3RG REPORT

Focal Report 9: Risk Analysis

Visualizing Risk: The Use of Graphical Elements in Risk Analysis and Communications

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Purpose: As part of a larger mandate, the Swiss Federal Office for Civil Protection (FOCP) has tasked the Center for Security Studies (CSS) at ETH Zurich with compiling 'Focal Reports' (Fokusberichte) on critical infrastructure protection and on risk analysis to promote discussion and provide information about new trends and insights.

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1 INTRODUCTION – NEW DEMANDS FOR RISK COMMUNICATION

In the realm of risk governance, the question of how to communicate effectively with stakeholders and the public has become increasingly salient in recent years, leading to an "explosion of risk communication research"[1] as well as affirmations in official (policy) strategies of the centrality of effective risk communication.[2] Originally, when studies on risk communication emerged in the 1970s, their scope was mostly restricted to the information and education of lay people about expert judgements on the risks of industrial production.[3] At that time, the goal of risk communication was to reassure the public that even though unpleasant side-effects of industrial activity for neighbouring communities were not completely avoidable, the risks were calculated by experts with superior knowledge and assessed to be under control and therefore acceptable.[4] In other words, risk communication aimed to "sell" risk analysis.

Since then, the narrow concept of risk communication has undergone considerable change. The extensions and adaptations are based on experiences made with citizens that regularly refused to be "enlightened" about risks. Rather, it became apparent that effective risk communication necessitates both listening to the audience as well as public trust in the messenger.[5] Consequently, more focus was placed on **stakeholder involvement and risk dialogue**, which have gained increasing salience in parallel to the rise of participative concepts in risk management.[6] Today, there is a consensus in the literature that risk communication needs to be understood as an interactive process that involves policy-makers, private business actors, experts, stakeholders and the general public.[7] The goal should neither be to educate nor persuade, but to improve the effectiveness and legitimacy as well as the acceptance of collective risk decision-making through transparency, deliberation and open discourses. Furthermore, risk communication is supposed to empower: it should not only inform the public, but rather enable it to play an active role in crisis preparedness (and thereby help to increase societal resilience).[8]

Risk Communication:

- *interactive process that involves multiple stakeholders*
- *improves effectiveness, legitimacy, acceptance of risk governance*
- *helps to increase societal resilience*

In reality, however, risk communication is often still a one-way communication process. Largely due to the sheer complexity and ambiguity of many contempo-

1 Heath, Robert L.; O'Hair, H. Dan (2010): The Significance of Crisis and Risk Communication, in: Heath, Robert L.; O'Hair, H. Dan (eds.): Handbook of Risk and Crisis Communication, Routledge: London, 5–30, 27.

2 See for example: U.S. Governmental Accounting Office (2004): Homeland Security. Communication Protocols and Risk Communication Principles Can Assist in Refining the Advisory System. Report to Congressional Requesters, GAO-04-682, available: *http://www.gao.gov/new.items/d04682.pdf*

3 Plough, Alonzo; Krimsky, Sheldon (1987): The Emergence of Risk Communication Studies: Social and Political Context. in: Science, Technology, & Human Values, 12, 3/4, 4–10.

4 Leiss, William (1996): Three Phases in the Risk Communication Practice, in: Annals of the American Academy of Political and Social Science, 545, 5, 85–94.

5 Renn, Ortwin (2008): Risk Governance: Coping with Uncertainty in a Complex World, Earthscan: London, 228.

6 CSS (2009): Risk Analysis. Risk Communication in the Public Sector, CRN Focal Report 3. Center for Security Studies (CSS), ETH Zürich: Zürich, available: *http://www.isn.ethz.ch/isn/Digital-Library/Publications/Detail/?id=110683&lng=en*

7 U.S. National Research Council (1996): Understanding Risk. Informing Decisions in a Democratic Society. Committee on Risk Characterization, National Research Council, available: *http://www.nap.edu/catalog/5138.html.*

8 CSS (2009a): Examining Resilience. A concept to Improve Societal Security and Technical Safety, CRN Factsheet.Center for Security Studies (CSS), ETH Zürich: Zürich, available: *http://www.css.ethz.ch/publications/pdfs/Factsheet-Examining-Resilience.pdf*

rary risk issues, participative risk communication is wishful thinking in most instances. Whether it is the prediction of natural hazard events or the measurement of social vulnerabilities to man-made hazards, the handling of risks in modern societies is characterized by ever-increasing data inflows, complicated mathematical models and sometimes hermetical expert language. Combing through such complexity has led to the production of new risk communication tools – among them visual methods.[9] In fact, the trend to "visualize the risks around us" brings to light an area of inquiry that connects to recent CSS work on the way new information and communication technologies (ICTs), mainly the Internet, may be used to improve public risk communication.[10] Building upon this previous work, we look more closely at one specific form of risk communication in this Focal Report: **risk visualizations. Given that risk visualizations are growing in popularity within the world of risk communication**, the aim of this report is to explore how visual techniques can contribute to successful risk communication, as well as to identify the pitfalls and challenges of these techniques.

"Risk visualization is the systematic effort of using images to augment the quality of risk communication along the entire risk management cycle"
Eppler and Aeschimann, 2008

For the purpose of this study, we follow the definition by Eppler and Aeschimann, who suggest risk visualization is "the systematic effort of using images to augment the quality of risk communication along the entire risk management cycle".[11] Hence, the goal of specific risk visualization can be to support professional risk managers, to facilitate the interaction between risk professionals and stakeholders or the communication with the public about risks. To fulfil these diverse functions, risk communication generally can make use of any visualization technique. For instance, visual risk communication can use as its medium a drawing, a photograph, a movie or an organizational chart. Since it is impossible to cover all possible forms of risk visualization in this report, we deliberately restrict our analysis to risk diagrams that play a salient role in contemporary risk analysis and management. Especially, we focus on **risk maps which can be understood as a subcategory of risk diagrams**. In terms of examples, particular emphasis will be put on risk communication of natural hazards.

The remainder of this report is structured as follows: In the next section, the concept of risk diagrams (in a broad sense) will be introduced. We use different examples to illustrate how the design of risk diagrams influences the amount of information that can be communicated in diagrams and the information's usefulness for the public. In the third section, the special form of geographical risk maps will be assessed. We discuss traditional types of risk maps as well as new types of crowdsourced risk maps. In the final section, we draw conclusions and explore the implications for Switzerland.

9 Of course while most scientific reasoning - particularly in the humanities - as well as political decision-making is still based on numbers and words, visual methods are finding a place in many domains; see Glasgow, Janice; Narayanan, Hari N.; Chandrasekaran, B. (eds.) (1995): Diagrammatic Reasoning. Cognitive and Computational Perspectives, AAAI Press / MIT Press: Menlo Park, CA.

10 CSS (2012): Using the Internet for Public Risk Communication, CRN Focal Report 8. Center for Security Studies (CSS), ETH Zürich: Zürich.

11 Eppler, Martin; Aeschimann, Markus (2008): Envisioning Risk. A Systematic Framework for Risk Visualization in Risk Management and Communication, University of Lugano, ICA Working Paper 4/2008, http://www.knowledge-communication.org/pdf/envisioning-risk.pdf, 4.

2. VISUALIZING RISKS WITH DIAGRAMS

To support risk analysis and decision-making, ever-increasing volumes of risk data are produced every day, measured by sophisticated sensor systems, transmitted around the globe through broadband channels and compiled on servers measured in tera- and petabytes. For example, in 2011 the World Data Center for Climate (WDCC) stored 441 terabytes of climate data – roughly the volume of 100.000.000.000 pages of typewritten text.[12] The ability to master such large amounts of data by deciding what information is truly important and which information can be ignored is a key challenge for risk assessors and managers alike.[13] As Ellen Peters notes in her study on natural hazard risk analysis, "to a degree never before possible, individuals are in a position to understand natural disasters and their likelihood of occurrence and, in the process, increase control over their lives. The evidence demonstrates, however, that having an abundance of information does not always translate into it being used to inform choices. The challenge is not merely to communicate accurate information to users, but also to **present that information so that it is understood and used in decision making**".[14]

In contemporary risk analysis, this goal is mostly followed using sophisticated formal models that aim to reduce complex real-world phenomena, such as earthquakes and pandemics, to risk indicators that consist of only a few digits. Consequently, those risks or objects at-risk that score the highest should receive the most attention by risk decision-makers. However, the informative value of numerical risk data for risk decision-making is indirect at best, since **humans (particularly lay-persons, but also experts) judge probabilities not quantitatively**, but qualitatively.[15] Yet another, arguably even more important backdrop of these purely quantitative approaches to risk is that the **complexity and technicality of the analytical processes hardly allow a critical discussion of the results of these processes by non-expert policy-makers, let alone deliberative or participative forms of risk governance**. In order to develop strategies for risk governance that meet the increased requirements in liberal societies, innovative forms of risk analysis and risk communication need to be developed that enable policy-makers, stakeholders and members of the general public to understand the processes of risk analysis, which in turn enables their participation in risk governance processes to the largest extent feasible.

An alternative, though conventional form of risk communication (which is still marginal in comparison to linguistic or algebraic representations of risk), is the use of diagrams. A diagram can be defined as a form of abstraction which selectively focuses on those similarities between a sign and an object that are relevant for the semiotic process.[16] As Charles Peirce has shown, diagrams are more than hybrids between texts and pictures. Instead, they can be understood as an independent media of science that enable deductive, inductive as well as abductive reasoning.[17]

12 Deutsches Klimarechenzentrum (2012): Usage Statistics of the WDCC, available: http://www.dkrz.de/daten-en/wdcc/statistics.

13 International Risk Governance Council (2009): Risk Governance Deficits. An Analysis and Illustration of the Most Common Deficits in Risk Governance, IRGC Report, available: http://www.irgc.org/IMG/pdf/IRGC_rgd_web_final.pdf, 11.

14 Peters, Ellen (2008): Preferred Data Visualization Techniques May Not Lead to Comprehension and Use of Hazard Information, in: Technology, Risk, and Society, 14, 296–306, 296.

15 March, James G.; Shapira, Zur (1987): Managerial Perspectives on Risk and Risk Taking, in: Management Science, 33, 11, 1404–1418; Fischer, Frank (2003): Reframing public policy, Oxford University Press: Oxford, 171f.;

16 Bauer, Matthias; Ernst, Christoph (2010): Diagrammatik. Einführung in ein kultur- und medienwissenschaftliches Forschungsfeld, Transcript: Bielefeld.

17 Peirce, Charles S. (2000): Semiotische Schriften, Band I, 1865–1903, Suhrkamp: Frankfurt am Main, 393f.

The aim of a diagram is to reduce complexity of data through the deliberate omission of non-essential aspects. One of the major epistemological advantages is that diagrams allow eidetic thinking, i.e. using the photographic memory to perceive information and solve problems. This allows to test hypotheses and data intuitively against each other, while keeping the analytical process transparent and open to scrutiny.[18] These features make diagrams exceptionally interesting for collaborative risk analysis as well as dialogical risk communication.

Summary: Key features of a diagram

- Functions as a reduced graphical sign of a reference object
- Omits all non-essential aspects of the represented object
- Visualizes different information dimensions with multiple semiotic elements
- Allows eidetic testing of hypotheses
- Fosters transparent and collaborative analysis of complex data

Yet, to harvest the full potential of this form of risk visualization, each risk diagram needs to be designed according to the specific goals of the broader risk communication process. Therefore, the first question when designing a risk diagram should always be: *who* will use the diagram (target audience) and *what* is its core purpose? Since visualization of risk information should always be understood just as an element of a broader risk communication strategy, **the choice of a risk communication strategy should optimally determine the technique of visualization**.

More specifically, however, the role of context should be taken into consideration. In particular, factoring in the characteristics of the audience, such as visual literacy, attention span, topic expertise, can and should influence the type of diagram approach. Whether the goal of particular risk visualizations is to support the information exchange between experts, provide policy-makers with condensed information or engage the involvement of stakeholders should have chief consequences for the design of risk visualizations. For example, as we have lined out in our recent focal report on risk communication in the internet, developing interactive online applications can be a fruitful approach to provide target audiences with tailored information quickly and at relatively low costs.[19] Yet, 'going online' is by far a universal remedy. One of the drawbacks is that online risk communication is ineligible to integrate older or socially disadvantaged parts of society. As Alex Pang rightly highlights, "in the context of hazard communication, there are many stakeholders that need the information e.g. planners, emergency response teams, media, broader public, etc. Obviously, different stakeholders need different information and use it in different ways. A 'one-size-fits-all' approach in hazard visualization may therefore not be the right approach".[20] Rather, **diagrams should be designed to support the target user to answer specific questions** and the conciseness of the chosen representation is the central quality criterion for diagrams.[21]

In general, there exists a broad array of different diagram types that can be used to visualize risks, ranging from line, pie and dot charts over histograms to heat maps and density plots, depending on the data that should be represented and the goal of the visualiza-

18 Bogen, Steffen; Thürlemann, Felix (2003): Jenseits der Opposition von Text und Bild. Überlegungen zu einer Theorie des Diagramms und des Diagrammatischen, in: Patschovsky, Alexander (ed.) Die Bildwelt der Diagramme Joachims von Fiore. Zur Medialität religiös-politischer Programme im Mittelalter, Thorbecke: Ostfildern, 1–22, 10.

19 CSS (2012).

20 Pang, Alex (2008): Visualizing Uncertainty in Natural Hazards, in: Technology, Risk, and Society, 14, 261–294, 283.

21 See Bertin (1974: 17) for an excellent discussion of the quality criteria of graphical systems.

tion.[22] Rather than provide an exhaustive review we highlight and briefly assess three important visual techniques used in risk diagrams: spatial relationship, color and animation. We employ examples from different risk governance documents as well as from one online application to illustrate some of the opportunities and pitfalls of diagrammatic risk visualizations. We start with a simple risk matrix that uses two spatial dimensions to depict two dimensions of information. Then, we continue with another risk matrix that adds the semiotic element of color, although the example does not exhaust the potential of color use in risk diagrams. To contrast, we give a third example that illustrates how a distinguished use of color can add large value to visualizations of risk. Finally, we use an example to delineate ways to make use of the animation techniques in risk visualizations.

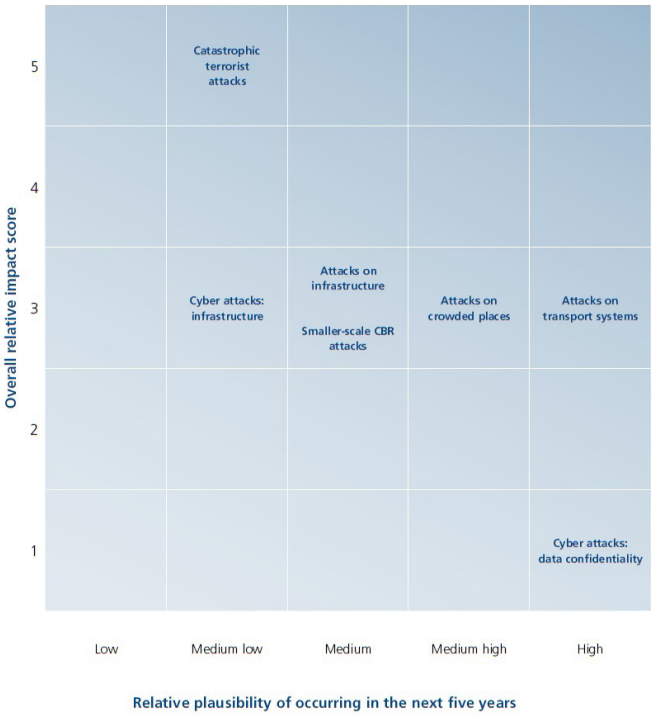

Figure 1: Risk comparison using 2-dimensional matrix (UK Cabinet Office 2012: 8)

2.1 Spatial relationships

A common purpose of risk diagrams is to compare different risks in order to support risk identification and prioritization. Graphical risk comparisons can be easily done by representing different **dimensions of risk as spatial relationships**. Such risk matrixes are frequently used in contemporary risk governance, especially to develop preparedness measures for future contingencies.[23] In most cases, risk matrices plot different risks in a two-dimensional space; with one dimension representing the probability and the other dimension representing the potential impact of the risks under examination. Figure 1 shows the diagrammatical comparison of risks in the United Kingdom Risk Register.[24]

This example illustrates both the main strengths as well as some common weaknesses of contemporary risk visualizations. The **main benefit of this diagram is that it allows comparing seven different risk types in respect to their estimated plausibility and impact at a glance**. Using this two-dimensional approach might aid policy-makers to debate whether to focus resources on low-impact, but rather frequent events or potentially catastrophic risks with a lower estimated frequency.

At the same time, the risk representation chosen in this case does not exhaust the full potential of risk diagrams. Neither does it use shapes, fuzziness, alphanumeric identifiers, nor any other graphical element that could add additional dimensions to the visual

22 For an excellent overview of different visualization techniques, see Yau, Nathan (2011): Visualize This. The FlowingData Guide to Design, Visualization, and Statistics, Wiley: Indianapolis.

23 Sometimes such risk matrices are also referred to as risk maps or heat maps. For the purpose of this paper, we reserve the term "map" for visualizations with a geographical component.

24 United Kingdom Cabinet Office (2012): National Risk Register of Civil Emergencies, 2012 edition, available: http://www.cabinetoffice.gov.uk/sites/default/files/resources/CO_National-RiskRegister_2012_acc.pdf.

representation (aside from a light use of coloring).[25] Instead, the example lies in what Edward Tufte has termed the "flatlands" of data visualizations, i.e. **the inability to represent more than two dimensions of information in one graph**. By adding further elements of visual display to the diagram, additional information could be depicted, for example temporal dynamics in the underlying data (especially since the study has a longitudinal design).

2.2 Using color

An important visual technique in many risk diagrams is the use of color. To illustrate the criticality of color in risk visualizations, we show another two-dimensional risk matrix, as used in the guidelines for construction projects in hazard zones in Switzerland (see figure 2).

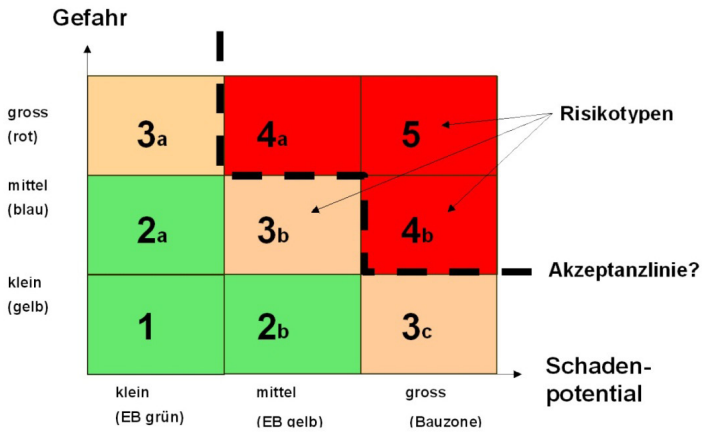

Figure 2: Risk matrix using colors (Amt für Wald und Naturgefahren Graubünden 2003)

Like in the previous example, the basic two dimensions of information (hazard and damage potential) are represented in a two-dimensional space. Yet, in comparison to the former example, this diagram is making intensive use of the semiotic element of color: Those risks that score the highest are colored in an alarming red, risks with low scores are given a mild green color, and risks in the middle category are depicted in apricot-orange.

The major advantages of this form of risk visualization are that the **viewer's attention is inevitably drawn to those risks with the highest scores and that this visual guidance is intuitively understood not only by experts, but also by lay people**. At the same time, this form of diagrammatic representation also brings its pitfalls. As Cynthia Brewer has shown, the incautious use of colors can lead to distorted visualizations.[26] In the example, the full attention is clearly guided towards the red-colored risk types. Yet in effect, due to the very broad categories, risks in the medium category may have risk scores only slightly lower than risks in the red categories. Further, the green color of low risk categories suggests that these types of risk are safe, even though they might still be considerable. But probably most important, the **alarming effect of the signal-color red works like an imperative**: Since the visualization sets the priorities itself, it does not leave much room for an independent exploration of the risk data or for an open dialogue on the acceptability of risk. The "line of acceptance" proposed in the matrix is largely predefined by the design of the diagram. While it is not the goal here to argue that color should not be used at all, the strong psychological effect of this semiotic element should always be kept in mind; otherwise visual risk communication easily gets perceived as persuasive instead of dialogue-oriented.

In contrast, the next example (figure 3) shows how the application of color can successfully support the exploration of risk data by the beholder. This exam-

25 See: Bertin, Jacque (1974): Graphische Semiologie. Diagramme, Netze, Karten, De Gruyter: Berlin.

26 Brewer, Cynthia A. (2005): Designing Better Maps: A Guide for GIS Users. ESRI Press: Redlands CA.

ple, taken from the Global Risk Report 2012 by the World Economic Forum[27], uses a so-called "small multiple"[28]. This visualization basically consists of five different small diagrams, each capturing one risk topic and a sixth diagram that combines all five diagrams into one. The diagram makes intelligent use of color, enabling the differentiation of the risk topics in the combined graph. Moreover, the variation of the dot size allows depicting the relative relevance of different risks. Yet, critically speaking, the goal of risk diagrams should not be the maximization of data dimensions within a single risk visualization. On the contrary, overloading diagrams with too much information can impede the view on those relations and thereby undermine their epistemological and communicative potential. In other words, data completeness needs to be balanced against data comprehensiveness – and sometimes less is more.[29]

27 World Economic Forum (2012): Global Risk Report. An Initiative of the Risk Response Network, 7th, available: *http://reports.weforum.org/global-risks-2012*.

28 Tufte, Edward R. (1990): Envisioning Information. Graphics Press: Cheshire, Connecticut, 67ff.

29 Peters, Ellen (2008): Preferred Data Visualization Techniques May Not Lead to Comprehension and Use of Hazard Information, in: Technology, Risk, and Society, 14, 296–306.

Figure 3: Small multiples (World Economic Forum 2012: 4f.)

2.3 Animation in diagrams

An interesting way to still add another dimension to risk diagrams is the use of animation techniques. Due to the broad dissemination of new information and communication technologies, animated diagrams can easily be integrated into public risk communication. A successful example of animated risk information is the Gapminder online tool. The Gapminder project aims to visualize, and thereby enable the exploration of global development statistics by experts as well as lay people via an interactive data visualization tool (see figure 4).

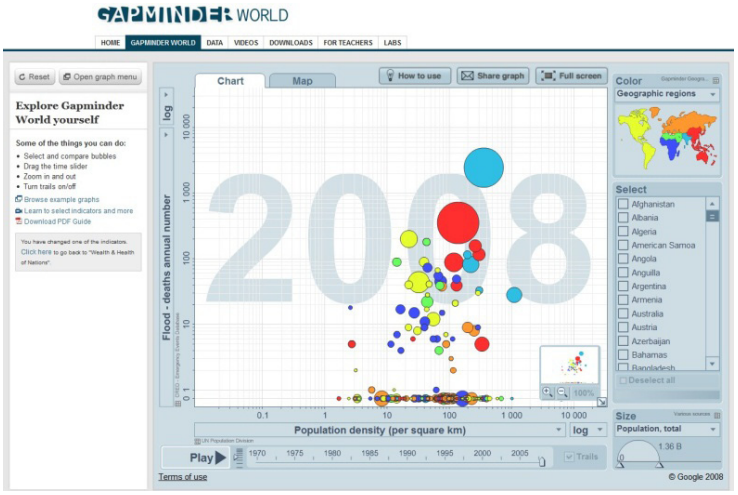

Figure 4: Interactive risk diagram (Gapminder Project 2012)

While this tool makes use of all the semiotic elements discussed previously (such as the basic two-dimensional space, color and dot size), it also uses the dimension of time to visualize data by allowing an animation of the temporal dynamics in the data. In this way, the application enables the user to plot correlations between assorted variables of choice, from human development indices to disaster risk data, rescale the variables and explore temporal dynamics. Thereby, users can 'play' with the data and investigate it visually following their own hypotheses. In particular, when the audience consists of lay people who typically lack the training and/or the patience to analyse large numbers of tables and charts, such interactive diagrams can be a fruitful solution to engage the audience in the analytical process.

Summary: Designing informative diagrams open for exploration

- Be clear about what kind of audience the diagram is made for and what the goal of your risk communication effort is
- Consider the use of various semiotic elements such as spatial relationship, shape and color
- Omit all information that is non-essential to the risk communication purpose
- Use strong signs such as alarming colors with caution
- Animate risk diagrams when time dimension is relevant
- Enable users to explore particularities and connections in the data by themselves

3. VISUALIZING THE GEOGRAPHY OF RISKS

From the world of risk diagrams we shift to a special type or subset of diagrams that is very frequently used, particularly on the operational level of risk prevention: **risk maps**. Risk maps can be defined as visual representations of the geographical location of a risk or several risks. In this chapter, we first discuss the role of maps in one-way risk communication from authorities responsible for risk management and the general public. Thereafter, we raise the question how maps can also be employed to foster two-dimensional, participatory risk communication processes.

3.1 Conventional risk maps

While maps have been used for thousands of years to communicate about dangers at particular geographical locations, the precise mapping of hazards, vulnerabilities and risks based on scientific analyses is a rather new development.[30] In Switzerland, for example, the "Gefahrenzonenpläne", developed in the 1970s, posed a major step forward in this regard.[31] Today, these hazard maps are frequently used in land-use planning and disaster prevention. At the same time, it is important to keep in mind that such hazard maps only visualize the probability of negative events such as avalanches or earthquakes, but do not map the consequences of the potential events. Therefore, hazard maps cannot be directly transferred into preventive and protective measures. Consequently, they should not be regarded as the final step of visual risk communication. Rather, they should be used to identify vulnerabilities, assess and prioritize risks and finally create risk maps. Steps to visually capture hazards as well as vulnerabilities have been taken in many recent risk visualizations.[32]

The trend to map hazards, vulnerabilities and risks has been particularly evident during the recent spread of geo-referenced information systems, which has led to the integration of geo-data at many steps in the risk management process.[33] Yet, not only have geo-technologies quickly spread, geo-data are no longer the domain of geographical experts either. In fact, the public is increasingly familiar with using spatial data, which in turn has led literally to an explosion of geo-referenced data and geo-applications.[34] Today, **maps are used in all stages of the risk management cycle**, from the exploration and analysis of risk data to the synthesis and presentation of risk information.[35]

Maps are principally well-suited to communicate risks to citizens, largely because they are able to relate rather abstract concepts (such as vulnerability and risk) to the areas where people and their assets are situated. Risk maps are often perceived as more

30 Monmonier, Mark (1997): Cartographies of Danger: Mapping Hazards in America, University of Chicago Press: Chicago, 286.

31 Keiler, Margreth; Fuchs, Sven (2010): Berechnetes Risiko, in: Egner, Heike & Pott, Andreas (eds.) Geographische Risikoforschung, Erdkundliches Wissen, Franz Steiner: Stuttgart, 51–68, 56ff.

32 See e.g.: Müller, M.; Vorogushyn, S.; Maier, P. Thieken, A.H.; Petrow, T.; Kron, A.; Büchele, B.; Wächter, J. (2006): CEDIM Risk Explorer – a Map Server Solution in the Project "Risk Map Germany", in: Natural Hazards and Earth System Sciences, 6, 711–720.

33 Egner, Heike; Pott, Andreas (2010): Risikotransparenz durch Verortung, in: Egner, Heike & Pott, Andreas (eds.) Geographische Risikoforschung, Erdkundliches Wissen, Franz Steiner: Stuttgart, 83–94.

34 Cutter, Susan (2008): Keep Representations Simple for Effective Communication, in: Technology, Risk, and Society, 14, 311–318, 313.

35 MacEachren, Alan M.; Kraak, Menno-Jan (1997): Exploratory Cartographic Visualization. Advancing the Agenda, in: Computers and Geosciences (special issue), 23, 4, 335–343; Radke, John; Cova, Tom; Sheridan, Michael F.; Troy, Austin; Lan, Mu; Johnson, Russ (2000): Application Challenges for Geographic Information Science: Implications for Research, Education, and Policy for Emergency Preparedness and Response, in: URISA Journal, 12, 2, 15–30.

concrete for the affected population than, for example, numeric representations of risk. Maps are also superior to other forms of diagrams due to their conciseness, as Nathan Yau notes: "You don't get the same effect with bar graphs or dot plots, but with maps, the data can become instantly personal".[36]

To note, a detailed map can be used by residents not only to assess their personal risk, but also to prepare for potential disaster and develop emergency plans. To give an example how maps can support risk decision-making, figure 5 shows a map of mudflow hazards at Mount Shasta volcano, California. Although the different sectors (A, B, C) do not depict risk but hazards, through the graphical overlay of potential emergency routes this map nonetheless provides valuable risk information. Though reading such thematic maps properly requires certain levels of visual literacy, in many cases maps can ease the assessment and analysis of risk data by lay citizens in comparison with numerical representations of risk. In particular, online applications that permit the user to zoom in and out of risk maps can provide detailed information on risks when needed, without losing the big picture.[37] Since many citizens already use these functions of maps as graphical user interfaces (GUI) in their everyday lives (e.g. when using traffic navigation software), online maps can serve as convenient user interfaces also to navigate through additional layers of geo-referenced data.[38] However, maps can easily get confusing if all potentially interesting data is displayed in a single map. As an example, in some instances it may be goal to visualize different types of hazards within a single map to enable a comparison between different risks. In such cases, it can be advisable to compare the different risks just pairwise or choose an interactive map in which the user can add and remove different layers of risk information according to his or her own preferences. As with diagrams more generally, **maps should avoid overloading their users with non-essential data**. In his seminal book on the visualization of information, Edward Tufte highlights the responsibility of the risk communicator to decide which risk information is truly essential and which design serves its communication when he summarizes that "confusion and clutter are failures of design, not attributes of information".[39] Therefore, effective use of maps in risk communication requires a profound knowledge of techniques of data visualization, risk perception and particularly of the audience's needs.

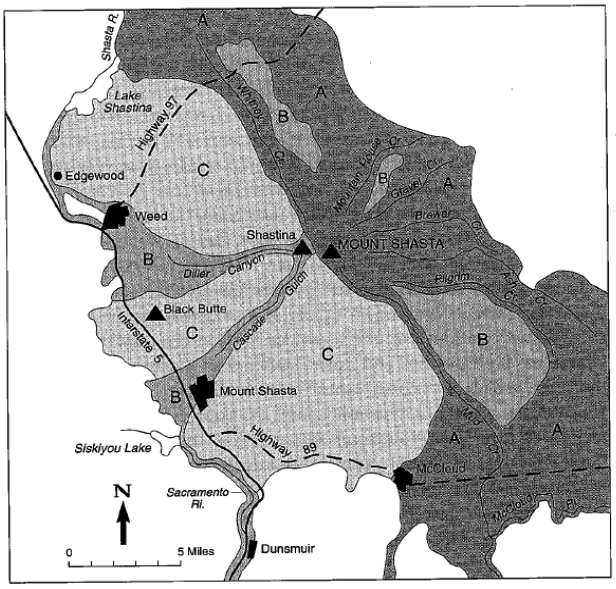

Figure 5: Actionable hazard map (Crandell & Nichols 1993: 18, as depicted in Monmonier 1997: 62)

36 Yau, Nathan (2011): Visualize this. The FlowingData Guide to Design, Visualization, and Statistics, Wiley: Indianapolis, Indiana, 272.

37 Example of such online risk maps include the CEDIM Risk Explorer for Germany (see Müller et al. 2006) or the Cantonal Hazard Maps in Switzerland (see Bundeskanzlei (2012): Kantonale Gefahrenkarten, available: *http://www.ch.ch/gefahren/02012/02048/02111/index.html?lang=de*).

38 E.g. the Strauss Center›s program on Climate Change and African Political Stability (CCAPS) uses an online map to visualize climate change vulnerability, but also allows to explore geo-referenced information on conflict events as well as aid projects in the same user interface, see Robert S. Strauss Center (2012): Climate Change and African Political Stability, available: *http://ccaps.aiddata.org/dashboards/show/539920*.

39 Tufte (1990: 53).

While risk maps can be extremely useful to communicate with the public about risks, the limits of risk maps should always be kept in mind. The mapping of risks is particularly fraught with problems if the geographical component of a risk is either negligible or knowledge about it insufficient (e.g. risks such as pandemics or terrorism where societal factors are prevailing). But not only can the lack of geographical information pose a serious impediment towards the mapping of risks. More generally, **whenever risk data (whether geographical or not) is highly incomplete or ambiguous, the use of risk maps should be reconsidered**, since the visualization of uncertainty in risk maps is often exceptionally challenging.[40] These limits of data visualizations should be openly addressed in order to manage expectations, as Monmenier highlights: "Imprecision and uncertainty are unavoidable, but autocratic pronouncements that 'the map is the map' are politically explosive, if not ultimately self-defeating, unless government maintains a high, uniform standard of data quality and provides prompt correction of obvious oversights".[41] Frequently the error is made to disregard the problems of uncertainty, ambiguity or measurability in risk maps. Yet the omission to address these challenges of risk mapping can undermine the analytical processes risk maps are designed to support, as Husdal warns: "Risk maps derived from risk analysis often portray only one possible scenario and do not leave much room for personal interpretation".[42] In particular when risk maps involve a balancing between different social values and interests, such as weighing risks to human lives against potential economic losses, developing risk maps should rely on a broad social involvement, deliberation and acceptance.[43] In doing so, as Eppler and Aeschimann highlight "the process of creating and modifying a risk visualization is as important (if not more) as the final result"[44], since it can help to mitigate political and social conflicts. In short, **risk mapping has to be understood as an inherently political process**. Consequently, professional risk communicators need to consider strategies to integrate stakeholders as well as the general public into participative risk mapping processes.

3.2 Bottom-up risk maps

Although it is widely acknowledged today that public risk communication should be a two-way process (see Introduction), most official publications nonetheless present risk information – be it numerical, textual or visual – in ways that put the public into the passive position as an information receiver. In order to overcome this shortcoming, risk communication can benefit from visualization tools that allow the user not only to explore the provided risk data along with his or her interests, but also contribute data to the visualization – making it a more dynamical two-way process.

In this respect, **mapping technologies appear promising since they involve stakeholders and citizens in the risk data generation processes**. To further develop this, one strategy can be to organize map-making workshops with relevant stakeholders and citizens from at-risk communities. Such events can be effective in bringing together experts, policy-makers and stakeholders as well as the broader public. The Illinois State Water Survey's (ISWS's) Risk MAP Project illustrates how stakeholder inclusion into risk-mapping

40 Pang (2008: 263), see also Peters (2008).

41 Monmonier, Mark (1997): Cartographies of danger: mapping hazards in America, University of Chicago Press: Chicago, 287.

42 Husdal, Peter (2001): Can it Really be that Dangerous? Issues in Visualization of Risk and Vulnerability, Husdal.com blog entry, available: http://www.husdal.com/2001/10/31/can-it-really-be-that-dangerous-issues-in-visualization-of-risk-and-vulnerability; see also Eppler & Aeschimann (2008: 19).

43 Tate, Eric; Cutter, Susan L.; Berry, Melissa (2010): Integrated Multihazard Mapping, in: Environment and Planning B: Planning and Design, 37, 646–663, 647.

44 Eppler & Aeschimann (2008: 27), brackets in original.

can function. At the start of the project, stakeholders were invited to so-called "discovery meetings" in different geographical areas with the goal to garner information about areas of concern and potential gaps in existing flood risk data. The comments and suggestions from the discovery meetings were then integrated into risk maps which then served as the basis for the next steps in the risk management process. Figure 6 shows one of the resulting maps, depicting *inter alia* streams of concern, community requests as well as areas that need further analysis.[45]

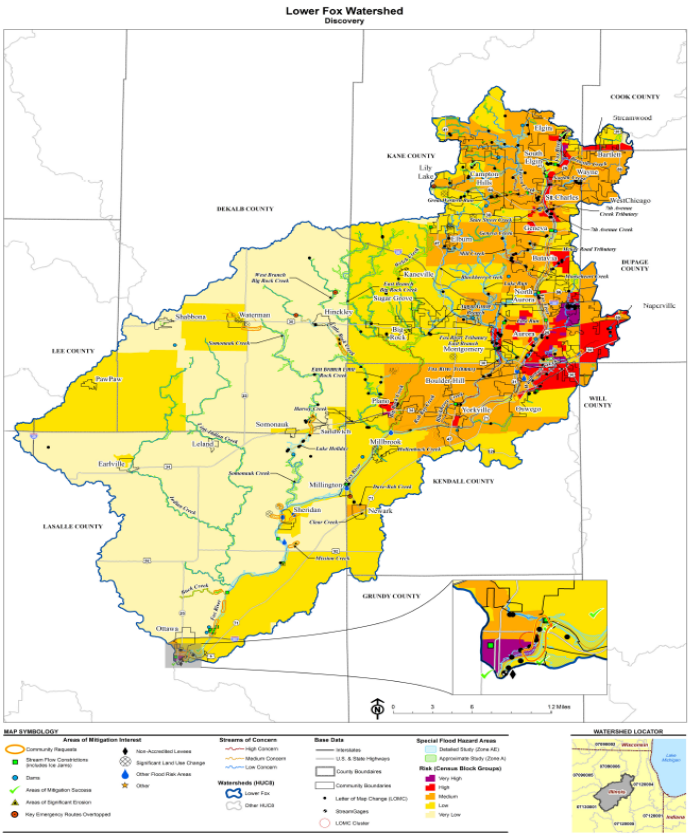

Figure 6: Stakeholder-driven map (Illinois State Water Survey Prairie Research Institute 2011)

An alternative strategy to engage stakeholders and citizens even more directly is map-making through so-called **crowdsourcing online services**. In a nutshell, crowdsourced mapping is the collection and compilation of volunteered geographic information (VGI) by large numbers of online users. Contributed data is verified by other users and then layered on existing online maps such as Open Street View or Google Maps.

In recent years, crowdsourced maps have been repeatedly used to collect and visualize risk and crisis information. Prominent examples include the crowdsourced humanitarian maps created shortly after the Haitian earthquake in 2008 as well as maps with evacuation information and radiation measurements provided by Japanese citizens after the Tsunami catastrophe in 2011 (see figure 7).[46]

45 Illinois State Water Survey Prairie Research Institute (2011): Lower Fox River Watershed Discovery Report, available: http://www.illinoisfloodmaps.org/images/MP-197%20Web.pdf; see also: Federal Emergency Management Agency (2011): FEMA's Risk Mapping, Assessment, and Planning (Risk MAP) Fiscal Year 2011, Report to Congress, March 15, 2011, available: http://www.fema.gov/library/viewRecord.do?id=4656, 6f.

46 CSS (2012a): Conceptualizing the Crisis Mapping Phenomenon. Insights on Behavior and the Coordination of Agents and Information in Complex Crisis. Focal Report 7. Center for Security Studies (CSS), ETH Zürich: Zürich.

Figure 7: Crowdsourced risk and crisis mapping (Sinsai.info 2010)

In their relatively short history, crowdsourced maps have mostly been created by 'grass roots' actors such as humanitarian activists or technophile students, and often followed by state actors. Professional risk and crisis managers were doubtful of the quality of the crowdsourced data and might also have feared a loss of control over crisis and risk communication processes. However, officials increasingly recognize the value of VGI for crisis and risk management. For example, a recent study by MacEachren et al. found that emergency management personnel expects map-making to be of high benefit for their future work.[47] Moreover, crowdsourced maps have been identified as an effective means of fostering public involvement in risk and crisis governance and thereby contributing to societal resilience. As Radke et al. observed more than a decade ago "there is a strong need for public participation, both in developing GIS for emergency preparedness and for gaining access to it during a disaster. This sense of participation and ownership has implications for empowerment within community and grassroots groups who are often relied upon during emergency response."[48]

With the spread of new information and communication technologies as well as of geo-information systems, the importance of crowdsourced maps and other forms of bottom-up risk visualizations will most likely increase significantly in the next years. Professional risk managers will have to adapt to these new developments in the realm of crisis and risk communication in which official communication is only one channel among different, sometimes competing voices. In other words, they should embrace these new forms of public involvement in risk governance; otherwise they face the danger of getting side-lined. In some instances governmental risk managers can consider ways to integrate crowdsourced mapping projects into their own communication strategies.

47 MacEachren, Alan M.; Kraak, Menno-Jan (1997): Exploratory Cartographic Visualization. Advancing the Agenda, in: Computers and Geosciences (special issue), 23, 4, 335–343.

48 Radke, John; Cova, Tom; Sheridan, Michael F.; Troy, Austin; Lan, Mu; Johnson, Russ (2000): Application Challenges for Geographic Information Science: Implications for Research, Education, and Policy for Emergency Preparedness and Response, in: URISA Journal, 12, 2, 15–30, 25.

4. FINAL REMARKS AND IMPLICATIONS

In this report, we have addressed the question of how visual techniques can contribute to the growing expectations related to public risk communication. The need to find new strategies to improve public risk communication stems in part from the increasing complexity of available information that must be synthesized for effective risk management. Also, there is an increased expectancy of the public to be provided with understandable, usable and verifiable risk information that allows citizens to engage in collaborative risk governance. Using different examples of risk diagrams, we have shown how semiotic techniques can be employed to create informative visualizations of risk data. Yet, we also pointed to different challenges in the use of risk diagrams. In addition, we focused our analysis on the visualization of georeferenced risk information with the use of risk maps. Again, we employed real-world examples from different countries to assess the opportunities as well as the pitfalls of this form of risk visualization. Bringing together the insights from our examination of risk diagrams on the one hand and from our discussion of risk maps on the other, we can draw different conclusions for the use of visualization techniques in public risk communication more generally below.

4.1 Benefits and drawbacks of risk visualization

Overall, our analysis shows that visualization techniques can be used very effectively in public risk communication. In comparison to lengthy risk reports – often written in the technical jargon of the risk analyst or manager – or columns of figures in risk statistics, visual forms of risk communication have major advantages. First of all, if risk visualization is well-crafted, the information provided is often easier to comprehend for both experts and lay persons than purely textual or numerical risk information. Further, by combining different semiotic elements, risk visualizations are able to facilitate the communication of multi-dimensional risk information. Since diagrams allow the eidetic testing of hypotheses against risk data, they are principally well-suited to enable the independent exploration of risk information when viewing the graphic. The possibility to easily explore complex risk data in turn allows the audience to take a more active role in public risk communication. At the same time, as particularly the examples of collaborative risk mapping have shown, visual techniques not only proliferate stakeholder and public involvement in processes of risk analysis but also into risk assessment and risk mitigation. Due to this versatility, risk visualizations appear as a promising way to foster public involvement and participation at different stages of the risk management circle.

However, to be really effective, risk visualizations need to be well-embedded into a broader risk communication strategy that matches the nature of the risk and the needs of the audience the communication is aimed at.[49] Therefore, risk visualization should never be confused with strategic risk communication. Even the fanciest risk visualizing application cannot replace such a strategy, which – at least according to contemporary best practises – should be guided by principles of transparency, fairness and inclusiveness.[50] A good illustration of how risk visualizations

49 Callaghan, James D. (1989): Reaching Target Audiences with Risk Information. In: Covello, Vincent T.; McCallum, David B.; Pavlova, Maria T. (eds.): Effective Risk Communication. The Role and Responsibility of Government and Nongovernment Organizations, Plenum Press: New York, 137–142.

50 Covello, Vincent T. (2003): Best Practices in Public Health Risk and Crisis Communication, in: Journal of Health Communication, 8, 5–8; CSS (2009): Risk Analysis. Risk Communication in the Public Sector, CRN Focal Report 3. Center for Security Stu-

can be integrated into an overarching risk communication strategy are the "Shaky Grounds" earthquake risk maps for California, produced by the Association of Bay Area Governments (see figure 8). In fact, the "Shaky Grounds" is more a risk information campaign than simply a series of maps. At the heart of the campaign are 35 different earthquake scenarios, visualized by using fine-scale risk maps. The scenarios are well-integrated into the broader disaster preparedness program of the Bay Area communities that addresses representatives of local governments as well as businesses and the citizens in the affected areas.[51]

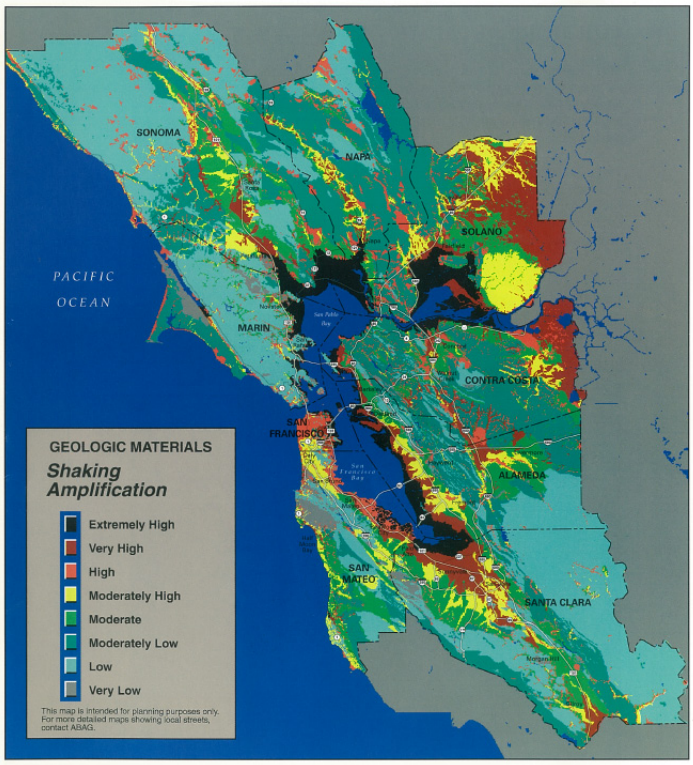

Figure 8: Mapping natural hazard risk scenarios (ABAG 2010: 24)

In order to employ risk visualizations successfully, it is central to keep in mind the strengths of this communication form, but also the pitfalls of risk visualizations. One major challenge in the visual communication of risk that our report identified was to avoid the (mis)perception of high precision information, when in fact the visualized data is characterized by high levels of uncertainty or ambiguity. Levels of uncertainty and ambiguity should be included in risk visualizations whenever necessary. If this point is neglected, risk visualizations can easily mislead the audience about the certainty of the risk information and thereby undermine the whole risk communication process. Consequently, to avoid such pitfalls of visual risk communication, a profound knowledge of different visualization techniques as well as their communicative effects is pivotal.

Related to the challenge of visualizing uncertainty is the issue of false objectivity. Monmonier's reminder that, "a single map is but one of an indefinitely large number of maps that might be produced for the same situation or from the same data" holds true for risk maps and risk diagrams in general.[52] In particular, when risk issues are controversial, for example due to diverging risk perceptions among different political actors, risk visualizations can easily suggest an objectivity that is in fact pseudo-objectivity. Yet, since risk analysis and risk management in disaster management (just as in many other domains) are highly political processes by nature, so is the visualization of risks.[53] Therefore, it is essential to integrate risk visualizations into a broader risk communication strategy that takes into account the political and social contexts.

dies (CSS), ETH Zürich: Zürich, available: http://www.isn.ethz.ch/isn/Digital-Library/Publications/Detail/?id=110683&lng=en

51 Association of Bay Area Governments (2010): On Shaky Grounds. The San Francisco Bay Area, ABAG Earthquake and Hazards Program study, available: http://quake.abag.ca.gov/wp-content/documents/2010-On-Shaky-Ground.pdf; see also Association of Bay Area Governments (2012): Taming Natural Disasters – Regional Hazard Mitigation Plan, available: http://quake.abag.ca.gov/mitigation

52 Monmonier, Mark (1991): How to Lie with Maps, University of Chicago Press, Chicago, 2.

53 Crampton, Jeremy W. (2010): Mapping. A Critical Introduction to Cartography and GIS, Wiley-Blackwell: Malden, 9.

Effective risk visualizations ...

- raises risk awareness and self-efficiency
- communicates about risks with audiences unfamiliar with statistics
- involves stakeholders and citizens in data generating processes
- activates the audience with interactive risk visualizations
- uses risk maps as interfaces to explore risk data with geographical components

Unsuitable risk visualization ...

- restricts risk communication to risk visualization
- visualizes low quality/ high uncertainty data uncritically
- uses risk visualizations to suggest false objectivity / avoid political controversies
- employs risk visualizations without profound knowledge of visual techniques and their effects

4.2 Risk visualization in Switzerland

In Switzerland, visual techniques are generally becoming increasingly well-established in official risk communication. Since many years, diagrammatic visualizations of risk, such as comparative risk matrices, are established techniques in strategic disaster risk identification and management in Switzerland. Further, in recent years, remarkable efforts have been put in the development of natural hazards maps that are particularly useful for land-use planning and hazard prevention on the operational level. Today, already 80% of the area of Switzerland is covered in the Hazard Maps, which are the responsibility of the Cantons. The remaining 20% are planned to be mapped by the end of the year 2013.[54] How such hazard maps can serve as the basis for further risk management activities, is impressively illustrated in the MobiGIS project by the Swiss insurance company Mobiliar. MobiGIS combines the Cantonal Hazard Maps with object-specific, geo-referenced insurance data and thereby allows visualizing the geographical location of risks.[55] At the same time, MobiGIS represents a good example of risk data integration through visual techniques (see figure 9).

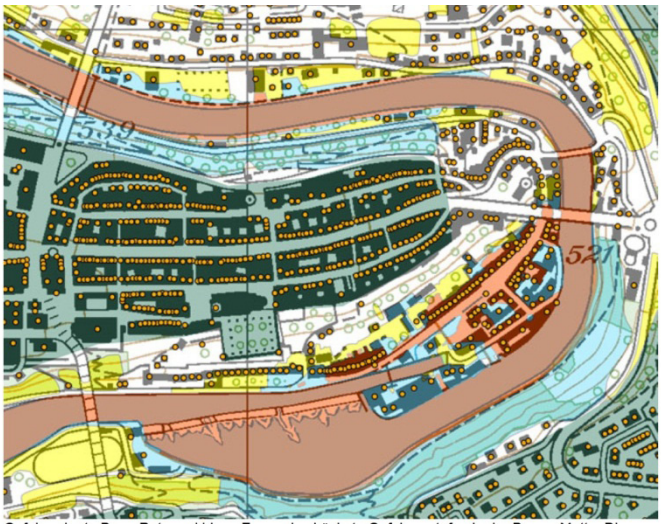

Figure 9: Integration of official hazard maps and geo-referenced insurance data (Mobiliar 2010)

In order to ensure the cooperation and understanding of local stakeholders and the affected public alike, the Swiss authorities increasingly employ communication approaches that situate natural hazard maps into interactive communication strategies. As an example, the National Platform on Natural Hazards (PLANAT) has designed a toolbox for risk dialogue that includes detailed guidance how to communicate with stakeholders and citizens about hazard and risk maps (see figure 10).[56]

54 Bundesamt für Umwelt (2012): Gefahrenkarten zu 80 Prozent erstellt, BAFU Press release, available: http://www.bafu.admin.ch/dokumentation/medieninformation/00962/index.html?lang=de&msg-id=44640

55 Mobiliar (2010): MobiGIS -Naturgefahren sofort erkennen, Mobiliar press release, available: http://www.mobi.ch/mobiliar/live/diemobiliar/engagement/praevention-sicherheit/mobigis_de.html.

56 Nationale Plattform Naturgefahren PLANAT (2012): Praxiskoffer Risikodialog Naturgefahren, available: http://www.planat.ch/de/infomaterial-detailansicht/datum/2012/04/23/praxiskoffer-risikodialog-naturgefahren

Gefahrenkarte
Quelle: Kanton St. Gallen

Risikokarte
Quelle: Kanton St. Gallen.

Figure 10: Making risk-mapping transparent and understandable (Nationale Plattform Naturgefahren PLANAT 2012: 3/4)

A prime example of the growing importance of risk visualizations is the National Hazard Analysis 'Risks Switzerland', in which diagrams and maps play an important role to support risk decision-making as well as public risk communication.[57] Yet, although visual risk communication is gaining ground in Switzerland, it still lags behind textual and numerical techniques that have dominated the disciplines of risk management for many decades. In order to better exploit the potential of visual techniques for the communication of risks in the Swiss context, it is important to invest in training programs that support the development of visual risk communicators as well as public visual literacy. More than 40 years ago, Eduard Imhof concluded in his seminal book on cartography that while advancements in the technics of map making can be useful, the key to better geographical and graphical representations lies in the training of those who produce the maps.[58] This statement still holds true in the age of Google Earth and 4D heat maps. In addition, diagrams, maps and other visual communication techniques require a specific type of literacy that is only peripherally taught at schools and universities today.[59] In order to foster public understanding and use of visual methods, Swiss authorities could possibly initiate workshops and other educational measures. An initiative that could serve as an example is the e-learning course Visual-Literacy.org, a teaching project by four Swiss universities that focuses on the creative use of visualizations in business, communication, and engineering.[60] In addition, to match the heightened importance of mapping techniques in risk communication, workshops dealing with the compilation and application of geo-referenced data could be organized. These workshops should not be restricted to professional risk managers and communicators, but also target at stakeholders in risk governance as well as the broader public.[61] In this way, visual methods can be employed to promote two-way risk communication.

57 Bundesamt für Bevölkerungsschutz (2010): Nationale Gefährdungsanalyse ‹Risiken Schweiz›. BABS strategic paper, available: http://www.bevoelkerungsschutz.admin.ch/internet/bs/de/home/themen/gefaehrdungen-risiken/nat__gefaehrdungsanlayse.parsysrelated1.32618.downloadList.90800.DownloadFile.tmp/risikenschweiz.pdf

58 Imhof, Eduard (1965): Kartographische Geländedarstellung, De Gruyter: Berlin, 402.

59 See Larkin, Jill H.; Simon, Herbert A. (1995): Why a Diagram Is (Sometimes) Worth Ten Thousand Words, in: Chandrasekaran, B.; Glasgow, Janice; Narayanan, Hari N. (eds.) (1995): Diagrammatic Reasoning. Cognitive and Computational Perspectives. AAAI Press / MIT Press: Menlo Park, CA, 69–109, 107f.;Goodchild, Michael F.; Janelle, Donald G. (2010): Toward Critical Spatial Thinking in the Social Sciences and Humanities, in: GeoJournal, 75, 3–13..

60 Bresciani S.; Eppler Martin J. (2010): Enhancing Group Information Sharing Through Interactive Visualization: Experimental Evidence, in: Proceedings of the Academy of Management Conference, August 6–10 2010, Montreal, Canada.

61 As an example, Harvard Humanitarian Initiative has organized different courses on the techniques of crisis mapping that aim to train citizens to partake in collaborative mapping projects, see Harvard Humanitarian Iniative (2012): Crisis Mapping and Early Warning, available: http://hhi.harvard.edu/programs-and-research/crisis-mapping-and-early-warning

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