stage.

Figure 2 summarises actions embedded in the procedure, times of actions and responsible actors. These last have been identified with respect to the Italian context. In detail, actions consist of:

– Acquisition of pre-existing knowledge on the hazard by extracting information from existing DBs (typically hazard assessment and information on past events provided by competent authorities). The objective is to organise available information on flood-prone areas to be used as the basis for field surveys.

– Acquisition of data on the hazard scenario. Satellite and aerial images collected soon after the event by national authorities and fire brigades are acquired when available.

– Survey of the flooded area. The survey is carried out in the field by teams of trained technicians. According to satellite and aerial data, as well as previous knowledge of expected flooded areas, regions to be surveyed are identified on a map. Survey simply consists of looking for watermarks on buildings and artefacts (levees, walls, poles, etc.) and natural elements (trees, rocks, etc.), and reproducing the water perimeter on the map. Information reported by citizens can also be useful for defining the water border.

The procedure was tested after the recent flood in Umbria in November 2014. Given the small extent of the event, no satellite or aerial images were available. Therefore, hazard assessment maps available in flood and landslide management plans (i.e. the so-called Piani di Assetto Idrogeologico) were used to identify regions to be surveyed. Two teams of seven people were equipped with a paper map of the identified area and common measurement tools (e.g. GPS localiser, measuring tape, compass and camera). The teams spent 4 h on surveying an area of about 1.5 Km^2 in the town of Foligno.

The test highlighted the need to professionalise technicians so that correct implementation of the procedure can be guaranteed, and data quality ensured. Moreover, there is a need to develop a mobile application supporting the survey. This application should enable the drawing of both the water perimeter and surveyed points on a georeferenced digital map, taking and storing measurements, and integrating data by means of georeferenced photographs.

Data collection for the residential sector

This activity is described here as an example of the sector-based activities embedded in the procedure for damage data collection. In particular, the activity refers to one of those sectors for which a field survey is required by the procedure.

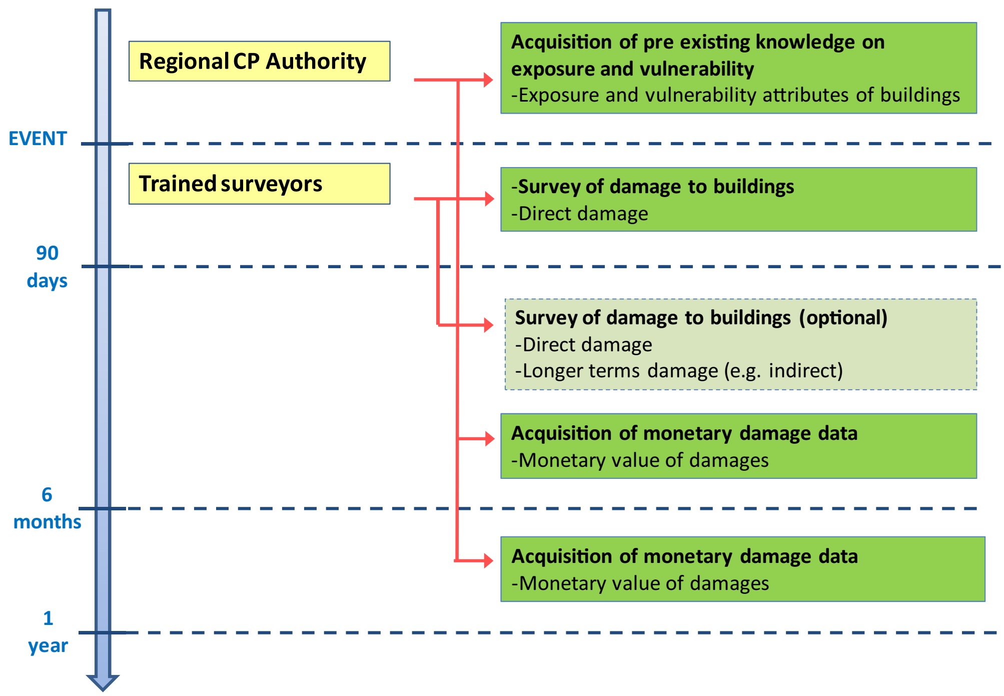

Figure 3 Scheme of the RISPOSTA procedure for data collection on the damages at the residential sector: actions to be performed, times of actions, collected data and responsible actors.

Actions to be performed within this activity are summarised in Figure 3. The timing of action is defined by considering both the nature of data and Italian regulations on damage compensation. The actors involved have been identified by referring to the Italian context. Actions to be performed consist in detail of:

– Acquisition of already-existing knowledge on the exposure and vulnerability of buildings by extracting information from existing DBs (e.g. cadastral or risk maps). Such information (like surface area, number of floors, age, level of maintenance) can be uploaded into the forms implemented in the damage survey.

– Survey of damage to buildings. The survey is carried out using the procedure described in Molinari *et al.* (2014a). Put briefly, on the basis of the flooded area surveyed and the knowledge of building locations, identification is made of the buildings to be investigated. The survey is then performed in the field by means of *ad-hoc* forms compiled by trained teams. The forms allow the collection of information on the location of the buildings, hazard features at the buildings' locations (e.g. water depth, presence of sediments), the exposure and vulnerability attributes of the buildings, direct and indirect damage suffered by the buildings and their occupants, and mitigation actions implemented before and during the flood. A second optional survey can be carried out some months after the event. The objective is to collect information on longer term damage (typically indirect damage, such as time spent outside the house or loss of rental income) not defined at the time of the first survey. On this occasion, data considered not satisfactory or missing after the first collection can be further acquired. Forms can be pre-compiled according to existing knowledge on the exposure and vulnerability of the buildings, as well as with data from previous surveys.

– Acquisition of monetary damage data. During the survey, damage is assessed in physical units (e.g. number of damaged doors, square metres of damaged floor). In a second step, the monetary damage value is assessed on the basis of the compensation requests submitted by owners, according to regional and/or national funds available at different times after the occurrence of the event.

Actions related to the acquisition of pre-existing knowledge were tested for the flood that hit the Umbria region in 2012; data were collected from the Region Authority (orthophotos, land use data) and municipalities (cadastral data). The test revealed several difficulties of data integration because of the lack of standard data formats among the different authorities. As a consequence, standards were defined for data to be used as input to, or produced by, RISPOSTA. For example, specifically for georeferenced data, the necessary attributes for each of the layers were identified, whereas all useless data and attributes were eliminated. As data integration is extremely difficult and time-consuming during implementation of the procedure, a key aspect for its feasibility is the sharing of identified standards among all data owners or, more reasonably, the development of IT

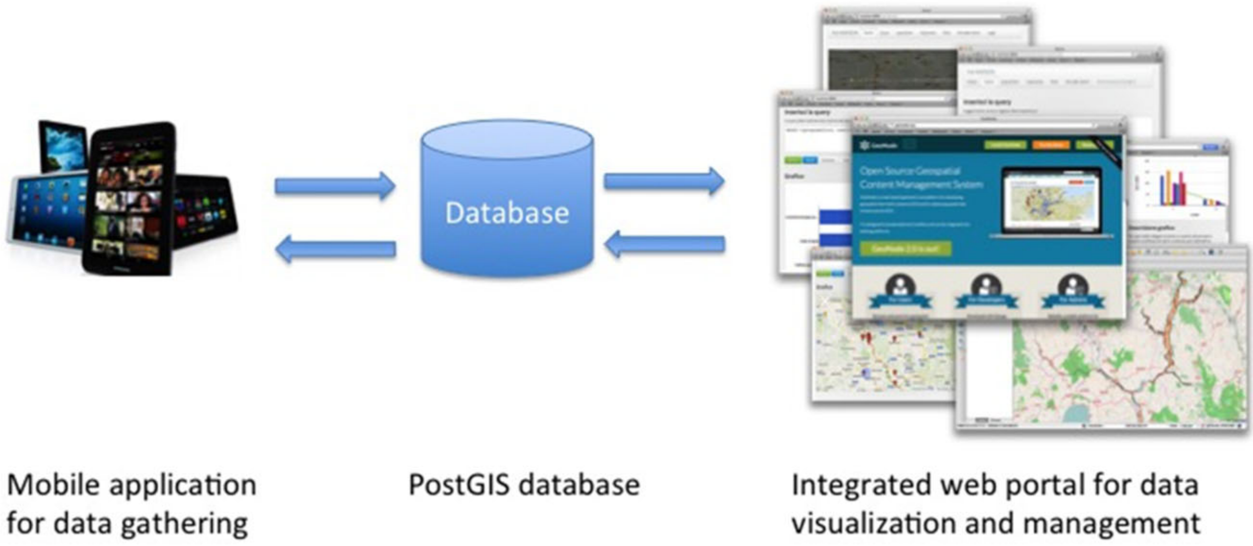

Figure 4 The RISPOSTA Information System architecture.

tools for the conversion of data acquired during the procedure into required formats.

In relation to the survey of damage to buildings, the forms were tested on the occasion of the flood events that hit the Umbria region in 2012 and 2013. As result of the first application, forms described in Molinari *et al.* (2014a) were validated and then adopted in the procedure. Field experiences clearly indicated the need to move from a paper-based form to a mobile application. In November 2013, the survey was performed with forms pre-compiled with aerial images, damaged building locations and information available from the cadastre in order to accelerate the survey and the back-office work. As a consequence of this second round of surveys, the RISPOSTA procedure was finally defined as described above. A current proposal is to involve private owners in the procedure because the national authority requires citizens to declare damage in order to access compensation funds. Forms filled in by surveyors may be made available to citizens so that they can apply for compensation.

A similar procedure has been developed for commercial and industrial buildings, using specifically designed survey forms tested in two industrial areas particularly affected by the 2012 flood. The organisation of the forms is, of course, different from those used for residential buildings in that significant space is allocated to the estimation of damage to machinery, raw materials and finished products.

ICT tools for data gathering, storage and analysis

As briefly introduced in the previous sections, an IS supports each activity of the RISPOSTA procedure.

The core component of the IS architecture (Figure 4) is a PostGIS DB, designed to fulfil the requirements for data management described in Molinari *et al.* (2014b) and briefly recalled in the second section of this paper.

Besides the DB, several applications have been developed to enable the management of data (insertion, update, visualisation, etc.) and help the various actors involved in the procedure to perform their tasks. With respect to Figure 4, there are two components: a mobile application for data gathering and a web portal for data visualisation and management. The IS components are now described in greater detail.

PostGIS DB

Figure 5 shows the Entity Relationship diagram according to which the DB was designed with respect to data collected for the residential sector. The DB stores all the data related to the procedure, including the surveyor teams, the exact locations of the buildings inserted and the main characteristics of the flood within the buildings (for example, water depth, presence of contaminants or sediments). In the DB, the damage that occurred to each unit surveyed, whether a single house, an outbuilding, a dwelling in a condominium or the common parts of the latter, is recorded. Damage attributes – not shown in the figure – range from damage to structures and content, through the physical disruption of equipment, to the days required for clean up. The DB was designed in a Database Management System (DBMS) that supports GIS functionalities; hence georeferenced information can be easily imported and processed. The DB was not directly validated by stress tests; however, its functionality was verified

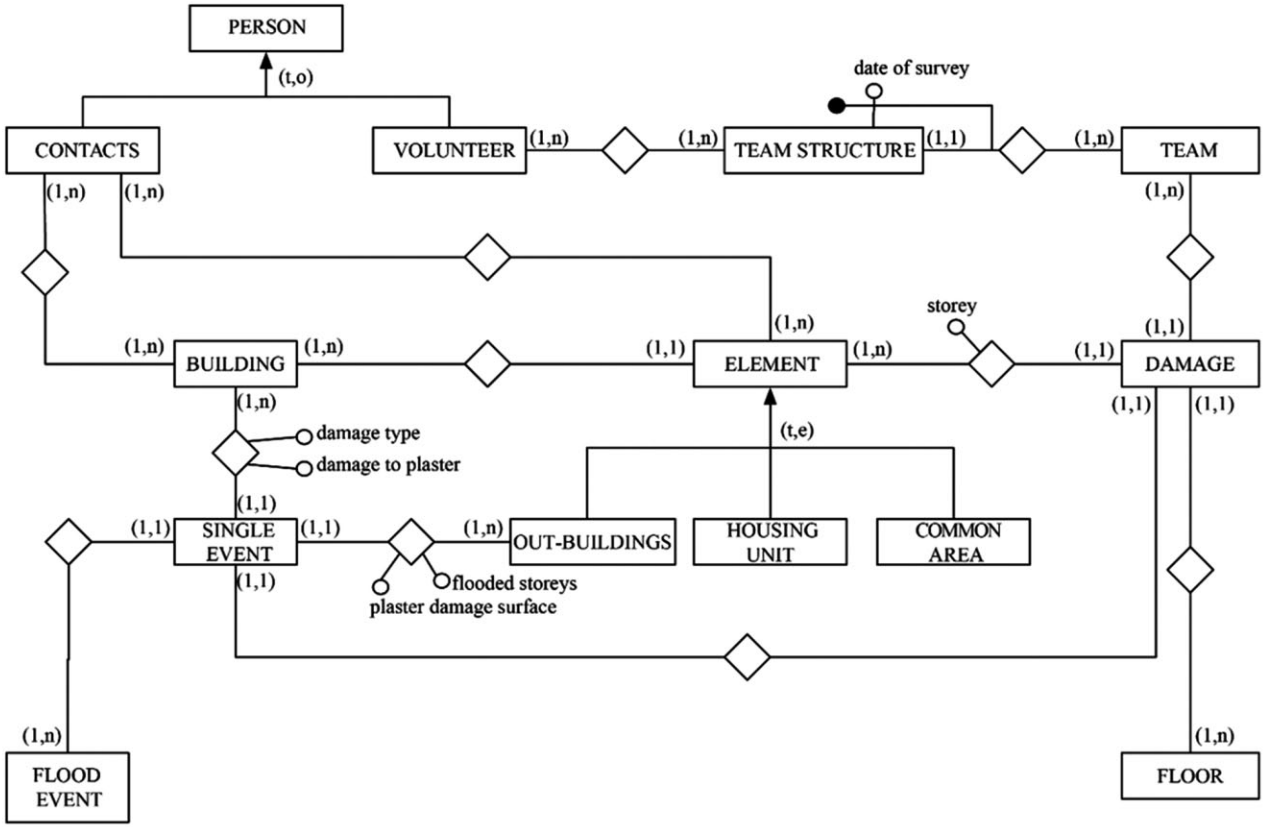

Figure 5 The Entity Relationship diagram of the DB with respect to damage at the residential sector.

through the tests on the single applications interfacing with the DB, as now described.

Mobile application

A prototype mobile application for the Android platform has been developed by exploiting OpenDataKit (https://opendatakit.org) tools. Its aim is to facilitate the field survey of buildings by enabling compilation of the forms in digital format. Trained surveyors are equipped with a rugged tablet running the mobile application; and they are initially given the set of buildings to survey. The application gives strong support when the forms are compiled. In particular:

– For each question in the form, the application provides information about its domain, e.g. text, numerical value. If the domain of an answer is constrained (e.g. there is a limited list of possible answers), the application provides a dropdown list and allows users to choose an option among those availables.

– The application is organised into multiple sections that correspond to sections in the forms (e.g. information about the building, information about the damage, etc.). Each section and question can be collapsed (or expanded) to improve user navigation through the survey.

– All the surveys performed are stored on the tablet and can be filled, browsed and modified. Then, complete forms can be sent to the DB, whereas incomplete forms are kept on the tablet until they are completed.

– The position can be easily detected in two ways: (1) automatically, by the application that exploits the GPS functionality of the tablet and (2) manually by the user, who can select a point on a map provided by the application in the case of low GPS signal.

The prototype mobile application was used by trained teams in the field while surveying damaged buildings in 2014. The teams highlighted some features that should be improved to facilitate the use of the application:

– Easy monitoring of the survey progress: that is, rapid understanding of which buildings have been surveyed and which are still unsurveyed. Moreover, teams asked to have an overview of the status of each survey performed (e.g. forms are complete, important questions are missing). Consequently, the application will be provided with an interactive map showing the area of interest with the assigned buildings; and for each building, showing the status of the survey performed. Whenever a team surveys a building or fills in a form, the map's status will be updated. Thus the teams can obtain an easy and quick overview of their current progress.

– Communicating with each other. For example, some technicians had doubts about how to complete some items on the forms because the answers given by people were too vague or very descriptive. Some teams were quick in surveying the assigned area and thus available to survey the buildings assigned to other teams. Moreover, some teams realised that they were very close to a building assigned to a different team and wanted to survey it anyway; or they found a building that was not shown on the map and did not know what to do with it. A chat functionality will be implemented so that technicians can write to each other and contact a central operator when necessary.

– Browsing the surveys in a more complex way than provided. Requests concerned more rapid access to questions regardless of their position in the form (e.g. users write words and the system shows all the questions containing the searched terms); receiving alerts on missing data or answers.

In order to remedy the mobile application's weaknesses, a new version based on the Android SDK is under development.

Web portal

The portal is an integrated access point to the data. It is a multifunctionality and multi-user portal where each actor (according to his/her role and security restrictions) can access and manipulate portions of data acquired during the procedure. The main features are:

– Users can query the DB to retrieve, visualise and eventually export information of interest. The portion of data accessible for querying depends on the role of the user: some users have access to all the information; others have restrictions. For example, surveyors can query the DB to retrieve all the data that they have entered, but they are not able to ask questions about reimbursements. Instead, an administrator, such as a Civil Protection manager, is allowed to access information about teams, surveys and reimbursements.

– Nonexpert users are supported by the system through the use of predefined forms, hints and natural language so that they can easily access the data without having to learn technology-specific tools (e.g. the SQL language for relational DB querying).

– Whenever the output of a query is a multidimensional matrix (e.g. damage to each building within a given area), the results can be visualised through charts with predefined structure.

– Users can share queries and charts. In this way, a specific portion of the DB, i.e. the result of a query, can be made available to specific users. This is especially useful because there are classes of questions that are more frequent than others, or which may be of interest to different users, like queries on the total damage for each building, the total damage in a municipality and the total damage for each event, etc.

The portal also offers functionalities specifically related to georeferenced data and their browsing through maps. This part of the web portal is based on Geonode (http://geonode.org), which is a free and open-source geospatial content management system. The main functionalities of the RISPOSTA web portal for georeferenced data are:

– Users can browse and search for geospatial data. Geospatial content (e.g. layers of cadastre, flooded area, survey points) in different formats (e.g. vector *.shp, raster * geoTIFFs) can be searched by category, date and keywords.

– Authorised users can upload and share geospatial content through standard protocols such as Web Map Service (WMS) and Web Feature Service (WFS). For instance, an orthophoto of the flooded area provided by the national authority can be included in the web portal using their WMS service, or a technician can use the layer of survey points by accessing the RISPOSTA portal WFS service. It is possible to publish raster, vector or tabular data with their respective metadata (e.g. date of creation, owner, key words) and associated documents (e.g. laws or directives associated with a certain layer, survey reports) that can also be downloaded.

– Users can create and share interactive web maps. The portal includes cartography tools for styling and creating maps graphically in the same way as traditional desktop GIS applications, including editing. Users can gain enhanced interactivity with GIS-specific tools such as querying and measuring. Maps of the flooded area, damage to buildings, points of survey and economic value of buildings can be visualised and shared using the web portal (see e.g. Figure 6).

As a stress test, a series of maps and tables were produced in regard to the 2012 flood in Umbria.

On the basis of this test, information to be represented in maps and tables was predefined to produce a complete event scenario. The information concerns damage, exposure, vulnerability and the physical event (see Table 1). The symbolisation, the categorisation of the legend and the colouring of the geographic features were designed to enable comparison among maps referring to different flood events and to minimise the user's effort of map creation. Figure 6 shows an example of a map corresponding to the fields (Vulnerability – Vulnerability of buildings divided by flooded levels – Type of use) in Table 1.

As a forthcoming improvement, the portal should support users not only according to their role, but also according to the timeline of the procedure. Hence, functionalities should be extended so that at each step of the procedure, the web portal provides users with the specific knowledge required to perform each action (e.g. flooded areas, locations of buildings), reminds them about tasks that they have to perform (e.g. gathering data) and alerts them when new information

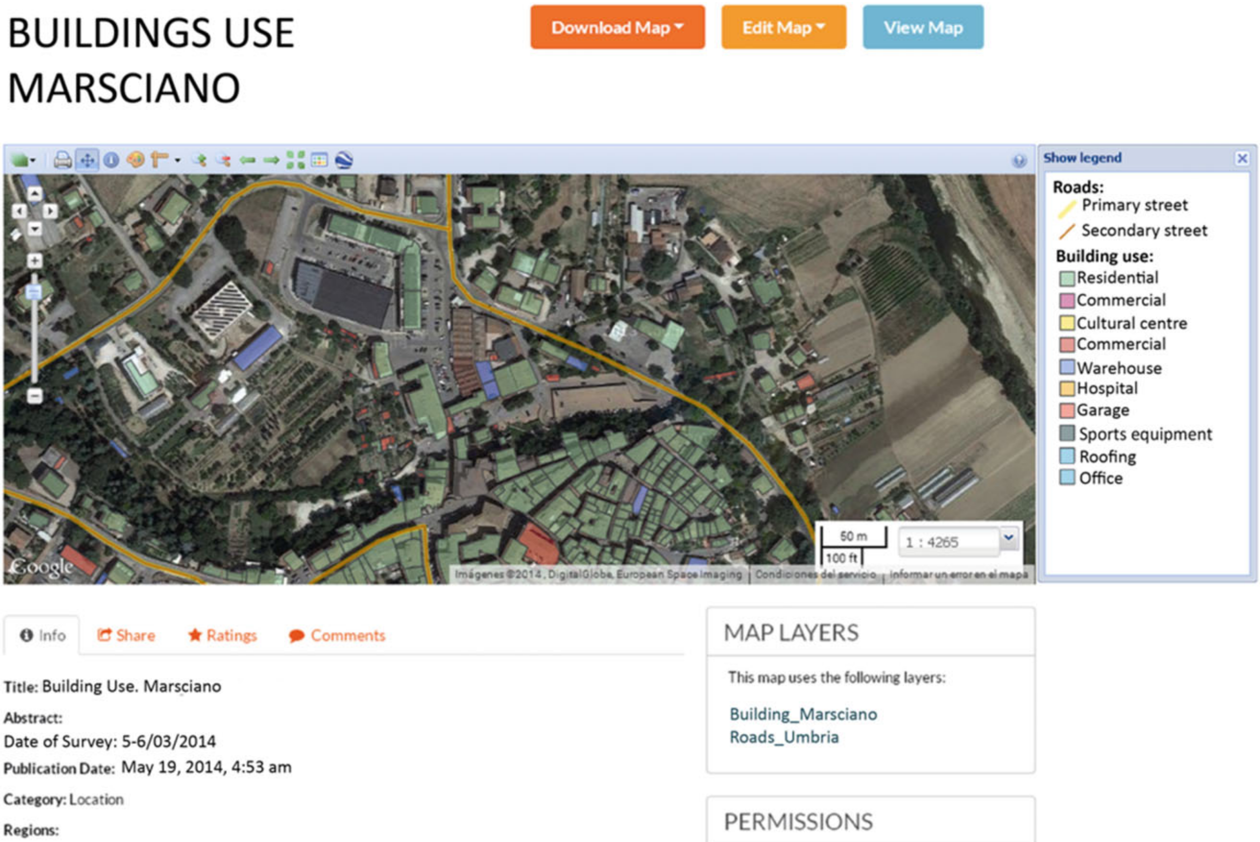

Figure 6 An example of standardised maps provided by the RISPOSTA procedure: building use map for the Municipality of Marsciano (Umbria Region).

is required or made available (e.g. data gathered during the field survey) according to their role in the procedure.

Transferability of the procedure

The integration of data and practices is the main strength of RISPOSTA. Both the procedure and the supporting IS are conceived so as to create a common platform through which (1) all data relevant to the definition of *ex-ante* and *ex-post* risk mitigation strategies are gathered and stored, and (2) all relevant actors are involved and coordinated.

The stress tests previously discussed proved the robustness of the general structure of the procedure and of its main distinctive features (i.e. the sector-based approach, the collection of data at different times and on the smallest possible scale, the collection of data on damage and their explicative variables, the integration of existing practices and responsible stakeholders). It should be acknowledged that the stress tests were performed under relatively homogeneous conditions: small-scale events in mountain regions within the Italian institutional context. However, given the structure of the procedure (and related IT tools), we expect it to be well transferable to different juridical and physical contexts: the general framework may remain substantially unchanged, whereas some specific aspects would certainly require revision and adaptation to the system under investigation.

For example, authorities responsible for data gathering may change from one juridical context to another; collecting methods may be adapted to the phenomena under investigation so that in the case of riverine floods lasting for several days over wide areas, survey of the flooded area can be avoided because of the existence of reliable satellite images. Collecting methods may change also because of different institutional contexts. In particular, field surveys may be required for sectors other than private residences and commercial/industrial units. In this case, the experience described in the paper highlights the need to design specific survey modalities and tools for each sector concerned, and which take account of both the features of exposed items and expected damage. In some sectors, it is likely that the field survey would be less straightforward than for residential buildings and industrial firms. This is the case, for example, of infrastructures that are complex systems, closely interconnected, spatially distributed on the territory and possibly

Table 1 Predefined and standardised maps develop by RISPOSTA for the residential sector

Type	Data	Description	Map	Table
Damage	Number of affected people per municipality		✓	✓
	Total direct economic damage per building and municipality		✓	✓
	Indirect damages	not accessible buildings	✓	
		Total indirect damage per building and municipality	✓	
	Direct damage to buildings divided by flooded levels	Damage to plaster board		✓
		Damage to doors and windows		✓
		Damage to floors		✓
		Damage to vulnerable equipments		✓
		Damage caused by high speed water flow		✓
		Damage to furniture		✓
		Damage to household appliances		✓
		Damage to vehicles		✓
	Photo gallery (per building)		✓	
Exposure	Buildings economic value		✓	✓
Vulnerability	Building typology		✓	✓
	Period of construction		✓	✓
	Building structure		✓	✓
	Vulnerability of buildings divided by flooded levels	Level of maintenance		✓
		Type of use		✓
		Presence of vulnerable equipments		✓
Physical event	Presence of sediments		✓	
	Presence of contaminant		✓	
Mitigation actions				✓

affected not only by physical disruption, but also by dysfunctionalities due to their interdependency. An appropriate balance between data of interest and efforts required must be found in these circumstances if the procedure is to be viable.

It may also happen that data survey/collection cannot be performed for certain sectors (for example, because of a lack of resources or because of bureaucratic impediments, e.g. private companies do not consent data sharing) or cannot be carried out at reasonable costs. The RISPOSTA procedure is flexible with respect to this, as the collection/gathering of data for a certain sector is not affected by the (un)availability of data to other sectors. An exception is represented by information on the flooded area, which is the knowledge base for performing damage data collection.

In the case data are missing for certain sectors, the procedure supplies a partial vision of damages that occurred. This must be explicitly reported when collected data are presented to decision makers in order to avoid confusion about 'lack of data' and 'unaffected sectors'.

Finally, information on the monetary value of damage may not be available for some sectors because estimations are not made or are difficult (as in the case of indirect damage, damage to public items, etc.). In such cases, because the translation of damage into monetary terms is not within the scope of the procedure, data collection should focus on physical damage only.

Conclusion

This paper has described a new procedure that addresses the need to standardise ways of collecting, storing and analysing data in the aftermath of floods. The procedure is part of a long-term project aimed at creating reliable, consistent and comprehensive flood DBs to be used in several ways to achieve risk mitigation objectives. In this regard, the procedure satisfies several requirements of loss data: (1) they should be collected at the finest scale so that the proper scale of analysis can be chosen by subsequent data aggregation; (2) they should be linked to the physical event, as well as to the features of the different exposed elements, so as to furnish a comprehensive view of flood impacts and their explicative variables; and (3) they should be collected at different times according to the unfolding of the event so that the entire range of possible damage can be described.

Integration of data and procedures is one of the main achievements of this project. RISPOSTA is conceived to furnish a common platform through which (1) all data relevant to the definition of *ex-ante* and *ex-post* risk mitigation strategies are gathered and stored, and (2) all relevant actors are involved and coordinated. A second achievement concerns the development of an IS supporting all the activities included in the procedure. The system is based on an appropriate data model that embeds data requirements, provides tools for each activity in the procedure and supports user-friendly data collection, visualisation and sharing, for a wide range of users.

From the methodological point of view, the research on which this paper is based highlighted the importance of involving stakeholders in the entire development of the procedure. Data gathering entails an active role by stakeholders; data analysis must be attuned to the needs of the different stakeholders. Accordingly, it is important to develop both methods and IT tools in close collaboration with the stakeholders.

Experience gained in the development of the procedure suggests that its general structure can be easily exported to other contexts. However, specific aspects (like actors, actions and timelines) must be defined case by case according to the juridical and physical context under investigation.

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