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Living near natural hazards in the age of climate change – the relationship between expert and local knowledge in risk governance

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Abstract: The paper addresses the integration between science-based risk monitoring and forecasting of snow avalanche risk, with the experience-based and local knowledge involved in field observations of snow and weather conditions on Svalbard. We present the result of a scoping review of literature and interviews with stakeholders involved in producing input information to the monitoring and forecasting system. We discuss the role of tacit knowledge and its translation into a standardized monitoring system, the importance of a professional community of field observers, the nature and content of local knowledge on Svalbard, the integration of the different forms of knowledge.

Keywords: Risk governance, snow avalanche, risk monitoring, uncertainty, local knowledge

1. Introduction

Existing research on risk governance and crisis management focus heavily on the roles, responsibilities and actions of formal institutions and organizations. However, risk governance and emergency preparedness consist of more than the planned efforts from authorities (Comfort et al., 2013), with an increasing focus on altruism, local knowledge and community capacities (e.g., Dynes, 1994; Tierney, Bevc & Kuligowski, 2006; Tengesdal & Kruke, 2018; Wisner & Luce, 1995). Risks and crises are also experienced, made sense of and coped with in the affected communities. This has made several authors argue for a general need to move from a whole-of-government approach to a whole-of-society approach in the governance of risk (e.g. Lindberg & Sundelius, 2013).

The contributions from knowledge embedded in local communities for dealing with crises has been previously described in the research literature (e.g., Meyer 2013). Less is known about the way this form of resilience can be tapped into for mitigating risks. This is the point of departure for this paper. Our research question is the following: What is the role of local knowledge in integration with sensor data and scientific knowledge in avalanche risk monitoring?

Several publications underline the need for integration across the two domains of objective and situated knowledge in risk governance (e.g. Gardner, 2014; Papathoma-Köhle & Dominey-Howes, 2018). However, there are few empirical studies showing how this integration may look like in practice. We aim to target this research gap by means of an in-depth study of the integration between expert and local knowledge in the risk governance of avalanche risk in Longyearbyen, the administrative centre of the Norwegian archipelago Svalbard. We present a brief scoping review of literature that is

specifically targeting the combination of expert and local knowledge regarding snow avalanche risk. This is complemented with an interview study of experts involved in the modelling and monitoring of risk, and field observers that feed knowledge into the monitoring and decision-making system based on qualitative observation and location-specific experience.

2. Monitoring of snow avalanche risk in Longyearbyen

Longyearbyen is a small Arctic community located on the Svalbard archipelago at 78 degrees north. It has an origin as a "company town" run by the mining companies since 1906. Today, it is no longer a company town but a part of Norwegian territory that is governed similarly to Norwegian municipalities and counties.

The possibility of snow avalanches is obvious on Svalbard, due to topography, climate and weather conditions. However, the management of avalanche risk was traditionally largely seen as an individual responsibility associated with hiking, skiing or snowmobiling in the terrain *outside* the village. This perception of avalanche risk changed dramatically following two urban avalanches in 2015 and 2017, causing two fatalities and shattering 12 houses. These events demonstrated that avalanche risk was clearly present also in the village itself. This, together with an increasing recognition of climate changes occurring at a faster pace in the Arctic than further south, led to the establishment of physical risk reducing measures and a centralized monitoring and forecasting system of avalanche risk in Longyearbyen (Indreiten, 2020).

The overarching responsibility for avalanche forecasting lies with NVE, but the monitoring and forecasting system is contracted by a company located on the mainland, with scientific expertise on both snow conditions and the modelling of avalanche risk. Information about snow and weather conditions is combined in order to make a forecast of the avalanche risk. This generalized expertise is complemented by the local expertise of field observers that are localized on Svalbard and employed by NVE. In addition to the field observers, any laymen can (and do) register information about snow conditions, also on the Internet platform "Varsom.no". The input data of the monitoring and forecasting system is thus comprised by quite different forms of knowledge.

2.1. The local forecasting and warning system for avalanches in Longyearbyen

The local avalanche warning system for Longyearbyen consists of a daily assessment that is made during the avalanche season between November 1st and May 31th Depending on the risk level identified in the daily assessment, a more detailed assessment is carried out based on the current situation and a prediction for the next 22 hours (Øien et al. 2022). The input data are meteorological data, wind measurements, images from laser scanning, web camera images and registered field observations that can be made by both trained observers and informal observers travelling in the terrain.

The heterogenous input data is processed into assessments and initial recommendations by a private company with expert scientific knowledge on avalanche risk and risk modelling. The risk assessments and recommendations (e.g. evacuation) are thus based on combining different forms of knowledge – some based on objective measurement, others based on qualitative considerations, all with associated uncertainty. It is the latter that is of particular interest in this paper. Whereas sensors are stationary and designed to measure a defined and limited number of parameters in a specific location, skilled observers and citizens move around in the terrain and can make more comprehensive assessments of snow conditions. The monitoring contributions of such actors thus bear the potential of providing rich information of high value to risk governance tailored to specific localities, temporalities and contexts (see also Gardner, 2014). At the same time, the integration of this qualitative and comprehensive knowledge with the quantitative and parameter-specific knowledge of sensors and other measurements are not unproblematic, as we will return to in section 4.

3. Research methods

The first step of the study was to get an overview of the current avalanche monitoring system in Longyearbyen. This involved an assessment of the actors involved in assessment of dynamic snow and weather conditions, in addition to a review of existing documents describing the

setup of the system. This was documented in a separate report (Øien et al., 2022)

Second, we performed a "scoping review" of literature that were specifically targeting the combination of expert and local knowledge regarding snow avalanche risk. A scoping review entails a literature search and review that is directed at determining the scope or coverage of a body of literature concerning a specific topic (Munn et al., 2018). The aim was thus not to conduct a formal literature review of the use of local knowledge in all domains, but to identify the main strands of research addressing local knowledge in the specific field of avalanche risk.

This literature was used as a backdrop for analysing the results from a qualitative study of stakeholders in the Longyearbyen risk monitoring system, including the local observers from Longyearbyen. In total, 28 key stakeholders were interviewed. Table 1 shows an overview of the distribution of roles in the interview sample.

Table 1. Overview of interview sample

Actor	**No. of interviews**
National authorities	4
Local and regional authorities	10
Companies providing expertise on avalanche risk forecasting	3
Consultants	2
Local observers	6
Members of local community and industry	3
Total	28

The interviews were semi-structured as they were organized according to a prepared interview guide, but with significant leverage for the informant to influence the order of topics and the possibility to introduce other topics related to avalanche risk monitoring (Kvale, 1997). All interviews were individual, except those with the local observers which were interviewed in two groups à three persons. All interviews were conducted by two researchers, where one of the researchers had the responsibility to make notes of the main information available immediately, for post-interview reflections in the researcher team. The interviews were also recorded and transcribed.

All these sources of information feed into the analysis and discussion aiming to draw out lessons from well-functioning integration of expert and local knowledge, as well as barriers for such integration.

4. Theoretical basis and previous research

The avalanche risk monitoring and decision-making process is approached from a risk governance perspective. This means that we analytically divide the process into the five basic steps IRGC (2017):

(i) Pre-assessment, where candidate hazards are screened, interpreted and framed.

(ii) Risk appraisal, consisting of an assessment of the risk's factual and physical characteristics, in addition to a concern assessment of different stakeholders' interpretations, interests and concerns about the risk.

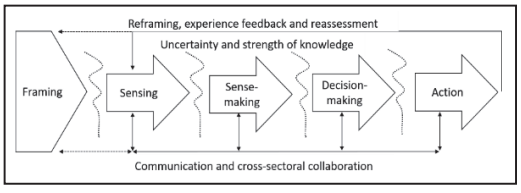
(iii) Risk judgement, i.e., making evaluations of the tolerability of risk as well as a risk characterization where complexity, uncertainty and ambiguity are key categories

(iv) Risk management, referring to processes of strategy development, decision-making and implementation efforts.

(v) Communication (both between the actors involved in analyses and an external audience) and stakeholder engagement.

With the risk governance process as a starting point, a more case-specific model was developed, to account for the different forms of knowledge involved, and the process of sensemaking that is involved in the transition from turning information into decisions and action (see figure 1).

Fig. 1. The process from risk framing to risk-reducing action.



The paper's literature study targeted the "sensing" and "sensemaking" dimensions of the model. Sensing and sensemaking are closely related as the first forms the premise for the latter. The ability to monitor and thereby "sense" changes in context refers to how individuals use retrospective knowledge, the available information, and the enactment of actions previously taken by agents. Sensemaking is hence "the ongoing retrospective development of plausible images that rationalize what people are doing" (Weick, et al. 2005: 409). Plausibility is an essential element in the process, as it determines to which a given community will provide legitimacy and thereby trust in the decision-making and, finally, the actions coming out of this process. It is fair to argue that trust is about social exchange (Blau, 1994) and thus dealing with risk and uncertainty. "I trust you because I think it is in your interest to attend to my interests in the relevant matter (Hardin, 2002: 6). This is also relevant in the sense making process involving actors with different background and knowledge.

The main bulk of literature on the relationship between scientific expert knowledge and more practice-based knowledge was found under the headings of Disaster Risk Reduction (DRR), Climate Change Adaptation (CCA) and Nature-Based Tourism (NBT). A strand of research rich on empirical studies, is the literature on disaster risk reduction (DRR) (e.g., Wisner, Gaillard, & Kelman, 2012). While the role of local knowledge in general disaster risk reduction (see Khan et al., 2013 for a conceptual discussion) has been subject to considerable research attention, and some promising research on indigenous population adaptation to climate change in the Arctic (Pearce, Ford, Willox, & Smit, 2015), there are few studies focusing explicitly on snow avalanche risk.

One exception is Solli and Ryghaug (2014), who studied the use of local knowledge in climate change adaptation activities related to avalanche risk. They found the local knowledge to be "externalized" in the design of physical avalanche prevention measures, as well as in emergency planning. This was attributed to a lack of acknowledgement of local knowledge from the actors representing the scientific field, causing challenges for the translation of knowledge between the two domains.

Another example is Reichel & Frömming's (2014) study of "participatory mapping" processes in the Alpine region of Switzerland. The participatory mapping was a cartographic approach where local inhabitants took part in a risk management process, achieving an integration of local knowledge in the sustainable management of a natural environment. Such anthropologically inspired studies are rare, as the authors state themselves: *[t]he integration of local knowledge, to broaden an adaptive governance approach in the face of the specific challenges associated with climate change and natural hazards in alpine areas, is just beginning.* (Reichel & Frömming, 2014: 52).

The bulk of the empirical research on the use of local or tacit knowledge in risk assessment seems to be on Nature Based Tourism, adventure sports, outdoor leadership, field operations and the like. This is where individuals or groups are either planning for trips in avalanche terrain, in need of skills to make ongoing risk considerations or actions for survival in case of a disaster (Stewart-Patterson, 2008; Shooter & Furman, 2011). This literature provides valuable insight into the content of local knowledge, tacit knowledge and the risk intuition involved in on-site naturalistic decision-making (e.g., Indreiten et al., 2018; Landrø et al. 2019), but usually without linking this knowledge to more comprehensive risk governance processes involving other actors.

In the more long-term perspective of risk governance, there are a few studies connecting snow avalanche research and land-use planning. Lopez-Cabo analyzed the transfer of knowledge about avalanches to land-use planning by means of a qualitative study of avalanches in central Europe. The emphasis was on studying the transitions of knowledge between different stakeholders in the knowledge generation sphere, to the decision-making sphere.

There are three main conclusions that can be drawn from the literature review. One is that there is limited available literature specifically targeting the integration of local knowledge into wider frameworks of governance of avalanche risk. The second is that several of the studies identified indicate that the integration of quantitative, scientific knowledge and the more qualitative local knowledge has proven problematic. The third is that field observations of avalanche risk involve highly situation-specific considerations where tacit knowledge and intuition plays an important role. In the next sections, these interpretations of the identified literature will be seen in relationship to the data from the interview study.

5. Results from the interview study and discussion of results

5.1. The role of tacit knowledge and the translation to standardized monitoring

We asked the field observers to put into words what they did when they observed and reported, and what kind of competence they saw as important to be a good observer. They described a comprehensive knowledge which included both scientific and experience-based knowledge.

The observers described an assessment process that started long before arriving at the given points where the specific snow tests were to be made. The comprehensive observation process started at the outset of the trip, sometimes with a hypothesis of what the relevant avalanche problems may be. Information is gathered through all senses also on the way to the specified sites and used as contextual knowledge for the detailed tests of snow conditions. This is an example of tacit knowledge and that we sometimes "know more than we can tell" (Polanyi, 1967:4), since experience-based knowledge and practice always will include craftmanship-like judgements that are hard to explicate.

Although there seems to be a significant contribution from experience-based intuition and tacit "feeling" for the snow, the results from observations are made explicit by being registered in a standardized reporting system, based on the methods of the so-called systematic snow cover analysis (see e.g., Kronthaler et al., 2013). This transition from tacit to explicit knowledge (Nonaka & Takeuchi, 1995) make the results available for both communication to other actors and combination with other sources of knowledge. The transformation of rich observations to standardized data involves an obvious reduction of information, with a corresponding risk of something getting lost in translation. This is, however, compensated by having direct communication between the observers and the modelling expertise in the company that compiles the various types of risk-related information. It is common for this interaction to take place in situations of uncertainty, or where there is increased risk of avalanches. Thus, there is a redundancy in the modes of interaction that enables both standardization and interpretation of the results and implications of specific observations.

Having several modes of interaction between field observers and the ones responsible for making an avalanche forecast is only a necessary, yet not sufficient, condition for the ability to integrate the two forms of expertise. In the interviews, both sides of this interface emphasize the importance of establishing interpersonal relationships between the actors. This was both a matter of knowing the other party and trusting the knowledge he/she possesses. This is a prosaic aspect of all social relationships, but it becomes a critical issue in the avalanche monitoring system since it influences the communication and interpretation of potentially critical information in potentially critical situations. In particular, trust in different forms of local knowledge is important in this respect, a topic we return to in section 5.3.

5.2. "Talk nerdy to me" – the importance of the community of field observers

The singular observations of snow conditions at a given point in time are usually made by individual observers. However, the observers in

Longyearbyen describe a community of observers where "nerdy" discussions about snow and weather, including informal observations made in their spare time, are key parts of their common interest and topics of conversation. This means that a singular observation at a given location can be contextualized both in time and space – it is put into patterns of previous observations and at different locations. Considerations of what an observation means in terms of risk is thus not only the result of isolated measurements, but also framed through a continuous collective process of pattern recognition and interpretation. This can be seen as a form of informal quality-control which has previously been described by Indreiten (2020) as an important mechanism for reducing uncertainty in avalanche monitoring.

The community of field observers is by no means a homogenous group. Their backgrounds are varied and include in addition to expedition guiding several areas of scientific expertise, e.g., in meteorology and avalanche risk assessment. What is shared is a far-above average interest in snow conditions, as well as for outdoor activities in an Arctic setting. This is a sort of community of practice (Wenger, McDermott & Snyder, 2002), within the community, but also with the experts responsible for the monitoring and forecasting system. We see this integration as an important prerequisite for the synthesis of the different forms of expertise involved in making accurate predictions and decisions related to avalanche risk.

5.3. Local knowledge - What does "local" mean?

As already indicated, the utilization of local knowledge has been emphasized as a key dimension for understanding natural hazard risk (e.g., Gardner, 2014). However, our data indicates that the term "local" needs refinement. Avalanche risk in Longyearbyen is obviously a phenomenon that is localized to the geographical place. At the same time, the local avalanche monitoring system is the product of a heterogenous actor-network where several key actors are not located on Svalbard. We found that the "local" was conceptualized along four different axes: First, several informants used the term "Svalbard experience", referring to experience that comes with having lived on Svalbard for a prolonged period of time. Second, having in-depth *experience-based* knowledge of snow and weather conditions on Svalbard, acquired by spending time on outdoor activities that required consideration of avalanche risk, and having a genuine interest in avalanche problems. A third form of possessing local knowledge was by having in-depth *scientific* knowledge of snow and weather conditions on Svalbard. Fourth, local knowledge was described as a relational capital in knowing people that spend a lot of their time in the Svalbard nature and make either formal or informal observations of snow conditions.

Thus, 'local' does not necessarily point to geographical presence, but to the strength of *local reference*. For references to be traced all the way from the observation point at a snow shovel to the experts office on the mainland, and back to the decision makers in the offices at Longyearbyen, there need not only to be fiber cables, but also sufficiently strong social ties – or relations of sufficient high quality – all the way. This put constrains to the exchangeability of key actors in the monitoring system.

The four axes link sensing and decision-making (see figure 1). The sensemaking process lends legitimacy to actors who have local experience and are considered trustworthy experts by the community. Being regarded as legitimate increases trust in the actions taken to mitigate or accept risks and the possible consequences that arrive from these. The combination of the different forms of knowledge, expertise, use of scientific methods and legitimacy in the community, forms the essential elements in the sensemaking process. The avalanche monitoring system is the result of "articulation work" spanning different forms of expertise and legitimacy. It is possible to acquire context-knowledge from a distance, that is considered legitimate from the other actors, by having experience with applying specialist knowledge to the specific context *over time*. The question of which form of knowledge can be considered local is therefore as much a matter of time then it is a matter of place.

5.4. A well-integrated monitoring and forecasting system

Examples from the literature study hinted at a "devaluation" of the qualitative observational

data in comparison to hard, scientific measurements. In our data, we do not find the same antagonistic relationship between these two forms of knowledge. Instead, the field observers are described as the "eyes and ears" of those responsible for the formal risk modelling. Field observers cover a lot of ground and make more comprehensive assessments of conditions (snow, weather, slope), compared to sensor data. And importantly, they not only report conditions – they also engage in interaction on interpretation of the severity of a situation and possible future development of the conditions. Should situations arise where there is discrepancy between sensor data and field observations, the tendency would be to place priority on the field observations.

6. Conclusion

How can then sensor data and aggregated expert knowledge on risk be complemented with the more local and often tacit knowledge involved in making observations about dynamically evolving situational conditions? To answer this question, we need first to understand that we need both the more quantitative expert data and the local and often tacit knowledge to understand the risk of snow avalanche and thus to implement resilient strategies to prevent avalanches, but also to prepare for the residual risk, the risk we could not prevent. Even with the most sophisticated and comprehensive avalanche forecast system, the uncertainty involved in avalanche forecasting means that we need all the data and inputs we can get, from experts and citizens, to deal with the dynamic risk of avalanches.

Although there are certainly examples that it is a demanding task for the field observers to translate the rich and comprehensive observations of snow conditions into a more standardized model, this seems to be more related to the relationships between the two knowledge communities than to properties of the knowledge in itself. The model presented (see figure 1) illustrates the process of risk framing to risk action by including both sensory and decision-making processes, which contribute to legitimizing the steps taken to mitigate, accept or stop a possible threat from materializing.

The discussion is then as to when and how various forms of knowledge is regarded as legitimate by the community, who eventually will be the ones implementing the actions that experts are recommending. Here we have argued that both time and spatial specific elements form the foundation for this process. Individual actions can gain trust by providing expert knowledge over a prolonged period, which the community regards as accurate in their specific context. Physically remote experts can, by virtue of their analytical accuracy, over time, overcome the legitimate concern that they do not have experience or expertise from the specific context by using rigorous scientific methods and gaining information from a comprehensive local network of people with substantial local knowledge.

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