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Enhancing two-way communication in disaster management in the EU—practical insights

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With the increase of natural and complex disasters, involving the population as victims or spontaneous helpers, effective risk communication is a central task for disaster relief organizations and civil protection agencies. At the same time, the increasing role of social media and other platforms where citizens can share information present new opportunities (such as making information from affected areas available to disaster relief organizations) but also challenges (such as rapid spread of misinformation). This requires effective two-way communication between organizations and the population, a communication focusing on active listening and interaction to address population concerns and to enhance mutual understanding. In two recently concluded EU Horizon 2020 projects, this challenge has been addressed from complementary perspectives. In PANDEM-2 (Pandemic Preparedness and Response), different conceptions of two-way communication were discussed in interviews and workshops with agencies, media and independent experts to identify ways through which authorities operationalize such communication. Notably, for the pandemic case, comprehensive data spanning different phases of the disaster management cycle were gathered. The project RiskPACC (Integrating Risk Perception and Action to Enhance Civil Protection-Citizen Interaction), employed a co-creative approach to develop technical, conceptual and strategic solutions to enhance two-way communication between citizens and civil protection authorities. Our findings highlight the imperative of co-creative methodologies involving multiple stakeholders including specific citizen groups, building relationships of trust, harmonization of narratives with collaborating entities, knowledge exchange and a careful handling of social media communication.

KEYWORDS

risk communication, pandemic, co-creation, participatory methods, two-way communication

1 Introduction

The 21st century has been marked by a steady stream of natural disasters, global health emergencies, and catastrophic events that underscore the need for effective risk communication. Perceived risk (i.e., the perception of being at risk) among European populations is on the rise, as evidenced by recent risk assessment reports ([World Economic Forum, 2024](#)). In response, governments and public authorities have prioritized risk communication as a critical tool for mitigating harm to citizens and infrastructure. By alerting the public to potential dangers, authorities aim to increase awareness, promote protective behaviors, and ultimately reduce the impact of disasters. However, questions remain about what constitutes “good” risk communication and why it is essential to invest resources in improving it.

One avenue for exploring this issue is the recently concluded EU-project PANDEM-2¹, which was active 2021–2023. The project aimed to improve the EU pandemic preparedness by developing an IT-system prototype and reviewed pandemic communication strategies to support planning, situational awareness and decision-making processes in the EU's pandemic management. PANDEM-2 examined how authorities communicate health protecting behavior and political measures in pandemics, drawing on a series of expert workshops and interviews. The project engaged practitioners in national public health agencies and first responder organizations from eight countries, as well as researchers, prominent scientists and journalists to reflect on their experiences during the COVID-19 pandemic.

The also recently concluded EU research project RiskPACC² focused on increasing disaster resilience in society by taking a closer look at the so-called risk perception action gap, i.e., a mismatch between risk perception and subsequent actions, different risk perceptions especially among citizens and civil protection authorities, and mutual expectations that often do not reflect reality. By taking a co-creation approach, the project aimed to develop a methodology, framework and tools that could help close said gap by enhancing two-way communication, and ultimately minimizing damages to societies by disaster.

Both projects have emphasized the urgent need to strengthen risk communication in non-crisis time, rather than waiting for the next crisis to emerge. Central to these efforts is the shift toward two-way communication. Traditional models of risk communication, which focus on one-way dissemination of information from authorities to the public, have proven insufficient. Effective communication requires not only transmitting clear, actionable messages but also listening to public needs, concerns and feedback. By fostering dialogue, public authorities can build trust, improve message relevance, and ensure that their guidance is accepted and acted upon by diverse communities. This approach lays the groundwork for more inclusive, transparent, and effective risk communication practices in future crises.

The article at hand will take a closer look into the results of both projects and examine their results in terms of effective risk communication. In a first step, a brief overview of most prominent guidelines and frameworks on risk communication will be given, looking into the different needs and challenges in effective communication, as well as possible approaches to address these challenges. Recent developments and current challenges in risk communication from the literature will be specified and it will be examined how they were discussed in a number of PANDEM-2 workshops with communication and public health experts. In a next step, the RiskPACC approach, and specifically how conceptual, strategic and technical approaches co-developed in the project, can address these challenges will be examined.

Thus, this article seeks to answer the following research questions: What are challenges in today's risk communication and what can

be done to address these challenges? How do solutions from the RiskPACC project contribute to addressing these challenges?

2 Why risk communication?

Historically, risk communication has always played a significant role in authorities' preparedness for and reaction to any potential disaster and is a vital part in any risk management strategy (Covello et al., 1989). Over the past few decades, however, researchers and experts have established a more formalized discipline, analyzing their experiences and knowledge of several high-profile crises. One notable crisis relevant for the research field occurred in 1979 in a nuclear power plant in south-east Pennsylvania, what later became known as the Three Mile Island nuclear disaster, at a nuclear power plant owned and operated by the Metropolitan Edison Company (also Met-Ed, now: First Energy Group). During a reactor failure in the power plant, the company was unable to clearly communicate the clear and imminent risk that close by residents were facing. Scientists and company representatives who stepped in front of the media were relying heavily on technical jargon, giving out unreliable information and tried to downplay the danger to residents and the media (Pell, 2020). Official calls for evacuation came days after the meltdown began. Clear communication on the risks and dangers of radiation leaks early on could have prevented confusion and unrest within the public and could have led to appropriate response (like evacuation of vulnerable groups) at a much earlier point in time (Pell, 2020).

Numerous campaigns of risk communication have been employed over the decades to raise awareness of the risks of smoking tobacco. A study from 2018 by Hoover et al. examined how these campaigns fail to reach individuals who are lacking the necessary health literacy, i.e., "the degree to which one has the ability to obtain, understand, and use health information to make appropriate decisions about health and medical care." While in this case the messaging is uniform across all channels (smoking can increase the risk of cancer and thus the chance of death), it is not adequately adapted to all audiences, neglecting the more vulnerable parts of the population (Hoover et al., 2018). In order for citizens to adequately prepare for and react to any type of risk, they first need to be able to understand it. Highly technical messages are only part of the problem causing misunderstanding and misinterpretation (Covello et al., 1988). Not every individual within the population has the same degree of scientific knowledge and understanding. Effective risk communication needs to tailor messages toward their audience and their level of knowledge/scientific literacy (Aven, 2024).

Risk communication, as defined by the World Health Organization (WHO), involves the "real-time exchange of information, advice, and opinions between experts, community leaders, or officials and the people who are at risk," positioning it as a critical component of effective emergency response (WHO, 2017). Its primary goal is to enable individuals at risk to understand and adopt protective behaviors. At the same time, it provides authorities and experts with an opportunity to listen to and address the concerns and needs of affected communities, thereby ensuring the guidance they provide is relevant, trusted, and widely accepted (WHO, 2017). Importantly, the WHO's definition of risk communication moves beyond a one-way flow of information, emphasizing the necessity of

1 EU H2020 project PANDEM-2 – Pandemic Preparedness and Response (02/2021–07/2023).

2 EU H2020 project RiskPACC – Risk Perception and Action to enhance Civil Protection–Citizen Interaction (09/2021–08/2024).

listening to and incorporating public feedback into risk and crisis management strategies.

More broadly, risk communication encompasses the exchange of information about an impending or potential hazard. Its objectives include raising awareness, providing warnings, and offering actionable advice to minimize harm to individuals and groups. According to the United States Environmental Protection Agency's (EPA) SALT (Simple, Actionable, Local, Timely) framework, effective risk communication must be meaningful, understandable, and actionable. The framework emphasizes the value of two-way communication, noting that "risk communication works best when it is a two-way process where the Agency listens to, learns from, and meets the needs of specific audiences." However, it also acknowledges that practical constraints, particularly in emergencies, can hinder this ideal in the short term (U.S. Environmental Protection Agency, 2021).

A 2016 OECD review of its member states' risk communication approaches collects a number of pillars and criteria for effective and sustainable risk communication. Among these, it lists six essential criteria:

1. Consistency: risk information must be consistent across all tools and channels, otherwise leading to ineffective policies or loss of trust in authorities/the sender.
2. Two-way communication: interactive approaches help stakeholders be engaged more actively in efforts of risk reduction. It also aids in gathering feedback on the effectiveness of risk communication tools.
3. Accuracy and trust: communication needs to be fully transparent, using the best available knowledge and articulating the information limits.
4. Accessibility: communication about potential risk must be accessible to everyone, especially to those most vulnerable to the risks.
5. Adapted to audience: while the message should be consistent across all platforms, some groups within a society might require dedicated forms of communication, i.e., language adapted to their needs or addressing their specific vulnerabilities.
6. Cross-sectoral and trans-boundary: risks are rarely simple and thus communication about the risks needs to incorporate information from different sectors, providing the target audience with a complete and clear picture, addressing also possible cascading effects. Since hazards and disasters do not stop at local or national borders, authorities also need to be clear and consistent when communicating with people who regularly cross these borders or live on the other side (OECD, 2016).

The COVID-19 pandemic of the early 2020s has brought renewed attention to the challenges and best practices of risk communication. Extensive research has explored what constitutes effective communication and highlighted pitfalls to avoid (Geurts et al., 2023; Linkov et al., 2024; Warren and Lofstedt, 2022). This body of work provides a wealth of real-world examples, many of which underscore the devastating consequences of ineffective communication, such as misinformation, mistrust, and non-compliance with public health measures. One example is the different communication strategies surrounding vaccination roll-out across Europe in early 2021.

Although hailed as the "light at the end of the tunnel" (WHO, 2020), government authorities and vaccine manufacturers had to take caution communicating the risks of the newly developed vaccines to the public. Even before the pandemic, vaccine hesitancy could be noted as a trend across the world, which has been partly related to low of health literacy in parts of the population (i.e., the ability to understand and use information which promote and maintain good health) and fueled by misinformation (Warren and Lofstedt, 2021). And while the communication around the now-available vaccines were able to address the concerns of many, they often failed to speak to people already experiencing vaccine hesitancy, which only lead to further mistrust and doubt in vaccine-safety (Michelle Driedger et al., 2023).

The EU H2020 project RiskPACC found that people's responses to risks often depend on their perceptions, which can be influenced by various factors, including the way risks are communicated (Mulder et al., 2024). A significant finding from this research is the concept of "elite capture" in risk management, where actions taken by powerful groups to reduce risk can inadvertently exacerbate vulnerabilities for less privileged populations. For instance, large-scale risk reduction measures, while essential, can lead to decreased public risk perception, which in turn may result in complacency and inadequate protective behaviors (Mulder et al., 2024, p. 14). This underscores the importance of communicating risk in a way that balances the need to reassure with the necessity of fostering ongoing vigilance and preparedness.

Effective risk communication requires the utilization of diverse communication channels to ensure that all affected parties are reached (Wendling et al., 2013). Among these, social media has emerged as a transformative force in the field. It enables near-instant dissemination of information and facilitates real-time, two-way communication between authorities and the public. This immediacy is particularly beneficial during crises, where timely updates can influence public safety and emergency response efforts. By fostering participatory engagement, social media empowers citizens to voice concerns and seek clarification, thereby enhancing trust in authorities and scientific experts (Shah and Wei, 2022; Wendling et al., 2013). Moreover, involving the public in this manner can increase acceptance of crisis outcomes, promote transparency, and reduce the financial and logistical costs associated with crisis management.

Social media's role, however, extends beyond information dissemination. It serves as a platform for interpersonal support, enabling people to connect with others in moments of uncertainty. By providing real-time updates and interactive engagement, public bodies can better address the concerns of vulnerable populations, ensuring more inclusive and equitable risk communication. The transparency fostered by social media also strengthens public trust, particularly when organizations provide timely, clear, and accurate information (Wendling et al., 2013).

Despite its potential, the use of social media in risk communication poses significant challenges. One major concern is the increased number of "players" in the communication space. Traditional risk communication often relied on local newspapers or official government announcements, but the current landscape includes a wide array of actors, from global news organizations to independent influencers and content creators. This complexity makes it difficult for public authorities to maintain control over messaging and to ensure the accuracy of information (Wendling et al., 2013). In addition, although social media suggests a way for citizens to directly

communicate with the organizations and authorities, there remains to be a mismatch between the few people behind public social media accounts and the vastly greater number of citizens demanding answers.

The most pressing challenge is the rapid spread of misinformation and disinformation. False or misleading content can spread at the same speed – or faster – than verified information, creating confusion and eroding public trust. Risk communicators must act swiftly to counter misinformation and avoid narrative voids, which can be quickly filled by unverified sources (Palen and Hughes, 2017). The public's heightened expectation for continuous, real-time updates further complicates this task. If authorities delay in providing information, people may seek it from unofficial channels, increasing the risk of exposure to misinformation. This “information hunger” can lead to heightened anxiety and reduced trust in official sources (Palen and Hughes, 2017).

Lastly, social media and other platforms also offer authorities the opportunity to crowd-source information from citizens on a large scale. By receiving information on disasters and risks from a vast variety of stakeholders, authorities can collect information previously unavailable to them. Nevertheless, this approach also requires a large degree of digital competences by authorities as well as literacy by citizens. The danger of collecting false information remains ever present and requires safeguards and validation processes (Chen et al., 2024; Nielsen et al., 2024).

3 Methodology for enhancing two-way risk communication

3.1 Identifying lessons in risk communication with practitioners – approach of the PANDEM-2 project

The PANDEM-2 project analyzed communication strategies in the literature and compared it to the communication practice of public health agencies and first responder organizations (in the following: practitioners), to ultimately provide practitioners in public health with practical, modifiable communication materials. To this end, the project investigated in a series of workshops together with experts and health authorities what pitfalls, lessons learned and recommendations they identified in their institutional communication during the COVID-19 pandemic response.

In the first workshop on 24th of June 2021 (WS1), during the second year of the COVID-19 response, only practitioners in public health institutions, namely from national public health agencies or first responder organizations (i.e., here: national ambulance services) were invited to participate (Overmeyer et al., 2021). Participants included practitioners from Austria, Finland, Germany, Italy, Netherlands, Portugal, Romania and Sweden (PANDEM-2 consortium partners). Discussions centered on key themes such as trust, mis- or disinformation, and two-way communication, and first addressed current communication practice in organizations as well as potential pitfalls in pandemic communication. Secondly, communication recommendations were collected by participants specific for the different steps of the disaster management cycle (preparedness, response, recovery). In the continuation of the project, adaptable communication materials were developed based on the literature and WS1 inputs. These materials were reviewed in a second

workshop on 28th of October 2021 (WS2) and tested in a pandemic management table top exercise with the same participants as in WS1 (Houareau et al., 2025; Kaluza et al., 2022).

A final lessons-learned and innovation workshop was held on 27th of July 2021 (WS3) and included the practitioners who participated in the previous workshops, as well as external experts in pandemic communication. These experts included key opinion leaders of the social media landscape, scientists, communication researchers, infodemic experts & journalists from Netherlands, Ireland, Portugal and Serbia, who added their external view on the institutional communication in their national contexts (in the following: experts). The experts shared insights on what aspects of communication went well, what failed, and what changes are necessary to better prepare for a next global health emergency.

3.2 Co-developing enhanced two-way communication strategies and tools – approach of the RiskPACC project

To efficiently enhance two-way communication among civil protection authorities and citizens, the RiskPACC project developed and implemented a co-creation approach, in order to properly reflect the different needs and perspectives of all stakeholders involved, and to maximize impact regarding the solutions' implementation and take-up by users (including both, civil protection authorities and citizens). The co-creation approach covers all phases of building enhanced communication, i.e., from the analysis of needs, discussion of possible functionalities, up to the actual development, testing and iteratively refining of two-way communication solutions. Most important means of implementing the co-creation approach was a series of workshops within case studies, involving a range of local stakeholders. Targeted participants were selected based on their role in disaster management, representing both pertinent responsible organizations, and possibly affected social groups, including most vulnerable and marginalized groups (Anniés, 2022; Vollmer et al., 2024a).

The workshops included four main phases: In the first phase of a workshop, the ‘Introduction Phase’, the pre-defined workshop structure was explained to the participants, facilitators and participants introduced themselves and the aim of the workshop was discussed and refined. In the ‘Conceptual Phase’, the methodologies to be used were explained to the participants. Methodologies (e.g., participatory mapping, storyboard user stories, co-design of risk communication processes) were selected based on what suited best the needs and objectives. During the ‘Collaboration Phase’, via the selected methodologies, the participants tested and evaluated suggested approaches in small sub-groups and developed ideas for innovative solutions, which they then presented to the other sub-groups. The final phase, the ‘Continuation Phase’, was used to facilitate follow-up communication among workshop facilitators and participants. Workshop facilitators were advised to ensure that all participants have an equal voice during the co-creation process (Anniés, 2022).

The co-creation workshop series in RiskPACC were divided into two phases: “Rapid prototyping” and “Refining.” In the first workshop series on “Rapid prototyping,” workshops in each case study were conducted focusing on the users' needs and requirements and discussing possible solutions and functionalities of possible technical

tools. The workshop results fed into the further development of solutions, which were then tested and iteratively refined in the second phase of co-creation workshops (“Refining”).

Mobile apps and web-based solutions, making use of social media and crowdsourcing, can be one way of supporting two-way communication, while considering restraints such as digital divide or energy and network dependency. A set of such technological tools were co-developed in RiskPACC by implementing the co-creation approach. Complementing this, conceptual solutions, especially dedicated methodologies for the co-creation workshops, were selected, adapted and implemented. In addition, to provide a consolidated conceptual and methodological guide for enhancing collaboration and communication between authorities and citizens, the project has co-developed a respective “collaborative framework” (Vollmer et al., 2024a).

4 Results

In this chapter, selected results from applying the methodologies in the two projects are presented. Chapter 4.1 provides insights on practical experiences in risk communication and practitioner’s recommendations as derived from workshops in PANDEM-2. Chapter 4.2 presents solutions co-developed in RiskPACC that aim to address current needs in risk communication and enhance two-way communication among citizens and civil protection authorities.

4.1 Results from PANDEM-2 workshops

Participants in all workshops generally emphasized the importance of all discussed pillars of risk communication, such as building trust, establishing two-way communication and combating mis- and disinformation. The participants however differentiated in the discussions: while trust was perceived as necessary pre-requisite of successful communication with the population and combating misinformation was an ongoing challenge, the concept of two-way communication was deemed central to devising a communication strategy for civil protection or public health agencies. Secondly, all pillars of risk communication described in the OECD SALT framework were central discussion points in the workshops (OECD, 2016).

In order to build an active relationship with the public, organizations first have to “*Establish yourself as a trusted source to the public*” (WS1). In response to a crisis, practitioners found that this trust is then a central resource, that agencies can to bank on if they have an already existing relationship with the public and building trust thus remains the central need in public risk communication. Consequently, institutional preparedness (as a phase in the disaster management cycle) plays a central role for an effective response. To maintain trust, practitioners advised to “*be a transparent source and as transparent as possible, especially about what you do not know*” (WS1), which proved challenging during the COVID-19 pandemic, as one “*cannot predict how the pandemic will go while also attempting to keep the public trust*” (WS3). A main point to avoid according to the practitioners is to be “*not communicating at all*,” which can leave room for speculations and for misinformation to grow in the public discourse. In a similar way, when organizations are “*not responding to*

fears of the public” or “*ridiculing /dismissing alternative viewpoints*” (WS1) in critical moments of the crisis, they will quickly lose the trust of the public and with it the opportunity to engage with it in an effective way.

The practitioners found that overall “*trust in governance is an essential factor*” and that “*trust in governance and trust in vaccinations were highly correlated*” (i.e., compliance to imposed measures in accordance to the risk communication during the COVID-19 pandemic, WS3). This shows that trust into the communicator as representative of a government organization is always embedded into the current political situation and that organizations communicating risks have to rely on overall good and trusting relations between the government and the public. Moreover, it highlights how the lack of trust can fuel the spread of misinformation, e.g., when there is a “*lack of transparency on data by [the] government*” and how “*misinformation is hard to fight when messages are political*” (WS3). Another pitfall named by participants was “*not communicating on time; not denying false information in due time*” (WS1). Lessons learned by participating health care agencies thus included to “*be the first to communicate*,” to “*respond via the same media in time in two-way communication*” and the advice: “*the information we are sharing needs to be at least as interesting as the rumors*” - “*remember that conspiracy theorists can be coherent in their context as well*” (WS3).

Maintaining consistency in the messaging was hard to achieve in the public COVID-19 pandemic communication, where the public received “*ambiguous and not univocal messages on correct behaviours*” (WS1) in the media and “*when experts disagreed on TV, people got confused*” (WS3). If “*the language used is too difficult to understand for people*” (WS1) or when the message contains too many scientific technical terms, the audience may disengage quickly. This problem accelerated, when there was “*changing information [being communicated] from experts to public*” or when “*scientists did not trust their own data (and communicate that)*” (WS3), which widely created confusion in the public audience. At this stage, organizations needed to realize that in many contexts the audience lacked the relevant health or scientific literacy to follow the complex debate: “*During COVID-19, some experts were surprised of the little public knowledge of how science works*”; “*People do not see how science works which leads to miscommunication /lack of trust*” (WS3). Consequently, several independent experts initiated their communication engagement at this point, providing basic scientific information on virology and epidemiology, which helped to establish themselves as trusted sources or key opinion leaders.

This lack of publicly perceived consistency in the messaging required public health agencies to re-think ways of cross-sectoral communication. While consistent trans-boundary communication was hindered by different analyses, conclusions and protective measures on national (or even state- and community-) level, organizations had to identify supportive communicators in different sectors and thus advised to: “*collaborate between institutions*” and as “*everyone has the same goal so build alliances, i.e., link up with private sector groups to divide the work*” (WS3). A central step identified by participants to address a lack of health literacy was to “*identify key opinion leaders (and create connections)*” (WS1), for them to add to and complement the official health messaging. An added benefit from this was that “*Private citizens can more freely react; as a public agency they have to have certain tone in their communication*” (WS3), which allowed independent communicators to relate to the public better or

to communicate a more nuanced view. The general conclusion of practitioners was that “we need to be more in dialogue: academia, public health and others” (WS3) and that for the future knowledge sharing between actors should be further improved, e.g., via a repository of successful communication strategies, including successful communiqués, memes or infographics.

The practitioners confirmed that they needed to first prioritize accessibility when establishing their communication channels: “have communication materials available on national level that regional/local institutions can use (both for public health and healthcare providers)” (WS1). Participants discussed the need for adaptable tools for communication (guidelines, checklists, press-, social media-, FAQ- and web-information templates) and tested the usability of tools developed in the PANDEM-2 project (WS2; Kaluza et al., 2022). Additionally, to “have simple visually attractive materials, i.e., infographics. With the main message” (WS1) proofed very helpful to gain attention.

The central topic of two-way communication was generally acknowledged as a goal during workshops, but exchanges about new solutions or best practice remained scarce. Participants shared the notion that on social media an “organization [that] does not engage with the public but just posts (like press releases)” (WS1) is not sufficiently committed to engage with the public. In most cases, it remained however unclear, how or how well they were able to interact with the public via their channels. Notably, some organizations stated though that they frequently used social listening methodology, such as CrowdTangle, Emplifi or WHO-EARS (WS3). Yet, in summary, while an established two-way communication with the public is recognized as a goal and practitioners do not lack knowledge on the topic, there is still a need of practical approaches and their implementation.

An established two-way communication is especially important to address vulnerable groups during a crisis: organizations recognized during the COVID-19 pandemic that they needed to “have a plan on how to reach ‘hard-to-reach’ groups and people who are illiterate. Also establish a collaboration and identify collaborators for this topic to get active input from these communities for your preparation plans.” In WS1 the following process was suggested to engage with vulnerable groups: “(1) Identify potential target audiences, (2) Identify which groups are hard to reach and develop specific communication strategies (3) Create networks to reach vulnerable groups (4) Identify a recognizable spokesperson for the group (5) Know where different groups of people get their information from (e.g., which social media channels) (6) Prepare to check that messages are actually received/how they are understood by the target public (e.g., via survey).”

With this process, several organizations were able to share success stories and outlooks: “We had good collaborations with journalists, local religious leaders and also influencers. We need to look for these new and different collaborations.” (WS3). One participant explained how their agency engaged the public in their country: “We had a video blogger which was effective and made interviews with religious groups to better identify, what perceptions are prominent in these groups and how to improve our two-way communication.” (WS3). A second participant added for another country: “We had success with a snowball method: find one community leader and have an open conversation, with no pre-concepts, to identify what hinders a vaccination campaign; when you establish a trusted relationship, there will be more people willing to talk and support. One example: single

mothers were not attending the vaccination centers, as they had no child-care for the duration of the vaccination. The solution was to provide short-term childcare on site” (WS3).

4.2 Co-developed two-way communication tools and strategies in RiskPACC

RiskPACC has developed the following solutions:

4.2.1 Two-way communication technological tools

The Aeolian AR Mobile App is a tool that enables bi-directional communication between civil protection authorities and citizens, including volunteers, during all phases of the disaster management cycle. It allows to share information (e.g., warnings) and media (e.g., photos, videos) and encompasses features like hazard maps, reports, training modules, notifications, and emergency calls. The app aims to provide an accessible and user-friendly format by blending real environments with virtual objects through augmented reality (AR) technology (Azuma et al., 2023; Vito et al., 2023).

HERMES is a social network-like platform, where civil protection authorities can create posts with warnings and weather alerts, while citizens can share their firsthand experiences and insights. Specifically, different communities of citizens can be created, where users, assigned to these communities, receive targeted emergency information. This way, HERMES can provide insight into the community for communicating originations, including information on similar profiles (e.g., specific vulnerable groups) or volunteers. It can help to build stronger connections within the community and facilitate collaboration and resource sharing in times of disaster (Vito et al., 2023).

The Mapping Damage Tool is based on Volunteered Geographic Information (VGI), focusing on floods and wildfires, which enables citizen participation in post-disaster damage mapping as well as in pre-event preparedness assessment. The volunteers refer to individuals with local knowledge, tasked to collect relevant information. The infrastructure of interest includes buildings, roads, and water and fire infrastructure, such as fire hydrants and rainwater manholes. Tasked routine checks on the water and fire infrastructure comprise the pre-disaster section of the tool in the case of both impending floods and wildfires. Post-disaster damage mapping includes reporting the conditions of burned buildings, roads, vehicles, fire hydrants, and manholes (Azuma and Kerle, 2023).

The ThermalComfort Tracker is based on VGI, too. It has been tailored to a specific case study and (only) works in combination with thermal sensors placed across the city. A target group consisting of individuals of different ages within municipal buildings volunteer to provide information about their age, gender, etc., as well as the current thermal state and the desired change in thermal state. Combined with data from the sensors, the results facilitate an understanding of perceptions regarding thermal comfort. The tool is designed to better understand citizen perceptions of heatwave situations, and the relationship between subjective perceptions and objective thermal indicators (Azuma and Kerle, 2023).

The PublicSonar tool can be used by civil protection authorities to extract important information from huge amounts of data on

social media websites. It allows sentiment analysis, i.e., to analyze digital text to determine if the emotional tone of the message is positive, negative, or neutral. By using artificial intelligence (AI) and natural language processing (NLP), the tool allows to measure citizen's emotional perception to a given event and can help civil protection authorities in early warning and comprehensive situational awareness.

4.2.2 Collaborative framework and conceptual approaches for enhancing two-way communication

To provide a consolidated conceptual and methodological guide for enhancing collaboration and communication between authorities and citizens, the RiskPACC project has developed a Collaborative Framework. It aims to build or strengthen capacity in authorities and citizens on how to best collaborate in disaster risk management (DRM), in an inclusive and context-specific manner. It shall promote trust and mutual understanding, and enable stakeholders to identify suitable existing strategies, methods and tools, as well as to develop own tailored solutions (Mulder et al., 2024).

The framework comprises four main modules, (1) *Understanding*, (2) *Sharing*, (3) *Relating*, and (4) *Building*. The module (1) *Understanding* serves to jointly enhance or develop an understanding of the local risk and social-political contexts. In (2) *Sharing*, civil protection authorities and citizens share risk perceptions and mutual expectations in risk management. Module (3), *Relating* targets constructive relationships between civil protection authorities and citizens, and in the module (4) *Building*, civil protection authorities and citizens jointly build effective risk communication tools and strategies. Related to each module, the framework document (Mulder et al., 2024) provides a list of resources, i.e., documents, strategies, tools or methods that already exist and that can contribute to specific objectives of the framework module. They address civil protection authorities, or citizens, or both, and can be selected according to the local context, specific goals and needs.

Targeting a valuable overview of such resources for civil protection authorities investigating a suitable approach for their specific city, municipality or region, a methodology for a Repository of Good Practices has been developed (Düerkop et al., 2023). The methodology foresees that resources are suggested by users and then evaluated along pre-defined assessment criteria. The derived criteria encompass (a) technical criteria, including aspects of accessibility and usability, (b) socio-ethical criteria, including aspects of privacy and non-discrimination, (c) governance criteria, including aspects of vertical governance structure, horizontal governance structure, and “governance and the governed,” (d) communication criteria, including aspects of multi-directionality, efficiency and uniformity, and finally (e) operational criteria, including aspects of community engagement, transparency and applicability. Exploring evaluation results of these assessment criteria related to different practices can help a user to identify a good practice that is most suitable to the specific case (ibid.).

The collaborative framework also comprises a staged approach, which takes account of the diverse levels of experiences that authorities have regarding the extent to which they engage citizens in DRM. These levels range from no citizen engagement up to community organizations being in the lead of DRM strategies and activities. The framework includes specific guidance for each stage, i.e., approaches to reach the next higher stage (Mulder et al., 2024).

Further, the collaborative framework is supplemented with a dedicated Framework Guidebook (Gatsogianni, 2024). Next to key points of each framework module and the Repository of Good Practices, the guidebook includes, amongst others, guidelines for communication. Guidelines for communication – building on experiences from case study representatives – are provided for civil protection authorities on how to generally improve communication with citizens as well as guidelines for civil protection authorities on how to effectively communicate with specific social groups, namely the elderly, children, and immigrants. In addition, guidelines for citizens to enhance their preparedness as well as for volunteers on how to communicate effectively with civil protection authorities and citizens are included (ibid.).

Within RiskPACC, while implementing and further developing the co-creation approach (see chapter 3.2), specific workshop methodologies have been adapted such as:

The Participatory Mapping Lite exercise addresses the Understanding, Sharing and Relating modules of the collaborative framework, through facilitated discussions and activities amongst civil protection authorities and citizens. To distinguish this exercise, which prioritizes the engagement and co-production of knowledge among participants, from traditional mapping projects, which focus primarily on the identification and visualisation of risks and hazards, it is called “Participatory Mapping Lite” (Gatsogianni, 2024).

The Risk Communication exercise addresses the Building module of the collaborative framework, and aimed to provide a flexible solution for workshop facilitators, i.e., case study partners, within their own specific context. Objectives of the exercise include enabling civil protection authorities to communicate an identified risk to citizens, and to provide a respective structured space for dialogue. In addition, the exercise aims to identify most suitable forms of risk communication to help citizens take the appropriate risk reduction measures. Finally, the exercise addresses the need to co-create, and build a trusting relationship (Gatsogianni, 2024; Vollmer et al., 2024b).

An online platform was developed to provide access to and/or descriptions of these solutions, and also offers comprehensive guidance and training material. Mirroring the online platform, a physical version has been developed, with a board game as its central piece. Applying the board game, stakeholders including civil protection authorities and citizens can jointly identify the most suitable solutions for addressing their pertinent needs (Düerkop et al., 2024).

5 Discussion and Conclusion

Both the PANDEM-2 and the RISKPACC projects aimed to improve our understanding of two-way communication to enable civil protection agencies to better employ risk communication strategies, but both projects built on different methodologies and offered different tools. PANDEM-2 analyzed communication strategies of different domains in the literature and established a series of workshops with communication practitioners in public health as well as external experts. In the workshops, a series of recommendations and lessons learnt were collected, mainly building on experiences responding to the COVID-19 pandemic crisis. Recommendations from practitioners, experts and literature were summarized in practical, modifiable communication templates and guidelines.

RiskPACC implemented a series of workshops, too. However, these workshops mainly addressed local representatives of civil protection authorities as well as citizens. Applying a co-creation approach, they served to jointly discuss and develop suitable solutions to enhance two-way communication. The RiskPACC solutions – technological tools, collaborative framework and conceptual approaches – aim to address the diverse needs and recommendations such as those identified in PANDEM-2.

Considering the research questions, i.e., *What are challenges in today's risk communication and what can be done to address these challenges? How do results from the RiskPACC project contribute to addressing these challenges?* this chapter reflects on results from the PANDEM-2 workshops (chapter 4.1) in context of the principles and challenges of risk communication derived from literature (chapter 2), and in how far results from RiskPACC (chapter 4.2) address these challenges.

The principles of risk communication were widely known by public health agencies and responder organizations participating in the PANDEM-2 workshops, where most public health organizations directly adopted the WHO definitions, i.e., to both listen to and address the concerns of affected communities (WHO, 2017). Moreover, action fields identified in the workshop discussions closely aligned with the principles of the (EPA) SALT framework (U.S. Environmental Protection Agency, 2021), particularly following the S = Simple “*have simple visually attractive materials, i.e., infographics*” (WS1), A = Actionable: “*keep it simple and action oriented: main point, what do you want people to do and why, repeat*” (WS1) and T = Timely: “*be the first to communicate*” (WS3). Curiously, the L = Local required most time and attention in the communication, as messages needed to be embedded into a national local context or even needed to be tailored to local contexts of particular population groups. In practice this meant, that first understanding and analyzing the local context(s) to reach certain groups and identify vulnerabilities was a very demanding task, which had the potential to overwhelm the institutions. Many organizations further had to realize during the COVID-19 response, that approaching vulnerable groups was only a first step, but that they needed to start build and maintain a relationship with local community leaders, a task where some were more successful than others (WS3). Here, it became apparent how important it is to foster such relationships beforehand and to find practical approaches to include population representatives into the process of developing communication strategies.

The local level was a general focus in RiskPACC, where solutions were co-developed in five local case studies (plus one global pandemics case study). Thus, implementing the co-creation approach required involving local stakeholders, and the co-developed solutions mainly serve the local level. The *Understanding* module of the RiskPACC collaborative framework includes specific questions on identifying the relevant social groups as well as the most vulnerable groups, also offering respective resources that can support the necessary *Understanding* process (Mulder et al., 2024). For reaching certain groups, the HERMES tool offers a technical channel. People can assign themselves to pre-defined groups on the platform, and receive targeted information. This bilateral communication function provides direct connection to people vulnerable to specific hazards, facilitating targeted support in case a respective hazard occurs. Restrictions are seen in the required registration, and thus accessibility for those who lack the necessary interest, skills or knowledge. In some cases, this may

be overcome by allowing third-party users to register and/or access the platform for them (Vito et al., 2023). The ThermalComfort Tracker can support better understanding perceptions and impacts of heatwaves, especially on people vulnerable toward heat. However, the tool only works in combination with sensors (Azuma and Kerle, 2023). In general, it is recommended to identify vulnerable groups, engage with them, develop targeted communication strategies and possibly utilize family or other trusted persons (Gatsogianni, 2024; Mulder et al., 2024). In addition, the co-creation methodology includes specific recommendations for the inclusion of vulnerable groups or their representatives in the co-creation process (Anniés, 2022). This is of course also true for other population representatives, to jointly co-develop suitable solutions. Regarding local community leaders, the RiskPACC collaborative framework, too, advises to “support effective local leaders who can facilitate dialogue, build consensus, manage power dynamics, and enable marginalized groups to participate effectively” (Mulder et al., 2024, p. 55) and to build and maintain respective relationships.

While some pillars of risk communication according to the OECD framework (OECD, 2016), like accessibility, audience specificity, consistency and cross-sectoral alliances were addressed by participants of the PANDEM-2 workshops with lessons-learned or clear advice, others remained a great challenge. The first main criterion of the OECD framework, consistency, was only indirectly addressed in RiskPACC: By co-developing risk communication approaches, involving all relevant stakeholders, consistency should be assured. Regarding the second main criterion of the OECD framework, two-way communication, all organizations and experts in the PANDEM-2 workshops acknowledged the need for actual two-way communication, following the WHO postulate to address peoples' concerns regarding a risk or crisis (WHO, 2017). As described, enhancing two-way communication has been a main objective of the RiskPACC project, and thus, all solutions described in chapter 4.2 can potentially facilitate two-way communication, be it conceptually, strategically, or technologically. Considering the third main criterion of the OECD framework, accuracy and trust, the PANDEM-2 workshops showed that building and maintaining trust can rarely be done just for the own institution, as the institution, particular when it is a government agency, is embedded into the current political context and may not be perceived as independent voice in a crisis but rather as a face of the government. In addition, some organizations found themselves under dual pressure, as they could not contradict their superior minister yet needed to maintain a “*certain tone in their communication*” (WS3), while also being targeted by actors seeding disinformation. Consequently, though maintaining trust was a clear goal for organizations, it remained partly out of their control. This is where several organizations found great value in building alliances with external communicators, e.g., journalists, scientists or other non-governmental communicators who build an independent standing in the public to communicate risks and mitigating behavior. The lack of health literacy (i.e., the audiences ability to understand and adequately react to health advice) as already described by Hoover et al. (2018), remained a continuous challenge for public health practitioners. Here, linking up with external communicators who filled this gap proved extremely valuable. In RiskPACC, building trust was recognized as an essential requirement and was generally addressed by a variety of approaches, including the co-creation workshops, other participatory approaches and initiatives to build relationships (such as

dedicated steps in the *Relating* module of the RiskPACC collaborative framework). The accessibility criterion of the OECD framework, was also recognized in RiskPACC, where actions were taken to overcome respective hurdles such as limitations in participating to co-creation workshops or using a technological tool, e.g., by addressing third-party persons as mentioned above. The fifth main criterion of the OECD framework, adapted to audience, was addressed, e.g., via the approaches on involving specific social groups as mentioned above, or by translating co-developed tools (AEOLIAN and HERMES) to the case studies' language (Vito et al., 2023). The final criterion of the OECD framework, cross-sectoral and trans-boundary, was not directly addressed in RiskPACC. It can however be addressed by properly identifying the specific social-political context as well as the relevant groups to be involved. Further, while an implementation of the solutions in non-EU contexts has not been specifically analyzed, they are presumably generally adaptable into non-EU contexts.

While other authors hailed the opportunities of two-way communication when utilizing social media to empower citizens to voice concerns and seek clarification (Shah and Wei, 2022; Wendling et al., 2013), in reality most practitioners contributing to the PANDEM-2 workshops were overwhelmed with the task in adequately monitoring social media, to counter misinformation. This first has to do with the simple fact that a small communication team in an organization is never able to engage in a one-to-one conversation with a whole population. Additionally, many discussions on social media develop after business hours, where people spend more time in their networks, where it can be crucial to rectify otherwise run-away misinformation in online debates. Here, technical tools for social listening can be an aid (WS3), but may lack wide-scale implementation. This might be even more critically relevant in an extended crisis, such as a pandemic, where continuous messaging is necessary. In any case, enlisting the support and aligning with external communicators can benefit the official communication strategy, much in line with the WHO framework (WHO, 2017).

The impossible task of reacting to all messages remained a challenge for RiskPACC solutions as well. However, other approaches such as continuous effective communication and trust building initiatives may reduce the risk of wide-spread misinformation. In addition, the PublicSonar tool, facilitating the assessment of huge amounts of data from social media, can provide a basis on suitable and targeted response measures to counter misinformation.

While PANDEM-2 and RiskPACC were originally not designed to build on each other, this work shows that even though one project focused pandemics, whereas the other one followed an all-hazards approach, common elements and challenges are shared. In sum, it can be noted that RiskPACC solutions are in general suitable to address challenges in risk communication as identified in literature and by practitioners in PANDEM-2. However, the significant challenge remains on effectively, thoroughly and widely spread solution implementations. A major challenge concerns limitations of time and resources, even already during a project's run-time, but especially after a project has ended and continued funding is lacking. In addition, the tools developed within a project often reach a stage (according to funding requirements) in which they are not completely ready to use and/or market ready. It thus remains imperative to build on, adapt and further develop prototype developments for two-way communications from projects such as PANDEM-2 and RiskPACC.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

MV: Conceptualization, Methodology, Project administration, Writing – original draft, Writing – review & editing. MO: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. BK: Conceptualization, Methodology, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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