Bulletin of Geophysics and Oceanography Vol. XX, n. X, pp. XXX-XXX; Xxxxx 20xx
DOI 10.4430/bgo00488

Seismic risk communication in Europe: trends and effectiveness evaluation

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(Received: 15 September 2024; accepted: 19 February 2025; published online: 4 April 2025)

ABSTRACT Seismic risk communication (SRC) is a crucial element of disaster risk management, vital for enhancing awareness and fostering preparedness. In this study, we build on insights from a scoping review of SRC in Europe from 2000 to 2022. Our findings highlight the evolution of approaches, tools, and models in SRC across Europe, confirming the surge in interest since 2000. We extend previous research by analysing the increasing trend in SRC publications and by providing an overview of how communication effectiveness is evaluated. While, particularly in Europe, there is a clear upward trend in the volume of publications about SRC, our review of 109 papers shows that only 48 evaluated the effectiveness of communication strategies. Those that did primarily employed quantitative methods, such as surveys, while qualitative approaches were underused. Critical factors like recipient understanding of seismic vulnerability and the credibility of information sources were often overlooked. Overall, the assessment of communication effectiveness remains inconsistent and underexplored, underscoring an urgent need for more comprehensive and standardised evaluations in future research.

Key words: seismic risk communication in Europe, publication trends, communication effectiveness, participatory models, qualitative assessment.

1. Introduction

Seismic risk communication (SRC) plays a crucial role in disaster risk management by raising awareness, promoting preparedness, and encouraging communities at risk to take protective actions. Over the years, international frameworks such as the Sendai Framework for Disaster Risk Reduction 2015-2030 (UNISDR, 2015) emphasised the importance of tailored, inclusive communication strategies.

In a comprehensive scoping review, we analysed the characteristics of SRC in Europe over the 2000-2022 period through the examination of 109 papers (Musacchio *et al*., 2023). Our study found that scientific attention to SRC has increased significantly since the early 2000s, especially after the implementation of international frameworks such as the Hyogo Framework for Action 2005-2015 (UNISDR, 2005) and Sendai Framework (UNISDR, 2015) (Fig. 1).

The analysis looked at different aspects of SRC, including the approaches, messages, tools, and channels used, and how these have evolved over time. A graphical summary of the results

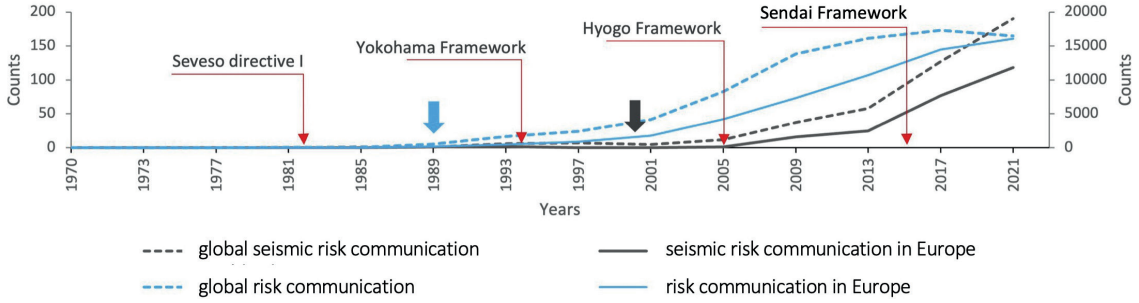

Fig. 1 - Trends in SRC publications over time. The data are obtained from search on Google Scholar, applying the filters "find articles with the exact phrase" and "anywhere in the article". The research covered Europe, the United States, California, Mexico, Asia, and Japan. The number of publications on risk communication (right y-axis) and SRC (left y-axis) are shown for both Europe and the world. While publications on all risks in Europe and globally begin nearly simultaneously in 1989 (blue arrow), it takes over 18 years for SRC to show a parallel growth (black arrow). Key international frameworks - the Seveso Directive I (in 1982), Yokohama Strategy and Plan for Action for a Safer World (IDNDR, 1994), Hyogo Framework (UNISDR, 2005), and Sendai Framework (UNISDR, 2015) - are included as reference points (from Musacchio *et al*., 2023).

provided in our review study is shown in Fig. 2. The primary objectives over the past two decades have been to share information, raise awareness, change behaviours and beliefs, and enhance preparedness, with most communication efforts occurring during the pre-crisis phase of the disaster lifecycle (Fig. 2a). This phase is crucial for building risk awareness and improving the ability of communities to cope with hazards. Pupils, students, and citizens emerged as the main recipients of these communication activities.

Over the years, two-way, transdisciplinary, and bottom-up communication models [see Stewart *et al*. (2023) for a definition of communication models] have increasingly replaced the traditional one-way model (Fig. 2b). Our research has also documented a notable shift towards more interactive and participatory approaches that actively involve communities in the communication process (Fig. 2c). In addition, there is a growing emphasis on encouraging proactive behaviours rather than simply informing the public. The favoured means of communication are face-to-face conversations, hands-on activities, and serious games (Fig. 2d). The study also emphasises the increasing importance of social media to reach different audiences, provide timely and actionable information in times of crisis, and encourage citizen engagement. Nevertheless, we found that earthquake risk communication practices vary widely across European countries (Fig. 2e). Cultural and geographical factors play a pivotal role in shaping these practices. Therefore, it is not surprising that European countries require different communication strategies. For example, Musacchio *et al*. (2019), in their establishment of communication strategies implemented in three pilot areas (Portugal, Iceland, and Italy) as part of the KnowRISK project, highlight the distinct characteristics influencing each country's approach. These include differences in hazard ranking, earthquake recurrence, time since the last damaging event, building construction, building code enforcement, type and relevance of damage, level of implementation of protective measures, and cultural attitudes towards prevention. Consequently, the cited authors recommend the application of the Knowledge-Attitude-Practice approach, which emphasises the understanding of the knowledge and attitudes of the target audience in order to design effective communication strategies (NSET, 2017).

Building on our earlier scoping review, in this paper we extend our work with a new analysis to delve into the growth of SRC publications over time and examine the effectiveness evaluations of SRC strategies. For this analysis, we relied on the same sample of papers shortlisted in the

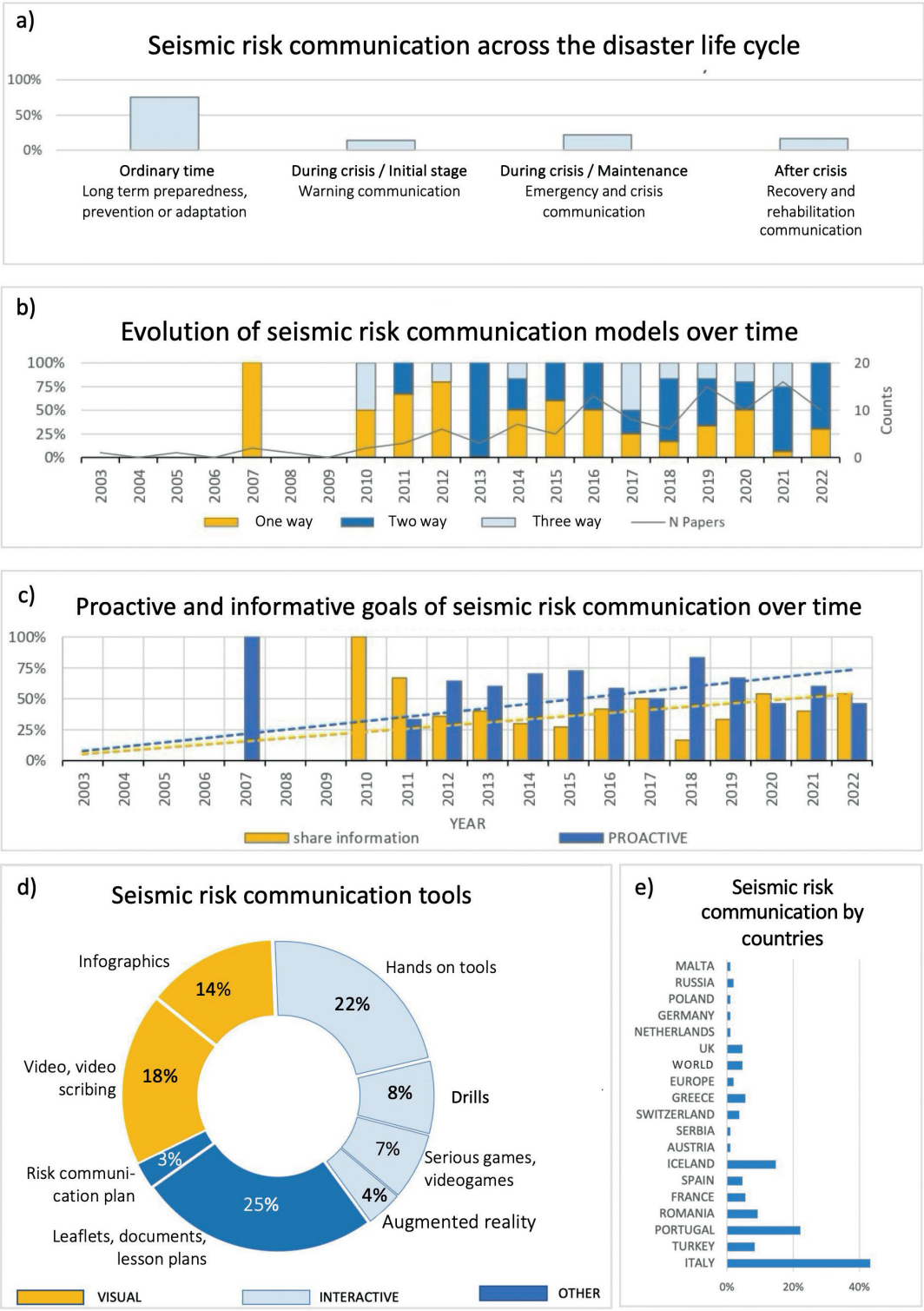

Fig. 2 - Main findings of our scoping review on SRC: a) the main phases of the disaster life cycle in which earthquake risk communication is applied, as identified in the analysed publications; b) the evolution of communication models over time; c) the reported objectives of the communication efforts; d) the communication tools used; e) the geographical distribution of the case studies in the selected publications (adapted from Musacchio *et al.*, 2023).

original scoping review, but we collected and analysed new data (e.g. on communication effectiveness). While our literature review was limited to publications up to 2022 to maintain a clear and focused scope, we recognise the rapid advancements in risk communication, including the integration of emerging technologies and innovative participatory approaches (e.g. Dallo *et al*., 2024; Faravelli *et al*., 2024; Gargiulo *et al*., 2024). These developments underscore the dynamic nature of the field and highlight the need for continued research to stay aligned with these evolving trends.

In the following sections, we present a statistical analysis of the growing trend in publications and attempt to determine whether the growing interest in SRC in Europe shows a genuine increase in engagement or simply mirrors the general increase in academic publications. In addition, we provide an overview of how the effectiveness of these communication efforts has been evaluated, describe our methodology, and summarise our main findings.

2. Evolution of seismic risk communication publications over time

In our earlier work, we examined global and European trends in general and in SRC, and analysed how these areas have evolved over time (Fig. 1). The documents collected from Google Scholar, covering the period from 1970 to 2021, show a steady increase in publication numbers, with a notable increase after 2000 in all categories of risk communication. We found that, although it is gaining momentum, SRC still lags behind general risk communication in terms of publication volume, especially in Europe (Musacchio *et al*., 2023). Around 2010, a significant increase in publication rates can be observed in all categories, indicating an acceleration of the field. This trend may be related to increased risk awareness, advances in communication technologies, and better funding opportunities, or it may simply reflect the general global expansion of academic publishing.

Over the last 20 years, the number of scientific publications, including reviews and original papers, has significantly increased (e.g. Fire and Guestrin, 2019). This growth is evidenced by quadratic patterns in academic databases such as Scopus (R^2 = 0.993), Web of Science (R^2 = 0.994), and PubMed (R^2 = 0.995), with an average annual growth rate of 5.08% in scientific literature since 1952 (Bornmann *et al*., 2021).

Given the general rise in publications across all disciplines, field-specific growth rates can sometimes be obscured. To address this, various methods have been developed to adjust for overall trends by comparing discipline-specific growth with the broader publication landscape [see e.g. Nelis *et al*. (2022) and references therein]. To better understand the factors driving the rise of SRC, we have analysed how publication trends in this area compare with those in risk communication more generally.

A simple way to quantify the relative growth trend is by calculating the S_{trend} ratio, which compares the slope of the field-specific publication trend to the slope of the overall publication output. According to this metric, a S_{trend} value less than 1 indicates a relative decrease in field-specific output, a value of 1 suggests no change, and a value greater than 1 signifies an increase in field-specific output relative to the total output. To enable a clear comparison of trends across different fields and with the overall publication output, publication rates are often normalised to a 1–100% scale (Nelis *et al*., 2022). However, this approach is not always suitable, as growth patterns can vary (linear, quadratic, or exponential) making direct comparisons with general publication trends more complex. Alternative methods, like the General Growth Tendency, adjust for inflation and calculate field-specific annual growth rates (Nelis *et al*., 2022). Despite

these improvements, comparing trends across fields with vastly different publication volumes remains challenging. This is particularly true for smaller fields like SRC, where the lower number of publications can result in more pronounced fluctuations, leading to less stable or reliable results. For such a reason, and after a first attempt to apply this method with scarce results, we preferred to quantify the relative SRC growth trend by simply calculating the S_{trend}.

At the beginning of our analysis, we focused on the data presented in Fig. 1 and specifically examined the period from 2000 to 2021, when, according to the documents found in Google Scholar, publications on earthquake risk communication became increasingly important. Recognising that our results can be influenced by the choice of database, search terms, and search field, we extended our publication search to Scopus, which offers a more precise selection of search fields (i.e. title, keyword, abstract). The database, search terms, and corresponding fields used for each query are listed in Table 1. In our recent searches, publications on SRC related to European countries may have been underrepresented. The inclusion of the term "Europe" in the search string did not consistently produce relevant results, but results varying across fields.

Table 1 - Overview of the search parameters applied to find publications. Fig: query case plot representation; Database: databases where the publications were searched; Field: fields within the databases where the search strings were applied; String: search strings in the database: ETQ+SEIS (Earthquake and Seismic), RC (Risk Communication), RC EU (Risk communication in Europe), SRC (Seismic Risk Communication); ERC (Earthquake Risk Communication), SRC EU (Seismic Risk Communication in Europe). For each string the slopes (*S1-S6*) obtained from linear interpolation of search results are reported, as shown in Fig. 3.

Fig.	Database	Field	String					
			ETQ+SEIS ***S1***	**RC** ***S2***	**RC EU** ***S3***	**SRC** ***S4***	**ERC** ***S5***	**SRC EU** ***S6***
3a	Google Scholar	All		3.8	4.7	4.8		5.0
3b	Scopus	Title	2.9			3.1	3.0	
3c	Scopus	Keywords	4.2	3.5		4.4		
3d	Scopus	Abstract		3.6	3.5	4.3		4.5

To enable meaningful comparisons between the numbers of publications retrieved by different search queries, we normalised the data on a scale of 1–100. For each search query, we plotted publication trends over time and performed a linear regression analysis from 2000 to 2021. The regression equations and the corresponding R-squared values, which show how well the data fit the regression model, are shown in Fig. 3. The slopes of these regression lines, labelled as *S1*, *S2*, *S3*, *S4*, *S5*, and *S6*, are shown in Table 1 and were used to calculate the corresponding S_{trend} values.

We computed different S_{trend} values for each query case to capture variations due to the use of different databases or search terms. To quickly identify the emerging discipline from our analysis, it is sufficient to identify the highest S value in each row of Table 1. Our analysis shows that SRC always has the highest trend both globally (*S4*) and within Europe (*S6*). This indicates that scientific interest in the field of SRC is increasing over time, especially in Europe, independently of the general increase in publications related to risk communication and seismic or earthquake-related topics.

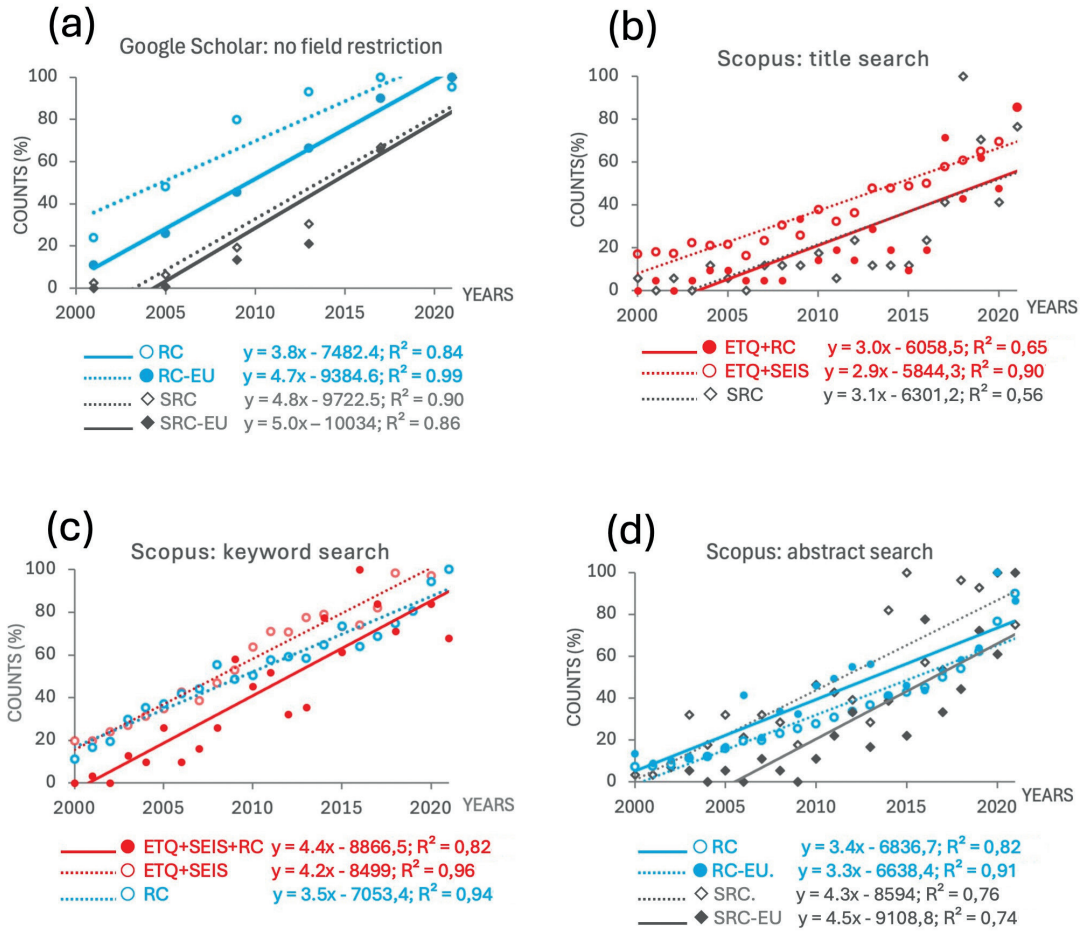

Fig. 3 - Number of publications (counts) from 2000 to 2021 using different search terms as indicated in Table 1. The publication counts are normalised to their maximum value and scaled to 100 for better comparability. For each search term, the data are linearly interpolated, and the resulting regression equations are given together with the R-squared values: a) publications for the search terms SRC, SRC EU, RC, and RC EU found in the Google Scholar database without field restrictions; b) publications for the strings ETQ+SEIS, SRC, and ETQ RC found in the Scopus database (title search); c) publications for the strings ETQ+SEIS, ETQ+SRC+RC, and RC found in the Scopus database (keyword search); d) publications for the search terms SRC, RC EU, RC, and SRC EU found in the Scopus database (abstract search).

3. Effectiveness of seismic risk communication

Of the 109 publications shortlisted by Musacchio *et al*. (2023), less than half included an assessment of the effectiveness of communication, with only 48 directly addressing this aspect, as detailed in Annex 1. The small number of studies offers only a partial understanding of how the effectiveness of SRC has been addressed thus far. To enhance the insights gained from the scoping review (Musacchio *et al*., 2023), we employed binary or multiple response options to assess the evaluation approach described in the papers.

We examined four key aspects of evaluation (Fig. 4): the methodologies and tools used, the timing of the effectiveness assessments, and their impact on recipient knowledge and behaviours. We first investigated whether researchers prefer quantitative over qualitative methods, then closely examined the specific tools and techniques used. Additionally, we assessed the timing

of the evaluation, whether conducted immediately after communication activities or at a later stage. This temporal perspective is crucial for understanding the long-term effectiveness of SRC and its sustained impact on recipients.

To gain further insights into the assessment process, we identified five key parameters that define the tools used to assess the effectiveness of SRC:

- the use of custom-designed questionnaires,
- structured or unstructured interviews,
- round table discussions or workshops involving communication recipients,
- focus groups addressing specific aspects of the communication,
- other tools employed during the assessment.

We, then, categorised the 48 papers according to several criteria to determine which aspects of communication were deemed most valuable by scientists and practitioners. Specifically, we assessed whether:

- the assessment measured recipient general understanding of the concepts and practices presented during the risk communication,
- it evaluated recipient understanding of key elements like hazard, risk, vulnerability, and their adoption of safety-enhancing behaviours,
- the evaluation included an assessment of the credibility of the information sources used in the communication.

Our analysis revealed several important findings. Firstly, the majority of risk communication effectiveness evaluations rely on quantitative methods (73%; Fig. 4a), with questionnaires being the most commonly used tool (65%, see Fig. 4b). While qualitative methodologies are less common (27%), they can still provide valuable insights. For example, Tekeli-Yesil *et al*. (2020) investigated information-seeking behaviour related to SRC 21 years after the 1999 M_w 7.6 Izmit earthquake in Turkey. Their study used focus groups with younger individuals, who lacked first-hand experience of the event, and older generations who lived through it. This approach highlighted how past disaster experiences shape the effectiveness of risk communication and demonstrated the importance of building collective memory through ongoing communication efforts. Similar results were found by Peruzza *et al.* (2018), who investigated the memories of the M_S 6.5 1976 Friuli earthquake, among young people living near the affected area.

Most of the evaluations were conducted long after the communication activities (Fig. 4c), indicating a growing interest in assessing the long-term impacts of these efforts.

When examining the content of these evaluations, no single factor was notably more prevalent than others (Fig. 4d). Yet, the most frequently assessed aspects are, in decreasing order: general receiver understanding, protective behaviour understanding, seismic hazard, and risk understanding. On the contrary, recipient understanding of seismic vulnerability and the credibility of information sources are the least frequently assessed elements. Fewer than 20 out of 48 papers considered these factors crucial for evaluating the effectiveness of SRC. Despite their fundamental importance, these aspects are often overlooked, indicating a significant gap in the evaluation of communication effectiveness.

Concerning the credibility of the information sources, we found, for instance, that some authors incorporated a question regarding the source of information in their assessment questionnaire, signalling the importance of understanding the origin of the information (Herovich *et al*., 2020). Others addressed the credibility of sources with the aim of addressing the pervasive problem of misinformation and fake news that can distort the public's understanding of important issues. Tekeli-Yesil *et al*. (2020) embedded source evaluation into the process of information seeking, emphasising that the way people seek and evaluate information is as crucial as the content they access.

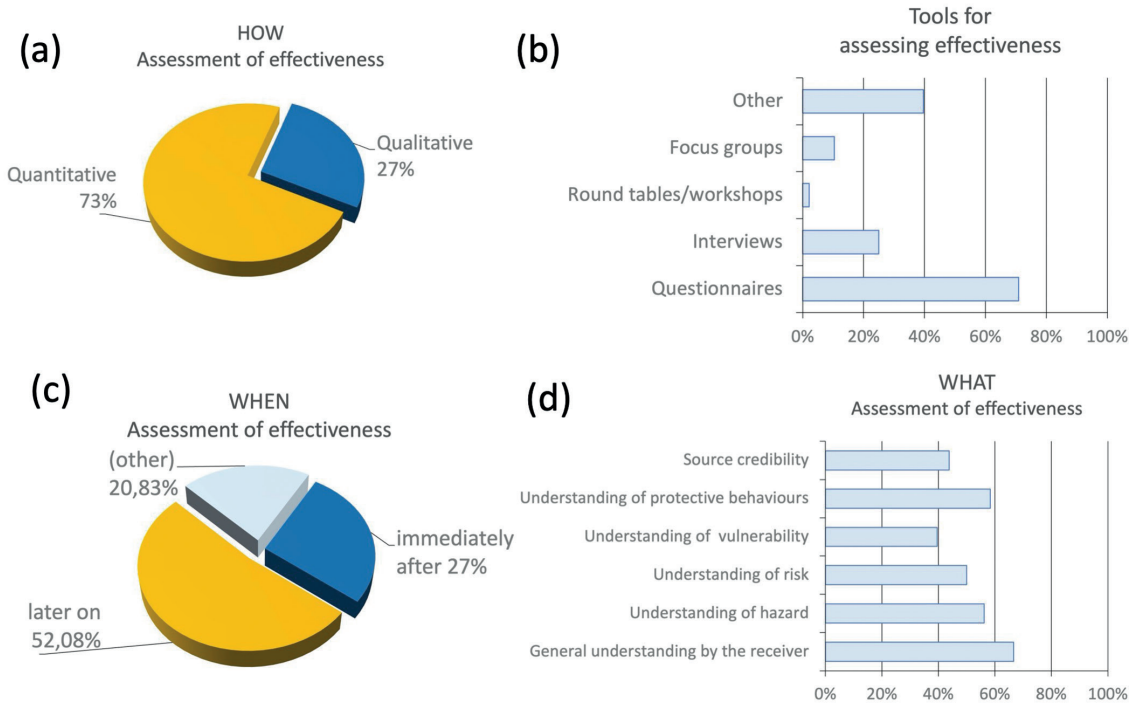

Fig. 4 - Parameters analysed to assess the effectiveness of SRC: a) the type of assessment (qualitative or quantitative); b) the assessment tools used; c) the timing of the assessment; and d) the specific aspects of communication that were assessed.

4. Discussion

4.1. Evolution of seismic risk communication publications over time

The growing interest in SRC in Europe is underscored by the increasing volume of scholarly publications and the adoption of advanced communication models. Our analysis using the S_{trend} ratio demonstrated substantial growth in SRC both globally and within Europe, indicating a significant rise in interest in this field. This metric shows an increase in SRC, particularly in Europe, despite the overall growth in related disciplines. However, the S_{trend} approach does not capture short-term variations or diverse growth patterns, highlighting the need for more nuanced methods to accurately assess discipline-specific trends. Understanding the historical and social context in which these publications emerged is crucial. Although a direct cause-and-effect relationship cannot be definitively established, key milestones such as the Yokohama Strategy (1994), the Hyogo Framework for Action (2005–2015), and the Sendai Framework for Disaster Risk Reduction (2015–2030) have likely played a significant role in shaping the growing focus on SRC. Similarly, major seismic events, including the Izmit earthquake (in 1999) and the L'Aquila earthquake (in 2009), have underscored the critical need for effective communication strategies, catalysing research to address pressing societal demands. In Italy, the historical and social landscape has been profoundly influenced by the 2002 San Giuliano di Puglia earthquake (M_W 5.7), which tragically claimed the lives of 26 schoolchildren and their teacher. Even more transformative was the judicial trial of scientists in the aftermath of the 2009 L'Aquila earthquake (M_W 6.3), which brought SRC to the forefront of public and scientific debate. This pivotal moment

significantly redefined approaches to communicating seismic risk, as documented in studies such as Jordan *et al*. (2011) and Herovic *et al*. (2014).

These observations emphasise the importance of situating SRC research within its broader socio-historical framework. Future studies that delve deeper into the interplay between societal challenges, policy developments, and seismic events could offer valuable insights into how these factors have shaped and continue to shape the evolution of this critical field.

Equally important as future research area is the evolution of international and national SRC policies over time and the analysis of the key drivers of change. This qualitative research can contribute to a better understanding not only of the observed changes in publications, but also of the role played by scientific knowledge, expertise, events, and policy advocacy on risk communication pathways and models.

Cultural and geographical factors also play a pivotal role in shaping communication strategies, which often need to be tailored to specific regional contexts across Europe. Recognising and addressing these variations could help develop SRC approaches that are better suited to local needs and circumstances. Investigating these dimensions further would provide valuable insights into how strategies can be adapted to enhance their practical applicability and overall effectiveness in diverse European settings.

4.2. Enhancing evaluation frameworks for seismic risk communication

Our study also provides an overview of the aspects that are considered when evaluating the effectiveness of seismic communication. One of the most striking findings is that less than a half of the risk communication procedures analysed included some form of evaluation. This limited use of evaluation methods poses major challenges, not only for understanding the actual impacts of these communication efforts, but also for the identification of good practices and failures. Evaluation is important not only to learn from past experiences, but also to refine and improve current risk communication practices. Quantitative assessments, such as *ex-ante* and *ex-post* questionnaires or surveys, are frequently used, especially in non-crisis times and particularly in SRC conducted in ordinary times (see references in Annex 1). These methods are effective for measuring broad trends, such as levels of awareness or preparedness, and for producing results that are easily comparable across different contexts, countries, and risk types. However, these assessments remain underutilised. Expanding their application could bridge gaps in understanding and provide deeper insights into the social and cultural dimensions of risk communication. Complementary to quantitative methods, qualitative approaches, such as focus groups, semi-structured interviews, and participatory workshops, can uncover nuanced factors that shape community responses to seismic risk information. For instance, focus groups can provide a platform for participants to share their experiences with past seismic events, revealing how collective memories influence current perceptions of risk (Morgan, 1996; Patton, 2014). Similarly, semi-structured interviews can capture individual attitudes, emotions, and concerns that might be overlooked in standardised surveys. Participatory workshops, on the other hand, can foster dialogue between stakeholders and target audiences, enabling the co-creation of tailored communication strategies that resonate with specific communities (Reed, 2008). These qualitative approaches are particularly valuable for exploring cultural nuances and community-specific contexts, which are often critical in Europe's diverse socio-cultural landscape. They can help identify barriers to effective communication, such as language differences, distrust in authorities, or deeply rooted traditional beliefs, and suggest tailored solutions to address these challenges (Pidgeon *et al*., 2003). Integrating qualitative and quantitative methods through a

mixed-method approach could lead to more comprehensive evaluation frameworks. By combining measurable outcomes with in-depth behavioural insights, such an approach enables researchers and practitioners to design communication strategies that are both scientifically rigorous and socially relevant. Future research should emphasise interdisciplinary methodologies, combining expertise from fields such as social sciences, behavioural psychology, and communication studies with seismology, to address the complexities of SRC. This ensures that strategies are not only effective but also practical and contextually appropriate (Kaplan and Garrick, 1981; Lejano and Leong, 2012).

Evaluating the effectiveness of communication strategies is particularly important in terms of their impact on risk awareness, preparedness, and behaviour. Drawing from established literature in project assessment and environmental decision-making (e.g. Reed, 2008; Wilder and Walpole, 2008; Grunwald *et al*., 2011; Fohlmeister *et al*., 2019), evaluation frameworks should address the notable gap in research on the effectiveness of natural hazard communication strategies (Weyrich *et al*., 2020; Scolobig *et al*., 2022). Table 2 outlines criteria and indicators for evaluation, describing their aims, potential metrics, and the phases of the risk communication lifecycle they apply to [e.g. ordinary time, crisis initiation, crisis maintenance, and post-crisis recovery; see Musacchio *et al*. (2023)]. Effective risk communication is most likely to result from initiatives that incorporate these characteristics. Evaluating these criteria requires both qualitative and quantitative methods, including interviews, observation, focus groups, workshops, informal conversations, secondary data analysis, and surveys. A mixed-method approach that integrates these techniques can provide richer insights and more actionable findings.

Finally, our overview, of which aspects of communication are most valued by academics and practitioners, points to a critical gap: the credibility of information sources used in communication is still underresearched. This is worrying because the quality and impact of the information communicated is highly dependent on the trustworthiness of its source. In today's world, where misinformation and fake news are increasingly common, the credibility of sources is of paramount importance. A more rigorous assessment of the credibility of the sources should be a priority in communication strategies, especially in areas, such as public safety or disaster preparedness, where misinformation can have serious real consequences. To address this issue, we suggest systematically incorporating source credibility into SRC strategies. Potential approaches include developing standardised trust metrics to evaluate and monitor the reliability of information sources, promoting institutional transparency by openly sharing methodologies and data, and engaging trusted community figures to bridge the gap between experts and the public. Furthermore, strategies to identify and combat misinformation, such as collaborations with media platforms to flag or correct misleading content, are essential for maintaining public trust. These measures not only enhance the effectiveness of the communication efforts but also strengthen societal resilience by ensuring that seismic risk information is disseminated by credible and reliable sources.

5. Conclusions

Our study highlights a significant rise in scholarly attention to SRC, particularly in Europe, where it is in line with global frameworks such as the Sendai Framework for Disaster Risk Reduction 2015-2030. Analysing publication trends over time confirms a growing interest in this topic. While this trend may partially reflect increased awareness of seismic risks, it is essential to investigate additional potential drivers, such as advancements in communication methodologies, the influence

Table 2 - Criteria and indicators for evaluation during the phases of the risk communication lifecycle.

Criteria monitoring	Aim and description	Potential indicators	Phase
Clear and agreed objectives	At the beginning, clear objectives and contents are formulated which are agreed on by the main stakeholders responsible for the activity. This shared vision results in a high degree of ownership and efficient implementation of the process.	- Level of stakeholder participation in the formulation of objectives/contents - Stakeholder agreement with objectives/contents - Degree of achievement of objectives over the process lifetime	Ordinary time (primarily)
Active involvement	Stakeholders are involved in all stages of the communication activity, including the early ones.	- Number of stakeholders involved over time (e.g. different phases of the risk communication life cycle) - Number of receivers reached by the communication activity - Qualitative evaluation and opinions about the involvement	All
Facilitation of the process	A highly skilled/professional facilitation results in a positive and constructive atmosphere, openness to different points of view, increase in trust and mutual respect.	- Appointment of a facilitator - Use of suitable facilitation methods - Perceptions of process quality	Ordinary time and after crisis
Resources availability	The human and economic resources necessary to ensure and support communication are provided during the entire communication process/ activity.	- Number of staff members involved in the activity - Budget and budget use - Perception of suitability of temporal and spatial scope - Facility quality - Perception of obstacles to participation - Reasons for nonappearance/exclusion	All
Suitable communication process, channels, and methods	The selected channels and methods are suitable for the communication process.	- Perception of the process structure by participants - Feedback on the channels and methods used - Perception of suitability of methods by participants (and, if appropriate, facilitators and external observers)	All
Transparency	The process is transparent, and its structure is documented in detail (purpose, process, results).	- Accessibility of up-to-date information during the process - Quality of process documentation - Availability and accessibility of a contact person - Perception of the degree of transparency by participants (and, if appropriate, external observers)	All
Evaluation			
Individual knowledge, behaviours, capacities	Stakeholders' knowledge, skills, and capacities are improved. Communication practice influences actions and behaviours.	- Message characteristics: understanding, clarity, inclusion of hazard, risk and impact information, inclusion of scientific uncertainty, integration of local and scientific knowledge - Usefulness/behavioural change - Increase of knowledge and skills by stakeholders	All
Mutual learning	Stakeholders are affected by a mutual learning process, where risk communication enables citizens, decision-makers, researchers, and other stakeholders to learn from one another.	- Perception and judgment of the learning effect by stakeholders involved	Ordinary time (primarily)
Institutional capacity building	Risk communication increases the capacities and skills developed by the institutions by learning from the communication process/strategy.	- Perception and judgment about trust, credibility, and legitimacy of sender/information source - Collaboration amongst stakeholders/institutions involved	All

of major seismic events, the implementation of international policy frameworks, advocacy efforts, and the growing prioritisation of disaster risk management in research funding. Future studies should delve deeper into these factors to better understand what is shaping this trend.

Despite the growing body of research on SRC, a notable gap remains in evaluating the effectiveness of these strategies. While many studies recognise the need for evaluation, the actual practice itself is often limited and inconsistent. This paper attempts to address this gap by providing an overview of four key evaluation aspects: the methods and tools used, the timing of evaluations, and their impact on recipients. Our findings show that, while quantitative methods such as surveys and questionnaires are commonly used, critical elements such as recipient understanding of seismic hazard and the credibility of information sources are often overlooked. Incorporating assessments of source credibility and recipient understanding into risk communication strategies could significantly improve their effectiveness and contribute to a better informed and more resilient public in the face of seismic hazards. Specific strategies for improving evaluation frameworks are urgently needed. Interdisciplinary collaboration is essential, bringing together expertise from social sciences, behavioural psychology, communication studies, and seismology to design frameworks that address both technical and human dimensions of risk communication. Mixed-method approaches, integrating quantitative tools (e.g. surveys) with qualitative methods (e.g. focus groups and interviews), can provide a more comprehensive understanding of communication effectiveness. Iterative evaluation models, which include continuous feedback from stakeholders such as policymakers, scientists, and local communities, are essential for refining strategies over time. Additionally, participatory techniques, such as co-design workshops, can actively engage target audiences, ensuring that communication strategies are both contextually relevant and effective.

Establishing clear criteria and indicators for monitoring communication processes and outcomes is also crucial. Drawing on established evaluation methods in other sectors, such as healthcare, could also provide valuable insights. By refining these methods, applying them to a wider range of practices, and addressing overlooked areas such as the credibility of sources, the relationships between knowledge and behaviours, and the impacts of attitudes and behaviours, we can significantly improve public preparedness and resilience to seismic hazards.

Acknowledgments. We sincerely thank the editor, Dario Slejko, for his kind availability throughout the editorial process. We also extend our gratitude to the two anonymous reviewers for their valuable comments and suggestions, which significantly improved the quality of this manuscript.

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Annex 1
Supplementary references for the effectiveness analysis conducted in this study

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