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Learning from crisis: The 2015 and 2017 avalanches in Longyearbyen

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ABSTRACT

Longyearbyen has been hit by two avalanches in 2015 and 2017 causing severe damages to housing and two fatalities. In this study we investigate organised learning processes regarding emergency preparedness and response following the avalanches. Longyearbyen provides a case of particular interest as climatic change rapidly is altering the environmental conditions, including the risk of avalanches.

First, the study outlines the organisation, scope and participation of learning processes, that is, who learns, when and what is the scope. Second we investigate whether the lessons learnt are single-loop or double-loop; if they focus on corrective actions of existing systems and policies, or if they address the more fundamental aspects, such as norms, strategies and policies. Third, we consider how contextual factors influence learning. Finally, we investigate how learning has been followed up by implementation. The study concludes that the first avalanche of 2015 led to a broad and inclusive evaluation and learning process and a series of recommended measures, including the establishment of an avalanche warning system. It also initiated a broader double-loop process of reassessing risks, redrawing the plans and maps of Longyearbyen, and raising physical preventive barriers. However, the second avalanche demonstrated the limitations of the established system in 2015. This spurred a range of corrective actions to the system, but also it established that in a time of climate change, historical experience no longer provides a basis for assessing risks.

1. Introduction

Svalbard is a high-Arctic archipelago located 700 km north of the Norwegian mainland, midway between continental Norway and the North Pole. Longyearbyen, the largest settlement and the administrative centre, is located in the centre of Svalbard's main island, Spitsbergen. Svalbard's mountainous landscape has experienced frequent avalanches in recent decades (Eckerstorfer, 2012). On Saturday morning, 19 December 2015, following a powerful storm, a naturally triggered avalanche swept down the slopes of Mt. Sukkertoppen, hitting part of Longyearbyen and causing two fatalities and many injuries. Eleven houses were displaced from their foundations and totally destroyed; over two hundred people were evacuated. The whole community spontaneously organized a massive search and rescue effort in addition to the official emergency response (DSB, 2016). Slightly more than a year later, on meteorological conditions similar to those of December 2015, another avalanche from Sukkertoppen February 2017, hit two blocks of flats near to those that had been destroyed in the 2015 avalanche. No one was injured, but the Governor of Svalbard ordered parts of the town evacuated. These two avalanches of 2015 and 2017 are historically unprecedented, as no previous avalanches from Sukkertoppen had resulted in major infrastructure damage (Hancock et al., 2018).

The area around Svalbard is among the most climatically sensitive in the world (Rogers et al., 2005). The special climate around the archipelago creates unique avalanche conditions, rendering Longyearbyen exposed (Longyearbyen Local Government 2012). However, research on avalanches in Svalbard has been limited (Prokop, et al., 2018), and knowledge of Arctic snowpack conditions related to avalanche initiation in Svalbard is incomplete. The situation is further complicated by the changing climate and weather patterns of recent years due to global warming. All these circumstances make accurate avalanche forecasting difficult, potentially leading to increasing numbers of fatalities and infrastructure loss (Hancock et al., 2018; Eckerstorfer, 2012). In addition, the growing numbers of residents and tourists pose new demands to basic avalanche research as a basis for future forecasting (Eckerstorfer, 2012).

This study contributes to the literature on post-crisis organizational learning, addressing the need for more empirical studies (Moynihan,

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2009; Broekema et al., 2017; Pursiainen, 2018). Crises trigger organizational change, and disasters offer opportunities for learning in order to improve performance (Birkland, 2009). Since the avalanches of 2015 and 2017, the Norwegian authorities have taken various measures aimed at protecting Longyearbyen residents. Our in-depth study examines how the characteristics of the processes of learning and their contextual factors affect the outcomes of post-crisis learning. First, we provide a timeline and overview of the organization, scope and participation of the learning processes: who learns, when, what and how. In particular we explore the distinction between organizational-, inter-organizational and network learning. Second, we turn to the outcomes of the learning process, asking whether the lessons learnt are single-loop or double-loop – focused on corrective actions and measures to improve the performance of existing systems and policies, or addressing more fundamental aspects, such as norms, strategies and policies. Third, our study sheds light on how the post-crisis context as regards elements like political biases and time pressure affects the learning process. Finally, we investigate how learning has been followed up by implementation, examining whether and how the lessons identified are implemented and factors that affect effective implementation.

2. Material and methods

In this qualitative case study, we examine organizational learning from the avalanches that hit Longyearbyen in 2015 and 2017, covering the period from the first avalanche in December 2015, until the present. We focus on the role of formal authorities: the Governor of Svalbard (state authority), the Norwegian Water Resources and Energy Directorate (NVE) (sector agency), Longyearbyen Local Government (local authority) and Longyearbyen Red Cross – key actors with regard to providing crisis response, and developing and implementing measures aimed at reducing the probability and impact of future avalanches and protecting the local community.

Our study draws on formal documentation from learning processes – evaluation reports, policies, planning documents and conceptual studies. Evaluation reports have provided essential data on lessons identified and partly on measures implemented. After the avalanches, several reports have been issued, particularly by NVE and the Local Government, focusing on safety measures, risk reduction and more accurate avalanche warning for Longyearbyen. We have examined these to establish an overview of implemented measures.

Further, in April 2019, five anonymized, semi-structured interviews (Kvale and Brinkmann, 2009) were conducted with key actors in avalanche preparedness and emergency response in Longyearbyen, to investigate the learning process and implementation among key local actors. These interviews provided otherwise unavailable data on measures implemented with regard to lessons identified, particularly on the 2017 case and the impact on local avalanche preparedness. They shed light on the process of learning as such, including the intra- and inter-organizational aspects. Further, they help to clarify whether any other lessons could be identified, in addition to those noted in available evaluation reports. Finally, they offer different viewpoints on what happened and the aftermaths of the accidents.

An interview guide was developed by the authors, based on study of the literature. Questions were both fact-oriented, in terms of clarifying facts about the processes, and directed at respondents' individual experiences and attitudes. All informants are number-coded (see Table 1) and referred to by number in the text. The general criterion for selecting individual informants was their familiarity with of the cases. All interviews were conducted in Norwegian; portions were subsequently translated into English by the lead author. Interview notes were collectively studied by the authors, employing directed qualitative content analysis (Frey et al., 1999; Hsieh and Shannon, 2005). Interview data were categorized into four main themes: process and context of learning; outcomes of the learning processes; measures implemented; and their impact on local avalanche preparedness. Categorizations and data analysis were reviewed collectively to ensure the validity of interpretations and findings (Silverman, 2005).

Informant 2 provided the coding of the 2017 case on implementation. In addition, one of the authors is currently employed at the Governor of Svalbard's office. The knowledge and competence of this author were invaluable for completing this study, enabling access to all available reports on both cases and specific internal documents. This author undertook the initial round of coding of the measures taken in response to lessons identified in the 2015 case.

Table 1
Informants and their affiliations.

Code	Organization
INF 1	Norwegian Water Resources and Energy Directorate (NVE)
INF 2	Norwegian Water Resources and Energy Directorate (NVE)
INF 3	Longyearbyen Red Cross
INF 4	Longyearbyen Local Government
INF 5	Governor of Svalbard

3. Theory

3.1. Organizational learning

The concept of 'organizational learning' (Schön, 1983) entered organization studies in the late 1970s (Argyris and Schön, 1978, p. 111) and early 1980s (Hedberg, p. 22, 1981; Dery, 1982; Peters and Waterman, p. 110, 1982). However, understanding of the field is still 'vague and elusive' (Gherardi, 1999). and there is no generally accepted definition of the concept or common analytical framework (Broekema, et al., 2017; Levy, 1994; Stern, 1997). The concept of organizational learning has been regarded as a metaphor: organizations do not literally 'learn' in the same sense as individuals do (Levy, 1994, p. 287). Organizational learning occurs through individuals (Argyris and Schön, 1978, p. 28) but is not a 'cumulative result of their members' learning' (Hedberg, 1981, p. 6). Learning is a cycle that 'involves a multistage process in which environmental feedback leads to individual learning, which leads to individual action to change organizational procedures, which leads to a change in organizational behaviour, which leads to further feedback' (Levy, 1994, p.288). Importantly, it can be both formal (i.e. planned and structured) and informal (based on spontaneous interaction and knowledge sharing) (Janowicz-Panjaitan and Noorderhaven, 2008). Our study understands the learning in question as 'the acquisition of new knowledge and the translation of this knowledge into more effective organizational action' (Broekema, et al., 2017). This approach recognizes that organizational learning has both a cognitive and an action dimension (Fiol and Lyles, 1985) and provides a bridge to the issue of implementation that we address further in the study.

If learning is produced through both the detection and correction of error, we may conclude that 'the lack of either or both inhibits learning' (Argyris, 1976, p. 365). The detection of errors is associated with some sort of investigation following an event. Sound instrumental policy learning from disasters can be achieved through careful investigation following an event leading to 'policy change as a result of careful investigation, assessment, and policy design' (Birkland, 2009, p. 150). However, evaluating crisis management is challenging, as criteria against to measure success/failure are commonly lacking (McConnell, 2011) and the processes are prone to subjectivity (Drennan, McConnell and Stark, 2015, p. 216).

Studies have focused on measuring and categorizing organizational learning (Argyris and Schön, 1978; March, 1991; Miner and Mezias, 1996). Argyris and Schön (1978), who distinguish between single-loop and double-loop learning, offered one of the most influential categorizations of organizational learning; learning is single-loop (hereafter: SLL) '[w]henever an error is detected and corrected without questioning or altering the underlying values of the system (be it individual, group,

intergroup, organizational or inter-organizational) (Argyris and Schön, 1978, p.8). By contrast, 'when errors are corrected by changing the governing values and then the actions', double-loop learning (hereafter: DLL) occurs (Argyris, 2002, p.206). SLL works best when 'the external environment changes slowly or when organizational premises and the environment are not in conflict. In times of rapid change, however, managers may feel an urge to undertake inquiries that question the organizational status quo' (Deverell, 2009, p. 181). SLL is about doing the same things better, whereas DLL is a deeper form of learning that addresses 'the root causes of the disaster, not the superficial causes' (Choularton, 2001, p. 64). Error detection is connected to the 'very norms which define effective performance' (Argyris, and Schön, 1978, p. 22). SLL and DLL learning are 'not contrary to each other or mutually exclusive' (Deverell, 2009, p. 185); in practice, there is a continuum between the two types of learning. However, in order to turn crisis management from being an efficiency problem to involving successful change of the whole system, there should be a balance between 'doing things right' (SLL), and 'doing the right things' (DLL) (Bakacsi, 2010, p. 5). 'Double-loop efforts may cause actors to overlook or forego useful single-loop lessons (van Duin, 1992 cited in Dekker and Hansén, 2004; Argyris and Schön, 1996)'. On the other hand, 'placing a great deal of attention on single-loop lessons may cause organizations to miss out on valuable double-loop learning' (Deverell, 2009, p. 185). Although the two strategies are intertwined, SLL has been held to be more common than DLL (Birkland, 2009), and 'lessons that are more fundamental are learnt with difficulty' (Choularton, 2001, p. 61). Moving from SLL to DLL is demanding, as there always is a trade-off between allocating resources to the exploitation of existing practices or to the exploration of new alternatives (March 1991). However, achieving a level of learning which addresses the root causes of disasters is important, as failure to do so could lead to disaster (Miner and Mezias, 1996, p. 89). Far too often, extensive focus on SLL becomes the enemy of organizations seeking to solve many difficult problems (Argyris and Schön, 1978).

3.2. Learning in crisis management

Organizational learning in crisis management literature is a relatively recent topic (Smith and Elliott, 2007). Therefore, our understanding of the relationship between crisis and learning is limited (Deverell, p. 179, 2009; Bakacsi, p.4, 2010), and research has highlighted the need for further empirical knowledge and theory building in the field (Broekema et al., 2017). In particular, limited attention has been paid to organizational and network learning (Moynihan, 2009). Post-crisis learning requires further investigation, 'especially concerning the mechanisms and conditions through which individual lesson identification is transported into institutionalized lessons' (Pursiainen, 2018, p. 155). Further research is needed, focusing on the barriers to and the facilitators of learning from post-crisis evaluations, to transfer new understandings into revised norms and behaviours within organizations (Elliott, 2009, p. 166).

Organizational learning has been increasingly recognized as both a central process and a challenge in crisis management. Through learning, an organization can enhance its crisis-management capabilities and build resilience (Crichton, Ramsay, & Kelly, 2009). '[T]he literature on post-event learning is often characterized by an assumption that crises will lead to rational policy evaluations, clear-headed lessons and organizational improvements which will enhance future crisis management efforts' (Drennan, McConnell and Stark, 2015, p. 193). However, the question 'whether crises trigger systemic change or whether they forestall' it still remains open (Boin,'t Hart, Stern and Sundelius, 2005, p. 134). Disasters as 'focusing events' (Kingdon, 1995) open an opportunity for organizational change and learning (Birkland, 2009; Stern, 1997; Dekker and Hansén, 2004; Smith and Elliott, 2007). Yet this does not imply that learning always happens (Smith and Elliott, 2007, Deverell, 2009). Research has acknowledged that organizational learning from crises is complex and difficult (Stern, 1997; Smith and Elliott, 2007; Broekema, et al., 2017), highlighting that the limited learning capacity of policymakers and public organizations (Sabatier, 1987; Levy, 1994; Stern, 1997; Deverell, 2009; Broekema, et al., 2017). Too often, learning processes 'simply result in ['fantasy documents' (Clarke, 1999)] that [due to lack of instrumental utility] fail to address the real problems revealed by an event' (Birkland, 2009, p. 155), turning the whole process into a 'fantasy exercise' (ibid, p. 154). We must bear in mind that organizational learning 'in theory and in practice are somewhat different' (Carley and Harrald, 1997, p. 326).

Another aspect of organizational learning concerns the context of crisis management. All learning is context-dependent (Gherardi, 1998). The difficulty of effective learning increases with the rising complexity of the problem in question (Argyris, 1976, p. 365). Organizational learning from crises differs from organizational learning in routine situations (Moynihan, 2008a) as crisis brings in new dimensions. This is the 'arduous paradox' of crises: 'the need for learning is regarded highest under circumstances in which it is most difficult to achieve' (Dekker and Hansén, 2004, p. 212). The crisis context is characterized by considerable uncertainty and ambiguity, and high external pressure on public organizations, combined with political criticism and possible loss of institutional legitimacy. This makes it challenging to draw clear-cut lessons from events (Dekker and Hansén, 2004) and could lead to defensive and introverted organizational behaviour that may inhibit learning (Hermann, 1963). Crisis creates a sense of urgency: decisions have to be made in haste. This entails the risk of superficial learning 'without some sort of attempt to analyse the underlying problem' (Birkland, 2009, p. 148). Moreover, crisis is often associated with political involvement, which will influence the learning capacity of public organizations. 'Political attention may contribute to more fundamental reflection on the basic principles and values of an organization' (i.e. to DLL) – but it may also 'cause biases in the analysis of organizational failures' (Dekker and Hansén, 2004, p. 132). This further implies that 'organizational learning in the public domain cannot be understood fully without considering its broader political environment' (ibid., p. 212).

Crisis management typically depends on more than one organization in terms of responding and learning (Moynihan, 2008b), which leads into the topic of *network learning* (NL) (Moynihan, 2009, p. 190). Network learning refers to learning by a group of organizations – with more or less formal or loosely structured relations (Moynihan, 2008a) – in a given context (Knight, 2002). This will bring together more knowledge and skills than a single organization (Brass et al., 2004), and provide greater potential for joint action (Kraatz, 1998). With network learning, the network is both the 'learner' and the learning context. Ultimately, network learning leads to changes in network attributes, like interaction, processes and structures, institutionalization of coordinated practices, implementation of shared views and interpretations (Dunford and Jones, 2000) and to improved network performance (Knight, 2002). NL should be distinguished from *inter*-organizational learning (IL), which is learning by individual organizations *within* a group of organizations (network) (Knight, 2002, p. 435). IL has a focus on learning by the individual organization as the 'learner'. However, the distinctions are subtle (Knight, 2002), and some view IL as synonymous with NL (see e.g. Dyer and Nobeoka, 2000). The point here is that we assume that how learning takes place – as intra- or inter-organizational, or through networks – will have an effect on the outcomes.

3.3. Implementation

The correction of errors is related to implementation of lessons identified (Argyris, 1976). It is not sufficient to identify lessons. In order to be 'learned', lesson must be implemented: errors must be corrected through systematic alteration of organizational behaviour (Deverell, 2009, p. 180). This makes implementation a central issue in learning from crisis. Learning should not be taken for granted. There is a clear difference between lessons *identified* (organizational ability to declare new information or knowledge based on the crisis experience), and

lessons *learned:* the latter involves the ability to alter behaviour systematically in response to new knowledge (Deverell, 2009, p. 180). Research has focused on what affects learning from crises (Broekema et al., 2017), more specifically why organizations fail to learn (Argyris, 1976; Stern, 1997; Smith and Elliott, 2007), and has identified organizational inertia as the most obvious explanation of failures in post-crisis learning (Pursiainen, 2018, p. 156). Lessons identified too often remain mere declarations. 'Efforts to learn after crisis often result in small-scale changes because reforms are constrained by institutional legacies and intransigent public policies' (Drennan, McConnell and Stark, 2015, p. 191). Political involvement is an important factor here. It may inhibit organizational learning (Argyris, 1976; Senge, 1990) but may also contribute to learning processes within the public sector (Dekker and Hansén, 2004). Elliott (2009) claims that when there is a gap between policy and practice, it may constrain opportunities for learning. On the other hand, the synergetic interaction of politics and practice may enhance learning.

3.4. Analytical implications

Thus, we can note a series of critical issues in the study of post-crisis learning. First, assessing learning requires including both the identification of lessons and their implementation (Deverell, 2009): whether lessons identified remain 'fantasy documents' or are acted upon in practice. Second, do lessons identified address fundamental challenges and causes of unwanted events through double-loop learning – or are they directed primarily towards corrective actions within the established system (Argyris and Schön, 1978)? Moreover, these forms of learning are not mutually exclusive (Deverell 2009): it is necessary in each case to consider the balance between lessons aimed at 'doing things right' and 'doing the right things' (Bakacsi, 2010). Third, post-crisis learning is difficult due to a range of factors that include the complexity of the crisis itself, political biases and time-pressure. Thus, it is important to identify how contextual factors, such as the political environment or the attributes of the case, facilitate or inhibit learning processes (Dekker and Hansén, 2004; Elliott, 2009). Fourth, how does the participation in and organization of the learning process affect its outcomes? This influences who learns what and how, and ultimately the effectiveness of learning in terms of identifying important lessons and implementing the right solutions. Here it is essential to distinguish among organizational, inter-organizational and network learning (Knight, 2002).

4. Results

4.1. Crisis management on Svalbard: Key actors and regulatory framework

Norway's crisis management system for avalanches is complex, involving multiple actors on Svalbard and on the mainland. Nationally, the Ministry of Justice and Public Security has overall responsibility for civil protection and emergency preparedness (DSB, 2016). The Polar Affairs Department of the Ministry deals, *inter alia,* with the administration carried out by the Governor of Svalbard (hereafter: 'Governor'), who is the Norwegian government's highest ranking representative on Svalbard (Norwegian Ministry of Justice and Public Security, 1925, 2019). The Governor is both Chief of Police and also has the authority corresponding to that of a County Governor on the mainland. The Governor has overall responsibility for the all work concerning public security, emergency preparedness and crisis management in Svalbard (Norwegian Ministry of Justice and Public Security, 2012). To gain an overview of risk and vulnerability, the Governor is to prepare a risk and vulnerability analysis for Svalbard (Svalbard ROS) in close cooperation with other actors. The Governor shall also follow up the work of Longyearbyen Local Government (hereafter: LLG) on public security through supervision, exercises and advice (Norwegian Ministry of Justice and Public Security, 2016). The Governor also heads the Preparedness Council established as a forum between all central public, voluntary and private organisations that contribute to emergency preparedness and crisis management. The Preparedness Council discusses issues based on risks and vulnerabilities, and will coordinate response between participating organisations during a crisis.

Rescue operations on Svalbard are conducted in collaboration between public bodies, non-governmental organizations and private actors, through the Local Rescue Coordination Centre (hereafter: LRCC Svalbard). LRCC Svalbard consists of all major actors involved in rescue operations; LLG, Fire and Rescue, Telenor Svalbard (telecom), Longyearbyen Hospital, Store Norske Spitsbergen Kulkompani AS, the SAR helicopter service Lufttransport and the Longyearbyen Red Cross (Norwegian Ministry of Justice and Public Security, 2016). The LRCC has an Emergency Response Council lead by the Governor that coordinates local response during unwanted events (Norwegian Ministry of Justice and Public Security, 2015). The Council consists of representatives from research institutions, companies, the Longyearbyen Red Cross, the Church, and Longyearbyen Hospital, and functions as an arena for discussing and exchanging information on civil protection and emergency preparedness (Norwegian Ministry of Justice and Public Security, 2016). The Joint Rescue Coordination Centre of Northern Norway (JRCC NN) located in Bodø on the mainland, leads all maritime and large-scale rescue operations (Norwegian Ministry of Justice and Public Security, 2016).

Longyearbyen Local Government (LLG) functions largely in the same way as a mainland municipality. It is responsible for working 'systematically and holistically with social security work across sectors, with a view to reducing the risk of loss of life or damage to health, the environment and material assets' ((Norwegian Ministry of Justice and Public Security, 2016), para. 2). This includes risk and vulnerability analysis, area- and contingency planning, and having a programme for training and exercises. LLG is also responsible for safeguarding people during evacuations. The Norwegian Water Resources and Energy Directorate (hereafter: NVE) is responsible for mapping the risk of landslides and floods, and warning in case of avalanches. From 2013, NVE has responsibility for avalanche prevention in Svalbard, providing expertise and resources for mapping, area planning, protection, monitoring, warning and emergency preparedness. Since 2015 NVE has been responsible for the avalanche warning system on Svalbard. NVE also acts as an adviser to the Governor and LLG on avalanche preparedness and crisis management. Emergency preparedness in Longyearbyen also relies on the competence and capacity of the Longyearbyen Red Cross, in terms of preparedness and in response capacity. Further, Longyearbyen has an emergency medical hospital with 24-hour emergency preparedness, a branch of the University Hospital of North Norway (2019). Longyearbyen Hospital provides health services during emergencies (Norwegian Ministry of Health and Care Services, 2015).

4.2. December 2015 avalanche

4.2.1. Evaluation process and lessons identified

The evaluation of the December 2015 avalanche was organized as a project and conducted by representatives from the Norwegian Directorate for Civil Protection (DSB), the Norwegian Police University College and the Joint Rescue Coordination Centre Southern Norway (DSB, 2016). The involvement of DSB was based on an initiative from the LLG (INF 4). The quality of the evaluation report was ensured by a reference group consisting of representatives of all the actors involved. The comprehensive evaluation process was based on a qualitative approach using interview and document analysis as key methods of data collection. The evaluation group conducted interviews with representatives of 19 authorities, from both Svalbard and the mainland. In addition, the relevant regulatory framework, laws and regulations, guidelines, reports, logs, risk assessments, contingency plans and scientific literature were studied. Based on this evaluation, a set of lessons learned was

identified, and categorized according to different response tasks (see Table 2; DSB, 2016).

The evaluation report identified 27 lessons (Table 2), categorized according to how they relate to the functions of emergency response; warning (L1), response (L2–12), crisis communication (L13–15), first aid and crisis medicine (L16–17), evacuated, affected persons and relatives (L18–20), role of lead ministry (L21–22), avalanche prevention (L23–27). Lessons vary in scope from specific roles and responsibilities to the establishment of an avalanche warning system; six concern prevention and preparedness regarding future avalanches (L1, 23–27).

Of the lessons identified, eleven concern defining, delineating or formalizing the roles and responsibilities of the actors and how they are to interact in the avalanche preparedness system on Svalbard (L2–5, 8, 10, 11, 18, 19, 24, 27). This applies to the role of the Ministry of Justice and Civil Protection, NVE, JRCC NN, the Governor of Svalbard, LLG, and consultancy companies. In many cases it implies acting upon already existing rules and regulations, clarifying or delineating responsibilities, or establishing new routines. In other cases, these roles and responsibilities need to be defined formally in the context of Svalbard. As was confirmed by informants (INF 1–5), there was a perceived need to establish clear roles and responsibilities for avalanche preparedness and response on Svalbard.

A further set of issues concerns crisis communication, warning and notification (L6, 7, 13–16) and situational reporting (L8, 9, 12, 21, 22) – internally within the local warning system and externally to emergency actors and the public. The need to dedicate resources and establish routines also applies to other functions of the emergency response system (L12, 17, 20 26). In sum, the suggested changes reflect the need to establish the building blocks of an effective avalanche preparedness system equipped with a formal structure with dedicated resources and established procedures.

Many of the lessons focused on formal roles and responsibilities; others aimed to establish avalanche preparedness in Longyearbyen from 2016 onwards. L1 addresses the need to establish preparedness plans and check-lists for local avalanche warnings. L 23 raises the need for preparedness actors to follow up on findings from the risk and vulnerability analyses. Finally, L 25 establishes the need to establish monitoring procedures for avalanche danger in Longyearbyen as a basis for a local avalanche warning and preparedness system. These lessons identified have triggered comprehensive responses, as they are being acted upon and implemented.

4.2.2. Implementation

Since the avalanche in 2015 there has been a strong focus on avalanche prevention, preparedness and response on Svalbard (INF 1–5), and many implementation efforts have been initiated to follow up the lessons identified. All 11 lessons concerning defining the roles and responsibilities of the actors in the avalanche preparedness system on Svalbard (L2–5, 8, 10, 11, 18, 19, 24, 27) have now been formally implemented through plans, checklists, and regular meetings assigning roles and responsibilities. The evaluation report also identified a series of challenges related to crisis communication and situational reporting (DSB, 2016), leading to the adoption of new infrastructure and procedures (Table 2).

The most extensive measures taken have concerned L1, L23 and L26. In 2016, NVE conducted a hazard assessment of avalanche paths around Longyearbyen (NVE, 2016). This was based on gathering local expert knowledge about past events and the natural conditions (INF 2), and showed that portions of Longyearbyen were in areas with high avalanche risk. In addition, preparedness plans and checklists have been developed for local avalanche warnings.

Several measures have been implemented to follow up on risk and vulnerability analysis, in terms of prevention and preparedness (L23). Some measures are temporary; others are permanent. Preventive structures have been built in the Lia area, and several residents of other particularly exposed areas have been allocated new housing units in

Table 2
Lessons identified and measures implemented following the 2015 avalanche (unofficial translation).

No.	Lessons identified	Measures implemented
1	Emergency preparedness actors should establish standard operating procedures to handle warnings of extreme weather. These should be based on existing knowledge of relevant risk areas based on previous experiences, thereby improving the basis to consider all relevant risk factors in handling warnings of extreme weather.	Preparedness plan and checklists have been developed for local avalanche warnings in the form of hazard assessment for exposed buildings in Longyearbyen. Plan and checklists are continuously evaluated and revised.
2	In emergency operations on Svalbard it is important to use established structures and routines, so that roles and responsibilities are clear among the participating actors at all times.	This has been a recurrent theme during exercises since 2015. It has proven challenging, as regulations are not always adaptable to the structure of the emergency management agencies in Svalbard.
3	The use of LRCC and its Rescue Management Council, according to the operation and their mandates, provides a basis for operational (tactical) and strategic assessments and decisions. It is important that the role of the Rescue Management Council is clear.	The Governor is working to clarify the role of the Rescue Management Council. A central problem is that many emergency management agencies in Svalbard lack the capacity to operate simultaneously on the operational and strategical level during a crisis.
4	The Rescue Management Council should be involved at the strategic level during major incidents (also between incidents).	See nos. 2 and 3. Additionally, the Rescue Management Council meets 4 times per year, as does the Preparedness Council.
5	JRCC NN should take responsibility to coordinate support from the mainland during rescue operations. Close communication with JRCC NN will provide support for LRCC Svalbard.	The Governor and JRCC NN collaborate and communicate closely during rescue operations. Routines for situational reports have been established. Contact meetings and desktop exercises are held yearly. The agencies have extensive contact on other arenas.
6	Emergency response actors on Svalbard should consider developing joint warning- and communication channels.	There is a common channel on Sysselnett (radio communication) for police, LLG (fire corps), Longyearbyen hospital and the Red Cross. This initiative was initiated pre 2015.
7	The Governor should consider acquiring a system for rapid notification of relevant internal and external resources.	DSB-CIM (Crisis and Incident Management Software) has been established as a tool for warning distribution and rapid notification, both internally and externally.
8	Situational reporting based on established guidelines should be conducted in demanding emergency situations, to contribute to a joint overview and situational awareness and that relevant issues are raised to responsible authorities.	Situational reporting to the national Emergency Support Unit, JRCC NN and the National Police Directorate (POD) (cc DSB) has been integrated into checklists for major accident scenarios (i.e. Governor's contingency plans).
9	The implementation of CIM, as used by local government and the Ministry of Justice, can contribute to effective situational reporting between local government, the Governor and Ministry of Justice.	CIM was implemented by the Governor in 2018. Relevant personnel have received training in the module for situation reports. Keeping logs and reporting throughout the crisis has received increased focus.
10	NVE should clarify its role as scientific/professional coordinator as the State directorate for avalanches.	This has been settled after extensive contact between the Governor, LLG and NVE. The role of the NVE is clearly defined in The Governor's avalanche preparedness plans and checklists.
11	The delineation and coordination of responsibilities with NGI and other consultancies should be clarified.	See no. 10. Skred AS[1] is the primary consultancy agency per 2019.
12	By dedicating and training internal personnel who are not active otherwise in the rescue operations,	Governor's employees who are not police personnel have received

(*continued on next page*)

Table 2 (*continued*)

No.	Lessons identified	Measures implemented
	for writing logs and situational reporting and such, one can ensure continuity in these functions using emergency personnel.	training in the various CIM modules (log, situational report, etc.).
13	Emergency actors on Svalbard should to a larger extent prioritize public information in English.	Information concerning preparedness and crisis situations is always published on Governor's web pages in English as well as Norwegian (Governor's web pages).
14	Emergency actors with communication responsibilities on Svalbard should formalize agreements of support with internal and external resources to ensure capacity during lengthy operations.	Governor and LLG collaborate on producing and publishing information online. Governor and The University Centre in Svalbard (UNIS) have formalized an agreement on mutual support on crisis communication. JRCC-NN provides support during large-scale events and whenever it is necessary
15	Emergency actors with communication responsibilities on Svalbard should establish and maintain dialogue and cooperation also on a daily basis. This will contribute to cooperation during crisis.	See no. 14
16	It is recommended that the emergency services on Svalbard in cooperation with state authorities assess whether crisis communication is sufficient.	Governor, Longyearbyen hospital, fire rescue services and Red Cross have a common channel on Sysselnett (radio communication). Additionally, steps are being taken to develop a common log in CIM for Svalbard's emergency management agencies.
17	There is a need to upgrade equipment inventory both at Longyearbyen hospital and at the University Hospital of North Norway (UNN) Tromsø, in addition to upgrading some medical equipment at the Longyearbyen hospital.	Medical equipment has been stationed in Longyearbyen to allow for more rapid transportation from Tromsø during an acute crisis. The modernization of non-medical equipment has been put on hold, awaiting the allocation of civil defence resources in Longyearbyen.
18	Clarify the responsibility for psycho-social preparedness and following up victims and relatives.	This responsibility lies with LLG, and is part of preparedness plans and checklists.
19	All relevant professionals in Longyearbyen should be part of a formalized psycho-social emergency team.	The psychosocial emergency team consists of qualified representatives from LLG and Church on Svalbard.
20	There is a need for a system to map and follow up persons in need of long-term psycho-social follow-up, including participants in the emergency response operation as well as others not directly involved.	This is not the responsibility of LLG, Governor or other authorities on Svalbard. No implementation action taken.
21	On incidents on Svalbard, the lead ministry/Emergency Support Unit should follow up relevant actors to ensure inclusion in situational reporting.	There is increased focus on situational reporting both from KSE and Governor, Routines for Governor's reporting are formalized through plans and check lists.
22	The Emergency Support Unit, JRCC NN and any others emergency centres should clarify reporting routines for incidents on Svalbard.	The standard procedure is situational reports from Governor to KSE, JRCC NN and POD, cc DSB.
23	Preparedness actors on Svalbard should to a greater degree follow up on risk and vulnerability analysis. Where probabilities cannot be reduced, mitigating measures should be implemented.	There has been a focus on implementing permanent and temporary avalanche prevention measures, evacuation routines, area planning etc. The Svalbard risk and vulnerability analysis (SvalbardROS) is followed up through Preparedness Council meetings.
24	Relevant actors, also at the state level, should clarify responsibility for avalanche prevention in avalanche-prone areas in Longyearbyen.	Responsibility for avalanche prevention measures lies with LLG.
25	Monitoring procedures should be established for avalanche danger in Longyearbyen, with possibilities for warning and evacuation.	A local avalanche warning system was established in 2016 by NVE in cooperation with LLG and the Governor. UNIS conducts field observations that are shared on www.regobs.no. Based on observational data and local weather forecasts, Skred AS conducts daily local avalanche danger assessments. If the assessment indicates an increased risk of avalanches, Skred AS conducts a detailed risk assessment. UNIS, Governor, NVE and LLG all participate in the system and have developed relevant plans and checklists.
26	There should be a system that ensures experience- and knowledge transfer when organizational and personnel changes take place, both at the local government and Governor's office.	There is a system of 2-week overlap between old and new employees at the Governor established prior to 2015. There is also greater focus on formal documentation e.g. in CIM and other databases. All unwanted events are evaluated. LLG experience transfer and training exists, but has limitations (INF 4).
27	The Ministry of Justice and Civil Protection should to a larger extent cooperate with DSB to clarify requirements and expectations regarding the Governor's follow-up of the County Governors Civil Protection Instructions	The Ministry of Justice and Public Security has emphasized the Governor's responsibilities and role in civil protection and preparedness since the 2015 avalanche, e.g. as reflected in the Ministry's letter of allocation to the Governor.

[1] Skred AS is an independent consultancy that offers advice on issues related to floods and landslides.

other parts of Longyearbyen.

The 2015 avalanche, and NVE's subsequent avalanche hazard assessments, triggered the initiation of a local warning and evacuation system in Longyearbyen. In early 2015, there was a trial period for a regional avalanche warning system for the Nordenskiöld Land area of Svalbard (including Longyearbyen). The regional avalanche warning system was established on a permanent basis from 2016 onwards.

A local warning system for Longyearbyen was established by NVE in the direct aftermath of the December 2015 avalanche with the assistance of the University Centre in Svalbard (UNIS), LLG and the Governor of Svalbard (INF 1, INF 3). This was a follow-up of L25. The local avalanche warning system continued under NVE auspices, including local monitoring, avalanche observers, and local avalanche danger assessments. From 2019, the responsibility for the daily avalanche assessments was taken over by Skred AS. The current warning and evacuation system is a result of continuous evaluation, revision and dialogue between the agencies responsible. NVE, LLG, the Governor of Svalbard and UNIS are all involved and have developed and coordinated their organizational preparedness plans and check lists. Skred AS coordinates evaluations following each weather-cycle indicating a yellow alert level, which allows for exchange of experience and continuous revision of existing systems and routines.

The Svalbard Preparedness Council also has an important role as an arena for coordinating the efforts of emergency management agencies. It is particularly important with regard to information sharing, and works as a platform for discussion on risk areas identified for Svalbard. The forum has also been central in the process of implementing the measures identified measures in the DSB report.

4.3. February 2017 avalanche

4.3.1. Evaluation process, lessons identified and implementation

The evaluation process was conducted by experts from the

Norwegian Water Resources and Energy Directorate (NVE) and the Norwegian Geotechnical Institute (NGI) (NVE, 2017). They either were part of the local warning system or had substantial experience and knowledge of the local conditions (INF 2). The focus of evaluation was on the event itself and the avalanche warning preceding it. The key purpose of the evaluation was to learn from the accident in order to achieve better local warnings in future.

The evaluation report identified 15 lessons (see Table 3). In line with the focus of this evaluation, all were related to the functioning of the local warning system. As such the scope was narrow in comparison to the evaluation of the 2015 avalanche.

Of the lessons identified, six had a focus on how specific weather or other natural conditions create uncertainties for the warning system, in assessing danger levels and the measures to be adopted (L1–3, 5, 7, 8). Five of the lessons identified concern how forecasters and the NVE/warning system should consider, communicate and handle uncertainties (L4, 9–12). Lesson 6 confirms that local observation functions well as a basis for assessing local avalanche danger. Lesson 13 is comprehensive in that it recommends the consideration of building infrastructure for meteorological observations. The report concludes that, based on identified uncertainties and local risk acceptance, one should expect more recommended evacuations, and that in many cases there will be no avalanches (L14, 15).

Importantly, five of the lessons identified did not recommend any further action. Lessons 6 and 7 are confirmations of practice and experience drawing on local observers. Lesson 9 identifies the error in not considering uncertainty in data-basis and judgement when assessing avalanche danger. Lessons 14 and 15 provide conclusions and expectations for future practice of recommending evacuations, rather than offering a basis for future action.

4.3.2. *Implementation*

As noted above, eleven of the lessons identified in the report following the 2017 avalanche concerned uncertainties in assessing danger levels. In many cases this is a question of how the forecasters are to consider and handle specific factors that create uncertainties when assessing danger levels and the appropriateness of measures. In the implementation of six of the lessons identified (1–5, 8) new practices are implemented as 'rules of thumb' or raising awareness when forecasters are to consider uncertainty when assessing danger levels. There is no further formalization beyond being identified by the evaluation report as such. It is assumed in these cases that the evaluation report will be applied as a basis for future practice (INF 2). In four cases, the lessons identified have triggered changes in organizational practice. A checklist and new format for forecasts have been formally introduced to communicate uncertainties in the published avalanche warnings (L10). Practices for peer-reviewing local forecasts have been tightened, in that a peer with local expert knowledge should always conduct the review (L11). This was however not formalized beyond the report and establishing a new practice. Further, in cases of professional disagreement between forecaster and reviewer, a third person should become involved; or, if not possible, the most conservative assessment should stand (L12). This new practice was implemented as a new routine, however, without being formalized through written routines (INF 2). Finally, Lesson 13 recommended the establishment of new stations for meteorological observation. This has partially been implemented by more frequent observations (Sukkertoppen, Gruvefjellet, Huset), measuring poles in Lia, and meteorological station at SvalSat (INF 2). However, camera stations have not been established, partly for reasons of funding and partly because responsibility for the local warning system has been transferred from NVE to LLG (INF 2). Implementation of the lessons identified was considerably facilitated by the participation of central actors in the local avalanche system in the evaluation process (INF 1, 2).

Table 3
Lessons identified and measures implemented following the 2017 avalanche.

No.	Lessons identified	Measures implemented
1	Weather conditions indicated increased probability of an avalanche in the Lia area of Longyearbyen. In such situations, evacuation should be recommended unless the local warning system can demonstrate with a high degree of certainty that this is not necessary.	Rule of thumb. Not formalized beyond report. Raise awareness of such situations.
2	Summits where there have not been previous avalanches should be included in assessments of avalanche paths that may pose a threat to buildings.	Rule of thumb. Not formalized beyond report. Less weight on local experience when making assessments.
3	Snow and weather conditions created conditions for the avalanche to travel far. Avalanches can occur after limited precipitation and strong wind in Longyearbyen. To cover most situations with heightened danger levels it is important to have good observations and that uncertainty is assessed if observations are missing.	Rule of thumb. Not formalized beyond report. Under uncertainty or lack of data, opt for 'worst case'.
4	Assessments of avalanche run-out zones are challenging in Longyearbyen. There are small safety margins. To provide larger margins of error, it should be assumed that avalanches may reach buildings.	Rule of thumb. Not formalized beyond report. Raising awareness of the issue. A confirmation of what was already known, though not formalized.
5	Small avalanches that gain speed can reach far and cause substantial damages. Danger-level, avalanche size, and weather conditions considered typical of avalanches are not definitive	Rule of thumb. Not formalized beyond report. Not all factors need to be in place for an avalanche to occur – e.g., snowfall is not required, wind may suffice.
6	The local observers provide a good basis for assessments of local avalanche danger. The observations were frequent enough and provided a good basis for the local warnings/forecasts.	Confirmation of practice
7	Observers experience that the amount of fresh snow available for transport often has greater effect than reflected in forecasts.	Confirmation of lesson identified No 5.
8	Climatic conditions in Longyearbyen make it challenging to forecast avalanche danger. To identify most dangerous situations, it is important to consider uncertainty. A changing climate and previous snow and avalanche history do not necessarily provide a full account of the current situation. It is important to operate with a sufficient margin of error in the future.	Rule of thumb. Not formalized beyond report. Changing climatic conditions imply that historical experience is not as useful any more as a basis for assessments. Hereafter, 'All terrain that is steep enough must be assessed in the situation' (INF 2)
9	The local assessment was sufficiently accurate to provide the technical information necessary for the decision whether to evacuate. In this case uncertainties regarding available data and possible errors of judgement were not taken sufficiently into consideration.	Error identified. Reference to lessons other lessons identified on uncertainty.
10	Local forecasts should to a larger extent communicate uncertainties in the assessments and data. A checklist should be introduced to highlight uncertainty.	Checklist introduced and new format for forecasting, including communicating uncertainty.
11	The local warning system was peer-reviewed by other forecasters and in communication with observers, but more systematic routines should be established to ensure this.	Established practice tightened. There should always be two forecasters with local knowledge. Forecaster 2 may be internal or external to NVE.
12		

(*continued on next page*)

Table 3 (*continued*)

No.	Lessons identified	Measures implemented
	In situations (not the case in week 8) where there is professional disagreement between forecaster and peer reviewer, a third person should be involved. If this is not possible, the most conservative scenario should be applied.	New practice. Not formalized beyond report. Has been followed up in practice.
13	More stations with meteorological observations should be considered. In addition, observations of powder snow in loading areas is important.	New monitoring infrastructure. Partially implemented. Various actors have responsibility for implementation. Depends on resources and perceived need for new infrastructure.
14	Local warning system assessments and communication of uncertainty may lead to an increase in recommendations to evacuate.	Expected consequences of lessons learned
15	One should expect evacuations of populated areas. During most evacuations there will be no avalanches. That does not imply that the forecast is wrong, but that uncertainties and local risk acceptance have been taken into consideration.	Expected consequences of lessons learned

5. Discussion

5.1. Process and participation

The evaluation processes of the avalanches in 2015 and 2017 differed considerably. After the 2015 avalanche all emergency preparedness actors in Svalbard had their own internal learning processes in addition to the process related to the evaluation report by the Norwegian Directorate for Civil Protection, DSB (DSB, 2016; INF1-5). In addition, the Longyearbyen community was involved through public meetings where findings from reports were presented and discussed. The evaluation report concentrated on multiple functions and phases of emergency management, including warning, response, communication, crisis medicine and prevention (DSB, 2016). As noted, 16 of the lessons identified had a focus on the system level (multiple actors) of the avalanche preparedness system; 12 of the lessons identified concerned intra-organizational issues, the roles and responsibilities of individual actors in particular. The scope of the lessons identified reflected the need to establish an operative avalanche preparedness system for Longyearbyen.

The evaluation following the 2017 avalanche (NVE, 2017) was narrower in scope, with the focus on the warning system as such. Participation in the process was limited to the Norwegian Water Resources and Energy Directorate (NVE), plus one expert from the Norwegian Geotechnical Institute (NGI), although there was also some community participation through public meetings. Of the 15 lessons identified, 5 had a system-level focus (multiple actors), while 11 had an intra-organizational scope (NVE, 2017). Implementation of all the lessons identified except L13 (monitoring infrastructure) was under the NVE mandate.

Experiences from learning across organizations have varied after the events, according to our respondents. The Governor of Svalbard, Longyearbyen Local Government (LLG) and the NVE all highlight the continuous learning and development among participants in the local avalanche preparedness system (INF 1, 2, 4, 5). This is facilitated by their participation in joint meetings during planning processes, the emergency preparedness council, and other arenas where avalanche preparedness is on the agenda. However, our informant from the Red Cross (INF 3) mentioned the lack of joint learning processes after the avalanches, noting that the actors had extensive intra-organizational learning processes in addition to the DSB-led process, but that there was no joint learning process for emergency preparedness actors in Longyearbyen in the aftermath of the 2015 avalanche (INF3). This shows how learning among organizations can be both facilitated and inhibited by hierarchies and rights of participation (Moynihan, 2008b), and makes clear the need to analyse both formal and informal arenas where learning takes place (Janowicz-Panjaitan and Noorderhaven, 2008). As Governor of Svalbard, the LLG and the NVE participate in formal arenas based on their mandates as public authorities, they can have more continuous inter-organizational dialogue and be involved in learning processes. By contrast, the Red Cross is not represented in all these public processes and may thus be excluded from learning-processes there. Over time, such differences in actor mandates, roles and participation across various arenas may create uncertainties (Moynihan, 2009), as actors within the same system may not learn the same lessons and or share the same understandings (Dunford and Jones, 2000).

5.2. Single- and double-loop learning

The post-2015 learning process was a comprehensive process with a broad scope. Our review of the lessons identified shows that there was a need to establish formal roles and functions for avalanche preparedness. In some cases, these roles and functions had to be adapted to the specific regulatory framework for Svalbard; in others, they simply had to be activated. These are typical cases of single-loop learning (Argyris and Schön, 1978), where participating actors are seeking to 'do things right' (Bakacsi, 2010, p.5) and thereby improve performance.

However, it is also clear that the post-2015 learning process had a strong double-loop learning dimension in redefining the risk picture and establishing the need for avalanche preparedness: 'doing the right things' (Bakasci 2010, p.5). During the 1990s and 2000s, research at the University Centre in Svalbard (UNIS) and the NGI had highlighted the danger of avalanches in the mountainside above Lia; and the mountain area had been monitored (DSB, 2016). Moreover, there had been monitoring of the mountainside above Lia during the 1990s (DSB, 2016). However, this was later discontinued (INF3). The question of a regional avalanche warning system had been on the agenda for Svalbard ever since such a system was established on mainland Norway in 2013 (INF 1; DSB, 2016). However, the perceived need on Svalbard had been moderate, and in 2014 the Ministry of Justice had informed local actors that flood and avalanche warning on Svalbard would not be prioritized (DSB, 2016). Nevertheless, a two-week test of an avalanche warning system, including local observers, had been conducted in late winter 2015, and a new one was planned for 2016 (INF 1, 3). Thus, avalanches were on the agenda prior to the 2015 disaster, but did not have high priority (INF1, 2, 4). It is not unknown for disasters to trigger action (Kingdon, 1995; Birkland, 2009). This happened on Svalbard, as a local avalanche warning system was established as a crisis measure in December 2015; the regional warning system for Nordenskiöld Land was permanently established from 2016. Due partly to the level of avalanche danger, and partly to the multiple measures implemented (evacuations, road-closure, spatial planning, housing policies, etc.), the issue of avalanche prevention and preparedness has remained high on the agenda since then. Thus, the learning process had a double-loop learning effect not only on avalanche preparedness, but also for a range of other policy areas, including housing, planning and infrastructure.

As noted, the aim of the NVE evaluation after the 2017 avalanche was rather narrowly defined (NVE, 2017). It was to identify and implement lessons to improve the local avalanche warning system (INF1, 2) – single-loop learning (Argyris and Schön, 1978). Further, participants in the evaluation were actors directly involved in the avalanche warning system, which can explain the notable lack of formalization as regards implementation of most of the lessons identified. Most lessons identified were implemented as 'rules of thumb' for future practice, with no written procedures beyond the evaluation report itself. While this may be understandable, as the forecasters were

part of the evaluation process (NVE, 2017), it also gives rise to questions regarding how individual (or group) learning could be converted into organizational learning (Levy, 1994), by setting up new measures and procedures. When learning becomes dependent on informal routines and institutional memory, in a society like that on Svalbard with its high population turn-over, this may entail substantial vulnerabilities. Moreover, in 2019 the local avalanche warning system was taken over by Skred AS. Although the 2017 NVE evaluation report was an attachment in the tendering process, and there are expectations that Skred AS will take into consideration the lessons identified, this has not been formalized directly (INF 2).

There has also been an element of double-loop learning in the post-2017 learning process. The evaluation of the 2015 avalanche (DSB, 2016) had called on actors to establish avalanche preparedness based on existing local knowledge and experience (L1). The NVE gathered data and conducted a series of interviews to gather information on avalanche paths and natural conditions, to provide the basis for the prevention and preparedness measures to be implemented, and, not least, the local avalanche warning system. This shows high reliance on historical data and experience as a basis for local avalanche warnings (INF 2). However, in 2017, the NVE concluded that historical experience was not reliable as assumed (L8). The avalanches in 2015 and 2017 had demonstrated that what had been 'known' to be true, based on historical experience, was not longer so. Hereafter '…all terrain that is steep enough must be assessed…' (INF 2), rather than relying on known avalanche paths. With the onset of climate change, the warning system could not be built on historical experience, or known weather-patterns: it would have to be based on dealing with uncertainty, as reflected in practically all lessons identified in the evaluation report (NVE, 2017). Thus, while the vast majority of lessons identified and implemented were typically single-loop learning (Argyris and Schön, 1978), they were based more fundamentally on a process of double-loop learning as to the basis of avalanche preparedness on Svalbard. This was also reflected in the fact that new assessments for Lia and Sukkertoppen were conducted in 2018 (NVE, 2018), only two years after the previous ones (NVE, 2016).

5.3. Contextual factors

In the aftermath of the disastrous avalanche in 2015 there was controversy over the lack of monitoring and preparedness. Also after the avalanche in 2017 it was questioned why evacuation orders had not been issued. This might easily have led to a situation where conflicts regarding questions of liability, costs, bureaucratic turf-wars, political blame-games, etc., could have obstructed learning processes. Research has shown that many such factors may hamper learning processes during and in the aftermath of crisis (Dekker and Hansén, 2004; Birkland, 2009). However, this does not seem to have been the case with the Svalbard avalanches. Instead, the events served to mobilize public awareness, political will and funding (INF 3). This provided a context where participating organizations were willing to learn and undergo organizational change, as shown by the evaluation processes and their follow-up.

Crisis evaluations often suffer from lack of evaluation criteria, and from subjective interpretations (Drennan et al., 2015). One reason why the evaluation process in 2015 could be so comprehensive was that the lessons identified and evaluation criteria could partly be based on the system for avalanche warning and preparedness already developed on mainland Norway (INF 1). Many of the measures proposed in the 2015 evaluation report (DSB, 2016) were based on solutions formally established by laws and regulations and/or established in regions of mainland Norway that had operative avalanche preparedness systems. This made it possible for crisis measures to be implemented in the short-term in 2015/16, while a more comprehensive evaluation and learning process could be set in motion. This avoided a situation where political pressures could have made it necessary to take action without any analysis of the underlying problem (Birkland, 2009).

5.4. Implementation

Simply identifying lessons from unwanted events does not in itself ensure that necessary measures will be implemented (Deverell, 2009). Too often, whether due to organizational inertia, institutional legacies or other factors, post-crisis learning leads to inadequate, small-scale changes (Drennan et al., 2015; Pursiainen, 2018). Many factors may be involved in why organizations fail to learn (Argyris, 1976; Stern, 1997; Smith and Elliott, 2007). One striking feature of the learning processes following the Svalbard avalanches in 2015 and 2017 is the extent to which the lessons identified have been acted upon, and measures implemented to address them. The mobilization of public awareness, political will and funding have been critical factors in ensuring the implementation of measures identified by the two evaluation reports. As shown above, all 42 lessons identified by the two reports have triggered some form of action in terms of implementation, with the exception of L20 from 2015, which does not lie within the mandate of the Svalbard local authorities (INF 4). We can also note great variety in measures taken for implementing the lessons identified, ranging from no action (identification of established practices), to informal implementation like establishing 'rules of thumb' among forecasters – and to comprehensive changes, like implementing a local avalanche warning system for Longyearbyen, and following up on risk and vulnerability analysis.

Although it is not within the scope of this study, it also noteworthy how the evaluation processes and the implementation of avalanche warning and preparedness systems have snowballed. The new understanding of avalanche danger and preparedness has led to a series of organizational changes, rules and regulations, prevention and preparedness measures, plans and policy documents beyond what was identified by the evaluation reports (DSB, 2016; NVE, 2017). This includes temporary measures like evacuation and road-closures, as well as permanent measures like physical barriers and resettlement plans (LLG, 2017). This is partly based on L23 from 2015, on the need to follow up on risk and vulnerability analyses (DSB, 2016). However, it is also an outcome of the new perceptions of risks related to avalanches and the new knowledge generated by the avalanche warning system (INF 1–5). Indeed, the learning process and consequent changes have taken on a dynamic of their own.

5.5. Lessons for post-crisis learning

The literature is divided on the effects of post-crisis learning. Some studies have highlighted that post-crisis learning is difficult (Stern, 1997; Smith and Elliott, 2007; Broekema, et al., 2017), often result in 'fantasy documents' (Clarke. 1999), findings are not acted upon (Deverell, 2009; Pursiainen, 2018), or are without practical value for solving the problem at hand (Birkland 2009). This can be further aggravated by uncertainties and external pressures on decision-makers that often follow in the aftermath of a crisis (Dekker and Hansén, 2004). Others assume that crises will lead to rational evaluations, lessons and improvements that enhance future crisis management (Drennan et al., 2015). Birkland argues that sound instrumental policy learning can be achieved by 'careful investigation, assessment, and policy design' (2009, p. 150). It is therefore important to identify factors that promote or inhibit processes of post-crisis-learning (Elliott, 2009).

5.5.1. Factors facilitating and inhibiting learning

Our findings from the 2015 and 2017 post-crisis learning processes are generally positive: the lessons identified (with one exception) have been followed up by some form of action, resulting in extensive processes of change. Three factors were central in facilitating the relatively expedient actions taken in establishing a preparedness system following the 2015 avalanche. First, all the relevant actors – the public and volunteer organizations responsible for emergency response – were to some extent involved in the evaluation process in 2015/2016. This ensured that the learning process did not result in mere 'fantasy

documents' (Clarke, 1999) without instrumental effect (Birkland, 2009). Such participation was also crucial during the implementation stage. This was also the case in 2017, where the evaluation was conducted by those directly involved in the avalanche warning system. Second, the existing model for avalanche monitoring and preparedness established regionally on mainland Norway could be adopted and at least partly adapted to Longyearbyen. Consequently here were no means–ends conflicts, and authorities could take swift action, thereby reducing the political pressure (Dekker and Hansén, 2004). The local avalanche warning system followed a similar model, but to a larger extent adapted to local conditions. Third, the level of public awareness ensured that the issue remained high on the agenda. Previous research has found that political involvement may both facilitate (Dekker and Hansén, 2004) and inhibit (Argyris, 1976; Elliott, 2009; Senge, 1990) post-crisis learning. Our study provides evidence of positive synergies between politics and practice, where the avalanche events led to mobilization of public awareness, political will and resources.

However, we also find cases of lessons *not* learnt. Achieving a level of learning which addresses the root causes of disasters is important, as failure to do so may lead to further disasters (Miner and Mezias, 1996, p. 89). The avalanche in 2017 necessarily prompts the question: what lessons were *not* learnt after the 2015 avalanche? The local and regional avalanche preparedness systems adopted were based on an established model from mainland Norway, and drew on the best available meteorological and historical avalanche data from Longyearbyen. However, this proved to be flawed: the inputs of climate change had changed the natural conditions far more severely on Svalbard than on the mainland. Thus, an important lesson *not* identified concerned climate change and the consequences for uncertainties regarding natural conditions, avalanche paths and increased vulnerabilities. That was a root cause to the events in 2017 and became a main focus during the ensuing evaluation. What today is common knowledge about climate change on Svalbard was not so in 2015.

Another case-specific factor relevant to emergency response in Svalbard is the high turnover in the resident population. This was one reason why historical knowledge of the avalanche danger in Lia had been 'lost' by response authorities prior to 2015. And yet, when the NVE evaluated the avalanche in 2017, most lessons identified were followed up by informal implementation measures, 'rules of thumb', rather than formal rules and procedures (NVE, 2017). This clearly makes the avalanche preparedness system vulnerable to changes in personnel and loss of institutional memory, not least as the Svalbard avalanche system has now been out-sourced to private consultants. The need to formalize rules and procedures seems to be a lesson not learnt after the 2017 avalanche.

5.5.2. *Mechanisms of learning*

The findings of our study underline how organizational learning processes are not a question of either-or in terms of single- and double-loop learning. We have seen how double-loop learning (the need for avalanche warning and preparedness in 2015; or uncertainty, rather than cumulative knowledge, as a basis for assessments in 2017) has been followed up by a range of single-loop lessons: the effectiveness of the learning process relies on both forms of learning. This is in line with the findings of Deverell (2009), and makes clear the need to balance between 'doing things right' and 'doing the right things' (Bakacsi, 2010, p. 5).

The emergency management system in Svalbard can be seen as a network of public and private actors (Moynihan, 2008a). This provided the context for both the identification and implementation phases of post-crisis learning following the 2015 avalanche. The identification of lessons was structured by the DSB-led evaluation process, where all relevant actors provided inputs (DSB, 2016). In addition, actors in the network conducted processes of intra-organizational learning (INF 1–5). Further, during the implementation stage, actors met in diverse arenas to discuss solutions and experiences in implementing measures. Learning here was inter-organizational. The arenas were not specifically dedicated to the purpose, and not all relevant actors participated. One informant noted that this lack of a joint, agreed process inhibited network learning (INF 3). Although the network (the preparedness system) provided the context and focal point for post-crisis learning, the learning processes themselves were organizational and inter-organizational. However, the learning outcomes were largely the same, as they did lead to fundamental changes in system attributes such as interactions, processes and structures, institutionalization of coordinated practices, implementation of shared views and interpretations (Dunford and Jones, 2000).

Following the avalanche in 2017, the focus was more on (intra) organizational learning by the NVE, with the identification and implementation phases largely organized as intra-organizational learning processes. However, the results had system-wide implications, as the organization in question was the NVE, the dominant actor in avalanche preparedness throughout Norway. What both cases highlight is how learning continues during the implementation stage, and through diverse arenas within a network. This in turn indicates that effective learning relies on the long-term participation and efforts of relevant actors using multiple channels – also after media, political and (to some extent) public attention has lessened.

6. Conclusions

Learning from crisis in order to avoid future unwanted events is a central purpose of crisis management. Among the main research challenges here is lack of empirical studies or examination of the factors that promote or inhibit learning in often complex and turbulent post-crisis contexts. We have analysed a double case-study of avalanches on Svalbard that occurred in the same location within little more than one year – a highly relevant case for analysis of post-crisis learning.

We find a mixed picture as to the effectiveness of learning. On the one hand, the learning processes can be said to have been successful. In only a few years after the 2015 avalanche, an avalanche warning and preparedness system (local and regional) had been established, setting the standard for many regions of mainland Norway (INF 1–5). On the other hand, the avalanche in 2017 indicates that this system failed: it had not taken into full account the consequences of climate change on local avalanche danger in Longyearbyen, as became clear from the learning process after that second avalanche (NVE, 2017). On the other hand, it should be noted that what is now common knowledge about climate change on Svalbard was not so in 2015.

The nature of the dramatic avalanche events brought willingness to evaluate fundamental aspects of existing approaches through double-loop learning. Here the effectiveness of double-loop learning relied, among other factors, on the implementation of multiple single-loop lessons; through defining roles, rules and procedures. However, as this double-case also demonstrates, learning once is not enough: it must be a continuous process.

'Learning', in the sense applied here, includes both the identification and implementation of lessons (Deverell 2009). We find that learning within and among organizations continues on multiple arenas throughout the implementation stage, with discussion of solutions and experiences. This highlights the importance of long-term involvement by all relevant actors in the learning processes, not something that ends with the written evaluation report. In cases of a larger scale and complexity than the two avalanches on Svalbard, the consequences of not establishing a joint network or inter-organizational learning arena could be more severe, not least as interactions in other formal and informal arenas may not be as frequent.

A main uncertainty for post-crisis learning is the effect of contextual factors like political turbulence and public pressure. In the Svalbard case, there were synergies between political involvement and public awareness and the ability to act on the lessons that were identified. The two avalanches served as focusing events (Kingdon, 1995) that provided

opportunities for change (Birkland, 2009). The availability and experience with avalanche monitoring and preparedness models meant that the authorities could act relatively swiftly and reduce pressure. And finally, there were also synergies between political will, public awareness and the ability of the involved actors to keep the issue high on the agenda and mobilize the necessary resources to get changes implemented.

This study has illuminated some of the central challenges in post-crisis learning. However, there is a need for further in-depth studies on under what conditions post-crisis learning takes place.

One strategy is to analyse how actors within crisis management systems handle challenges posed by climate change. The uncertainties stemming from climate change often pose fundamental challenges to authorities and managers responsible for dealing with them, as also demonstrated in this study. There is the need to find the right balance between continuity and change; under what conditions should learning be focused on single-loop learning improving the performance of existing crisis management systems ('doing things right'), and when does it require that these systems undergo more fundamental changes ('doing the right things') through double-loop learning (Bakacsi, 2010, p.5). Moreover there is a need to investigate how single- and double-loop learning relate to, in terms of facilitating or impeding, each other. As such, in-depth studies provide opportunities for analysing critical issues in post-crisis learning. In particular how to handle increased uncertainties and achieving at times high-cost lessons through double-loop learning. By gathering more knowledge one may also achieve increased cross-sectoral learning, i.e. between different issue-areas or crisis management systems. Such knowledge is important to avoid future crisis that could have been avoided if the 'right lessons' had been learnt at an earlier stage. Further it may teach us much about the resilience of crisis management systems and their ability to learn and implement changes under dynamic conditions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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