Review document for "What does my technology facilitate? A toolbox to help researchers understand the societal impact of emerging technologies in the context of disasters"

Round 1:

Reviewer 1:

Reviewer Comments for author and editor

The paper describes the iterative, co-development of a toolbox for considering societal dimensions when developing emerging technologies for DRR/Saftey culture. The paper adds value, the toolbox appears useful.

The methodology used (Delphi study) is appropriate and well followed. They are described in sufficient detail.

Overall the paper is well written and very clear. However, the paper is unnecessarily long and could benefit greatly from being rewritten to be more concise.

The State of the Art section is quite repetitive throughout, naming again and again the technology and its applications, instead of focusing on either the benefits or the barriers. The Table (table1) does a great job and doesn't need to be further developed in the written part of the paper.

The part on digital divide could be reduced to 1 sentence.

When discussing vulnerability, it is pretty well agreed in the scientific community that it is context dependent, and this is found even in the ISO -> An individual is not defined as vulnerable by the nature of their vulnerability, but by their personal circumstances at the time of the emergency. […]." (ISO 22395:2018).

Other concepts that the authors don't mention but seem worthwhile for societal impacts include:

- Universal Design (Connell, B. R., Jones, M., Mace, R., Mueller, J., Mullick, A., Ostroff, E.,Sanford, J., Steinfeld, E., Story,M., & Vanderheiden, G. (1997). The Principals of Universal Design. NC State University, The Center for Universal Design.

- what makes AI, IoT & Remote Sensing technologies different from other technologies (especially ICT) for DRR/Safety Culture, as many articles about societal dimensions for DRR tools exist, , epecially since the title of the manuscript simply says "technologies" and not only AI, Iot & RS, e.g.

-- Petersen, L., Havarneanu, G., McCrone, N., Markarian, G., Burlin, Å., Johansson, P-E. (2022). CBRNe, a universally designed app for that? In Hedi Karray, Antonio De Nicola, Nada Matta, Hemant Purohit (Eds.), ISCRAM 2022 Conference Proceedings – 19th International Conference on Information Systems for Crisis Response and Management. Tarbes, France.

-- Gjøsæter, J, Radianti, J., & Chen, W. (2021). Universal Design of ICT for Emergency Management from Stakeholders' Perspective - A Systematic Literature Review. Information Systems Frontiers. doi: 10.1007/s10796-020-10084-7.

-- Petersen, K. & Buscher, M. (2015). Technology in Disaster Response and Management: Narratives of Ethical, Legal, and Social
Issues https://idl.iscram.org/files/katrinapetersen/2015/1296_KatrinaPetersen+MonikaBuescher2015.pdf

The discussion reads more like an introduction than a reflection on how the results of the Delphi study confirm/reject the findings from the literature review and I think this section could benefit greatly from being redone.

Lastly, the paper starts off with DRR and Safety Culture, and this is reflect in the first toolbox, but by the end, only Safety Culture appears in the toolbox. This is not described in the paper. Why was this choice made?

I also think the paper would benefit from defining those two terms earlier on, and arguing why they go together/apart.

Reviewer 2:

Reviewer Comments For author and editor

The revised paper fits well to the profile of the Seismica journal. Its topic concerning societal impact of digital technology (IoT, remote sensing, AI technologies) on Disaster Risk Reduction is very timely and of current interest. The manuscript's title is adequate to its content. In terms of writing technique it represents high academic level. It is written in a clear language, has a proper and clear structure. The article has well formulated research problem which as mentioned above is timely and relevant to academia and may have practical implications for broader readership. The aim of the authors is to draw attention to the societal aspects of the use of new technologies in the DRR sector. The article is a result of the comprehensive and rigorous research, based on the combined methodology – explorative literature review and DELPHI study. Such methodological approach is appropriate to the goal set by the authors. The goal of the research is to build the toolbox which may be of use by the relevant stakeholders in order to raise societal awareness about the application of digital technologies in the DRR.

As much as the goal is relevant, it is not clear how authors envisage the promotion of use of the proposed toolbox among stakeholders. Authors use the categoric language (ex. " Further, to advance the toolbox, it must be actively used and applied by professionals and there must be continuous evaluation of how vulnerability and inclusiveness can be addressed in a technologically fast-evolving world." – side number 660), yet do not explain how they see it truly integrated in regulatory processes and governance structures of relevant actors. It would be interesting to reflect on the enforcement of proposed toolbox.

Overall the article represents high academic value and quality, hence I recommend it for publication.

Authors response:

Dear Laure Fallou,

We would like to thank you and the two reviewers for the helpful suggestions and the careful consideration to improve our manuscript. We are happy to resubmit our manuscript with the title *What does my technology facilitate? A toolbox to help researchers understand the societal impact of emerging technologies in the context of disasters*.

In our revisions, we followed all reviewers' comments, which improved both the clarity as well as the relevance. Following the suggestions of the reviewers we implemented two main revisions: First, we shortened the *State of the Art* section to avoid redundancies and added insights about the application of universal design within ICT. Second, we restructured the discussion to better describe whether the literature review and Delphi study were in line and to discuss how the steps of the toolbox are linked to the project and policy cycle. We also addressed all other (minor) suggestions, as illustrated below.

As mentioned by the reviewers, our manuscript provides a toolbox which allows professionals, both researchers and developers, to critically reflect on the social impacts of their technologies. This is indispensable to ensure that emerging technologies effectively contribute to the enhancement of safety culture and, consequently, disaster risk reduction. We therefore hope for a full consideration of our revised manuscript to encourage other researchers to use the toolbox.

Kind regards,

the authors

COMMENT REVIEWERS

Based on the reviewers' comments, we revised our manuscript. In the following, we listed and explained all changes taken in the manuscript in detail.

REVIEWER # 1

The paper describes the iterative, co-development of a toolbox for considering societal dimensions when developing emerging technologies for DRR/Saftey culture. The paper adds value, the toolbox appears useful.

Thank you for this summary. We agree that the toolbox is useful for researchers to reflect on the societal issues and impacts of their technological developments.

The methodology used (Delphi study) is appropriate and well followed. They are described in sufficient detail.

Thanks for this comment.

Overall the paper is well written and very clear. However, the paper is unnecessarily long and could benefit greatly from being rewritten to be more concise.

Thanks for this comment. We rewrote the section State of the Art, following your details (see below) as well as trying to remove redundancies. See track changes in the revised manuscript, most of which are as well copied below for better visibility.

The State of the Art section is quite repetitive throughout, naming again and again the technology and its applications, instead of focusing on either the benefits or the barriers. The Table (table1) does a great job and doesn't need to be further developed in the written part of the paper.

Thank you for pointing this out. We have now crossed out the repetitions and lay the main focus on table 1.

- 2.2.1.1 The current application of emerging technologies for DRR

In Table 1, we summarize different applications of emerging technologies in DRR, distinguishing between the *technologies* AI, IoT, and remote sensing and the following hazards: terror attacks, flash floods, wildfires, and earthquakes. ~~AI is broadly used and applied to all the hazards analysed - terror attacks, flash floods, wildfires, and earthquakes. The technology is being (further) developed, evaluated, and applied to predict hazards such as flash floods (e.g. Costache and Tien Bui, 2019) or wildfires ('Firefighters relying on artificial intelligence to fight California wildfires', 2022). It is also used in earthquake early warning (Wu et al., 2021) and applied in mitigating and responding to terror attacks (Kahn, 2022; Singer, 2022).~~

~~IoT applications are also found for all the hazards analysed - terror attacks, flash floods, wildfires, and earthquakes. The technology is applied, elicited, and further developed to monitor disasters such as flash floods (Furquim et al., 2018) or wildfires (Kaur and Sood, 2019). It is also used in earthquake early warning (Wu et al., 2021) and can help detect mass panic in the context of a terror attack (Alsalat et al., 2018).~~

~~Remote sensing data is broadly used. Applications can be found for all looked at hazards - terror attacks, flash floods, wildfires, and earthquakes. It is mainly used for event monitoring (Mishra, 2021) or prediction (Huot et al., 2022).~~

The part on digital divide could be reduced to 1 sentence.

We implemented this and combined it with the next paragraph, as visible in the manuscript with the track changes (lines 210-235).

When discussing vulnerability, it is pretty well agreed in the scientific community that it is context dependent, and this is found even in the ISO -> An individual is not defined as vulnerable by the nature of their vulnerability, but by their personal circumstances at the time of the emergency. [...]." (ISO 22395:2018).

Thank you for this valuable comment. We added this standard in line 326.

a disaster response (Vickery, 2018). It is important to acknowledge that every person can be made vulnerable in a disaster, and that this is contextual. Thus, also the International Organization for Standardization (ISO) includes the personal circumstances in the assessment of vulnerability (ISO 22395, 2018) The Iintersectional awareness helps to understand vulnerability better.

Other concepts that the authors don't mention but seem worthwhile for societal impacts include:

- Universal Design (Connell, B. R., Jones, M., Mace, R., Mueller, J., Mullick, A., Ostroff, E.,Sanford, J., Steinfeld, E., Story,M., & Vanderheiden, G. (1997). The Principals of Universal Design. NC State University, The Center for Universal Design.

- what makes AI, IoT & Remote Sensing technologies different from other technologies (especially ICT) for DRR/Safety Culture, as many articles about societal dimensions for DRR tools exist, , epecially since the title of the manuscript simply says "technologies" and not only AI, Iot & RS, e.g.

-- Petersen, L., Havarneanu, G., McCrone, N., Markarian, G., Burlin, Å., Johansson, P-E. (2022). CBRNe, a universally designed app for that? In Hedi Karray, Antonio De Nicola, Nada Matta, Hemant Purohit (Eds.), ISCRAM 2022 Conference Proceedings – 19th International Conference on Information Systems for Crisis Response and Management. Tarbes, France.
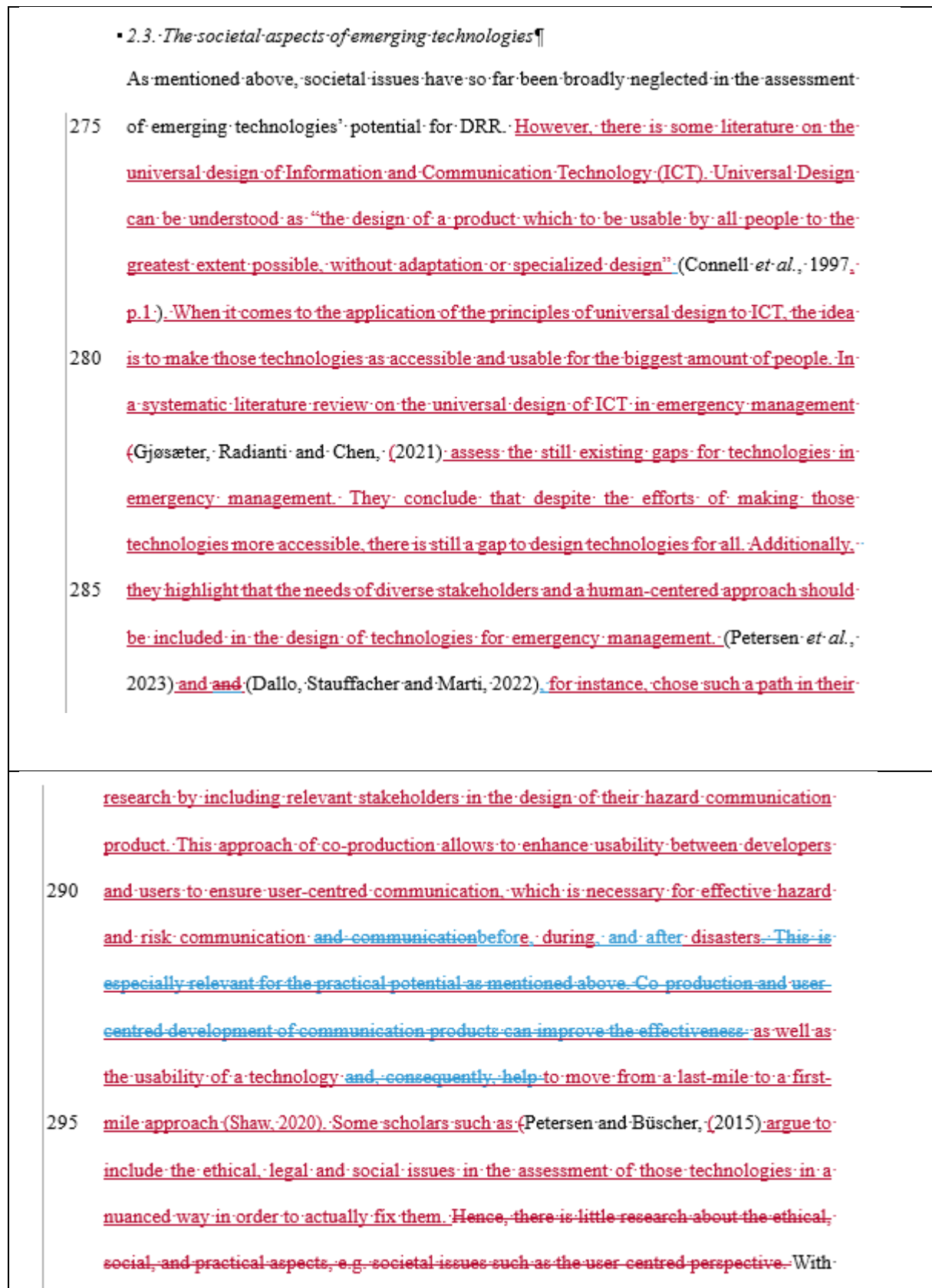
-- Gjøsæter, J, Radianti, J., & Chen, W. (2021). Universal Design of ICT for Emergency Management from Stakeholders' Perspective - A Systematic Literature Review. Information Systems Frontiers. doi: 10.1007/s10796-020-10084-7.

-- Petersen, K. & Buscher, M. (2015). Technology in Disaster Response and Management: Narratives of Ethical, Legal, and Social Issues https://idl.iscram.org/files/katrinapetersen/2015/1296_KatrinaPetersen+MonikaBuescher2015.pdf

Thank you for drawing our attention to this important aspect, which we had overlooked in our manuscript. Indeed, the concept of universal design as well as the ethical, legal, and social aspects in emergency response should be included in the State of the Art in order to understand how our toolbox is a distinctive added value. We have applied this by adding a specific paragraph (see box below).

Indeed, you are correct that ICT is broader than AI, remote sensing, and IoT. That is why we added a respective paragraph. Still, we keep the focus on AI, IoT, and remote sensing because those are the widely used umbrella terms for emerging technologies in disaster risk reduction and safety culture. Further, these technologies were relevant for the specific

case study of seismology. Due to these two reasons, we set a focus on AI, remote sensing, and IoT. However, we added a paragraph about the application of universal design within ICT to provide a holistic overview of the assessment of emerging technologies as visible in the following screenshot.

2.3. The societal aspects of emerging technologies

As mentioned above, societal issues have so far been broadly neglected in the assessment of emerging technologies' potential for DRR. However, there is some literature on the universal design of Information and Communication Technology (ICT). Universal Design can be understood as "the design of a product which to be usable by all people to the greatest extent possible, without adaptation or specialized design" (Connell *et al.*, 1997, p.1). When it comes to the application of the principles of universal design to ICT, the idea is to make those technologies as accessible and usable for the biggest amount of people. In a systematic literature review on the universal design of ICT in emergency management (Gjøsæter, Radianti and Chen, (2021) assess the still existing gaps for technologies in emergency management. They conclude that despite the efforts of making those technologies more accessible, there is still a gap to design technologies for all. Additionally, they highlight that the needs of diverse stakeholders and a human-centered approach should be included in the design of technologies for emergency management. (Petersen *et al.*, 2023) and and (Dallo, Stauffacher and Marti, 2022), for instance, chose such a path in their research by including relevant stakeholders in the design of their hazard communication product. This approach of co-production allows to enhance usability between developers and users to ensure user-centred communication, which is necessary for effective hazard and risk communication and communicationbefore, during, and after disasters. This is especially relevant for the practical potential as mentioned above. Co-production and user-centred development of communication products can improve the effectiveness as well as the usability of a technology and, consequently, help to move from a last-mile to a first-mile approach (Shaw, 2020). Some scholars such as (Petersen and Büscher, (2015) argue to include the ethical, legal and social issues in the assessment of those technologies in a nuanced way in order to actually fix them. Hence, there is little research about the ethical, social, and practical aspects, e.g. societal issues such as the user-centred perspective. With

The discussion reads more like an introduction than a reflection on how the results of the Delphi study confirm/reject the findings from the literature review and I think this section could benefit greatly from being redone.

Thank you for this critical comment. We agree that in the initial manuscript we did not manage to fully reflect the findings of our literature review and the Delphi- Study. We have now structured it as follows:

- In sub-section5.1, we discuss how the Delphi-Study has confirmed and/or rejected our findings from the literature review.
- In sub-section 5.2, we discuss how the toolbox could be applied by using the framework of the policy cycle and the project management cycle.
- In sub-section 5.3, we discuss the limitations of the study.
- .

All the changes can be seen in the section 5 highlighted with track changes.

means of a toolbox. Although established tools such as technological assessments exist, there is little research on the potential of an emerging technology to enhance safety culture. With our toolbox, we provide a concise framework for professionals as a starting point for a holistic reflection on emerging technologies to enhance safety culture within DRR. Our toolbox allows and encourages professionals to look at their technologies from a societal perspective by critically reflecting, among other things, on helping societies to enhance their safety culture, ethical implications, inclusiveness, practicability, and potential risks (e.g. privacy, security).

5.1 The comparison of the literature review and Delphi study need to include the societal perspective and for co-production

Safety culture, as defined by Marshall (2020), can be understood as risk reduction measures and action plans for and planned by individuals within the whole society. To serve this aim, emerging technologies must be intentionally designed for such purposes. This can be achieved by initiating reflective processes among developers of such technologies. Our toolbox is designed for this purpose and willto help professionals to reflect on the technologies' contribution to enhancing societal benefits, encouraging collective actions towards an enhanced safety culture DRR, and including marginalized groups within society. The importance of including societal aspects emerged from both the literature review and the Delphi study. Past research on the potential of technologies for DRR has mainly focused on the functionality and the usability of emerging technologiesthose and thereby neglected the societal perspective and their impact on safety culture. The insights from the Delphi study support this finding, with the statements about the technological and practical potential generating most consensus. At the same time, fewer neutral answers

660 were given in these areas (see Figure 6 and Figure 7Figure 7), indicating a shared scientific understanding. ¶

The International Telecommunication Union (ITU) (Minges, 2019) conclude in their assessment that disruptive emerging technologies for DRR are improving disaster management but that further research is required to ensure large-scale impacts. With

665 particular regard to increasing societal impacts, they recommend fostering public outreach, i.e. consideration of the purpose and specific target audience, and partnerships between academia and the private sector to improve disaster management overall (Minges, 2019). This is also stressed in the literature review of (Gjøsæter, Radianti and Chen, (2021). In addition, our study shows that experts are interested in reflecting on their technologies, but

670 emphasize that this is not just their responsibility but the task of all actors involved in the development, implementation, deployment, and use of a technology. This is indicated by the neutral answers for the practical and social potential statements (see Figure 6Figure 6 and Figure 7Figure 7). Our toolbox thus consists of questions that are applicable for all actors involved. ¶

675 Further, existing research indicates that co-production of knowledge is required to improve DRR measures (Ismail Zadeh et al., 2017; Izumi et al., 2019), i.e. involving stakeholders from the beginning in line with the first mile principle (Shaw, 2020) and strengthening the collaboration between science and society (Minges, 2019). This can, according to Ismail Zadeh et al. (2017), lead to an improvement in resilience because the disasters are seen as

680 societal phenomenon and treated as such. The evaluation of the three pillars – functionality, usability, and societal dimension – of our toolbox indicates the same: there is a need for a guided discussion and reflection on the consequences of a technology in the scientific

685 The literature review demonstrated that clear definitions of the technologies looked at are lacking: the applications of AI, IoT, and remote sensing are very broad and this is why there is only a tendency towards a common understanding. However, distinct definitions are required in order to be able to discuss the societal impacts of a technology. Consequently, a common understanding needs to be strengthened through further societal and scientific

690 cooperation. This will form the basis for, among other things, drawing up regulations and policies for the development and application of AI (Harasimiuk and Braun, 2021) or IoT in order to enhance safety culture.¶

It is therefore not surprising that AI in seismology is also lacking a common definition, as hinted by the literature review and the Delphi study. Despite the fact that most respondents

695 called themselves experts on AI in seismology, they did not provide the same definition. Given the broad range of possible applications of AI in seismology and the different specializations of the respondents, this seems logical (e.g. Mousavi and Beroza, 2023). Still, the results show that the experts agree on some of the potential and the limitations of AI in seismology. Hence, AI in seismology cannot be reduced to just a single definition but

700 rather should be discussed in the context of each application, with its limitations and pitfalls, and should not be overestimated (Mousavi and Beroza, 2022). In order to understand the potential of AI in seismology to enhance safety culture, the first step should be to understand which specific application of a technology is discussed. Given the variety of definitions, the toolbox and its categories are kept broad, while still serving as a catalyst

705 for critical reflection on the issues under discussion and enabling an assessment of the potential in each specific application.

Still, the comparison of our literature review and the Delphi study shows that we were able to iteratively derive a toolbox which can support professionals in reflecting the societal impacts for safety culture of the technology they use. The specific case study of AI has

710 shown that the toolbox does support professionals.

5.2 The implementation of the toolbox

To reach the purpose of being further developed, the toolbox should be actively used. This can only be achieved if the toolbox is known. One possibility would be organizing workshops with practitioners, by doing more outreach, possibly with the ITU, in order to

715 ensure further development and in the end possibly standardization.

Further, existing research indicates that co-production of knowledge is required to improve DRR measures (Ismail-Zadeh et al., 2017; Izumi et al., 2019), i.e. involving stakeholders from the beginning in line with thefollowing the first-mile principle (Shaw, 2020) and strengthening the collaboration between science and society (Minges, 2019). The

720 evaluation of the three pillars — functionality, usability, and societal dimension — of our toolbox within the Delphi study indicates the same: there is a need for a guided discussion and reflection on the consequences of a technology in the scientific community as well as societies to increase awareness, which the toolbox can facilitate by guiding relevant stakeholders in their reflection from the outset.

725 Once the toolbox is known, potential areas of influence must be identified. To this end, we linked the elements of the toolbox to After the toolbox is known, reflection of the potential role of an emerging technology for safety culture could happened. In order to understand

where this could occur, we use the policy cycle adapted from (Schubert and Klein, (2020), as well as the project cycle adapted from the (European Commission, (2004); (see Figure 10.) as a starting point. ¶

Setting the agenda firstly is crucial in the project initiation: in this step the goal to enhance safety culture is manifested, and hence the goal to use the toolbox in the process. With the second step, the formulation of the policy, the different foci of the use of the technology and thus the application of the different pillars of the toolbox is chosen. This then leads to the third step, the decision, where the time to reflect is spent. In the two final steps, the implementation and the evaluation of the technology happens, once again with the reflection guidance of the toolbox. All these steps happen cooperatively, co-productively, and iteratively, both first-mile to last-mile. ¶
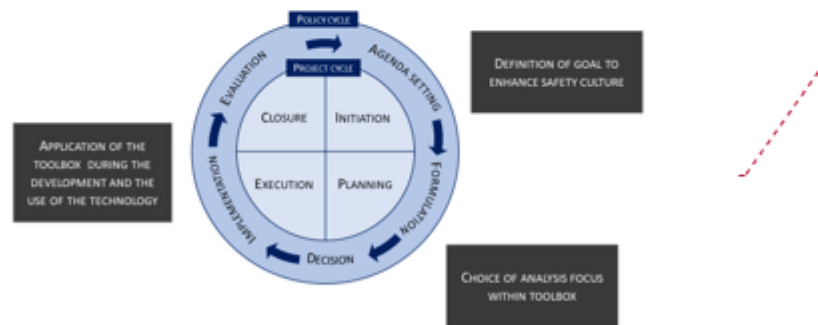

Figure 10: Application of the toolbox (black squares) in the policy cycle (adapted from (Schubert and Klein, 2020) (blue arrows) and the project management cycle (adapted from (European Commission, 2004) (blue squares). ¶

¶

5.4 Limitations and next steps

Our study has several limitations that could be addressed in future research.

Our explorative literature review was not conducted fully systematically but rather iteratively, meaning that there was a broad timeframe and limited sample chosen. However, the literature review was solely needed to identify the categories forming the basis of the toolbox and to grasp the state of the art of these technologies in DRR and to then develop the first solid draft of the toolbox. Further, through the expert elicitation (Delphi study), we aimed to overcome these issues by gathering more knowledge and reviewing these results. ~~This procedure also allowed us to consider newly published studies throughout the development of the toolbox, which was key to incorporating the latest insights in this fast evolving field.~~

The Delphi study is a proven method for eliciting consensus and dissent among experts and identifying potential achievements and developments in the future (Dalkey and Helmer, 1963). A key benefit of the method is that experts around the world can be involved. This was not fully achieved with our sample. We involved experts from different nations, but not from all continents and mainly from the European Union and the United States, so the results may have a Eurocentric bias. One explanation could be that the development of these technologies is still lagging in African and Latin American countries because there are other priorities for DRR. Additionally, we only conducted two rounds, since little consensus was found for the different statements. Our findings indicate the diversity of the topic, as even after two rounds there was still little consensus. However, the experts' answers show some tendencies of opinions and needs. This outcome can be explained by the broadness of the topic but also by the sample size and the participants' characteristics,

which are two key limitations within this study. The sample was fairly diverse in terms of the specific research fields of seismology, despite a specific target group being formulated for recruitment. This does not, however, delegitimize the results (Hsu and Sandford, 2007), because the diversity of the group can reveal additional tendencies. It seems that, in order to understand the impacts of these technologies, rather than focusing on a common definition, case studies are helpful to understand the impact of using these technologies for society.¶

The Delphi study is an appropriate tool to explore ~~tendencies and possible further research topics but also~~ policy needs. In the two survey rounds, this was achieved both by showing the differences in the understanding of AI for seismology but also by further developing the toolbox and finding more guiding questions to elicit tendencies as to whether a technology actually enhances DRR and safety culture. These policy needs could be fulfilled by applying a standardized tool for the inclusion of societal matters or targeted funding of research on those matters. Additionally, further research should be conducted with case studies on the other technologies, as well as the different pillars of the toolbox, i.e. the societal dimension and the usability. To this end, it would be beneficial to conduct studies that explore both the acceptance and practical utility of the toolbox, thereby gaining a comprehensive understanding of its usability. Further, to advance the toolbox, it must be actively used and applied by professionals and there must be continuous evaluation of how vulnerability and inclusiveness can be addressed in a technologically fast-evolving world.¶

Lastly, the paper starts off with DRR and Safety Culture, and this is reflect in the first toolbox, but by the end, only Safety Culture appears in the toolbox. This is not described in the paper. Why was this choice made?

Thank you for highlighting this inconsistency. In the literature review and the Delphi-Survey process, we realized that those two terms go hand in hand and, thus, it makes more sense to focus on the concept of safety culture, as it is an important part of all disaster risk reducing efforts. Accordingly, we expanded our manuscript. We now elaborate in the section State of the Art (see below) that established safety culture, taking into account different contextual and cultural factors, facilitates disaster risk reduction. Hence, enhanced safety culture leads to elaborated disaster risk reduction. Further, we added a respective comment about our findings in 4.4.

2. State of the Art

2.1 Safety culture and DRR

Disaster risk reduction describes efforts of preventing new and reducing ands well as managing already existing risks, in order to enforce resilience. (UNDRR, no date). Safety

110 culture as part of DRR considers contextual factors and describes "the behaviors and actions of individuals inclusive of decision-makers both public and private, and civil society that reflect a commitment to and are concerned with minimizing risk, injury and losses to human life and the environment" (Marshall, 2020, p. 5). Safety culture thus describes societal dynamics that are manifested and reproduced in individuals' actions the

115 actions of individuals when it comes to safety, and thus encompasses how people deal with disaster and disaster risk and whether they apply safety measures. Consequently, aA system, community, or society, which is exposed to any risks and hazards thus reacts differently depending on its existing safety culture. Therefore, it is crucial to understand local safety culture to enhance DRR and to successfully implement a technology for DRR.

120 If local safety culture is neglected, the implementation of DRR measures may not be

successful.

4.4. Final toolbox

595 After analysing the results of the second round, we made two big changes. Firstly, we chose to solely analyse the enhancement of safety culture and not safety culture within DRR and not DRR overall and not DRR overall. The rationale behind this was that only if the contextual safety culture is improved, disaster risk reductionDRR effort are/become effectiveffective, as realized within the literature reviewe. are/become effective. Hence, the

600 assessment of safety culture is enough (see 2.1 Safety culture and DRR). Secondly, we chose to remove the metrics from the categories. The thinking behind this reasons was that the toolbox should be directly applicable and not require in-depth studies for each category.

I also think the paper would benefit from defining those two terms earlier on, and arguing why they go together/apart.

Thank you for this comment. We agree that defining the two terms earlier in the manuscript will increase the clarity of the concepts underlying the toolbox. We thus added the definitions at the beginning of the State of the Art.

2. State of the Art

2.1 Safety culture and DRR

105 Disaster risk reduction describes efforts of preventing new and reducing and managing already existing risks, in order to enforce resilience. (UNDRR, no date) Safety culture as part of DRR considers contextual factors and describes "the behaviors and actions of individuals inclusive of decision-makers both public and private, and civil society that reflect a commitment to and are concerned with minimizing risk, injury and losses to

110 human life and the environment" (Marshall, 2020, p. 5). Safety culture describes societal dynamics that are manifested and reproduced in the actions of individuals when it comes to safety, and thus encompasses how people deal with disaster and disaster risk and whether they apply safety measures. A system, community, or society, which is exposed to risks and hazards thus reacts differently depending on its existing safety culture. Therefore, it is

115 crucial to understand local safety culture to enhance DRR and to successfully implement a technology for DRR. If local safety culture is neglected, the implementation of DRR measures may not be successful.

REVIEWER #2

The revised paper fits well to the profile of the Seismica journal. Its topic concerning societal impact of digital technology (IoT, remote sensing, AI technologies) on Disaster Risk Reduction is very timely and of current interest. The manuscript's title is adequate to its content. In terms of writing technique it represents high academic level. It is written in a clear language, has a proper and clear structure. The article has well formulated research problem which as mentioned above is timely and relevant to academia and may have practical implications for broader readership. The aim of the authors is to draw attention to the societal aspects of the use of new technologies in the DRR sector. The article is a result of the comprehensive and rigorous research, based on the combined methodology – explorative literature review and DELPHI study. Such methodological approach is appropriate to the goal set by the authors. The goal of the research

is to build the toolbox which may be of use by the relevant stakeholders in order to raise societal awareness about the application of digital technologies in the DRR.

Thank you for this precise and extensive summary of our study.

As much as the goal is relevant, it is not clear how authors envisage the promotion of use of the proposed toolbox among stakeholders. Authors use the categoric language (ex. " Further, to advance the toolbox, it must be actively used and applied by professionals and there must be continuous evaluation of how vulnerability and inclusiveness can be addressed in a technologically fast-evolving world." – side number 660), yet do not explain how they see it truly integrated in regulatory processes and governance structures of relevant actors. It would be interesting to reflect on the enforcement of proposed toolbox.

Thank you for this valuable comment. We agree that we missed to add the promotion possibilities of the toolbox in our first draft of the manuscript. In order to reach the needed promotion, we suggest firstly, to further promote the toolbox at conferences. The further development of the toolbox using co-productive methods, such as workshops and active promotion would be a second step. Through them, questions of the actual users could be answered and the use of the toolbox can be trained. The other possibility is the analysis of where in the project and policy cycle the use of the toolbox should be situated. As visualized in Figure 10, the toolbox can be used in every step, as we have shown in the following paragraph:
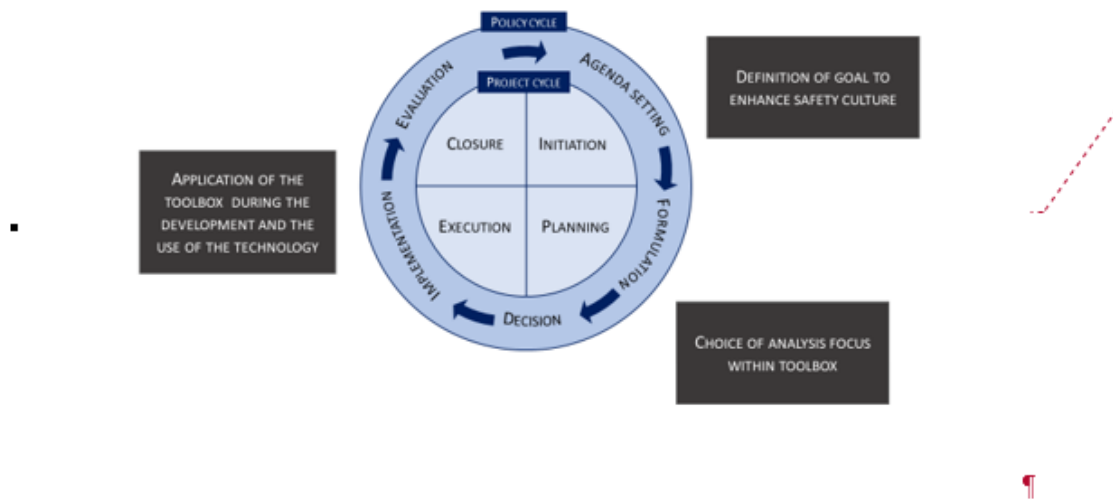
5.2 The implementation of the toolbox

To reach the purpose of being further developed, the toolbox should be actively used. This can only be achieved if the toolbox is known. One possibility would be organizing workshops with practitioners, by doing more outreach, possibly with the ITU, in order to ensure further development and in the end possibly standardization.

Further, existing research indicates that co-production of knowledge is required to improve DRR measures (Ismail-Zadeh *et al.*, 2017; Izumi *et al.*, 2019), i.e. involving stakeholders from the beginning ~~in line with the~~ following the first-mile principle (Shaw, 2020) and strengthening the collaboration between science and society (Minges, 2019). The evaluation of the three pillars — functionality, usability, and societal dimension — of our toolbox within the Delphi-study indicates the same: there is a need for a guided discussion and reflection on the consequences of a technology in the scientific community as well as societies to increase awareness, which the toolbox can facilitate by guiding relevant stakeholders in their reflection from the outset.

Once the toolbox is known, potential areas of influence must be identified. To this end, we linked the elements of the toolbox to ~~After the toolbox is known, reflection of the potential role of an emerging technology for safety culture could happened. In order to understand~~

~~where this could occur, we use~~ the policy cycle adapted from ~~(~~Schubert and Klein~~,~~ (2020)~~,~~ as well as the project cycle adapted from the ~~(~~European Commission~~,~~ (2004)~~;~~ ~~(~~see Figure 10~~.)~~ ~~as a starting point.~~ ¶

Setting the agenda firstly is crucial in the project initiation: in this step the goal to enhance safety culture is manifested, and hence the goal to use the toolbox in the process. With the second step, the formulation of the policy, the different foci of the use of the technology and thus the application of the different pillars of the toolbox is chosen. This then leads to the third step, the decision, where the time to reflect is spent. In the two final steps, the implementation and the evaluation of the technology happens, once again with the reflection guidance of the toolbox. All these steps happen cooperatively, co-productively, and iteratively, both first-mile to last-mile. ¶

Figure 10: Application of the toolbox (black squares) in the policy cycle (adapted from (Schubert and Klein, 2020) (blue arrows) and the project management cycle (adapted from(European Commission, 2004) (blue squares). ¶

¶

Overall the article represents high academic value and quality, hence I recommend it for publication.

Thank you. We agree that the manuscript is a relevant piece for the scientific community to foster the active reflection on societal impacts of (emerging) technologies.

Round 2:

Reviewer 1:

Reviewer Comments For author and editor:

The authors did a fantastic job of responding to the comments and the revised article is much improved :)

A small revision is necessary, though, as it seems that in section 2.3, the references to Connell et al. & Gjøsæter et al. are missing (suggest to add what is in italic):

Line 223 - "This is also confirmed by a review study on universal design, referring to designs that are usable by everyone with a maximal benefit (*Connet et al., 1997*)."

Line 224 - "They *(Gjøsæter et al., 2021)* conclude that despite the efforts of making ICT emergency technologies more accessible, there is still a gap to design those technologies for everyone, i.e. every possible..."

(I assume this happened when switching between track changes & different versions, as I see the references are in the reference list at the end - an easy fix!)

Reviewer 2:

Reviewer Comments For author and editor:

I have no further comments and recommend the article for publication.