Comprehensive Flood Risk Management – Klijn & Schweckendiek (eds)
 ISBN 978-0-415-62144-1

Review of the current risk management strategies in Europe for hydro-meteorological hazards at protection and emergency level

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ABSTRACT: A review of the current emergency response strategies at European level was carried out from the key conclusions and recommendations identified within past experiences of developed platform for civil protection and emergency management. The review is focused on the recent research initiatives funded by the European Community about methods and techniques for emergency response in case of flooding and debris flow risks, mainly. The ultimate aim is to reduce the fragmentation of the research on hydro-meteorological hazards so to possibly identify a best practice on disaster risk management. This paper is organized as follows, first a brief overview on emergency response strategies is presented along with an analysis of the challenges that arisen while implementing the following tools: geo-information and remote sensing, emergency plans, early warning and decision support systems. Then, conclusions have been drawn.

1 INTRODUCTION

Typically, emergency management is coordinated by one or more local authorities with the first aim of safeguarding people and assets exposed to particular threatens derived by natural or human-caused disasters (referred as civil protection activities, hereafter). In the places at risk of hazards, emergency strategies are managed as protocols in contingency or emergency plans, which are often compulsory by law and with different set-up for each country's policy. However, the significant increase in the number, scope and complexity of disasters suggests that the role and interaction between institutions, communities and individuals was not sufficiently taken into account in state regulations (Piatyszek & Karagiannis 2012; Alexander 2005). In response, new legislation is devoting great attention on the process of modernization of civil protection approach for emergency preparedness and response with direct involvement of the interested parties. Some examples at the Western European level are in Germany the Committee for Disaster Reduction (DKKV 2007), in Italy the decentralization of Civil Protection (Decree 112/1998) and the National Early Warning System (DPCM 27/02/2004), in The Netherlands "Room for the River programme" and in United Kingdom (UK) the Civil Contingencies Act of 2004 (UK Cabinet Office 2004). This occurs under the UN Hyogo Framework (UN 2005) and the European Directive 2007/60/EC.

At the European level, the tasks and responsibilities of the institutions or agencies involved vary according to the decentralization of disaster risk reduction functions. Nevertheless, the fundamental modes of action outlined for emergency management comprise the following steps according to Frigerio et al. (subm): i) preventing risks and damages to people, properties and infrastructure; ii) increasing the degree of preparedness of people; iii) improving techniques and methods of response to emergency; iv) enhancing public information, education and awareness; and v) granting the recovery phase.

This paper focuses on the last decade European initiatives that aim at improving the emergency response methods and techniques, in doing this accounting their applicability for different spatial and temporal scales of the whole emergency cycle has taking into account. Although there are many scientific projects funded by the European Union on early warning and risk reduction strategies for hydro-meteorological hazards, such as FloodSite, HYDRATE, MOUNTAIN RISKS, Monitor II, CapHaz-Net, among others, here special attention is devoted to hazard due to floods and related processes such as debris flows.

The starting point for this review was a common platform which was designed and applied at basin-local level in the Consortium of Mountain Municipalities of Valtellina di Tirano, (Lombardia region, Italy) that soon will be transferred to the

Barcelonnette Basin, in the Ubaye valley (French South Alps). The platform has been developed by the CNR—IDPA, CNRS and University of Strasbourg, and the ONF-RTM Service of Barcelonnette, jointly; the final users of this platform are mainly targeted to local professional organizations (who form disaster management teams). The emergency operations were designed on already prepared scenarios with tools for outlining, analyzing and integrating in advance the derived scenarios of hydro-meteorological hazards and the information from the available resources and structures for emergencies.

The system relies on the sequence of actions as defined from the laws in force, which are collected in a relational database system that uses mapping tools, object oriented interactions and communication system to share information and to control the flow of actions, object relations and contact management of people operating in the field (Sterlacchini et al. 2011). With that experience as a reference, this paper presents first a brief overview on emergency management, then presents the research agenda that was put forward on the tools considered for the reviewed response strategies, with references to some implemented examples for floods and debris flows risks.

2 EMERGENCY MANAGEMENT

The term "emergency management" means the coordinated activities both to prevent disaster happening and to face them when the event takes place (Zerger & Smith 2003), understanding disaster as a "serious disruption on the functioning of a community causing widespread losses and impacts which exceed the ability of the affected community to cope by using its own resources" (UNISDR 2009). Consequently, emergency is "an exceptional event that exceeds the capacity of normal resources and organization to cope with it" (Alexander 2002), whose authorities generally manage by preventive measures implemented according to the event management phase: first planning, throughout the assessment of relevant hazards and vulnerabilities, considering their dynamics and variability; then with mitigation activities that aim to reduce the effects of unavoidable disasters. Preparedness, where possible event scenarios and plans are developed, enhances disaster response operations and public awareness; response activities controls, provides assistance and keeps update the development of the event scenario. Finally, recovery phase comprises both short term activities that aim to recover the minimum operating standards and long term activities (reconstruction) to return or improve the living conditions. All together form a cycle that starts every time the analysis of the emergency cause takes place. (Leitinger 2004).

2.1 *System of sub-systems*

Basically, the emergency management is prescribed on a system that brings together various components from the cycle described before into a modular interaction that depicts how societies respond to disasters. (Cutter 2003). Indeed, the emergency systems can also integrate the early warning concept, understood as "the provision of timely and effective information, through identified institutions that allow individuals exposed to hazard to take action to avoid or reduce their risk and prepare for effective response" (UNISDR 2009). This case is commonly known under the conception of Early Warning Systems (EWS). However, the modules integrated and activities carried out rely on the level of involvement of the regional and local authorities, which responsibilities and interactions are legally framed and vary from country to country at the European level (Gaetani et al. 2008). Table 1 presents an overview of the overall modules.

Table 1. System of sub-systems for emergency management.

Sub-system	Activities involved
Monitoring and forecasting: (Survei—llance loop)	Monitoring activities based on availability and mechanisms for real-time acquisition, transmission and validation of data. Use of technical predictions of threats and triggering factors as well as the time of occurrence. Using information to decide about the need of warning.
Prevention	Generally risk scenario-based for the assessment of potential consequences, including consideration of the vulnerable elements most likely to be affected.
Emergency response	Knowledge, resources and preparedness to act.
Communication	Dissemination of clear and understandable warnings using multiple communication channels to reach those at risk. Although communication role is implicit for the coordinated interaction between all sub-systems.

Based on Piatyszek & Karagiannis 2012; Alexander 2002.

In civil protection systems three different levels of decision tasks are identified as detection, evaluation and execution that generally correspond to the monitoring and forecasting, prevention, and emergency response sub-systems, respectively (Mueller et al. 2007). Moreover, Creutin et al. (2009) distinct the type of response activities according to their main objective (information, organization and protection) and the type of actors involved (individuals, communities and institutions), which combination characterize the response activities. Commonly, in operational forecasting systems the decision to warn authorities is taken by the forecasters using the gui-dance from the operational forecasting subsystem (i.e. before a critical level of some quantity needed for a process to take place is exceeded), (Verkade & Werner 2011). Whereas prevention and response are managed by civil protection authorities on alarm-based for on-going processes of events (Halonen et al. 2006). The independent distribution of roles has made the emergency management components continuously presented as isolated sub-systems in a linear systematic function in which interrelationships between them require further consideration as proposed by Garcia & Fearnley (2012).

2.2 *Operational staff of the emergency management*

Civil protection organizations work collaboratively in emergency scenarios, where local and central coordination of teams belongs to different organizations such as government agencies, local administrations, non-governmental and volunteer forces. Despite the variety of actors, there are generally two typologies of users: back-end and front-end users. Front-end users are all the operators acting directly on the field during emergencies. Back-end users are all the operators who manage the situation from control rooms, by providing goals/ instructions/information to front-end operators (de Leoni et al. 2007).

In this context, disasters due to hydro-meteorological hazards not only occur when the hazard forecasted or not does not allow to take preventive measures. Or when people as individuals have limited ability and/or behavior to prepare for and to respond to an emergency, as described by Molinari & Handmer (2011). But also when communication between response agencies fails or lacks of coordination (De Marchi et al. 2007). Then, the initial responders or coordinators are unable to communicate with their control rooms and usually mobile, radio and internet communications might not operate at the incident location (Comfort & Kapucu 2006). This highlights that operations of the emergency management are not just about warning people as individuals but also about providing information for agencies and institutions starting at early stages on a precautionary basis. Therefore, coordinators can activate emergency protocols in advance; initiating from the monitoring and forecasting subsystem and not only reacting by mobilizing the necessary resources later in the event (DEFRA 2009).

Finally, it is widely recognized the importance of community-based knowledge and the need for their involvement specially when managing localized hazards with limited response times. This approach is commonly used for the implementation of People-Centered Early Warning Systems as described by Garcia (2011). Indeed, considering that communities are the direct affected, community-based organizations are the first on respond and local management leads to securing local support and ownership. However, while acknowledging its importance, the involvement of more stakeholders will not automatically translate into a more efficient system (DEFRA 2009); the roles, needs and values of the involved must be clearly defined (Garcia & Ferney 2012). This is still an open research field where different participation efforts need to be done at different disaster risk management stages, even on the recovery phase (Scolobig et al. 2008).

3 RESPONSE MANAGEMENT STRATEGIES

A proactive emergency response requires the rapid search, exchange and absorption of valid information regarding sudden and damaging events as transmitted throughout a network of actors for civil protection (Comfort & Kapucu 2006). This flow of information relies on early warning strategies and emergency plans with permanent good communication among risk actors. The former one is aimed at early stage preventive actions, such as early warning messages or early water system controls, to reduce vulnerability and/or consequences, respectively. The second (latter) one is typically aimed at the short term coordination between different levels of actors. In any case, their role and feasibility within the whole emergency cycle are strongly linked with planning and preparedness phases, as long as their integration facilitate a quick response to potential emergencies. In the European context the following tools outline the strategies for emergency response.

3.1 *Geo-information and remote sensing*

Due to the increasing access of information from natural hazards such as literature, maps, remote sensing technologies and data implementation from the field; it is a priority the use of standardized relational database structures to support decision-making processes. National and regional initiatives on spatial data infrastructure SDIs have most often been initiated at central or federal government levels. These decentralized efforts have raised the need of their interoperability and standardization which have been the focus of several initiatives at supranational level, among which the European INSPIRE directive, and the Open Geospatial Consortium. As example, Giardino et al. (2012) proposes a multi-scale method to provide this required support. The method starts by correlating the rules and procedures to store, manage and exchange all relevant information derived from the features included in the database at the specific level of implementation (local, regional, national and global). The methodology also considers the use of digital pictures and maps from different sources (i.e. remote sensing) with dedicated forms for data collection and representation possible to display on a palm/pocket PC as a field mapping tool.

Another reference, is WORKPAD project (Catarci et al. 2010; Humayoun et al. 2009) that developed a two-level architecture (back-end users and front-end users) applying an user-centered software development process. The method accounts a continuous interaction with end-users through questionnaires and interviews, where each evaluation step enabled an improvement of the prototype from online pre-tests, controlled experiments, cooperative evaluation, text with external users and showcases. The overall process was applied on the context of Regional Civil Protection of Calabria (Italy) up to the generalization of the user requirements that comprise:

i. Information Communication Media Technology support for back and front-end teams: automation and interoperability in exchange of data and information among possible back-end information systems.
ii. Reliable communications: need for redundancy in strategies and transference media.
iii. Smart hand-held devices for front-end teams. not distractive smart devices to front-end operators, working also in disconnected mode with options to synchronize with the back-end teams at the time required.
iv. Access and collection of geo-information about the affected area: alternative data models are based on landmarks combined with selected context needed for the specific use case.

Finally, the use of geo-information alternative to the official one is also a source of data, as the one collected by the crowed-sourcing information systems developed in the last decade (Google maps, OpenStreetMap, Wikimapia, Ushahidi and web 2.0). Every human is a potential intelligent sensor if is simply equipped with a GPS or even by having the means of taking or report observations (Goodchild 2007). Challenges are posed on the need to integrate this new flow of information, known as Volunteer Geographic Information (VGI), into the SDI to validate and standardize procedures, to make use of this "new data" and to consider them as complementary source of information for scientific knowledge.

3.2 *Emergency Plans (EP)*

The development of EP is an integral part of the emergency management effort. It defines the roles and responsibilities of the organizations and individuals based on the available resources for each activity. Generally they should cover all potential hazards but some plans are more hazard specific (Alexander 2005). According to Miki (2011), emergency guidelines develop under categories, such as collection and communication of information, support for people who need assistance and improved awareness of disaster prevention. Piatyszek & Karagiannis (2012) and Karagiannis et al. (2010) proposed a system based approach for the systematic and industrial analysis of EPs. This by looking at each task based on the input and produced outputs, controls, mechanisms and actors. Steps forward look at the consideration of time in the sequence of operations and the quantification of the analysis outputs.

Evacuation and rescue can be important in the context of all hydro-meteorological hazards, the general problem is the limited time to complete them. Therefore as Mens et al. (2008) suggests, an important issue for both evacuation and rescue actions is the availability of the transport in which traffic management forms an important part of the decision support especially for planning mass evacuation in urban areas. Additionally, protection may be based on confinement in buildings, departure from the zones at risk or a combination of the two. The plan of action and consequently the decision support differs from the available time and type of hazard. For lowland river floods the problems involve the operation of water controls and the evacuation of people from areas at risk, whilst in sloping areas focus is on the regular monitoring of hazard locations and on forecast which parts of the road network would become affected.

In this regard, FloodSite project compared different models that could be generally classified in traffic models, evacuation behavior models and time/critical path, whose advantages vary according to the scale of application (van der Vat et al. 2007). Another example is the European project

THESEUS in which the design of an evacuation plan process was based on semi-formal language and its diagrams, known as actigrams. These methods consider the design parameters based on the constraints and levels of action according to their control by crisis managers and the action plans based on the methodology defined in OSIRIS project (Morel et al. 2011).

3.3 *Early warning systems*

Prevention activities can comprise either structural or non-structural actions. Actions which aim is to reduce the event occurrence probability or decrease its impact. On the other side, non-structural actions such as EWS are considered to gain time on the response phase by including detection, forecasting and warning to mitigate event consequences.

In this case the maximum potential warning time starts when a trigger is detected/forecasted, the lead time accounts from the moment the threat is recognized and mitigation time is considered while actions are taken to mitigate the event damage (properties damage, injuries occurred or lives lost) (Carsell et al. 2004). At the level of operational forecasting, Werner et al. (2005) make a difference between warnings with target to the public and the warnings target to the operational staff of the established sub—system, known as "pre-warnings". Distinction that is still valid for the emergency response sub-system.

However, if only considering the uncertainty involved in the pre-warning decision, the uncertainty involved may lead to the following instances: false warning, missed event, forecasting event and a situation of calm. In this context, scientific research has tried to estimate and communicate uncertainties involved in the forecasting, as categorized by Todini (2004) in three: i) measurement uncertainty, mainly regarding the sparseness or lack of measurements stations and the need to interpolate these measures; ii) meteorological forecasting uncertainty, which relates to the possibility of extending the forecasting horizon beyond the response time and iii) model uncertainty, which relates to the nature and the reliability of the different models used to transform the measurements into forecasts.

On the other hand, in order to understand better EWS efforts are also focused on expressing their benefits as compared to the cost—benefit analysis that structural measures could provide (Verkade & Werner 2011). Challenges are posed for the estimation of damage and the characterization of the elements at risk. This due to the limited tools and standarised procedures for data collection and assessment; as well as the different components of the vulnerability involved, at least physical, social, institutional and economical (Molinari 2011).

At the European level, the European Flood Alert System (EFAS) is an initiative that operates in the Danube river since 2005 and proposed a way for a correct interpretation of the forecasted situation by users from different hydrological operational forecasting centers and forecasters. EFAS flood forecasts are based on two deterministic weather forecasts and one ensemble prediction system. Pre-warnings are issued to forecasters 3–10 days in advance, so they can analyze different scenarios for location and severity of a flood event before deciding on issuing warnings. Sequential and simplified temporal diagrams are combined with visualization in a box-counting approach with the history of forecasted threshold exceedance. This approach was found as major step forward to evaluate the persistence of the forecasted signal, meanwhile it also improves the understanding and overview of the situation (Ramos & Thielen 2007).

Finally, as an attempt to look at the overall early warning system and not only at the quality of its individual components (Basher 2006), community-based early warning systems are taking increasing relevance. Particularly in Western Europe, more attention is now on questions related to risk assessment and emergency planning by including social aspects like people awareness, community engagement, knowledge sharing, communication and trust. This strategy is broadly used in developing countries due to the opportunities to overcome the technical constraints of the surveillance loop while enhance mechanisms for self-warning and voluntary evacuation (Garcia et al. 2011).

3.4 *Decision Support Systems (DSS)*

Decision support systems are widely recognized as a computer-based system developed to support users on decision-making process. So far a DSS implies both functionalities of Information Systems and of Management Systems. Due to the wide number and diversity of risk communication practices as the ones inventoried by (Höppner et al. 2010) within CapHazNet project. Information systems are generally used for risk communication on assessment of risks, preparation and implementation of hazard maps, warning dissemination, as well as communication practices for several purposes and functions such as: risk awareness, preparedness activities and exchange knowledge. Whereas management systems are more specific application, target to decision-makers or authorities responsible for management and they also provide aim of solving tasks.

In the emergency situations at the institutional level context, the decision refers to the problem that civil protection authorities phases at coordinating activities in case of the occurrence of hydrometerological hazards. The system aspect implies the information and applications of knowledge, in the form of models, that need to be consider from the different sub-systems for risk and emergency management. And support implies the use of computer and software technologies to present on well-structured way the information required by emergency managers.

Therefore, one or many of the tools discussed in the previous sections can be supported by a DSS. In case of hydro-meteorological hazards they are typically customized to suit the human context and the hazard requirements. However, the need for open-model approach, user-center design and generalization of requirements is better recognized on the search for flexibility and adaptability of the system (Werner et al. 2006). Challenges for implementation are posed in rapid onset hazards and considerations for multiple interaction of hazards.

For emergency management, a common practice is the implementation centered on the monitoring and forecasting sub-system due to the very technical and specialized models involved. This in order to provide support to the decision about the actions that can be taken before an emergency. According to van der Vat (2007), the main challenges remain on the definition of risk and consequently the decision style which slightly differs from the common approach for risk management on a planning phase. This considering that, due to the high probability of the event, risk is defined in terms of its consequences for different event scenarios. Therefore, event management not only relies in spatial multicriteria analysis but also on the sequential activities at different emergency level, leading to many options according to the available time.

The variety of DSS in operation or proposed in the literature is large and the structure of the system in adjacent regions or countries may be very different. This paper highlights some examples throughout their particular approach for floods and debris flows as described in the next sections.

4 HYDROMETEOROLOGICAL HAZARDS

In principle, emergency management implies an approach that addresses all relevant hazards in an integrated fashion, and not as separate unconnected systems (Basher 2006). However, the management of a crisis begins with its recognition, which typically involves technical monitoring for specific triggers that are likely to precipitate a disaster (Bacon et al. 2007). Therefore, the capacity for crisis identification relies not only on the physical processes and contexts in which it occurs but also on the monitoring, instrumentation, data collection, and data processing (Gladwin et al. 2007), whose improvements from advances in theories and models to predict, detect and forecasting vary for different hydro-meteorological hazards.

In this context, such a 'multi-hazard' or 'all-hazard' approach is intended to be applied first at the level of centralized data gathering and processing, with as well as in public risk awareness and disaster preparedness efforts. Despite this approach, the practical implementations that facilitate sharing and exchange of data are generally constrained by the ways in which "local agencies and services operate and show how they diminish the overall capacity of a specific system to deal effectively with disasters and emergencies" (De Marchi & Scolobig 2011). Example of this institutional and politically supported cooperation is the joint project to launch the so-called Common Information Platform for Natural Hazards GIN ("Gemeinsame Informationsplattform Naturgefahren''). The platform is restricted to federal, cantonal or municipal intervention forces who are differentially familiar with GIS and web services. GIN is looking towards standardized warnings and the provision of joint bulletins in critical multi-causal events. Currently data are delivered by the three official warning centres with positive end-user's feedback on the visualisation of relevant data in real time (monitor parameters and bulletins), (Heil et al. 2010).

However this 'common language' for 'all-hazards' is not only applied to dissemination of warnings but also to the documentation of disasters in the response and recovery phase, which timely exchange between several authorities could potentially improve the emergency management (i.e. cross agency portals). Such initiatives comprise the systematic collection of field data, review of existing catalogues of historical landslide and flood events as additional inputs for the risk analysis (Hübl et al. 2006). In Europe, due to the threaten of multiple hydro meteorological hazards, these practices are highlighted throughout coastal zones, mountainous regions, and volcano vicinities within projects such as the PREVIEW Global Risk Data Platform (Giuliani & Peduzzi 2011), and at national level the SICI Project (Guzzetti & Tonelli 2004) and the Swiss flood and landslide damage database (Hilker et al. 2009).

Despite the hazard approach, each hydrometeorological hazard exhibits different characteristics such as time of onset, duration, extent and the resulting impact on humans and elements at risk. This constitutes essential information to set priorities for emergency management. Additionally, relevant distinction is made in between stepwise-onset hazards and sudden-onset hazards as lead time is a crucial point on this regard (Monitor II 2010). The first one allows longer forwarning times in the hazard management cycle, whereas on the second on extreme meteorological conditions can trigger rapid-onset processes evolving even in a multi-hazard scenario (Kappes et al. 2012). Here only focused on floods and debris the following initiatives are highlighted.

4.1 *Floods*

According to Todini (2004), flood emergency management on large rivers has been traditionally approached as follows: assessing the location and the extent of flood prone areas for given return periods; defining alert threshold levels; measuring levels at given upstream locations; estimating downstream levels either via correlation or via hydraulic models; issuing warnings at the downstream locations whenever the estimated values overtop the threshold levels. Unfortunately, when dealing with smaller rivers, especially subjected to 'flash floods', forecasts are issued based on rainfall predictions and rainfall-runoff models rather than the models generally used on large rivers, such as hydraulic models or alternative options like data driven models (Borga et al. 2008). In the context of flood forecasting/warning, rainfall thresholds have been generally used as strategy for detection of threats. However, the criteria for determining threshold runoff estimates vary from one basin authority to another. Challenges remain on better estimate the triggering factors and accounting the change on initial state conditions at the onset of a storm event. These conditions tend to increase the number of false alarms specially for short term predictions (Werner et al. 2006).

In Germany for example there are mainly three integrated flood management systems developed within the EU-INTERREG IIIB projects (Gretzschel et al. 2010). FLIWAS (FLood Information & Warning System) applied on the Rhine River watershed is one of the operative systems with implementations in The Netherlands, Ireland and ongoing process in Romania. The system is a web-based system comprised on different independently usable modules that integrate technical, mapping, organizational and communication tools targeted to managers, coordinators and operational employees. They provide support under initialization, training, preparedness and operational modes of the emergency cycle to facilitate the information exchange during flood and threatened flooding. Decisions are taken about protection and inspection of hydraulic structures at the operational level, based on a database management system with pre-calculated scenarios of flood (De Gooijer & Reuter 2009). Another, operating system under development for several decades and with more target to forecasting centers is Delft-FEWS, which runs at the European level in The Netherlands, Switzerland, Scotland, England and Wales. It includes modules to support emergency management for flood and environmental purposes and its structure allows to manage internal and external modeling results from different modeling packages (Weerts et al. 2010).

4.2 *Debris flows*

Debris flows are a severe natural hazard in mountainous regions due to their high velocity, large volumes and long run-out distances that generally show flow behaviors intermediate between sediment-transporting floods and landslides. In case of debris flow management, the principal uncertainties that affect such system are: first the exact spatial distribution of rainfall at different elevations. Secondly, the uncertainty related to geomorphology of the debris-flow systems. Those that require channel recharge to produce flows at the crossing of hydroclimatic thresholds and those with abundant sediment that will always trigger a debris flow when a hydroclimatic threshold is exceeded (Jakob 1996). Consequently emergency response for these kind of events are based on real time-monitoring data and warning systems; with the sufficient level of warnings to activate watching protocols even when events are considered unlikely to occur (Jakob et al. 2011). In Europe, because of the limited availability of real-time monitoring of debris flows and the very short time span after the detection of the event and its propagation downstream. Such systems often combine rainfall forecasts and real-time measurements of precipitation within the basin over a variety of time scales (Bordoux et al. 2008, Baccini & Zannoni 2003). This in order to exemplify antecedent moisture conditions and rainfall intensity as compared to empirical regional thresholds for debris flow triggering. However, such approaches are heavily affected by the quality of rainfall prediction and the reliability of threshold curves (Comiti et al. 2010).

IFKIS-Hydro is an implemented example of information and warning system for floods and debris flows in medium-small basins, which is a pilot DSS based on significant experience and infrastructure of the Swiss avalanche warning system IFKIS. The system's structure comprises three pillars incorporated on a Java-based information platform such as: (1) monitoring of changes in the catchment on a period-based (at least once a year) and after each event; (2) real-time information from weather forecasts, discharge predictions, measurement data and local observations (quantitative and qualitative); (3) collection and documentation of former events, stored nowhere else for future use. The standardized information and visualization processes also support the long-term use of the system for monitoring purposes and data storage. Additionally to the platform, the DSS includes available meteorological forecast information, real-time data from the existing and operational gauge network, a rainfall-runoff simulation models and event-related information from people working in the field for later interpretation (i.e. slopes instabilities, debris flow activity, floating wood or bed load) (Romang et al. 2010).

5 CONCLUSIONS

There are several EU projects that have studied the possible impacts of hydro-meteorological hazards such as floods and debris flows and proposed different strategies for early warning systems and disaster risk reduction. Some of them referred here with focus on the techniques and methods implemented for civil protection purposes on the response phase. From the reviewed strategies and research, better practices and ongoing challenges were identified as outlined in the following tools commonly used by civil protection authorities:

1. Geo-information and remote sensing: Focus is given to interoperability and standardization combined with dynamic Information Communication Media Technology to keep the flow of real-time data and information. Some initiatives are already looking for multi-scale methods, user center-design software processes and the use of different sources of data for collection and representation in devices, also portable in the field. However, with the technological development in communication media, volunteer geographic information depicts an alternative way to extend the monitoring activity. Although the role and responsibility need to be clarified while recognizing limitations on mechanisms for collection, processing and validation of this data.
2. Due to the increasing impact of natural hazards the need for emergency plans and local involvement has been recognized in the European legislation. In order to overcome limitations in their implementation, the cross-institutional cooperation on an earlier stage of the event management is getting relevance, particularly to manage emergency response due to rapid onset hazards and decentralize the role of each subsystem of the emergency management.
3. For a better implementation of early warning systems there are ongoing efforts to estimate their benefits while accounting the uncertainties involved. However, challenges are posed to estimate and communicate both of them. Additionally the combined implementation of traditional EWS with community-based EWS depicts opportunities to overcome some of the technical limitations of the existent tools for detection and forecasting of hazards. Meanwhile alternative mechanisms for awareness and preparedness at risk could be provided to support the warning and response activities.
4. DSS are commonly implemented to support the forecasting and civil protection activities, considering the options to integrate tools and address different users. However, challenges for implementation are posed especially in areas threaten for multiple hazards. Therefore, it is better recognized the need for an 'all hazards' approach, particularly on data collection and dissemination of warnings as well as the need to implement simple and open source tools to support local communities.

Finally, throughout the carried review, it is worthy mention that there is not full protection against natural hazards especially under the need for continuous adaptation to climate and changing environments. Indeed challenges are posed to better consider the interrelationships between the sub-systems for emergency management, to combine development and implementation of EWS and emergency plans, facilitate participatory activities and continue scientific efforts on the assessment of multiple hydrometeorological hazards.

ACKNOWLEDGEMENTS

This paper has been supported by CHANGES project (Changing Hydro-meteorological Risks as Analyzed by a New Generation of European Scientists) that is a research network part of the Marie Curie Initial Training Network, Seventh Framework Programme, Grant Agreement no.: 263953.

REFERENCES

Alexander D. 2002. Principles of Emergency Planning and Management, Terra Publishing.

Alexander D. 2005. Towards the development of a standard in emergency planning. *Disaster prevention and management*, Vol. 14, No. 2, pp. 158–175.

Bacchini, M. & Zannoni, A. 2003. Relations between rainfall and triggering of debris-flow: case study of Cancia (Dolomites, Northeastern Italy). *Natural Hazards and Earth System Sciences* 3: 71–79.

Bacon, D.P., Ahmad N.N., Dunn T.J., Monteith M.C., & Sarma, A. 2007. An operational multiscale system for hazards prediction, mapping, and response. *Natural Hazards* 44 (3): 317–327.

Badoux, A., Graf, C., Rhyner, J, Kuntner, R., Mc Ardekk, B.W. 2008. A debris-flow alarm system for the Alpine Illgraben catchment: design and performance, *Natural Hazards* 49 (3): 517–539.

Basher, R., 2006. Global early warning systems for natural hazards: systematic and people-centered. *Philosophical Transactions of the Royal Society* 364: 2167–2182.

Borga, M., Gaume, E. Martina, M. & Thielen, J. 2008. *Real time guidance for flash flood risk management*. FloodSite.

Catarci, T., de Leoni, M., Marrella, A., Mecella, A., Bortenschlager, M. & Steinmann, R. 2010. The WORKPAD Project Experience: Improving the Disaster Response through Process Management and Geo Collaboration.. In Proceedings of the 7th International Conference on Information Systems for Crisis Response and Management, ISCRAM Seattle, USA, May 2010.

Carsell, K.M., Pingel, N.D., and Ford, D.T. 2004. Quantifying the benefit of a flood warning system, *Natural Hazards Review.*, 5: 131–140.

Comfort, L.K., & Kapucu N. 2006. Inter-organizational coordination in extreme events: The World Trade Center attacks, September 11, 2001. *Natural Hazards* 39 (2): 309–327.

Comiti, F., Macconi, P., Marchi, L., Arattano, M. Borga, M., Brardinoni, F., Cavallil M., D'Agostino, V. Hellweger, S., Trevisani, S. & Vischi, M. 2010. Debris flow monitoring and warning systems: a new study site in the Alps, *WG F Thematic Workshop on Implementation of the Floods Directive 2007/60/EC "FLASH FLOODS AND PLUVIAL FLOODING" 26th–28th May 2010, Cagliari, Italy.*

Creutin, J.D., Borga, M., Lutoff, C., Scolobig, A., Ruin, I. & Creton-Cazanave, L. 2009. Catchment dynamics and social response during flash floods: the potential of radar rainfall monitoring for warning procedures. *Meteorological Applications* 16 (1): 115–125.

Cutter S.L. 2003. GI Science, Disasters, and Emergency Management. Transactions in GIS, vol 7 (4), pp. 439–445.

DKKV 2007. German Committee for Disaster Reduction Germany's Policy on Disaster Reduction Abroad. 9 p.

DEFRA 2009. *Understanding of and response to severe flash flooding*. Science Report: SC070021. Environment Agency.

de Gooijer, K., Reuter C. 2009: FLIWAS, The right information on the right time for the right person to take the right decision. In: E. Pasche; N. Evelpidou; C. Zevenbergen; R. Ashley und S. Garvin (Hrsg.): Road Map Towards a Flood Resilient Urban Environment, *Proceedings Final Conference of the COST action C22 Urban Flood Management in Cooperation with UNESCO-IHP, Paris, 26./27.11.2009*.

de Leoni, M., De Rosa, F., Marrella, A., Mecella, M., Poggi, A., Krek, A. & Manti, F. 2007. Emergency management: from user requirements to a flexible P2P architecture». *Proc. 4th International Conference on Information Systems for Crisis Response and Management (ISCRAM 2007)*.

De Marchi, B. & Scolobig, A. 2011. The views of experts and residents on social vulnerability to flash floods in an Alpine region of Italy. *Disasters*: 22.

De Marchi, B., Scolobig A., Delli Zotti G., & del Zotto M. 2007. *Risk construction and social vulnerability in an Italian Alpine Region*. Task 11: Risk perception, community behaviour and social resilience; case study Italy. FloodSite.

EU. 2007. Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks. *Official Journal of the European Communities* L288: 27–34.

Frigerio S, Sterlacchini S, Malet JP & Pasuto A. 2011. Emergency management support by geo-information technology. A common methodology in different European contexts. Proceedings of GEORISQUE 2011—7EME EDITION—Plan Communal de Sauvegarde & Outils de Gestion de Crise. 25–26 January 2011, University of Montpellier III, Montpellier, France.

Gaetani, F., Parodi A., Siccardi F., Miozzo., D., & Trasforini, E., 2008. *The Structure, Role and Mandate of Civil Protection in Disaster Risk Reduction for South Eastern Europe*. South Eastern Europe Disaster Risk Mitigation and Adaptation Programme. International Centre on Environmental Monitoring Research Foundation (CIMA).

Garcia, C. 2011. *Mountain Risk Management: Integrated People Centred Early Warning System as a risk reduction strategy, Northern Italy*. Unpublished PhD thesis. Program in Environmental Sciences, Università degli Studi di Milano-Bicocca.

Garcia, C., De Amicis, M, Sterlacchini, S., Pasuto, A., & Greiving, S. 2011. Community Based Early Warning System for mountain risks, northern Italy: identifying challenges and proposing disaster risk reduction strategies. *On prep*.

Garcia, C., & Fearnley,. C.J. 2012. Evaluating critical links in early warning systems for natural hazards. *Environmental Hazards*: 1–15.

Giuliani, G. & Peduzzi, P. 2011. The PREVIEW Global Risk Data Platform: a geoportal to serve andshare global data on risk to natural hazards, *Natural Hazards and Earth System Science* 11:53–66.

Gladwin, H., Lazo, J.K., Morrow, B.H., Peacock, W.G. & Willoughby., H.E. 2007. Social science research needs for the hurricane forecast and warning system. *Natural Hazards Review* 8: 87.

Goodchild, M.F. 2007. Citizens as sensors: web 2.0 and the volunteering of geographic information». *GeoFocus (Editorial)* 2: 24–32.

Gretzschel, M., Jüpner, R., Grafe, M., Leiner, R. 2010. Application of Flood Management Systems in Germany. *Conference Proceedings of the First European IAHR Congress, May 4th to 6th, 2010, Edinburgh*.

Guzzetti, F., & Tonelli, G. 2004. Information system on hydrological and geomorphological catastrophes in Italy (SICI): a tool for managing landslide and flood hazards. *Natural Hazards and Earth System Sciences*. (4): 213–232.

Handmer J. 2001. Improving flood warnings in Europe: a research and policy agenda. *Environmental Hazards* 3: 19–28.

Halonen, A, Verboeket. R, & Hedin, S. 2006. *Study report on alarm systems and early warning in the Baltic Sea region*. BSR INTERREG III B Programme.

Heil, B., Petzold, I., Romang, H., & Hess, J. 2010. The common information platform for natural hazards in Switzerland. *Natural Hazards*. doi:10.1007/s11069-010-9606-6.

Hilker, N., Badoux, A., & Hegg, C. 2009. The Swiss flood and landslide damage database 1972–2007. *Natural Hazards and Earth System Sciences* 9 (3): 913–925.

Hübl, J., C. Scheidl, Schnetzer I., & Kollarits S. 2006. Standardised event documentation, a starting point for modeling and design of natural processes. *Geophysical Research Abstracts* 8 (9540).

Humayoun, S.R., Catarci, T., Leoni, M., Marrella A., Mecella, M., Bortenschlager, M. & Steinmann, R. 2009. Designing Mobile Systems in Highly Dynamic Scenarios: The WORKPAD Methodology. *Knowledge, Technology & Policy* 22 (1): 25–43.

Höppner, C., Buchecker, M., & Bründl, M. 2010. Risk communication and Natural Hazards. In: C.-N. Consortium (Ed.) CapHaz-Net—Social Capacity Building for Natural Hazards—Toward More Resilient Societies, vol CapHaz-Net WP5 report, Birmensdorf, Switzerland, p. 169. Jakob, M. 1996. *Morphometric and geotechnical controls of debris flow frequency and magnitude in southwestern British Columbia*. Unpublished Ph.D. thesis, University of British Columbia, Vancouver, 232pp.

Jakob, M., Owen, T., & Simpson, T. 2011. A regional real-time debris-flow warning system for the District of North Vancouver, Canada. *Landslides*. doi:10.1007/s10346-011-0282-8.

Kappes, MS, Papathoma-Köhle, M. & Keiler, M.. 2012. Assessing physical vulnerability for multi-hazards using an indicator-based methodology. *Applied Geography* 32 (2): 577–590.

Karagiannis, G.M., E. Piatyszek, & J.M. Flaus. 2010. «Industrial emergency planning modeling: A first step toward a robustness analysis tool. *Journal of hazardous materials* 181 (1): 324–334.

Leitinger SH. 2004. Comparison of GIS-based Public Safety Systems for Emergency Management. *In: Fendel E, Rumor M (eds) Proceedings of UDMS '04, Chioggia, Italy.*

Miki, C. 2011. Warning and evacuation in response to sediment-related disasters. *Natural Hazards* 56 (2): 499–507.

Molinari, D. 2011. *Flood early warning system performance. An approach at the warning chain perspective*. Unpublished PhD thesis, Politecnico di Milano. Program in Hydraulic Engineering.

Molinari, D. & Handmer, J. 2011: A behavioural model for quantifying flood warning effectiveness, *Journalof Flood Risk Management*, 4, 23–32, 2011.

Monitor II. 2010. *New methods for linking hazard mapping and contingency planning*, by Stefan Kollarits, Diethart Leber, Alessandro Corsini, Joze Papez, Tanja Preseren, Ingo Schnetzer, Albert Schwingshandl, Stefan Kreutzer.

Mens, MJP, Erlich, M., Gaume, E., Lumbroso, D., Moreda, Y., van der Vat, M., & Versini, P.A. 2008. *Frameworks for flood event management*. Task 19 FEM Framework D19.1. T19-07-03. FloodSite.

Morel, G., Hissel F., & Jia. X.J., Suport for preventive mass evacuation planning in urban areas. *ISSC 2011*.

Mueller, M., Wnuk M., Dransch, D. & Raape, U. 2007. Spatial GUIs for complex decision support in time-critical situations. *In XXIII International Cartographic Conference*, Moscow, Russia.

Piatyszek, E. & Karagiannis, G.M. 2012. A model-based approach for a systematic risk analysis of local flood emergency operation plans: a first step toward a decision support system. *Natural Hazards*. doi:10.1007/s11069-011-0079-z.

Ramos, M-H., Bartholmes, J., & Thielen, J. 2007. Development of decision support products based on ensemble forecasts in the European flood alert system. A*tmospheric Science Letters* 8: 113–119.

Romang, H., Zappa, M., Hilker, N., Gerber, M., Dufour, F., Frede, V., Bérod, D., Oplatka M.„ Hegg, C., & Rhyner.J 2010. IFKIS-Hydro: an early warning and information system for floods and debris flows. *Natural Hazards* 56 (2): 509–527.

Salvati, P, Balducci V, Bianchi C, Guzzetti F, & Tonelli G. 2009. A WebGIS for the dissemination of information on historical landslides and floods in Umbria, Italy. *GeoInformatica* 13 (3): 305–322.

Scolobig, A., Castan, V., & Zabala A. 2008. Integrating multiple perspectives in social multicriteria evaluation of flood-mitigation alternatives: the case of Malborghetto-Valbruna. *Environment and Planning C: Government and Policy* 28: 1143–1161.

Sterlacchini S, Frigerio S (subm.) Civil Protection Plans: an integrated solution by GIS, DSS, and ICT. An example in a Consortium of Mountain Municipalities. International Journal of Geographical Information Science.

Steinfuhrer, A., Kuhlicke, C. De Marchi B., Scolobig A., Tapsell S., & Tunstall SM. 2009. *Local communities at risk from flooding* FloodSite, CapHazNet, Riskmap.

Thielen J., Bartholmes J., Ramos M.-H. & de Roo, A. 2009. The European Flood Alert System—Part 1: Concept and development. *Hydrology and Earth System Sciences*. 13, 125–140.

Todini, E. 2004. Role and treatment of uncertainty in real-time flood forecasting, Hydrological. Processes, 18, 2743–2746.

UK Cabinet Office. 2004: *Civil Contingencies Act (2004) A short guide*. http://www.cabinetoffice.gov.uk/media/132428/15 mayshortguide.pdf.

UN. 2005., Hyogo framework for action 2005–2015: building the resilience of nations and communities to disasters, Available on line at: http://www.unisdr.org/eng/hfa/hfa.htm.

UN/ISDR. 2009. *UNISDR Terminology on Disaster Risk Reduction*, Available on line at: http://www.unisdr.org/eng/library/lib-terminology-eng.htm.

Verkade, JS, & Werner M. 2011. Estimating the benefits of single value and probability forecasting for flood warning. *Hydrology and earth system sciences* 15: 3751–3765.

van der Vat, M., Lumbroso D. & Mens. M., 2007. *Methodology for Decision Support Systems for Flood Event Management*. Project Report Task 19 DSS Methods. FloodSite.

Weerts, AH, Schellekens, J & Weiland, F.S. (2010). Real-Time Geospatial Data Handling and Forecasting: Examples From Delft-FEWS Forecasting Platform/System. *IEEE Journal of selected topics in applied earth observations and remote sensing*, September, Vol. 3.

Werner, M., Reggiani P, De Roo A., Bates P.D. & Sprokkereef, E. 2005. Flood Forecasting and Warning at the River Basin and at the European Scale. *Natural Hazards* 36 (1–2): 25–42.

Werner, M., Schellekens J., & Kwadijk, J. 2006. Flood Early Warning Systems for Hydrological (Sub) Catchments. *Encyclopedia of Hydrological Sciences*.

Zerger, A. & Smith, D.I. 2003. Impediments to using GIS for real-time disaster decision support. *Computers, Environment and Urban Systems*, vol 27 (2), pp. 123–141.