Crisis information to support spatial planning in post disaster recovery

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In this paper we propose to explore the complex node of post disaster reconstruction, knowledge and data necessary to support spatial planning, and new information technologies. The methodology that is illustrated assumes that post-event damage assessments are useful to verify to what extent hazard and risk assessments that were available to planners to make decisions before the disaster were correct and if they were actually used as a basis for locational and zoning choices. Our contribution is aimed at the creation and design of knowledge bases accounting for the dynamic evolution of disasters. New web based technologies provide the opportunity to collect and analyse dynamic territorial crisis data using crowdsourcing and crowdmapping platforms. The proposed methodology permits to sort and classify a very large set of different types of data generated through the web. Semantic conceptualization using ontologies is performed to identify and select the information produced during the emergency that can support spatial planning in the post disaster reconstruction. The city of Tacloban in the Philippines, affected by the Super Typhoon Haiyan in November 2013 constitutes the test case for applying the methodology that has been developed.

Keywords: Crisis information Spatial planning Resilience, Knowledge management, Ontologies Crowdsourcing

1. Introduction

Post disaster reconstruction is a complex process entailing huge investments and requiring significant human and material resources. Among the latter, data and information regarding the damage that has occurred and how a given place has changed as a consequence of the disaster are key. The proposed contribution is part of an exploratory research which focuses on the type of damage and loss data that can better feed urban and spatial planning for post-disaster reconstruction. In particular the article explores the emerging opportunities that open data generated and shared through the web during the crisis may offer to support post-disaster reconstruction planning.

In their pioneering book Haas et al. [31] indicated reconstruction as the longest phase of the disaster cycle, distinguishing it from recovery, intended as a first return to normalcy, that follows the emergency phase, when immediate relief operations to rescue the population and to provide first answers to impellent needs are carried out. According to more recent literature [12,4] recovery encompasses both the reconstruction of the built environment, intended as physical restoration of assets and infrastructures, and the restart of economic and social functions and activities. Without entering too deeply in this debate, reconstruction is considered here as a process integrating physical restoration of the built environment, to which spatial planners have to provide a substantial contribution, and boosting of social and economic activities so as to guarantee that what will be rebuilt will not be an empty shell deprived of its vital functioning core.

Some studies followed the framework set by Haas et al. (see for example [26]), however for some time the attention of researchers and practitioners was driven towards other topics, mostly linked with the improvement of risk assessment modelling and preparedness capacities. In more recent years, though, as suggested by Guénard and Simay [29], there has been a shift from approaches focused only on risk prevention and mitigation towards studies acknowledging the need to prepare to cope with catastrophes, that are, to a certain extent, inevitable. From a rather aseptic consideration of risks in terms of probabilistic numbers regarding events that can be fully envisaged, a more realistic recognition of the complexity of both natural phenomena and exposed vulnerable human systems has arisen. As a result, being able to recover and reconstruct in a resilient way has been brought back on the agenda of decision makers, and there is a renovated interest in models to help decision makers understand how post-event actions may change the condition of risk and vulnerability in the future, in case another extreme event occurs [17].

Despite of the relevance of the reconstruction phase for the well-

Received 28 June 2016;
Received in revised form 3 February 2017;
Accepted 10 February 2017
Available online 01 March 2017

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Published Journal Article available at http://dx.doi.org/10.1016/j.ijdrr.2017.02.007

being of affected communities, the significant associated expenditures, there are still many aspects that need to be better understood. The conditions and the type of decisions and actions that drive urban and regional systems towards a successful or unsuccessful reconstruction require further investigation and research [4].

Even less attention has been devoted to spatial and urban planning as a key component of urban recovery. This has partly to do with the low participation of planners to risk mitigation research and practice at large [59] and partly with the institutional arrangements in place insofar to guide the reconstruction process. In most cases, authorities such as the civil protection or special committees are in charge of defining the strategies and modalities of reconstruction, leaving its translation into spatial patterns and definition of forms, zoning, location of functions and uses to planners who are only marginally involved in the boards deciding expenditures and strategies. In our contribution we wish to tackle this important topic from a rather specific angle that is the type of data that are necessary for planning a more resilient reconstruction.

It is conventional to define the disaster management cycle as the sequence of the activities of preparedness, response, recovery/reconstruction, and mitigation [5]. From a data management perspective, this implies to consider data production and use in its entirety as a unique workflow [39]. In other words, data management can be considered as a sequence of connected activities enabled by a structured organization of resources, defined roles and information flows, pertaining to an effort that can be documented and learnt [27]. Within this angle, it can be proposed that a significant part of the information created and used in the disaster management cycle is common to its consecutive phases [39]. An evident example is the use of available emergency planning information to manage the crisis, and vice versa, the use of crisis information as lessons learnt to feed planning for the next crisis. In this paper, we explore the assumption that data produced and used during the emergency may be supportive to the reconstruction phase. For this purpose crisis data should be considered as part of a whole, to be integrated with other information produced during other phases of the disaster management process including historical data.

The framework in Fig. 1 shows the type of data needed for planning the reconstruction and the phase of the disaster cycle when they are produced. Data and information planners use in ordinary times, that are available before the disaster impact, keep being relevant also afterwards. As an example one may consider statistical data regarding the population characteristics, economic activities, baseline maps showing how settlements are organized and interconnected by transportation networks, thematic maps representing hazards and eventually risk assessment in the area of concern. Cadastral data are often cited as very important, even though it may be extremely difficult to recognize properties' borders in the in the disaster aftermath. Exactly because the situation has dramatically changed, damage and loss data come into play as they should complement and many times substitute the data that were collected on ordinary basis before the event, to identify needs, priorities, implications of the disrupted services and urban functions for decision making.

Damage data are collected by a variety of stakeholders in the aftermath of a disaster, often in a fragmented and unsystematic way, to respond to specific requirements each organization and agency, either public or private, has to respond to the emergency and to intervene in order to restore services and assets it is responsible for. Damage data collection is a socially constructed process, in which different bodies, agencies, actors view damage, data collection priorities and relevance in a very different way [42]. Until now no agency or specific personnel has been appointed to coordinate such process and the subsequent use of the data (Gall, forthcoming [24]), a situation that needs to be changed if the aim is to enhance the quality and the comprehensiveness of damage and loss data (EU Technical Group, 2015).

In our contribution we will deal specifically with data that are collected, shared and produced within the era of the collaborative Web, also called Web 2.0. The concept of Web 2.0 was introduced during a conference organized by O'Reilly Media as the "new wave" of the Internet that "permits a new generation of services" [45]. In this configuration, the connected users are enabled to re-use and contribute information, thereby enriching the content distributed between the collaborative parties on the Web. Information and knowledge now can be shared, co-produced, co-developed in large virtual arenas that are activated for a certain time until common and commonly defined objectives are satisfactorily served. The data produced within the web 2.0 is a new set of data that is mainly produced during or immediately after the impact and throughout the emergency by a large public made of victims and digital volunteers [37]. Such data are increasingly used by national and international civil protection organisations and by NGOs for crisis management. The innovation and the challenge that we wish to propose here is the use of such data for another purpose that is informing urban planners for developing reconstruction spatial plans of the affected urban systems.

In order to use this new type of data it is not sufficient to simply collect it through the web. Actually both data gathering and successive management require quite sophisticated techniques for filtering, selecting, cross checking in order to obtain reliable and usable information. Once undergone such close and sharp quality scrutiny, data can be used to analyse the event, producing tables, graphs and especially maps to support planners. Maps and information can be then compared to data and maps developed using more traditional sources, such as those habitually developed by planners or to support planners in their choices, for example geological or hazard maps.

To achieve and apply the rather complex methodology described in this article it was necessary to congregate a really multidisciplinary team, constituted by a computer engineer, expert in the intelligent retrieval and management of data collected through the web, an urban planner with long experience in risk assessment and mitigation, a graduated in civil engineering in risk mitigation, a master program offered at the Politecnico di Milano, and a graduated in planning with a background in environmental science at the School of Architecture of the Politecnico di Milan.

In the following sections the methodological and conceptual approach that has been developed will be discussed. First, in Section 2, the challenges planners are confronted with when depicting spatial frameworks and visions for the reconstruction will be briefly addressed, focusing in particular on the knowledge, information and data they need to better perform such a difficult task. Section 3 is devoted to in depth discussion about the data collected through the web, their classification and the use of ontologies in order to be able select those data that will be of use for planning the reconstruction. In Section 4 the application to the case study of the city of Tacloban in the Philippines after the devastating Haiyan/Yoland Supertyphoon will be described. In the concluding Section 5 the novelty of the approach and possible future direction for research are discussed.

2. Planning for the reconstruction of urban systems: knowledge and data needs

"Rising from the ashes" [6] was the compelling title of a book investigating the huge human and financial investments to be provided when it is extremely difficult to believe that it will ever be possible to resurge from the destruction and disruption that is associated with extreme events' impact. In order to meet the challenges a bundle of factors are required: self-organization and sustain capacity of the victim communities, national support in terms of means, resources, specialized personnel, and in many cases, and not only in developing countries, international aid.

In the aftermath of a large disaster many alternatives seem equally possible with respect to the built environment, ranging from total rebuilding to more surgical intervention aimed at repairing and restoring whenever possible and adjusting new development in the

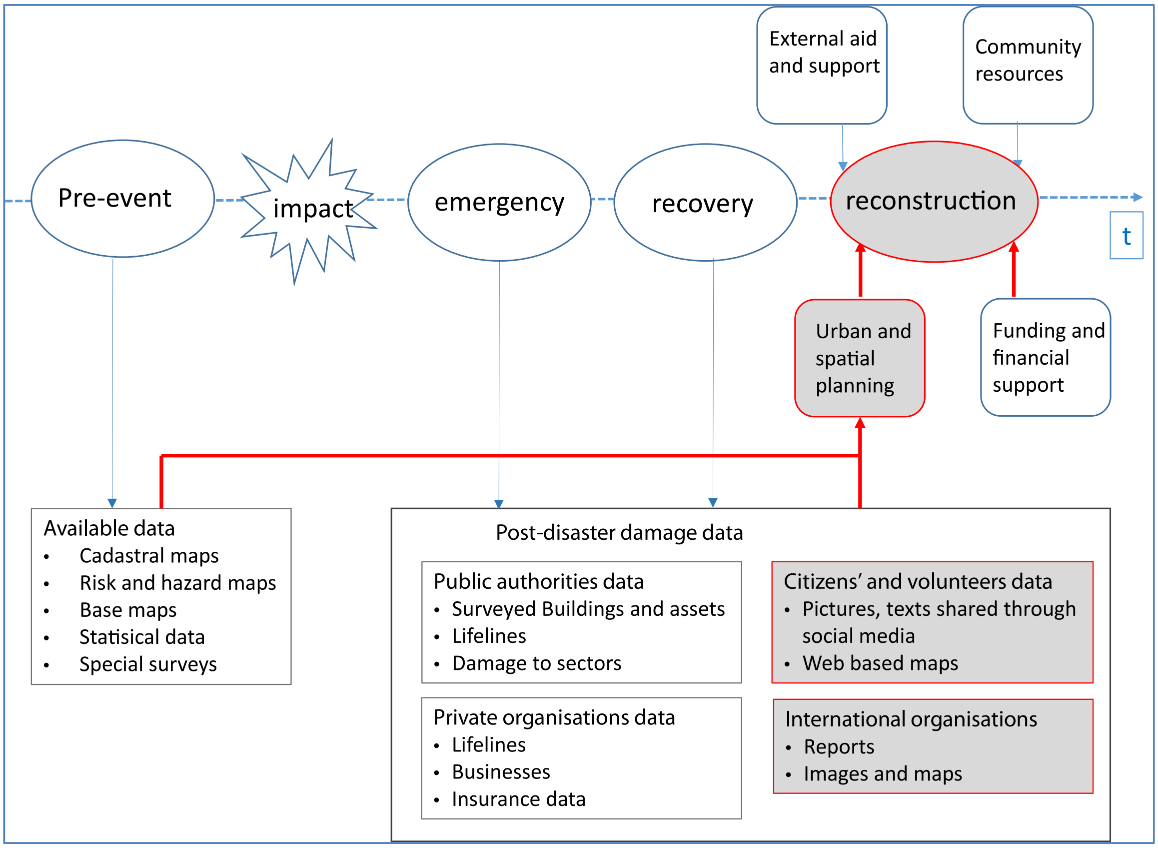

Fig. 1. Framework showing the relationship between data useful to support planning for reconstruction and the different event "phases".

fringes of recuperated pre-disaster buildings and infrastructures. The choice should not be the result of a cold and aseptic decision, based only on the extent and level of damage, as multiple dimensions including social and cultural preferences have to be considered for a resilient outcome, as Vale and Campanella [56] stressed in the many examples they discuss in their "The Resilient City". In the latter the Authors argument that reconstruction is never only a matter of physical rebuilding, as social and economic factors have to be integrated in the definition of density, intensity, frequencies of use and functionality of spaces and structures.

Vale and Campanella [56] insist on the importance of the post-traumatic healing of the community that substantiate also through the symbolic component of designing memorials and monuments devoted to remembering the event and the tragedy the community has endured. A similar departure for the meaning of "resilience" has been brought also by Norris et al. [47] who defined resilience as a "set of networked adaptive capacities". Among the latter according to several other authors [13,16,20], knowledge is key in providing a resilient response to disasters, both in terms of mitigation capacity before the impact, as suggested by Rose [54] and more often as the capacity to "bounce back" improving the pre-event conditions. Knowledge that should be embedded in the post disaster planning process should regard not only lessons learnt from the disaster and provided by literature, but also regarding tools, models of action that can be considered as a guideline for making and implementing decisions and enacting them so as to make reconstruction advance. It has been highlighted [53] that it would be of great advantage to have at planners' disposal models of ordinances to be issued for taking a variety of steps according to predefined procedures, and even a plan envisioning how a potential disaster would offer windows of opportunity to change the pre-event vulnerability and risk levels. Such knowledge would permit to cope with the "tension between speed and deliberation" ([51], p. 207) as one would not need to start from scratch each time as many steps and tools would be codified and at least constitute a reference for action, even if adjustments to the context at stake will be always needed.

Unfortunately, as recent research has demonstrated [46] there are not satisfactory models yet to guide reconstruction and to permit assessing what paths would be preferable given initial post disaster conditions in terms of damage and disruption. An important component of such a model is constituted by data and information that should feed the entire process and planning for the reconstruction of the built environment in particular. As suggested by the rather large literature on operational knowledge in the field of management that we have used and transposed in the field of disaster risk mitigation [41], the relationship between knowledge, data and information is bi-directional. Data are the bricks of knowledge, becoming information when a meaning is associated to them; however knowledge about what is key to search and for what purposes is essential as well to look for the "useful" data [2]. Such circularity is not easing the task of planners as the understanding of what constitutes the drivers and the conditions of the entire post-disaster recovery process has still to be developed. In the same vein what type of data and information is of greatest relevance and what are the best and more reliable sources is still an open question for researchers and practitioners.

In this regard, Fig. 1 can be a reference. Planners certainly need as already mentioned above data and information describing the situation before the disaster and also the type of risk assessment on which planning decisions had been taken (or that have been neglected). However, as correctly put by Atun [7], the environment after the impact has changed significantly, providing perhaps a window of opportunity for betterment, but also constraining significantly not only what can be actually restored from the pre-disaster city, but also the utility of data and maps portraying a built environment that does not exist anymore.

Damage and loss data, both in terms of tables, graphs, statistics and maps constitute therefore the essential baseline on which any planning activity must be grounded on.

In this respect data and information should permit to define:

- What has been destroyed and the level and extent of destruction, to determine if it can be repaired or need total rebuilding. In the latter case, if the pre-event ambiance is the objective of reconstruction, data, pictures, maps about the pre-event city are key for the reconstruction (see for example the “Come Facciamo” (What do we do?) website developed in l'Aquila after the 2009 earthquake to reconstruct virtually the damaged city);
- What indirect and systemic effects in multiple systems need to be addressed [4];
- What infrastructures and services have been affected and to what extent;
- And also more dynamically changing data relative to the migration of the population off and back to the damaged areas, the number and type of economic activities halted and restarting after the disaster [12].

That a post-disaster damage estimate needs to be drawn as accurate and multisectoral as possible is sometimes taken for granted [11]. However our own experience (see [43]), literature review and discussions in a number of important international fora [19,48] point at the limitations and incompleteness of available damage and loss data, that are rarely available in the quantity and quality that would be desired. Partly this happens because we lack sound damage and loss reporting; partly this is due to a lack of conceptual understanding of the links between the triggering events, first order damage, ‘higher order damage’ [55], enchained or cascading effects that are typical in complex systems.

Among recent initiatives aimed at improving the current situation and which it is possible to build on, two are of particular relevance here: the PDNA [28] and the initiative on Disaster loss data led by the European Commission.

The PDNA (Post Disaster Needs Assessment), resulting from a coordinated effort among the World Bank, the UN and the European Commission, constitutes a methodology for post-disaster damage data collection that has some important merits. First, it is multi-sectoral, in that it guides towards the collection and the analysis of data regarding the most important urban and regional systems that have been affected, ranging from agriculture to industrial, to services, to dwellings and infrastructures. Second, it is built as a process of data collection that must proceed in time, not only to capture trends and issues that are not visible or have not emerged yet in the immediate disaster aftermath, but also to provide a monitoring of the recovery process itself. Third, it acknowledges the relevance of the spatial scale in the damage data collection and analysis, suggesting how to conduct a thorough investigation when affected areas are very large, but also regarding the need to capture interdependency among sectors that are often visible only at larger spatial scales. Last but not least the PDNA indicates a reporting system in which the collected data should be analyzed so as to identify communities’ needs.

The European Commission started in 2013 a series of initiatives aimed at improving the damage and losses data collection effort in Member States with the objective of supporting a number of policies ranging from the Flood Directive to the Civil Protection Mechanism. A first report issued in 2013 [18] indicated the potential uses of such enhanced data, serving not only accounting and administrative purposes but a variety of other important objectives. Even though the support to recovery and reconstruction activities was not explicitly mentioned, the forensic investigation that is presented as one of the relevant uses constitutes a very important step towards a more resilient reconstruction. In fact, in the Report, “forensic” is intended as in the IRDR Forin initiative [9] and serves to analyse past events in order to elicit the weight and contribution of hazard, exposure, and vulnerability factors on the overall damage. Also, the forensic investigation [49] is aimed at identifying not only the relevance of those components, but also to investigate the drivers of risk, to be found in pre-event policies, strategies, legislation or lack of the latter. In order to plan a more resilient reconstruction such a forensic investigation is necessary to determine the mistakes to avoid repeating, to recognize weaknesses and fragilities that should be overcome. The relationship of enhanced data collection and management and the more sophisticated “forensic” reporting is rather clear: without data related not only to the most visible disaster impacts, but encompassing also systemic failures and repercussions across urban and regional systems at different spatial scales, it is impossible to achieve the in depth explanation of the event that such a reporting implies.

Planners however have additional specific needs when it comes to data required to inform planning and designing for reconstruction that must be taken into consideration. It is very important how knowledge and information about hazards, vulnerabilities and risks are conveyed to planners.

For example a crucial point regards the spatial scale at which data and information are represented that need to be compatible with the scale at which planners develop plans. This is a topic that has been addressed for example by the EU funded project Armonia in the VI Framework Program [23]. It has been shown how to make legends of hazard maps readable and understandable by planners; and how to match the scale at which natural phenomena are usually represented with the scale required by plans developed for different spatial levels. Planning in fact is developed at multiple scales with different objectives: at the local, where urban design and zoning is taking place; at county or provincial, where locational decisions regarding critical facilities and infrastructures are decided; at regional or even national when it comes to the strategic choices regarding development, urban specialization, high speed corridors for goods and people.

If the spatial scale is traditionally a fundamental factor in planning, the relevance of the temporal scale for what concerns in particular fast onset events, should be much better represented than it has been the case until now. Hazard and vulnerability factors are not easy to represent for planning purposes, because of the time scale aspect: while maps generally convey a rather static picture taken in a generally ordinary time or condition, what would be needed is a trustworthy representation of the dynamic processes that shape hazards and vulnerabilities overtime and may have dramatic accelerations when extreme events occur. Planners are generally not able to recognize such dynamic processes when looking at a map or at an apparently stable landscape; they are not trained to recognize the creeping or more evident signs of dynamic processes that may put at risk settlements and communities.

Here is where data coming from crisis sources, from agencies and organisations tackling the emergency when it blasts can be of great use. Such data may provide a better understanding of the complex interaction of systems, assets, organisations and communities that take place during a crisis, showing the hazard in-action, impacting dynamically a city, triggering the chain of interconnected consequences that are hard to imagine in ordinary conditions, before an event strikes.

3. New, open, volunteered data: generated during the crisis, used to support recovery and reconstruction planning decisions

3.1. The “crowd” and the “cloud”: a new configuration of crisis data management

Following Aitsi-Selmi et al. [3] available sources of data on which to ground risk assessment are improving also thanks to the rapid and continuous development of information technologies. For example, technology advances and changes in people's behaviors in the era of Web 2.0 represent a drastic transformation in crisis report and documentation. Indeed, dealing with the new uses of the internet and the ICT in general two main concepts of interest emerge: the "cloud" and the "crowd". The former delimits the shared "space" in which the new paradigm of data elaboration called "cloud computing" is facilitated [40]. The concept of "cloud" may be seen as a networking space that also permits to store data in order to share it when needed.

As for the latter term, a definition that suits here is that a "crowd" represents a large number of agents (persons) gathered in a common environment (physical or virtual) "following a common fate and exhibiting emergent collective common features" ([32], p. 3). By entangling technological, human and sociological aspects together, the combination of the two concepts of "cloud" and "crowd" point at the novelty in crisis information providing, sharing and dispatching.

It is during the Haitian earthquake of 2010 that the involvement of citizens in disaster response emerged "at an unprecedented level" as declared by Ted Turner, Chairman of the United Nations Foundation ([30], p.7).

Today these data are also produced in crisis time involving new actors:

– On the one hand, we find the affected population which "describes" the impact of an event from inside, visually, through videos and pictures, and textually. A part of the "crowd" compound of those people who decide to report the piece of reality they are experiencing during and in the immediate aftermath of the natural disaster. In texts, people report what they see and how their lives, habits, actions, the infrastructure they use and the spaces they occupy are affected during the disaster time. Pictures and videos are caught from different levels (i.e., street level to upper floors levels) and represent "unique" information from a physical point of view since they represent and are captured from residential buildings, schools, hospitals, plants. Visual and written reports are shared and exchanged via sms, tweets, Facebook status, blog posts, etc.
– The internet creates, on the other hand, the room for another group of data producers, who are not direct witnesses or victims of the event, but a new category of digital volunteers. Nowadays volunteering in disaster times can take many forms, one being the production of relevant pieces of information or applications that may help rescuers identify where unattended victims are located, to generate basic and thematic maps for georeferencing relevant information. Volunteers may include individual citizens or pertain to structured or emerging organisations. Generally also the data the latter produce are freely available and shared in the Web. Crisis mapping indeed allows the combination of "various streams of "crowdsourced" information that is verified, categorized, and visualized by volunteers using satellite imagery and open-source mapping platforms" ([10], p. 1).

If the issue of access to reliable data among the so-called "big data" present in the web is crucial to explore the opportunities that information provided by citizens may offer us, volunteered crowdmapping has to be considered a chance to face this challenge. One of the most successful experiences of crowdmapping in the last recent urban crisis is represented by Ushahidi's platform available online for customization to any typology of disaster. Ushahidi is a tool that allows users to send crisis information through sms, email, Twitter and other social networking contents. This crowdsourced information is firstly classified in predefined categories and subcategories describing the crisis and then located on maps. Ushahidi's crisis data illustrate a visual and geo-referenced way of treating information related to emergencies, threats, responder activities, news about individuals, location of resources, etc. We can consider this visualization as a dynamic spatial representation of the disaster impact through time.

Moreover, crowdmapping platforms such as Ushahidi and OpenStreetMap not only make crisis data visible and exploitable by the general public, but also provide the means for generating a historical memory of the crisis. In this way, they are not only platforms that facilitate connection between people and emergency managers immediately following the impact, but they also become an immense repository of public crisis data [44].

In order to understand the opportunities for exploitation of this type of crisis data for spatial planning to foster resilience in cities affected by natural calamities, we will first discuss the categories and characteristics of the available data and secondly how to organize them through ontologies. The use of ontologies permits the use of crisis data for a second stage, when the first emergency is over and the need to decide how to recover, where to rebuild becomes the priority.

3.2. Types of data that are generated during a disaster crisis and that can be reused for reconstruction purposes

Essentially, crisis data are a class of different categories of information including event description, impact and damage information regarding affected people, buildings, roads, facilities, services, and networks. It is originally used by crisis responders during the immediate aftermath of the disaster to support situational awareness for strategic, operational and tactical organisations [44]. Traditionally, official reports on the disaster impact and dynamics are mandated by national organisations and consist of internal-use purpose material. In the last decades, national and international organisations have increasingly adopted open access policies (Gurstein, 2011) using online platforms for publishing possibly georeferenced data (i.e., maps) and structured data in public databases. It is within this reality that new crisis data produced by the connected people are made available online through sharing functionalities across multiple media platforms [35]. They come in real-time, high volume, possibly georeferenced and timestamped.

Table 1 characterizes data related to risks and crisis that are relevant for supporting recovery and reconstruction in the aftermath of a disaster. This classification in *Traditional*, *New* and *New crowdsourced* data makes sense in the context of the configuration that has emerged with the extended and extensive use of the internet and especially of the so called web 2.0 technologies. These technologies make a major difference in the speed, interactive exchange, and analytical capacity for the organisations participating in the disaster response and recovery system [15].

The classification in Table 1 permits to underline some relevant aspects of the data that is produced today in the disaster context by official national and international organisations, by rescuers pertaining to different agencies and by citizens.

With reference to data sources three couples of characteristics are introduced. Firstly, the couple 'old' and 'new' tools refer mainly to the modality of data generation: the former refers for example to maps or statistical data generated through traditional channels of survey, while new mainly refers to the data generated through and by the internet. 'New media' as part of the new tools category specifies the use of web 2.0 services and applications that facilitate the collaboration and the sharing among users.

As for the second couple of terms it is necessary to highlight that the term private when naming the source of information, has two meanings. On the one hand, it designates the private sector as source of disaster information either during the pre-disaster phase (monitoring data) or after (e.g., commercial satellite imaging, sensor networks data, etc.). On the other hand, the term "private source" also denotes the population and the private citizens that may or may not be directly involved in the emergency.

Thirdly, one has to be aware of the fact that nowadays there is no exclusivity of one source or type of information over the others and also the traditional distinction between 'official' and 'unofficial' source is fading away. In fact, several institutions have understood the potential and the need to be in the web in order not to lose their capacity to talk to the public and have therefore increasingly and quite rapidly moved also to the newest forms of communication through the social media.

Table 1
Data characterization: a comparison between Traditional data, New data and New crowd-sourced data.

Characterization	Traditional data	New data	New crowd-sourced data
Producers	-Official national organisations	-Official national and international rescuers organisations	- Citizens
Production	Mandated	Mandated	Volunteered/Witnessed
Sources	- 'Old' tools - Private - Official	- 'New' tools - Public - Official	- New tools and new media - Public - Unofficial
Accessibility	Close	Open	Open
Volume	Limited	Limited	High-volume
Timeliness	Survey	Survey/Near real-time	Real-time/Near real-time
Localization	Not georeferenced	(possibly) Georeferenced	(possibly) Georeferenced

On the other hand, as testified by the example of Ushahidi, institutions are recurring to "external" unofficial media in order to overcome silos that their own organisations are creating and that is fundamental to eliminate in the frantic time of the crisis in order to facilitate interagency effective collaboration [58].

With reference to data accessibility, the terms 'open' and 'closed' refer to the secrecy or openness of the information. This is somehow independent from the technology as paper documents can be as open or as closed as data available through the web: the main issue is related to the transparency and the publicity of the data, if the latter can be freely accessed or not. These two words are usually associated with data producers and data keepers to distinguish between data that are governmentally managed from that provided by citizens. In the context of disasters, citizens produce data either as they witness or even are victims of the event and its consequences and/or as volunteers who offer their expertise to interpret the large amount of information that can be found in the web to support relief organisations by translating messages or producing maps.

With reference to timeliness and localization properties, we refer to positioning crisis data in time and in space. These are valuable characteristics of new crowdsourced data that are usually georeferenced and time-referenced, i.e., generated data is geo-localised, positioned in a map and associated to a timestamp [33]. Moreover information provided through new media maybe collected in real-time, following the development of the event itself, in terms of both unfolding conditions of the phenomena and the damage it provoked and of the emerging needs dispatched by victims or rescuers.

3.3. Data mining and knowledge production

The new technological configuration described till now shifted the web from being a large data and information reservoir to a platform enabling sharing and use of applications to memorize, organize and manage data online. Once recognized which are the characteristics of open access official and unofficial crisis data that are at our disposal the challenge moves to building specific knowledge bases useful for the reconstruction phase. In our approach, we propose the construction of shared ontologies which describe our specific domain as they are particularly appropriate for modelling objects, including their relationships and properties [21]. Ontologies are widely used in knowledge management activities [1] as they permit to develop shared conceptualisation of the reality among different groups of knowledge producers and consumers (in our case disaster managers and urban planners) to knowledge organization and further use. More specifically, ontologies are used for creating semantic community web portals for supporting intelligent search and retrieval algorithms in Intranet and Internet data. Ontologies as we have used them in this work consist of a 'target data structure' for crisis information gathering, extraction and integration. The development of ontology is an iterative effort that on the one hand aims at conceptualizing the knowledge that oversees the search for relevant data for recovery and on the other examines the data that is actually available in the field. The damage data obtained through the web permits to describe a situation in terms of disruption and destruction that will require efforts and design capacity in the rebuilding. On the other hand, such efforts and capacity are guided by knowledge regarding what needs to be done, how and grounding on what type of information. The ontologies are a way to combine empirical knowledge about the data that are available or can be made available and about spatial planning and recovery strategies in the aftermath of a disaster.

This is the reason why the ontologies that will be shown in the application hereafter have been developed jointly by the multidisciplinary team conducting the proposed research; in fact the functioning and the grammar of ontology is part of computer engineers' or knowledge managers' expertise while the meaning of individual elements that are part of the ontology and the relationships among them require the knowledge of risk managers on the one hand and of spatial planners on the other. We suggest that such integration of different expertise and disciplinary backgrounds is necessary to develop the kind of applications presented here in order to use data available in the web for specific purposes for which they had not been conceived originally. Also, the use of data that have been produced during the crisis and for the crisis management need to pass a reliability and usability check before they can be proposed to support longer term strategies that are closer to spatial planners' objectives.

For this purpose, we suggest that once the semantic conceptualization of the ontologies is agreed among the multidisciplinary team the criteria of data quality have to be defined. The extraction of reliable data is a time-consuming activity which is considered unaffordable during crisis due to the computational burden that does not allow for a real time answer. Clearly, this is not a major issue at 'peace time', once the crisis is over. In fact, in this post-emergency phase there is all the due time for the verification of data quality in terms of validity, accuracy and reliability. Moreover, the production of growing amount of crowdsourced crisis data [30] is essential when performing data quality assessment through sampling, triangulation and statistical classification methods.

4. The use of cloud and crowd data to support the recovery of the city of Tacloban in the Philippines after the impact of Supertyphoon Haiyan/Yolanda

In the following application using the case of Tacloban focuses on crisis data collection, classification and mining activities.

In order to provide an application of the disaster data management to support planning decisions, the case of the city of Tacloban in the Philippines was chosen. Reasons for this selection are: first there was the need to work on a recent event, for which most material was still available in the internet. This was the case of the Typhoon Haiyan that hit the Philippines in November 2013. Second, it was necessary to acquire also traditional type of maps and information, and this could be more easily done having a direct access to the administration in charge. As one of the young researchers who participated to this study is from the Philippines, she could provide such access and also use material written in Filipino, thus relying on more complete information beyond that available in English. Finally there was the need to find a large disaster that mobilizes volunteers and international organisations more than minor events.

4.1. Super Typhoon Haiyan: main figures

In the first weeks of November 2013, a major disaster struck the Asia-Pacific region in the form of a Saffir-Simpson Category 5 Typhoon, known as Super Typhoon Haiyan, locally renamed as Yolanda. It affected several countries, such as the Federated States of Micronesia (FSM), Philippines, Vietnam and China. However, the massive destruction was concentrated in the Philippines where the disaster affected 9 of the 17 administrative regions in the country. It claimed 6300 lives and caused immense damage amounting to approximately USD $2B. The City of Tacloban suffered the greatest devastation due to the inundation from the storm surge, aggravated by the forceful winds. In the city alone, 2678 people died, which accounts for 45% of the total number of fatalities in the country, and approximately 40,000 homes, representing the 88% of all households, were destroyed and damaged, leaving behind many displaced families, childless parents, and orphaned children (Table 2).

4.2. Emergent online activities

An impressive feature of this disaster as other recent ones was the increase in public participation, which resulted in the rise of freely available disaster information in the form of open data and freely available maps. Indeed, for the weeks following the event, a huge number of collaborative projects and platforms were developed by online communities of professionals and volunteers that thoroughly collected information and mapped them for emergency relief efforts. These virtual communities, centered on projects as OpenStreetMap and Ushahidi permitted the customization of the crowdmapping platforms to collect damage information and emergency requests. Moreover, online developer groups such as the Geeklist Corps of Developers recruited volunteer coders, product managers and other technical experts from around the world to develop online tools to help coordinate rescue efforts, enable crisis communication and make sure emergency supplies and food were quickly distributed to areas in need. The campaign named #Hack4Good was launched [25]. It is worth to underline that the local population largely participated in the crowdsourcing efforts confirming the assumption of Holderness (2014) that "one of the most exciting prospects for geosocial media is its ubiquity around the world, including its wide-spread adoption by the urban poor in many developing nations".

4.3. Data gathering

As a result of the emergent crowdsourced activities but also as Haiyan practically got the whole world talking, massive amounts of online related information were generated. Data collected during our study was aimed at firstly provide a practical sample of which kinds of data may be produced during crisis situations. We also collected useful 'traditional' information from the national authorities as well as gathered the open access data available in the authorities' websites.

4.4. Traditional data

The data obtained from the Tacloban City Government consist of hazard maps used in the land use plan in force at the time of the disaster; and the land use plan itself, consisting of maps in GIS, written reports, and zoning rules. The Comprehensive Land Use Plan (CLUP) of Tacloban was approved on June 18, 2013 under Resolution No. SP 229, just right before the occurrence of Haiyan. However, the proposed land use map that was prepared by the City Planning and Development Office (CPDO) was dated October 2011, while the storm surge hazard map was dated 2012. This actually suggests that even though formally both maps are included in the Comprehensive plan, the land use map could only partially embed the information included in the hazard map, as the latter was issued later. This official information cannot be considered as open data, as permission to use it was required by the local City Government.

4.5. New crisis data and new crowd-sourced data

The main data analysis technologies available today permit online information extraction, information retrieval, information filtering, data mining and decision support [34]. The literature review shows evidently that many methodologies are available specifically for the automatic and semi-automatic treatment of online and social media contents. As technology treating data in Filipino language was not readily available during the course of the study we adopted several manual methods for data gathering: (1) Keyword lookup using search engines, (2) Rich Site Summary (RSS) feeds subscription and monitoring, (3) Social media monitoring (i.e. Twitter, Facebook, etc.), (4) Forum and organization subscriptions (ALNAP, GDACS, etc.), and (5) Relevant website search (UNOCHA's Humanitarian Response, Reliefweb, Gov. PH, etc).

The overly utilized method was the search engine lookup. However, with this method, a single search yielded a minimum of a thousand to a maximum of six (6) million results. The keyword search was carried out using the most popular search engines such as Google, Bing, and Yahoo. In order to trim down the search results, specific keywords and combinations were determined and used, such as: Super, Typhoon, Haiyan, Yolanda, Tacloban, Damage, Crisis Map, Update, Rescue, etc. Nevertheless, due to the immense number of search matches, data collection is far from exhaustive, and the study may have overlooked some other useful information due to the results being displayed according to popularity rankings.

The other methods used to complement and support the data collected through the search engine lookup were the use of RSS feeds because it provided essential information without the need for visiting the actual website, and the monitoring of social media, relevant websites and forums. However, a drawback of this method is that it often displays the most current information, and if not monitored continuously, information may be missed as it is covered up by new one.

A more detailed description of the combination of methods used to obtain these data is presented in the following:

4.5.1. Search Engine with specific keywords

This process was highly used during the data collection. Some of the

Table 2
Main figures about affected households and population in Tacloban and the Philippines.
Source: NSO, NDRRMC, DSWD

DEMOGRAPHICS	TOTAL NUMBER	TACLOBAN'S HAIYAN-AFFECTED POPULATION		PH HAIYAN-AFFECTED POPULATION	
	(2010 TACLOBAN CITY CENSUS)	TOTAL	TACLOBAN % SHARE VS. CITY	TOTAL	TACLOBAN % SHARE VS. PH
Household (HH)	45,478	40,192	88%	1,174,463**	3.4%
Population	221,774	192,922*	87%	15,952,955**	1.2%

keywords (in Filipino language and in English) that were used are the following:

Haiyan Typhoon Super Typhoon Yolanda Damage Destruction Crisis Map Affected Area Affected Population Update Rescue Relief Storm Surge Flood Tacloban

These keywords were used either as a single phrase or in combination. Depending on the keyword/s used, a single search may yield millions of results or none at all. This appears to be an issue as it can be both exhaustive and exclusive. Most of the time, it is just plain overwhelming. Data is often displayed according to the source's popularity or ranking.

4.5.2. RSS Feeds from news websites

RSS stands for Rich Site Summary. It is a good way to receive updates from websites that you have configured to appear on your RSS reader. It allows getting the latest content without having to visit the sites individually. The only drawback is that it only pushes the latest content shared by the source, and old content, unless previously retrieved, may be missed.

During the Haiyan disaster aftermath, several news websites were configured for the RSS feeds such as BBC, Google News, and Philippine-based media sources. The feeds were retrieved using either the built-in reader of the web browser or through a standalone client.

4.5.3. Social Media

Dealing with social media bears some similarity to both using the search engine and RSS feeds. Depending on the social media network and platform that one is using, it may be customized as well. However, if there is high activity, certain information may be skipped or covered up by another. Twitter and Facebook were the most common social media platforms used during Haiyan. Unfortunately, these data were not readily available during the research and could be used only to a very limited extent, showing that this type of information is “perishable” and almost impossible to retrieve even a short time after the disaster.

4.5.4. Subscriptions to relevant sites

Another source of open data and information were the websites of international organisations. Some sites require membership prior to granting access and sharing the information, however such subscriptions are often free of charge. Some of the sites that were frequently accessed are Google communities, Humanitarian Response, GDACS, ALNAP, and Reliefweb.

4.5.5. Government/Organization websites

Haiyan proved to be a landmark and milestone for the emergency management communication in the Philippines. The Philippine Government updated its websites promptly and even uploaded copies of sensitive documents that one would usually need to request an access to, such as situational reports and updates. Perhaps, this was highly influenced by the commitment of the Philippines to the open data policy. A big advantage of using these sites were the validity and reliability of the published information since it is coming from a reputable source. However, discrepancies may also arise, as with the case of Haiyan. Some reports published by two different agencies may contain varying figures such as reports done by the National Disaster Risk Reduction and Management Council (NDRRMC) and the Department of Social Welfare and Development (DSWD) of the Philippines Government.

4.6. Data quality assessment

The collected data showed to have static (e.g., registered gas stations) or streaming (e.g., reports on open gas stations) nature. It represents a dynamic evolution of the assessment of the crisis providing an appropriate overview of crisis' evolution, and it includes information regarding which communities requested more aids, when and how, and subsequently which were the more resilient ones.

We collected a huge amount of diversified crisis data which came in multiple forms, including photos, videos, maps, written documents, exchange of tweets and messages in social media.

Furthermore, this collected data was usually presented in direct relationship with “context data”, namely the knowledge about the context affected by the disaster event in terms of exposure and vulnerability information and available resources to face the crisis.

Because of its nature, information collectible through the web pose challenges to both those acting in the field and to other end-users, as we are, trying to use the large amount of data generated not only for crisis management purposes but also for recovery. In this respect both categories of users need to integrate the “new” with the “old” types of data. For recovery purposes this means keeping the official zoning maps, the hazard maps of the areas that were used prior to the event to set building and development limitations.

Web based data pose also new challenges that must be met for their best use. Those include the most obvious ones, such as the need for data validation. Unreliable information and rumours have always characterized disaster related data and officers have been always overwhelmed by the amount of requests and information that was difficult to verify during crisis. Such conditions are amplified by the new media that not only target the receiver with unprecedented speed, but also provide easy means for data duplication and for multiple sources manipulation of the same data. Even in the disaster aftermath, when the pressure is not so high anymore, the need to navigate in the wide ocean of information and data produced during the event exists and requires ad-hoc treatment. We had the need to verify the consistency and the accuracy of data produced under the pressure of the event by performing double checks and triangulation of data among crowd-mapped platforms (i.e., OpenStreetMap and Ushahidi for Tacloban) and national official data.

4.7. Data classification and mining

A crucial aspect is in classifying the data according to criteria that help making sense of the large variety of data in different formats that can be found online and ‘offline’ during and right after the disaster. Among the huge amount of gathered crisis data, we identified the following categories:

- Natural hazard information: location of the storm, fire propagation, inundation zones, etc.;
- Damage information: damage to residential buildings (i.e., collapsed or unstable structures), damage to industrial plants; damage to public facilities; affected communication lines, electricity outages, water contamination, etc.;
- Restricted accessibility zones: areas that could not be accessed by rescuers because of a variety of impairments;
- Residual functioning of public services and utilities;
- Response of citizens, organisations and civil protection agencies.

Firstly, the mining activity among crisis data consisted into a conceptualization process based on the use of taxonomies and ontologies [38,57]. Ontologies as tools for knowledge representation are usually employed into a specific domain and in this case we propose to use them in the intersection of two different knowledge domains: emergency management and spatial planning.

Ontological semantics were used to conceptualize crisis data into hazard, exposure, and vulnerability ontologies, specifying each object category, eventual subcategories, attributes and relationships among them. Fig. 2 presents one of these ontologies illustrating the exposure

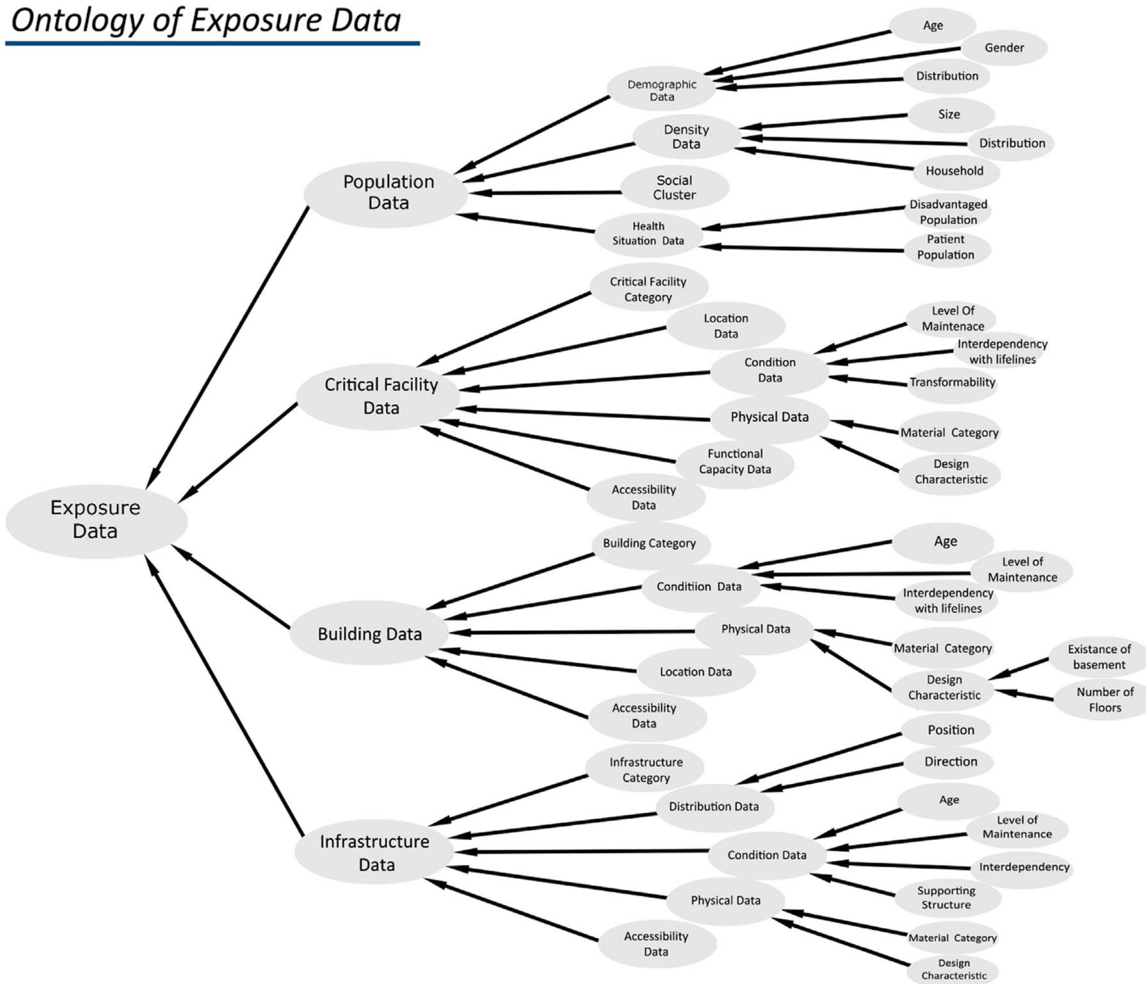

Fig. 2. Ontology of exposure data.

data conceptualization for population, critical facilities, buildings and infrastructures. This categorisation reports the classes of crisis data gathered online and offline through new, crowdsourced and traditional channels.

In order to move from crisis data availability to spatial planning data needs for reconstruction we explored the concepts represented in the crisis data ontologies in order to identify the eligible categories for spatial planning. For each developed ontology we shaped a 'coloured' version permitting to highlight in the same set of concepts those that are relevant for spatial planning (differentiating those who are highly relevant, partially and not relevant). Fig. 3 represents the example of the direct consequence data ontology depicting concepts relevant to spatial planning. A matching activity was performed to make meet concepts that are relevant for planners, regarding for example zoning, location of infrastructures and services, areas with high concentration of residents or visitors, and concepts that we found generally considered by emergency responders, such as hazards, mostly exposed areas and communities, vulnerable assets, mostly damaged zones, etc. These matching/intersection activities permitted to identify similarities and differences in the conceptualization of different types of information, including geospatial information, between the two communities of users.

Secondly, once completed the conceptualisation process of the crisis data and the identification of relevant concepts for spatial planning, a second level exploration of the data categories is performed through the use of tabulation. The Tables 3 and 4 aided us in the systematic organization of specific attributes and allowed easier regrouping of the data according to the requirements of emergency managers and spatial planners. Indeed, to produce data that are usable by planners for recovery decisions, the data were classified further detailing the characteristics of data necessary for emergency management purposes and for spatial planning as it can be seen in Table 3. In Table 4 the two classifications were overlapped to check if there were matches among them. Several matches could be identified, regarding for example population characteristics (age, social classes, level of education), population distribution and areas of high density, use of different zones and buildings.

4.8. Examples of the use of crisis data to support recovery planning in Tacloban

Even if collected, sorted and organized in a satisfactory way, data and information alone will not suffice to inform planning decisions, tables and written reports will have to be combined with maps, providing planners with the type of spatialized data they are more familiar with and which is better fit to represent assets, infrastructures, land uses and their relationship in a region. GIS technology is essential to "combine diverse types and formats of data, and to connect maps and databases, as GIS reveals trends or patterns that might not be observed if maps are manually reviewed or if geographic information is presented in a spreadsheet" ([22], p. 178).

Adopting and adapting crisis and response maps for uses other than emergency management proved to be challenging, as the latter maps are drawn to enable quick responses and decision, thus giving greater weight to well-timed responses and information dissemination over precision and accuracy. Web based maps were converted into static

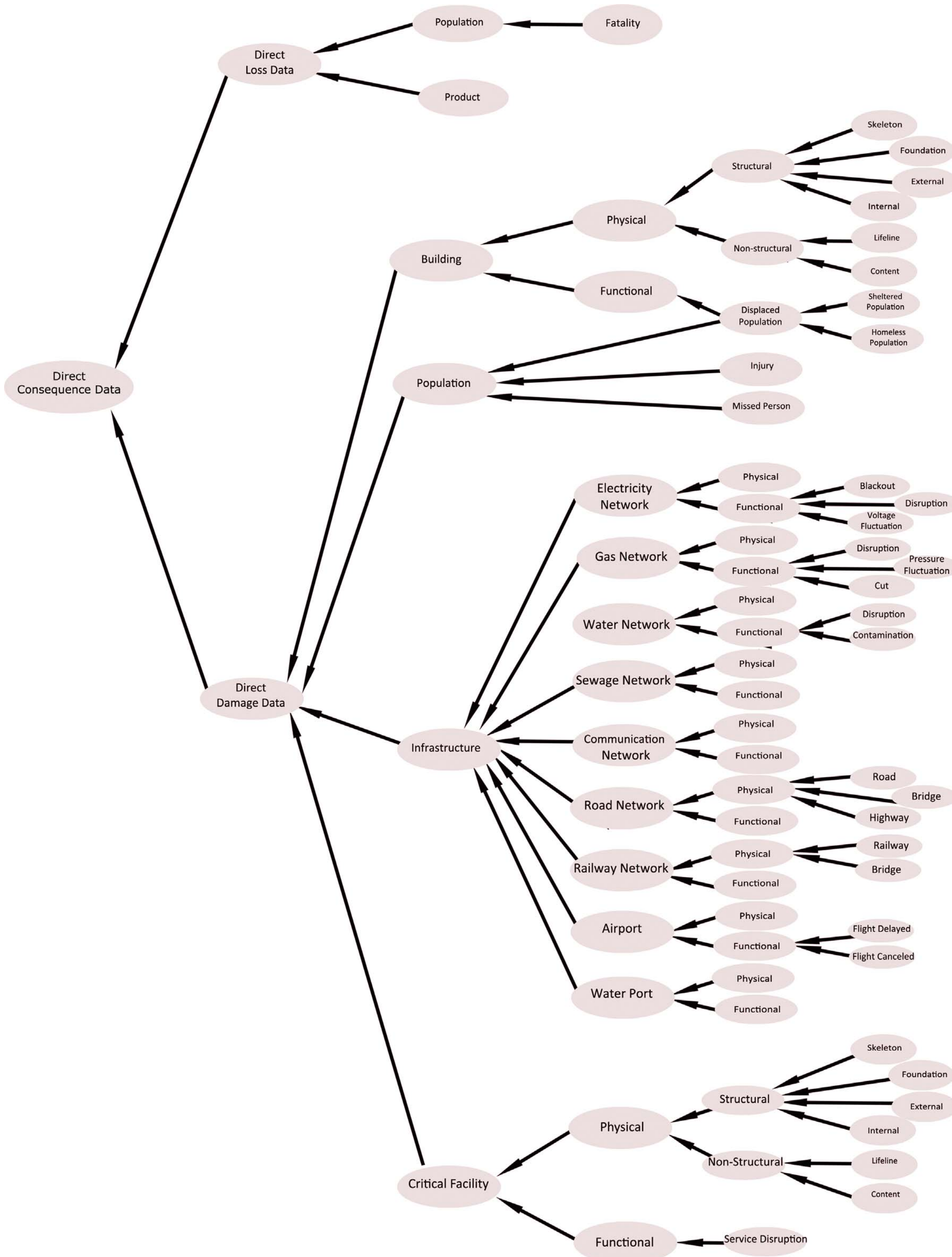

Fig. 3. Ontology representing direct consequence data depicting concepts relevant to spatial planning.

images that could be overlain one over the other to obtain thematic maps and to be matched with official maps provided by the Tacloban local government. The latter represented in particular the storm surge hazard map available at the time of the event with the indication of the maximum water depth expected in different city's locations and the land uses as defined in the urban master plan in force in 2013.

As Tacloban has a limited supply of disposable lands, it is forced to maximize its available buildable areas, and it is therefore a challenge to find a suitable place at acceptable and manageable risk. However priorities should be decided on well founded and reliable information on both hazards and risks. And here the result of our study can be of great use, as in the requirements for the disaster risk assessment to support the master plan only hazard maps, administrative boundaries, population density and properties value had been included.

There was no mention to risk assessment intended as evaluation and estimation of potential future damage. Therefore the damage map resulting from the merging of the open data produced during the disaster time can constitute a first step towards such risk maps and

Table 3
Charting the Overlapping of Emergency Management and Spatial Planning based on the EM Data Ontology.
Source: Author's own work

Disaster / Emergency Management Data Ontology				D/EM Cycle Phase Use				Plan Use	Remarks
				M/P	P	R	R		
Context Data									
1	Exposure	Population		x	x	x		x	May be useful for future planning
		Building		x	x	x		x	
		Critical Facility (CF)		x	x	x		x	CF damage and consequence required in recovery phase
		Infrastructure		x	x	x		x	May be useful for future planning
2	Resource	Human		x	x	x		x	May be useful in recovery phase and future planning
		Monetary		x	x	x		x	Necessary for resource allocation and prioritisation decisions
		Vehicles			x	x		x	May be useful in future planning (esp. considering response)
		Vital Lines			x	x		x	May be useful in recovery phase and future planning
		Shelter			x	x		x	Proper location identification during SP
		Equipment		x	x	x		x	Specific equipment considered in SP
Crisis Data									
3	Hazard	Monitoring		x	x	x	x	x	Regular monitoring including historical data is useful for SP
		Alerts			x	x			May be useful in recovery phase with secondary effects
		Incidents				x		x	Past incidents can be used as basis for future mitigation through SP
4	Consequences	Direct	Loss	x	x	x	x	x	May be used as references in M/P, P, R to cut down future losses
			Damage	x	x	x	x	x	
		Indirect	Loss	x	x		x	x	
			Damage	x	x		x	x	

Table 4
Charting the Overlapping of Planning and Emergency Management Data / Information Requirements.
Source: Adapted from the book "Rationalized Local Planning System in the Philippines"

Spatial Planning Data Requirements			D / EM Phase Use				Remarks/ Examples
			M/P	P	R	R	
Population and Social Services							
1	Population Size		x	x	x		It is necessary for estimating the needed shelter's capacity
2	Age- Sex Distribution		x	x	x		Necessary for considering special attention group during emergency planning
3	Household		x	x	x		Necessary for evacuation plans
4	Population growth /projection/doubling time		x	x			Needed for resource allocation and emergency preparations
5	Population Distribution / Urbanization		x	x	x		Predict most critical/ dense areas during crisis and planning for them during emergency plan
6	Social Clustering		x	x	x		Level of the knowledge of disaster requires different preparedness plan
7	Status of well-being of population		x	x	x		Providing facilities for poor population in evacuation plan
Economy							
1	Types			x		x	Reduce the effects of indirect damage in post disaster recovery
2	Level of Urbanization		x			x	Predict additional critical/ dense areas during crisis and planning for them during mitigation and emergency response planning
3	Structural Shift		x			x	Necessary to assess capacity to rebuild livelihood and economy
4	Linked Activities		x	x		x	Reduce systemic vulnerability in emergency plan/ prioritize recovery activities
5	Money Flow / Revenue			x		x	Necessary to assess capacity to rebuild livelihood and economy
Physical and Spatial Base							
1	Land and Land Uses Inventory		x	x	x	x	Location of critical facilities and infrastructures in Emergency planning
2	Political Boundaries		x	x	x	x	Considering boundaries for the interested area in each phase of E.M.
3	Thematic Maps						
	1	Land Classification	x	x	x	x	Use for hazard scenario development and mitigation / emergency plan and response prioritisation
	2	Slope	x	x	x	x	
	3	Elevation	x	x	x	x	
	4	Physical Constraints	x	x	x	x	
	5	Present Land Use	x	x	x	x	
	6	Road Network / Infrastructure	x	x	x	x	
	7	Protected Areas	x	x	x	x	
	8	Area coverage	x	x	x	x	
4	Map overlay analysis		x	x		x	Useful for risk estimation
Environmental and Natural Resources							
1	Natural Resource Inventory		x	x		x	Necessary for D/EM planning
2	Environmental Assessment		x	x		x	
LGU Capacity for Planning and Management							
1	Organizational Structure		x	x	x	x	Coordination and cooperation structure during response phase and planning
2	LGU Planning Relationship		x	x	x	x	Indicate responsibilities in E.M. cycle
3	Fiscal		x	x	x	x	Availability of financial resources for EM-related activities
4	Development Orientation		x	x	x	x	Necessary for D/EM planning
5	Public participation		x	x	x	x	Provide crisis information during emergency, improve disaster preparedness

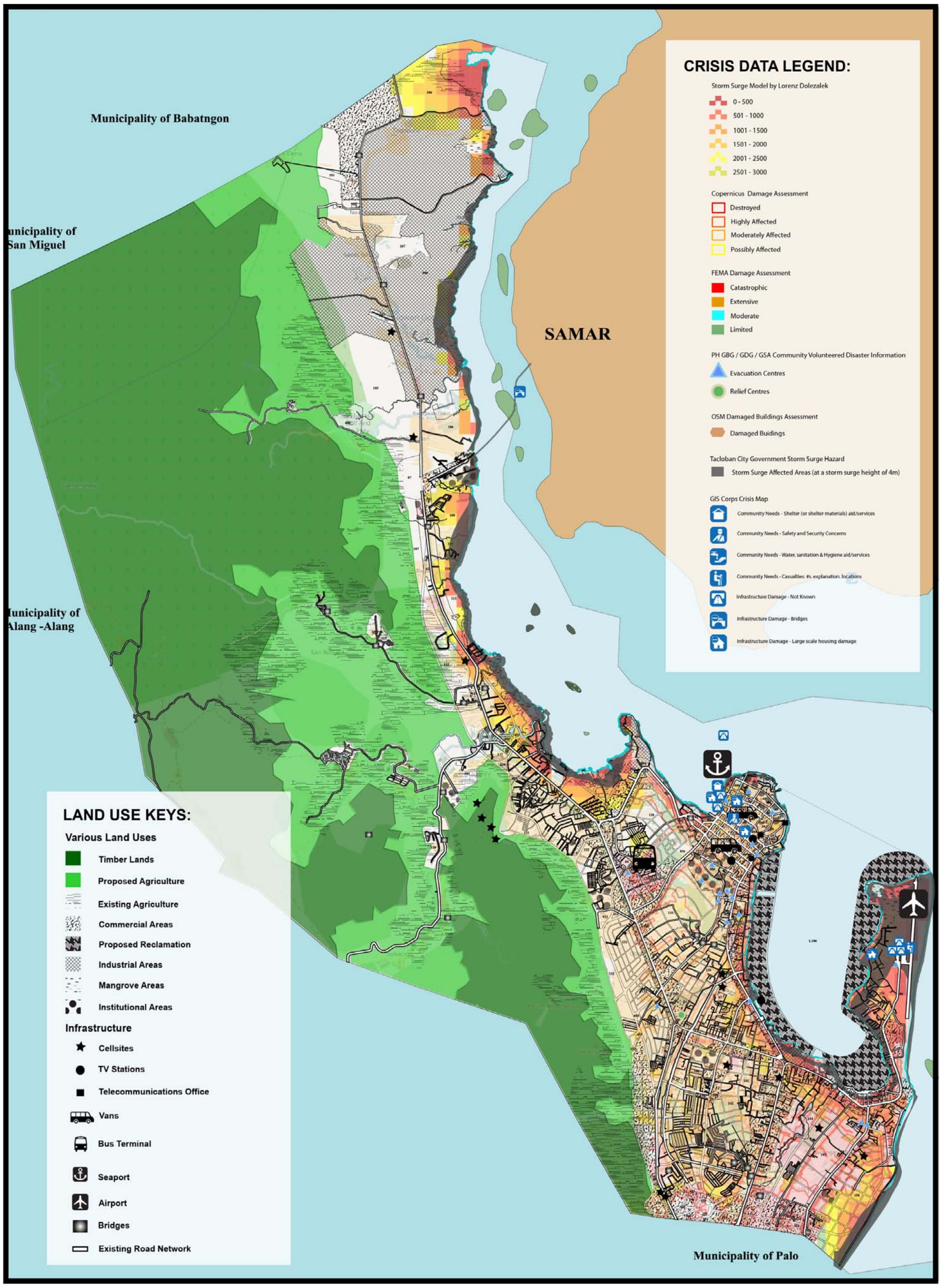

Fig. 4. Overlay of storm surge wave, land uses and web captured data.

may complement in a relevant way the information that was required by law insofar.

An example of maps that was produced to represent how the typhoon impacted the city can be seen in Fig. 4. The extent of the storm surge actually measured in different areas thanks to remote sensing and local surveys, the results of the damage assessment, and the distribution of relief resources have been overlain. In the resulting map (Fig. 3) one can see that the three parameters correlate quite well, suggesting that in fact the largest requests for help came from the most affected areas, those where the storm surge was the highest.

Due to the complex morphological context of the city, most damaged areas do not always correspond to the ones closer to the shoreline even though structural damage to structures was more severe where the waves hit first. As it can be seen, residential, commercial and industrial districts were significantly affected. However, also some critical facilities reported major damage. Both the seaport and the airport suffered huge blows, making the city inaccessible during the first emergency. It may well be worth thinking about relocating the airport on an area that is much safer or at least put surge barriers to protect both infrastructures.

This map was then confronted with the hazard map that had been produced to support the production of the urban master plan (see Fig. 5). The comparison showed quite clearly that whilst the storm surge hazard map showed a maximum height of 4 m, in Haiyan 5–7 m high surges were reported. The official hazard map fell short in predicting the “worse” or perhaps just a very severe occurrence.

Finally, the map in Fig. 4 was confronted with the land use defined in the urban plan in force and the map in Fig. 6 was produced. The latter highlights in particular the problems entailed in the forecasted new residential areas with differentiated densities and in particular in the social housing units for low income population that have been located just in some of the most affected areas.

Fig. 5. Official storm surge hazard map of Tacloban.

5. Conclusions

In this paper a method to use data generated during emergencies for responding to crises for recovery purposes has been discussed and an application has been shown in the case of the Super typhoon Haiyan/Yolanda disaster that hit particularly the Philippines in November 2013. The proposed method is rather innovative in that it uses new type of data, generated through the web to support spatial planning for reconstruction. Literature on the use of social media and data produced by digital volunteers is available, however it mostly deals with their use for the emergency phase to support crisis managers [37,8]. Here we have shown how such data can be used at a later stage, as a relevant repository of information to identify the most damaged zones, to recognize most vulnerable areas to support reconstruction decisions. In doing so, the research method that has been developed and applied was facing three distinct significant challenges. The first challenge refers to the need to dig into the recovery and reconstruction phases to get clues on how cities may recover from a disaster becoming more resilient to future threats. The second relates to the effort of collecting, sorting, and structuring massive data that are generated by multiple stakeholders and actors to support beyond crisis management also decision making in the recovery phase. The third regards how to make sensible use of such data to produce new information and maps that can be used by spatial planners in the reconstruction process. Those challenges are clearly entangled in the problem at stake, that is how to feed recovery with more accurate and useful damage estimates, but they also represent significant challenges per se, in the distinct domains of disaster studies, information technology, mapping and GIS tools to support planning.

The application of this method to the City of Tacloban matches perfectly the three challenges that have been just described. The extent of the devastation makes this event more like a catastrophe than a "disaster" ([50]; Quarantelli, 1999; [14]): recovery and reconstruction will require a huge effort, financial but also in terms of information and knowledge supply. Maps that have been produced as a visualization of data and information collected from different sources are useful to

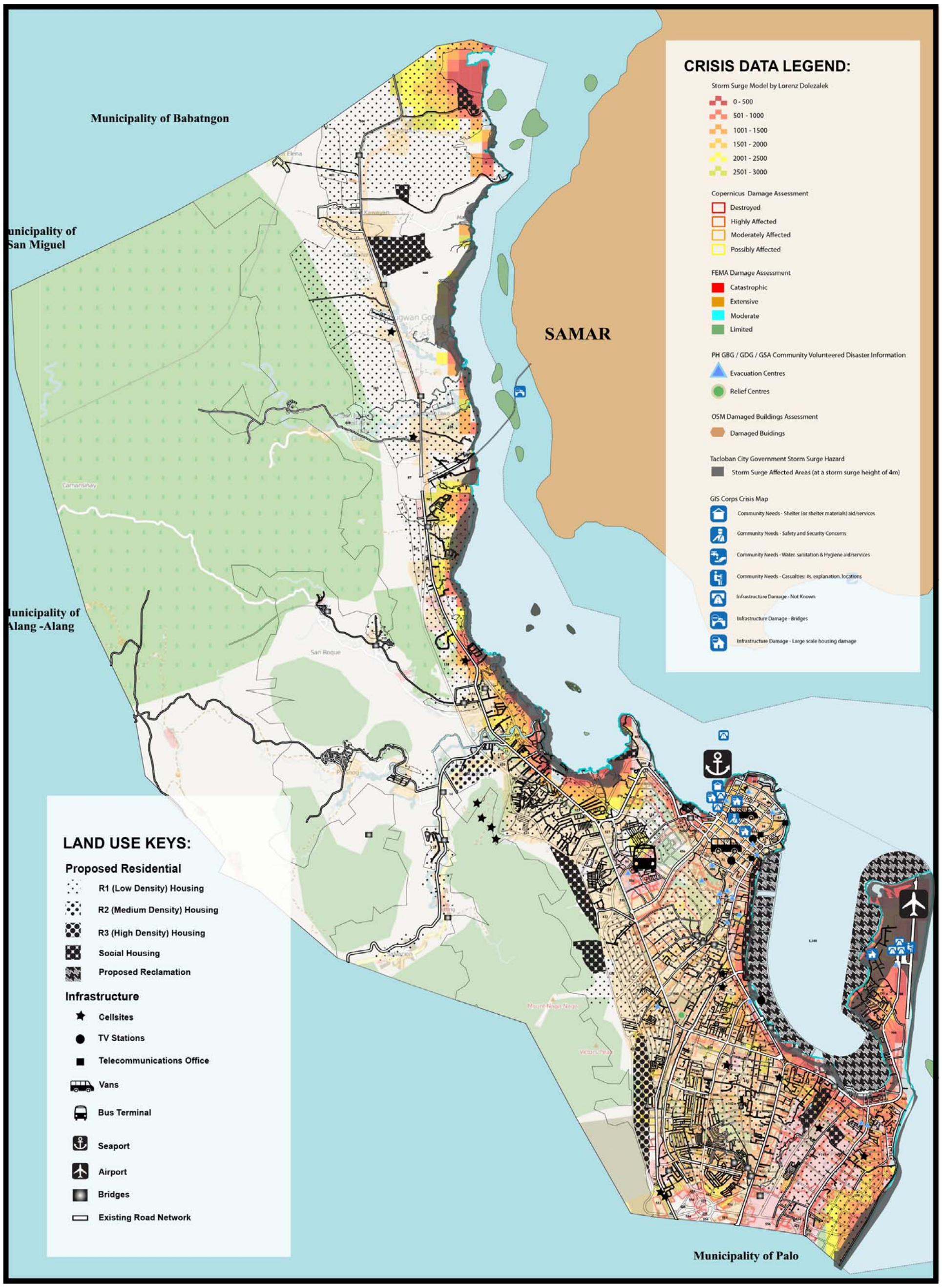

Fig. 6. Overlay of storm surge, web captured data and residential uses as forecasted in the Tacloban master plan.

show the damage, not just as dots on a drawing, but in reference to vulnerability and exposure parameters, such as the population density in each sector of the city of Tacloban, and to hazard, by showing the extent of the surge in comparison to what had been estimated before the event in official risk assessments. Such maps can be provided rather quickly and are particularly valuable in that they may be compared to the pre-event situation, either with maps available to public authorities or reconstructing such situation using pre-event satellite or other types of available images. Such maps take advantage also of the widespread volunteer participation after disasters, that is not anymore provided only in terms of money and means donations, but also in terms of time spent to digitalize maps and provide information that can be useful to manage the emergency.

If extended to other future cases, the type of procedures and products that have been shown in this paper may help provide much better and more systematic post-disaster data that is a major concern today.

Another important advantage is the possibility to feed the reconstruction process with data that is deriving not only from "official" sources but also generated collectively through a really participatory approach, thus augmenting the trust of some stakeholders that should be involved in the recovery and reconstruction decisions. "Practice shows that the added value of Geo-Ict lies in the opportunities it provides for integration, visualization, and communication of knowledge and information about spatial processes and patterns" [60].

In a still to be developed future, the geo-collaboration on which some researchers and practitioners are working for emergency purposes [52], could be proposed also to facilitate different stakeholders' participation to reconstruction decisions, providing a web based support to work together on a geospatial problem, share and maintain crucial information. Not only to store maps and data such as those that have been produced for the case of Tacloban, but also to monitor the development of recovery and reconstruction, so as to account for the changing conditions in the ground and tailor accordingly planning and implementation decisions.

This is perhaps possible in principle given the available technologies, however a strong effort must be still invested in designing the most suitable ways to capture relevant information in the web, in assessing its reliability, and in making the different stakeholders more aware about both the advantages and the limitation of resulting information and maps. Just as the Philippines government has successfully partnered with social media networks in the response emergency phase, it may also do so during the recovery. Available collaborative tools may be used as long as crisis data and information may be retrieved and perhaps also to continue collaboration to sustain more participatory recovery processes. In this regard, matching crisis data and mapping it in sensible ways, it is possible to align development goals, reconstruction and safety to ensure to "build back better" [36].

Acknowledgment

The research that is reported in the article has been developed within the Know-4-drr (Enabling knowledge for disaster risk reduction in integration to climate change adaptation) – C.N. 603807) project funded by the European Commission under the VII Framework Programme and the Idea project (Improving Damage assessments to Enhance cost-benefit Analyses) EU prevention and preparedness project in civil protection and marine pollution funded by DG-ECHO, G.A.N. ECHO/SUB/2014/694469).

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