International Journal of Disaster Risk Reduction 46 (2020) 101510

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: http://www.elsevier.com/locate/ijdrr

Operational framework for flood risk communication

Emanuele Intrieri [a,*], Giulia Dotta [a], Katia Fontanelli [a], Chiara Bianchini [b], Federica Bardi [a], Federico Campatelli [c], Nicola Casagli [a]

[a] University of Studies of Florence, Earth Science Department, Florence, Italy
[b] Laboratory X, Cerchio Blu NGO, Florence, Italy
[c] Associazione Nazionale Comuni Italiani (ANCI) Toscana, Florence, Italy

ARTICLE INFO

Keywords:
Crisis communication
Social media
Early warning
Natural hazards
Geohazards

ABSTRACT

Risk communication is a mutual process of understanding the risk among stakeholders and represents a measure to integrate lay knowledge into measures to prevent, mitigate, and deal with risk. Flood crisis communication, which takes place in the face of incoming danger, needs a practical and operative approach to cope with potentially destructive, large-scale natural disasters. Since floods are one of the most predictable georisks, communication is an efficient means to reduce risk, especially by reducing people's exposure.

Many authors discussed the nature of risk communication. Regarding flood risk, most works are devoted to long-term communication plans, but more practical indications on how to communicate during - or shortly before - an (expected) emergency are lacking.

Therefore, we present here a framework providing recommendations on what should be the information conveyed in a flood warning message and with what communication medium it should be issued, depending on the criticality level of the expected flood, on the resources of the institution in charge for the warning and on the specific advantages of each medium. Therefore, the framework shown in this paper provides an easy to employ handbook for civil protection operators to define the suitable content, shape and medium for warning messages toward the population. This framework addresses common issues such as the possibility of false alarms or the lack of personnel in charge of risk communication, as well as the role of social media (and their limits), that in many cases is still not well understood.

1. Introduction

Risk communication is a relevant part of risk management strategy. The modality and aims of the communication are different whether it is carried out few hours before a forecasted event ("crisis communication") or during "normal times". In "normal times" it is necessary to inform the exposed people about the risk, the safe behaviors, the timing and the functioning of warnings, in order to increase their reception [1]. This is also grounded in an assumption that the public has a generalized right to know about hazards and risks [2]; the availability of information allows the public to make informed choices regarding risk, thus facilitating decision making and risk sharing [3]. This point highlights the responsibility of people in the system, so one of the purposes of risk communication is to provide the information necessary for them to carry out such responsibility [2].

On the other hand, crisis communication is employed in face of (and during) sudden danger [4]. Crisis communication is typically carried out through warnings, that are considered by Wogalter et al. [2] a line of defense against hazards, beyond design alternatives (e.g. provided by a careful urban planning) [5,6]; and guarding (e.g. retaining walls against landslides or detention reservoirs against river floods); [7,8].

Communication is also one of the main components of an early warning system (EWS) and is possibly the most cost-effective countermeasure against natural hazards although, sometimes, it is underrated by risk operators [9–11]. In fact, risk management involves both scientific and social experts and, given this multidisciplinary nature, it is difficult to develop both at the same level. Therefore, it is possible that an accurate prediction is made but the relative warning is not properly issued, or it is not understood, causing the failure of the whole system.

While designing alternatives and guarding are intrinsically passive countermeasures, warning requires people to take action. The active role of people (people-centered systems) that are seen not only as recipients

* Corresponding author.
E-mail address: emanuele.intrieri@unifi.it (E. Intrieri).

https://doi.org/10.1016/j.ijdrr.2020.101510
Received 29 July 2019; Received in revised form 24 January 2020; Accepted 25 January 2020
Available online 27 January 2020

of warning messages is already a widely accepted concept [12–14] that can go as far as developing whole community-based early warning systems [15]. On the contrary, disengaged communication is often associated with a deficit model of public (mis)understanding in which experts are assumed to possess superior scientific knowledge of risk and to rely on risk communication to disseminate it to the ignorant [16].

Among the natural hazards, river floods are one of the most demanding in terms of economic losses and human lives [17,18]; in 2018 alone, Munich Re [19] recorded that flood events claimed 35% of the victims of natural hazards worldwide; although the average in the previous years was around 14%, this mean value is probably bound to increase due to climate changes [20,21], population growth and urbanization [22]. At the same time, floods are one of most predictable natural hazards in time and space, mostly because of their close causal correlation with rainfall (which is generally forecastable with good accuracy) and because the effects of the rainfall on the rivers discharge is delayed, sometimes significantly, depending on the characteristics of the basin (especially its extension and land cover). Concerning the spatial prediction, several methods exist to derive flood susceptibility maps from historical accounts, hydrological and geomorphological studies [23–25], for which data concerning rainfall, discharge, flow height, topography, shape and size of the riverbed and of structures. All of this makes flood early warning potentially very effective.

While communication in "normal times" to increase flood risk perception and foster self-protective behaviors is a widely investigated topic [26–29], studies dedicated to flood crisis communication are less common [30], and in particular those focusing on practical and operative solutions, such as the actual drafting of flood warning messages, are lacking. For such reason, this paper focuses on presenting guidelines for river flood crisis communication. These have been calibrated on Italy and France legal, economic and cultural framework, but are sufficiently generic to be applied also to other similar contexts. In particular, issues such as what should be the content of the warning messages and how they should be disseminated will be addressed. As Demeritt and Norbert [16] righteously pointed out, different aims will require different means, which precludes from the idea of some singular body of best practice; for this reason, the guidelines here presented are to be taken as a starting point requiring further customization and contextualization. For example, specific adaptations in the employed media may be required in municipalities with unbalanced demographics (e.g. under-30 missing) or with particularly critical or vulnerable infrastructures that need dedicated warning messages.

In the following sections, a practical approach to flood crisis communication will be described with the aim of addressing common issues such as uncertainty linked to weather forecasts and the possibility of false alarms, or such as the lack of technical personnel in charge of disseminating the alarm to the people (especially in small municipalities).

Some of the practical questions this paper aims to answer are *who should send the warning messages? What should be their content? When the warning messages should be issued? And how?*

The solutions proposed have been developed after a careful evaluation and collection of best practices from all around the world and by accounting for the input and feedback gathered during repeated meetings and workshops with local, national and international stakeholders and civil protection operators, whose direct experience served to calibrate the proposed solution to real contexts.

2. Review on the social media usage during emergencies

Before going into the details of the crisis communication analysis, particular attention should be paid to social media, which have been adopted globally by public administrations to interact with citizens [31–34], also when it comes to spread natural hazards warnings [35].

The choice of the optimal social media for risk communication must take into account their nature and distribution. The world most important trends regarding the Internet and social media are provided by the global agency We Are Social [36]; in collaboration with the social media management platform Hootsuite [37] and have been published on the Global Digital 2019 [36] survey (Fig. 1), which analyzes data in 248 countries, including Italy.

57% of the world population uses Internet and 45% (4.388 billion people) actively uses social media (Fig. 1). Importantly, 93% of the social media users accesses social media through mobile devices, which is relevant when it comes to early warning applications. These numbers are continuously growing every year. The most used social media are Facebook (2.27 billion people or 52% of the active users), followed by YouTube (with 1.90 billion or 43%) and a series of applications of instant messaging such as Whatsapp (with 1.50 billion or 34%), Facebook Messenger (1.30 billion or 30%) and WeChat (1.08 billion or 25%). Twitter, despite its history and narrative functions used for spreading news and commentary, ranks below with 0.32 billion active users (7%). In Italy 35 million people are active on social media (59% of the population); among them 87% uses YouTube, 84% WhatsApp, 81% Facebook, 55% Instagram, 54% Facebook Messenger, 32% Twitter, while only 11% uses WeChat [36]. More detailed graphs and data on Italy and other countries are made available by We Are Social [36].

The use of social media is no longer limited to social purposes but is also directed to gathering information and staying up to date with the latest news and events [38]. The first example of using Twitter during emergencies was the Haiti earthquake in 2010. For a long time, this event was at the top of Twitter's Trending Topics [39,40] and users used this platform to inform themselves and to offer their help, as for the digital volunteers who used the tweets to create an online map to find people and their main needs [41]. In these cases, users turn into information producers that supply photos and videos that, in the same way as official information sources, are published and spread through social media [42]. A detailed study on the adoption of location-based information sharing technologies, and the emergence of volunteered geographic information has been performed by Haworth et al. [43]. This usage has been acknowledged by some social networks themselves. Facebook, for example, after the earthquake that hit Nepal in 2015 developed Safety Check [44], which now allows Facebook users to confirm their status in an area affected by a catastrophe. The "Crisis response" menu item also provides information about ongoing emergencies, how to give or receive help and participate in charity and fundraising campaigns [45].

In recent years the use of hashtags able to monitor the conversations on a theme or an event in progress on social network platforms has increased. Hashtags are words preceded by the # symbol and are used to categorize the topic of the message or highlight some keywords. Originally conceived for Twitter, hashtags have been gradually introduced with the same functionality on other social networks (such as Facebook, Instagram, LinkedIn) but with very different dynamics; on Instagram, for example, they are used to classify photos and give greater visibility to the shots, while on Facebook the use is still limited, also because of the privacy settings that can reduce the visibility of the published content.

From an institutional point of view when it comes to risk communication, it is good practice to develop a glossary of hashtags, shared with all the participants in the institutional field. However, it is important to remember that communication on social media is fluid and, especially in the case of sudden emergency events, some hashtags can spontaneously become popular in a bottom-up fashion without the intervention of institutional channels, maybe because they have been adopted first by community or by accounts with a large number of followers (such as the so-called influencers) [46] or are particularly effective. In such situations, it is not possible to overly constrain the communication activity to a predetermined set of hashtags, but it is necessary to follow the choices made by users and adapt. An example of internationally coding hashtags was implemented in 2015 by the United Nations Office for Humanitarian Affairs [47]. It must be underlined that the coding of the hashtags cannot be carried out by the citizen-user, but

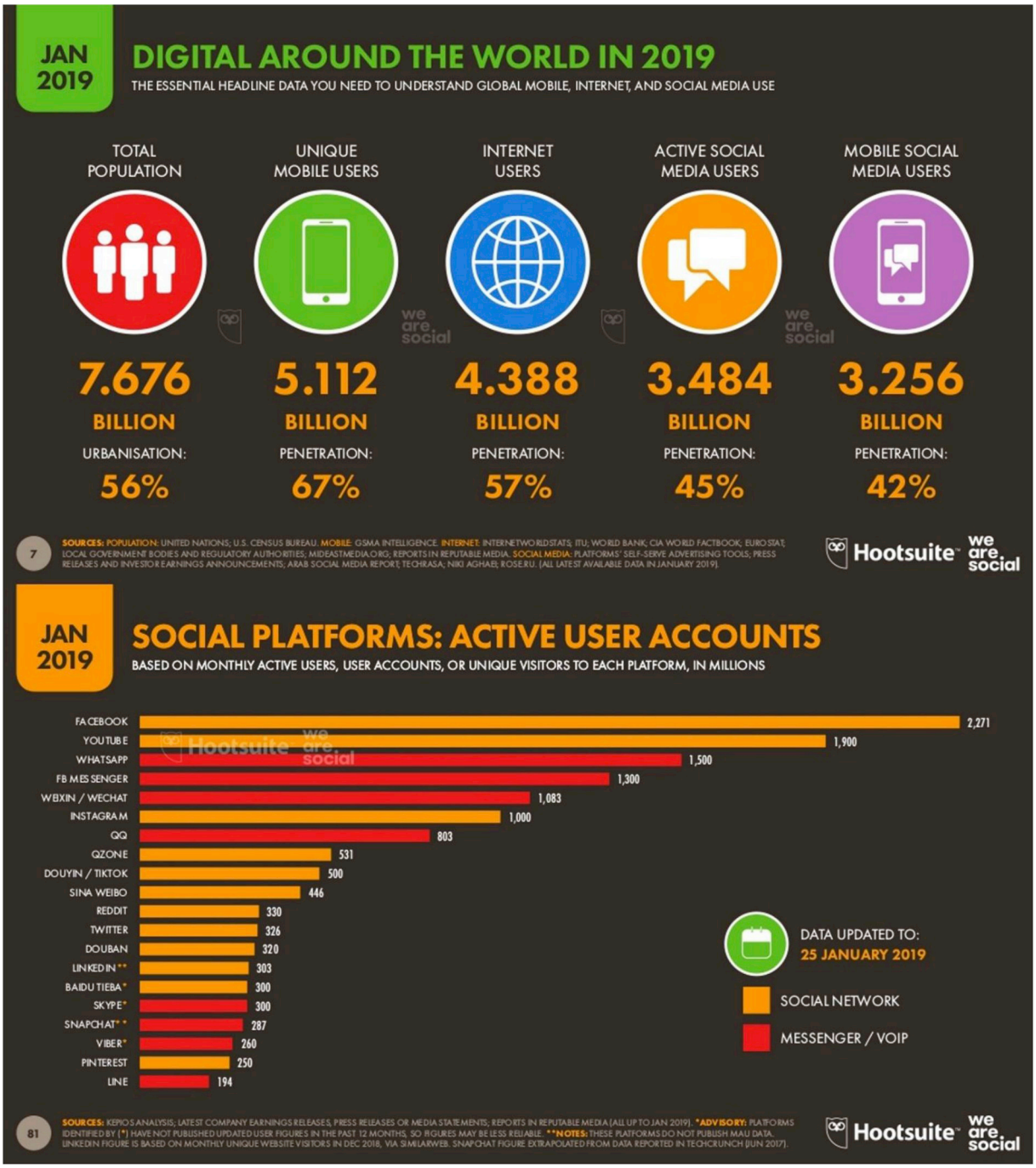

Fig. 1. "Digital around the world in 2019" (above) and "Social Platforms: Active User Accounts" (below) from the Global Digital 2019survey [36].

it is up to the institutional accounts in charge for risk communication in case of emergency. However, once the hashtags have been defined, they must be communicated and agreed with the community foster their use and facilitate the collection of information during a critical situation. For example, Italy uses a regional coding for weather alerts [48,49], which is the hashtag #allertameteo (which can be translated as "weather alert") followed by the first letters of each region (e.g. #allertameteoLIG for Liguria). This provides a great advantage to both institutions and citizens: official and institutional accounts have no uncertainties about what hashtag should be used; people, on the other hand, know that if they want to find out about institutional weather alerts, they can follow the reference hashtag for their region and consult the messages of the competent bodies. In addition, even the traditional mass media started to include these hashtags in tweets and posts on social media that report news about weather alerts, both to convey valuable traffic to their site and to offer readers real-time information on the subject.

3. Results

3.1. Limitations of the warning system

To make crisis communication effective, a robust risk education and communication during "normal times" must be carried out. On the other hand, the crisis communication itself can be an opportunity to educate the population about the self-protective behaviors and the communication channels that the Municipality uses to disseminate the alert messages.

In Italy, as in Europe, the criticality levels of the early warning

system for weather-related events (like floods, landslides, thunderstorms, etc.) are expressed as green (no criticality), yellow (ordinary criticality), orange (moderate criticality) and red (high criticality), from here on called color-codes. The criticality levels correspond to defined scenarios or ground effects which are expected to take place in each alert zone in which the national territory is subdivided accordingly to homogeneous hydrographic characteristics (Fig. 2).

The Italian law (D. lgs. n. 1/2018) establishes that the municipalities (specifically the mayors) are in charge of the risk communication. This means that a color-code is assigned daily to each alert zone by regional authorities (coordinated by the National Civil Protection Department), but it is mayor's responsibility to communicate this information to the population. In Italy the color-codes are defined as follows:

- Green: no intense or dangerous phenomena are expected.
- Yellow: intense, locally dangerous phenomena are expected.
- Orange: more intense than normal phenomena, dangerous for people and things.
- Red: extreme phenomena expected, very dangerous for people and things.

Given the localized nature of yellow alert levels and the probabilistic nature of weather forecasts, yellow alerts are relatively common and likely to concern only a small part of an alert zone, if at all.

When these situations happen too frequently, the citizen can perceive yellow alerts as false alarms and therefore distrust the municipal institution and the alert system as a whole. Therefore, in "normal times" communication, it is important to convey the meaning of the alert levels and the uncertainty related to weather forecasting to keep the trust in the institutions [50–53].

In Italy, education on weather warnings, on the confidence of forecasts and color-codes is entrusted by law to individual municipal entities. There are no national guidelines on how to inform citizens about this matter, therefore many different kinds of activities (civil protection courses addressed to all levels of school education, leafleting, communication campaigns such as the national campaign "IoNonRischio" developed by the Department of Civil Protection) are carried out, depending on the resources, level or risk and awareness of the mayor of each municipality.

Fig. 2. Alert zones in Italy [43].

Other than the trust relationship between population and local administration, another issue is the possible lack of technical personnel in the municipality (particularly the smaller ones) able to take care of the communication toward the citizens. If this problem is combined with the possible lack of awareness of the mayors about civil protection topics, managing effectively the communication becomes an extremely difficult task.

The national alert system in Italy is regulated by law and then managed by each Region, that can operate with a certain degree of freedom; in any case, currently, there is no manual or specific indication made by at national level to instruct about how crisis communication should be carried out. Therefore, guidelines for a standardized communication defining the contents and means of the messages, easily adaptable to the various communication channels (such as websites, social networks, messaging applications) and easily useable by the technical staff of the administration in charge, can represent a contribution to overcome the aforementioned issues.

3.2. The warning messages

The key elements to be defined for a warning message are who is the sender of the message, what is the content, when it should be issued and how (i.e. through what medium).

About *who*, in Italy the city mayor is the local civil protection authority and so responsible for transmitting weather alerts to the population. The crisis communication can be entrusted to the management of the municipal civil protection office (if present in the municipality), the press office, or the mayor secretariat, with the contribution of all the municipal personnel competent in these matters and the whole civil protection system (for example volunteering or first responders such as fire fighters).

Regarding *when* the warning message should be issued, the crisis communication occurs once the accountable authorities transmit to the municipality the color-code assigned to the connected alert zone. For example, in Italy weather forecasting is made by a central authority but then the calculation of the possible effects on the ground (i.e. understanding if a certain rainfall could exceed regional rainfall thresholds for landslide risk), the attribution of the color-code for each alert zone composing a single Region, and the communication towards the municipalities within the Region are all responsibilities of the regional administration.

Concerning the content of the warning message (*what*) toward the population, it should include the following information:

- Color-code: the criticality levels of the early warning system are expressed as green (no criticality), yellow, orange and red color-codes; even if this terminology is addressed to technicians dealing with civil protection, by now it is commonly used also among citizens.
- Municipality: as the city mayor is the local civil protection authority and so responsible for transmitting weather alerts to the population, the municipality where the alert takes place must be specified, avoiding to describe any territorial subdivision that may sound unfamiliar or too technical (like, in the case of Italy, the names of the alert zones).
- Risk type: municipalities are often exposed to different risks and risk scenarios, which are considered in municipal civil protection planning and must be clearly specified in the alert messages.
- Alert duration: The duration of the alert should always be provided. Sometimes alerts include the exact hour of start and end of their duration (for example, until midnight), information that is useful to activate internal procedures for technicians but that is not precisely relatable to the actual period of risk. A qualitative description of the

alert duration is more advisable for communication purposes (for example "in the evening of 4 November").
- "Simplified" and updated weather forecast description: weather forecasts and national or regional warnings are typically provided at a larger scale than municipalities. Furthermore, the actual ground effect of weather conditions (event scenarios) can considerably vary depending on the specific features of the territory and structures; e.g. the presence of underpasses or defense structures can respectively increase and reduce the flood risk in a way that cannot be defined in a large scale warning. Therefore, in the message to the people, the description of the weather forecast must be contextualized and made relevant to the territory, referring to some local critical issues and risk scenario, using terms understandable to the general public.
- Safe behaviors to employ before, during and after an event: to transmit safe behaviors to the population, if the medium allows it, it is useful to use infographics, images, photos or links (for example to a dedicated web page on the website of the municipality to strengthen its institutional role). For this purpose, an URL shortener can be used to reduce the length of website address.

The content of the message can be further customized depending on specific needs of the municipality, for example by informing if a particular bridge or critical road section will have to be closed. This requires a detailed knowledge of the territory, so these evaluations and consequent recommendations are generally based on the expertise of local civil protection operators and practitioners. Furthermore, within the message it is important to mention the source of information to convey authority and reliability, always remaining in the perspective of a simple and well-known language for citizens, like for the rest of the message.

Regarding *how* the warning messages should be issued, first of all the crisis communication should be institutional (formalized by the municipality), efficient, rapid, reliable and it should use multiple communication channels in order to reach a higher number of citizens.

In creating and disseminating an alert message, the following considerations must be taken into account:

- The message should adopt a shared glossary (especially concerning hashtags), so that the same terminology is used by all the (neighbor) municipalities during the alert communication phase;
- It should preferentially focus on the use of infographics, in particular regarding the safe behaviors, which are generally more immediate and effective than plain text, especially on social media;
- The crisis communication should include a hierarchy of the communication channels depending on the color-code. On the one hand this has the purpose of activating specific channels only for the most critical communications; in this way, communications relating to red alerts appear to have a greater resonance than those referred to yellow alerts (see the issue of false alarms described in section 3.1). Secondly, the hierarchization of the communication media also offers a priority scale of which channels a municipality should activate and supervise and which could be left behind if the human and economic resources are not enough (see the issue of lack of personnel described in section 3.1).

Concerning the definition of a shared hashtags glossary, this should be agreed upon at least among neighbor municipalities following these criteria:

- Hashtags can be used to indicate at least the following information: type of risk (e.g. #flooding, but the same message structure can be used for other risks as well, such as #wind, #storm, #avalanche), the territory interested by the alert (#Rome), the color-code (#YELLOWalert).
- Technical terms, designations and non-universal abbreviations that may not be understood should be avoided.
- As a possible exception to the point above, if some hashtags have been regularly adopted in previous warning message and people is already used to them, it is usually a good idea continuing to use them. For example, in the Italian region of Toscana the hashtag #AllertaMeteoTOS (which means weather alert, plus the first three letters of the name of the region) has become commonly used among many municipalities and other civil protection bodies. Although it is not particularly intuitive, by now it has become widely understood and a reference hashtag.
- Since communication on social networks is fluid, it is important to remember that hashtags are not always defined by the official accounts of civil protection institutions but are sometimes imposed by the community, especially during particularly serious emergencies, and are spread thanks to influencers or to the communication potential of the hashtags themselves. An example is #AustraliaOnFire used during the 2019–2020 grave wildfire emergency in Australia. In such cases, institution should catch these popular hashtags to intercept a greater number of users.
- Instead of adding a series of hashtags just used as keywords at the end of the message, they are better included within the sentences, to make them effectively part of the message.
- Capital letters can be used to separate words composing a single hashtag or to emphasize entire words.

To make the concepts described so far quick and easy to read and understand for beneficiaries (population) and end-users (civil protection operators), they have been represented in Table 1, which can also be used as a synoptic handbook for composing the alert message based on the available media.

As an example, a standard warning message for Facebook channel in the case of hydrologic risk and red alert is reported in Fig. 3.

4. Discussion and conclusions

Table 1 indicates, for each color-code, which contents are to be transmitted ("what") in the alert message according to the respective communication channels used ("how"). For each type of communication channel, the boxes corresponding to the information that the message must contain are checked; the main limit for a given channel is the possibility of inserting images, as in the case of a variable-message sign (VMS), and the maximum number of available characters (280 in the case of Twitter, up to 60 or 88 for VMS). The risk type and alert duration must be included in every case. The columns of Table 1 are sorted with a logic that follows the order of the contents of the message.

The communication channels (the rows of Table 1) are listed based on a hierarchical order that who are in charge of the risk communication can follow when selecting the channels to be used to inform the people about a possible warning. The choice of the channel must be made during "normal times" but considering the needs and constraints that could occur in the most critical conditions (red alert); this is to avoid that channels (for example an institutional Facebook profile) are activated and maintained only when the alert is less severe and the municipality personnel is able to cope with the tasks of a mild emergency but then are abandoned when the alert becomes red, thus neglecting the expectations of the population. In fact, once a channel is activated during a yellow alert, people relies on that channel for every future communication, also for red alerts. Furthermore, in the case of social networks, people have the possibility to directly relate and communicate with those who disseminate the alert and expect answers or updates (possibly also during emergency and rescue situations); this means that the municipal administration must have competent personnel able to monitor these communication channels and respond appropriately to the questions or requests made by the citizens, during a yellow, orange or red alert. For this reason, each municipality must evaluate the available human and economic resources in order to keep the communication channels updated and receptive, keeping in mind that the more is not necessarily

Table 1
Table containing what should be the content of the warning message and which communication channels use to transmit it.

Alert type			WHAT				
				Municipality		Event description	Safe behaviors
YELLOW	HOW	Municipality website	Risk type	✓	Alert duration	✓	✓
		Variable-message sign					
		App		✓			✓
		Facebook		✓		✓	✓
		Twitter		✓			✓
ORANGE		Municipality website		✓		✓	✓
		Variable-message sign					
		App		✓			✓
		E-mail		✓		✓	✓
		WhatsApp		✓		✓	✓
		Facebook		✓		✓	✓
		Twitter		✓			✓
RED		Municipality website		✓		✓	✓
		Variable-message sign					
		Phone call/SMS		✓		✓	✓
		App		✓			✓
		E-mail		✓		✓	✓
		WhatsApp		✓		✓	✓
		Facebook		✓		✓	✓
		Twitter		✓			✓

the better if this exceeds the capacity of the municipality.

The communication channels placed higher up in the list are considered the most important. If a municipality is not able to activate all the channels, the preference should be given according to this order of priority, which has been built considering several factors, such as the number and type of people that can be reached. For example, social networks are low in priority because they are scarcely used by older age groups and, in any case, require that the users actively follow the updates of the municipality account. On the other hand, VMS are present along highways, in motorway junctions, at the entrance to cities, along urban avenues, at pharmacies or bus stops and so are one of the few means to reach non-resident people (e.g. tourists or outside workers) that are not in any newsletter nor know and follow local media. For all types of alerts the maximum priority is given to the municipality website since each municipality should have its own institutional site, which should be make known to the citizens in "normal times" and always be kept update. Within the site, the alert message and the information regarding, for example, the civil protection and emergency plans or safe behaviors should be readily available and adaptable for both desktop and smartphone accesses.

Regarding the red alert, a further means of communication to the citizen can be the phone call, that is the information service that transmits a pre-recorded message of the mayor, which must be concise to be effective. The service can be easily activated for private landline telephone numbers in the municipal area or with a free registration by any who is interested. This channel is recommended only for the red alert because it has the strongest impact on the people risk perception and should be reserved when the risk is high and the possibility of a false alarm is low; furthermore, this service can be expensive for a municipality with little economic resources. Otherwise, the service could also

Fig. 3. Standard warning message for a red alert issued through Facebook. Reference for the infographic are to the Italian information campaign IoNonRischio [27] developed by the Department of Civil Protection.

be used for the orange alert, transmitting the message with a pre-recorded voice different from that of the mayor, for example the voice of an official of the municipality, in order to give a different relevance to the phone call in the two cases. The traditional short message system (SMS) is considered alternative to the phone call, since both are linked to the telephone number, do not include the installation of applications on the mobile phone and so can reach people without a smartphone.

Concerning the use of specific mobile apps, these allow the citizens to receive notifications or push messages whenever an alert is issued; depending on the app, they could also provide risk maps, civil protection plans (in particular, hydrologically dangerous areas and safe areas for the population), safe behaviors and other relevant information. E-mails have also been considered; also in this case an action is required by the citizen, but purposely registering to a newsletter and provide personal information has been considered a less likely action than downloading an app; furthermore app, since are dedicated tools optimized for the purpose of early warning, can implement additional features such as showing safe routes, hazard maps or civil protection plans. Similarly to e-mails, instant messaging applications, such as WhatsApp (or other popular alternatives, which greatly vary from country to country), allow citizens to receive notifications and messages but they necessarily require to provide the telephone number to the municipality. In every case, since these tools need a smartphone or a computer, they are not suggested as the top priorities among communication media, especially because elderly people are less likely to use such devices.

The phone call, SMS, e-mail and instant messaging applications with push notifications are not recommended for the yellow alert as they are considered too invasive for this level of alert; if no event occurs, their frequent use could undermine the trust in the system.

Regarding the social networks, Facebook and Twitter are both widely used and more suited to real-time, institutional communication, compared to others like YouTube, Instagram, LinkedIn or Pinterest. The main difference between the two social networks is that Twitter has a maximum limit of characters (280 characters) and is less popular worldwide, as shown in Fig. 1; it was therefore decided to give priority to Facebook in the hierarchy of social media channels. The institutionality of the communication is a central requirement because, differently from other one-way only communication systems, Facebook and Twitter allow for common people to generate their own warning messages, maybe using the same hashtags used by the Municipality, but providing partial, unclear, off-topic or utterly false information that can compromise the good use of these platforms in the crisis phase. This risk is higher for Twitter where the much larger use of hashtags increases the availability of messages concerning hot topics. On the other hand, such media allow for an engaged, two-way communication that provides a contribution towards a people-centered early warning system.

Among the communication channels, TV and local radio have not been included in Table 1 as they are not under the direct control of the municipality and cannot guarantee either the actual transmission of the alert or the right timing, as the communication depends on editorial policy, space and schedule. Therefore, their use should be conditioned to specific agreements and conventions so that the local media report the press release, which transmits the alert message, issued by the municipality. However, when available, they could represent an important means for reaching the elderly people, typically not easily reachable through the Internet and mobile phones.

Finally, during a red alert, the use of megaphones, loudspeakers or sirens by the municipality staff, with the support of voluntary associations, can be useful to alert citizens in small towns or living in specific areas at risk, to reach people of all age groups, especially elderly, and those who do not follow any of the aforementioned channels and to report dangerous situations.

The criteria and measures proposed in this paper are the result of the direct experiences of the many civil protection operators that took part in the preliminary workshops, that were necessary to calibrate the guidelines to real contexts. Currently the guidelines are being used in 11 municipalities in Italy as pilot test. A questionnaire about how the flood crisis communication was perceived by the population was performed both before and two months after the adoption of the guidelines. The short time between the two surveys was necessary to make results comparable, since risk perception and attention to communications concerning flood hazard is expected to decrease during the dryer seasons, when the number of alerts is also smaller. The surveys revealed that the number of people reached by warning messages increased by 15%. In detail, Facebook was the channel that most benefited from the application of the guidelines, probably also thanks to the use of more visible and user-friendly infographics. Interestingly, the number of people that did not fully understand the message (i.e. that did not understand at least one among the time of the alert, the area of the alert, the actions to be done in case of flood) decreased from 31% to 12%. This preliminary result shows an improvement both in terms of quantity of people reached and in the quality of the message received.

Eventually, it is important to remember that in this paper we have dealt with just crisis communication, which is only the last step of an early warning system. In fact, it also includes a technical-scientific part (i.e. providing accurate and timely weather forecasts and correctly predicting the consequences in terms of floods) and a necessary mutual education and communication in normal times, which is fundamental to provide the right risk perception and the importance of taking some actions. Widespread and periodical information and formation campaigns in normal times reduce the possibility that, even if a flood alert is correctly understood, people refuse to evacuate their houses.

Author contributions

The design of the paper was performed by EI. The first writing of the paper was carried out by EI and GD, except for the part relative to the social media, which has been written by CB. EI, GD, KF, FB carried out the research, which involved the study and framing of the problem and the solutions proposed in the paper. CB developed the part relative to social media and provided input concerning communication science. FC provided input, organized meeting with the stakeholders to collect feedback and contributed to the definition of the framework. NC supervised the work. All the authors contributed to the revision and polishing of the paper.

Acknowledgments

This research has been financed by ANCI Toscana through the European project “PROTERINA-3Évolution” within the Interreg Italia-Francia Marittimo 2014–2020 program and by the project “Realizzazione di linee guida per riduzione del rischio alluvione tramite un approccio non strutturale” (INTRIERIEMANUELERICATEN19 - Fondi di Ateneo per la ricerca scientifica) coordinated by Emanuele Intrieri and financed by the University of Florence, Italy.

The authors are especially grateful to Paolo Masetti and all the people who attended the workshops and meetings that were crucial to the realization of these guidelines.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2020.101510.

References

[1] EWC III, Developing Early Warning Systems: A Checklist, Third International Conference on Early Warning, March 2006, International Strategy for Disaster Reduction (ISDR), Bonn, Germany, 2006, pp. 27–29. secretariat, 13 pp. Available at: https://www.unisdr.org/files/608_10340.pdf.
[2] M.S. Wogalter, D.M. DeJoy, K.R. Laughery (Eds.), Warnings and Risk Communication, Taylor & Francis, Philadelphia, 1999, ISBN 9780748402663, p. 365.
[3] B. Reynolds, M.W. Seeger, Crisis and emergency risk communication as an integrative model, J. Health Commun. 10 (1) (2005) 43–55.
[4] R.E. Lundgren, A.H. McMakin, Risk Communication: A Handbook for Communicating Environmental, Safety, and Health Risks, John Wiley & Sons, 2018.
[5] G.D. Bathrellos, K. Gaki-Papanastassiou, H.D. Skilodimou, D. Papanastassiou, K. G. Chousianitis, Potential suitability for urban planning and industry development using natural hazard maps and geological–geomorphological parameters, Environ. Earth Sci. 66 (2) (2012) 537–548.
[6] S. Opricovic, G.H. Tzeng, Multicriteria planning of post-earthquake sustainable reconstruction, Comput. Aided Civ. Infrastruct. Eng. 17 (3) (2002) 211–220.
[7] G. Gigli, E. Intrieri, L. Lombardi, M. Nocentini, W. Frodella, M. Balducci, L. D. Venanti, N. Casagli, Event scenario analysis for the design of rockslide countermeasures, J. Mt. Sci. 11 (6) (2014) 1521–1530.
[8] B.M. McEnroe, Preliminary sizing of detention reservoirs to reduce peak discharges, J. Hydraul. Eng. 118 (11) (1992) 1540–1549.
[9] E. DiBiagio, O. Kjekstad, Early warning, instrumentation and monitoring landslides, 2nd regional training course, RECLAIM II, phuket, Thailand, 2007, pp. 1–24, 29 January–2 February 2007.
[10] E. Intrieri, G. Gigli, N. Casagli, F. Nadim, Brief Communication Landslide Early Warning System: Toolbox and General Concepts, 2013.
[11] UNISDR (United Nations International Strategy For Disaster Reduction), The international early warning programme – the four elements of effective early warning systems – brochure, platform for the promotion of early warning (PPEW), 4 pp., available at: http://www.unisdr.org/2006/ppew/iewp/IEWP-brochure.pdf, 2006, 2006.
[12] R. Basher, Global early warning systems for natural hazards: systematic and people-centred, Phil. Trans. Math. Phys. Eng. Sci. 364 (1845) (2006) 2167–2182.
[13] EWC II, Early warning as a matter of policy: the conclusions of the second international conference on early warning, 16–18 october, bonn, Germany, in: International Strategy for Disaster Reduction (ISDR) Secretariat and the German Disaster Reduction Committee (DKKV), 2004, p. 28.
[14] C. Keys, M. Cawood, Identifying and reducing inadequacies in flood warning processes: an Australian perspective, J. Flood Risk Manag. 2 (3) (2009) 190–197.
[15] UNISDR, Early Warning Practices Can Save Many Lives: Good Practices and Lessons Learned, United Nations Secretariat of the International Strategy for Disaster Reduction (UNISDR), Bonn, Germany, 2010, p. 67.
[16] D. Demeritt, S. Nobert, Models of best practice in flood risk communication and management, Environ. Hazards 13 (4) (2014) 313–328.
[17] J.I. Barredo, Normalised flood losses in Europe: 1970–2006, Nat. Hazards Earth Syst. Sci. 9 (1) (2009) 97–104.
[18] K. Smith, D.N. Petley, Environmental Hazards. Assessing Risk and Reducing Disaster, Routledge, London, 2009, pp. 205–226.
[19] Munich Re, The natural disasters of 2018 in figures, Accessed on July 2019, https://www.munichre.com/topics-online/en/climate-change-and-natural-disasters/natural-disasters/the-natural-disasters-of-2018-in-figures.html, 2019.
[20] Y. Hirabayashi, R. Mahendran, S. Koirala, L. Konoshima, D. Yamazaki, S. Watanabe, H. Kim, S. Kanae, Global flood risk under climate change, Nat. Clim. Change 3 (9) (2013) 816.
[21] IPCC, Climate change 2007: impacts, adaptation and vulnerability, in: M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, C.E. Hanson (Eds.), Contribution Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, 2007.
[22] M. Siegrist, H. Gutscher, Flooding risks: a comparison of lay people’s perceptions and expert’s assessments in Switzerland, Risk Anal. 26 (4) (2006) 971–979.
[23] M. Hagemeier-Klose, K. Wagner, Evaluation of flood hazard maps in print and web mapping services as information tools in flood risk communication, Nat. Hazards Earth Syst. Sci. 9 (2) (2009).
[24] M.B. Kia, S. Pirasteh, B. Pradhan, A.R. Mahmud, W.N.A. Sulaiman, A. Moradi, An artificial neural network model for flood simulation using GIS: johor River Basin, Malaysia, Environ. Earth Sci. 67 (1) (2012) 251–264.
[25] M.S. Tehrany, B. Pradhan, M.N. Jebur, Spatial prediction of flood susceptible areas using rule based decision tree (DT) and a novel ensemble bivariate and multivariate statistical models in GIS, J. Hydrol. 504 (2013) 69–79.
[26] M.S. De Wit, H. van der Most, J.M. Gutteling, M. Bockarjova, in: S. Martorell, C. G. Soares, J. Barnett (Eds.), Governance of Flood Risks in The Netherlands: Interdisciplinary Research into the Role and Meaning of Risk Perception. Safety, Reliability and Risk Analysis: Theories, Methods and Applications, 2008, pp. 1585–1593.
[27] T. Grothmann, F. Reusswig, People at risk of flooding: why some residents take precautionary action while others do not, Nat. Hazards 38 (1–2) (2006) 101–120.
[28] W. Kellens, T. Terpstra, P. De Maeyer, Perception and communication of flood risks: a systematic review of empirical research, Risk Anal. 33 (1) (2013) 24–49.
[29] M. Kievik, J.M. Gutteling, Yes, we can: motivate Dutch citizens to engage in self-protective behavior with regard to flood risks, Nat. Hazards 59 (3) (2011) 1475.
[30] T.L. Sellnow, M.W. Seeger, R.R. Ulmer, Chaos theory, informational needs, and natural disasters, J. Appl. Commun. Res. 30 (4) (2002) 269–292.
[31] H.M. Abdelsalam, C.G. Reddick, S. Gamal, A. Al-shaar, Social media in Egyptian government websites: presence, usage, and effectiveness, Govern. Inf. Q. 30 (4) (2013) 406–416.

[32] J.I. Criado, F. Rojas-Martín, Social media and public administration in Spain. A comparative analysis of the regional level of government, in: R. Gil-García (Ed.), E-government Success Factors and Measures: Concepts, Theories, Experiences, and Practical Recommendations, IGI Global, Hershey, PA, 2013, pp. 276–298.
[33] A.O. Larsson, Bringing it all back home? Social media practices by Swedish municipalities, Eur. J. Commun. 28 (6) (2013) 681–695.
[34] I. Mergel, S. Bretschneider, A three-stage adoption process for social media use in government, Publ. Adm. Rev. 73 (3) (2013) 390–400.
[35] A. Lovari, L. Parisi, Listening to digital publics. Investigating citizens' voices and engagement within Italian municipalities' facebook pages, Publ. Relat. Rev. 41 (2015) 205–213.
[36] We Are Social, Global digital report, Available at: https://wearesocial.com/global-digital-report-2019, 2019. Accessed on January 2020.
[37] Hootsuite, Accessed on, https://hootsuite.com, 2019. (Accessed July 2019).
[38] Global Web Index, What are your main reasons for using social media? GlobalWebIndex (2019). Q3 2017, https://blog.globalwebindex.com/chart-of-the-day/social-media/. Accessed on July 2019.
[39] B.G. Smith, Socially distributing public relations: Twitter, Haiti, and interactivity in social media, Publ. Relat. Rev. 36 (4) (2010) 329–335.
[40] D. Yates, S. Paquette, Emergency knowledge management and social media technologies: a case study of the 2010 Haitian earthquake, Int. J. Inf. Manag. 31 (1) (2011) 6–13.
[41] P. Meier, Human computation for disaster response, in: Handbook of Human Computation, Springer, 2013, pp. 95–104, 2013.
[42] A.M. Kaplan, M. Haenlein, Users of the world, unite! the challenges and opportunities of social Media, Bus. Horiz. 53 (1) (2010) 61.
[43] B.T. Haworth, E. Bruce, J. Whittaker, R. Read, The Good, the Bad, and the Uncertain: Contributions of Volunteered Geographic Information to Community Disaster Resilience, 2018.
[44] Facebook, Introducing Safety Check, 2020. Accessed on, https://about.fb.com/news/2014/10/introducing-safety-check/. (Accessed 24 January 2020).
[45] Facebook, A New Center for Crisis Response on Facebook, 2020. Accessed on, https://about.fb.com/news/2017/09/a-new-center-for-crisis-response-on-facebook/. (Accessed 24 January 2020).
[46] L. Dwarakanath, #Emergency: role of twitter hashtags during and after a disaster, Int. J. Sci., Eng. Technol. Res. 3 (4) (2014) 948–953, 2014.
[47] UN OCHA, Hashtag standards for emergencies. Technical report. United Nations office for the coordination of humanitarian Affairs, Tech. Rep. (2014), 2014.
[48] CapitanAchab, 20 hashtag per una protezione civile partecipata, Accessed on, https://capitanachab.tumblr.com/post/74053317969/20-hashtag-per-una-protezione-civile-partecipata, 2020. (Accessed 24 January 2020).
[49] V. Grasso, A. Crisci, Codified Hashtags for Weather Warning on Twitter: an Italian Case Study, first ed., PLOS Currents Disasters, 2016 https://doi.org/10.1371/currents.dis.967e71514ecb92402eca3bdc9b789529.
[50] J. Handmer, B. Proudley, Communicating uncertainty via probabilities: the case of weather forecasts, Environ. Hazards 7 (2007) 79–87.
[51] R.E. Morss, J.L. Demuth, J.K. Lazo, Communicating uncertainty in weather forecasts: a survey of the U.S. public, Weather Forecast. 23 (5) (2008) 974–991.
[52] D.V. Budescu, S. Broomell, H.H. Por, Improving communication of uncertainty in the reports of the intergovernmental panel on climate change, Psychol. Sci. 20 (3) (2009) 299–308.
[53] F. Zabini, V. Grasso, R. Magno, F. Meneguzzo, B. Gozzini, Communication and interpretation of regional weather forecasts: a survey of the Italian public, Meteorol. Appl. 22 (3) (2014) 495–504.