Decision support for Adaptive Action: Assessing the potential of Geographic Visualization

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Decision support for adaptive action _ assessing the potential of geographic visualization

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Abstract
This study explores the role of geographic visualization for supporting the implementation of climate change adaptation. Interviews and group discussions with planners and decision makers indicate that geographic visualization bears primary potential for communicative purposes. In order to respond to analytical needs a high level of interactivity including the exploration of background data and the ability to link the tools with own databases were some of the key requirements made by the participants. The study concludes that more than better climate predictions, awareness and involvement may be precisely what is needed to narrow the implementation gap in climate change adaptation.

Keywords: climate change adaptation; implementation; geographic visualization

1. Introduction
Regardless of future mitigation efforts, historical CO2 emissions imply a rise in global mean temperatures (IPCC 2013). As a consequence, recent years have seen rapidly growing scholarly and policy interest in climate change adaptation (Biesbroek et al. 2013; Vink et al. 2013). While the need to adapt to unavoidable consequences of climate change is increasingly being recognized as an important policy area for environmental planning and management, this has not necessarily translated into actual implementation of adaptive actions (Klein and Juhola 2014; Dupuis and Knoepfel 2013). Accordingly, there is now a need for explicitly addressing the role(s) of civil servants, e.g., planners and practitioners in order to obtain more knowledge on how to best support implementation. In this vein, it has been argued that the critical challenge in assisting climate change adaptation is improving the link between research and practice (Mastrandrea et al. 2010) and enhancing communication of climate change and adaptation relevant information.
Geographic visualization developed as a research field in the 1990s, particularly to support the environmental sciences in communicating complex data sets to a wider audience (MacEachren and Monmonier 1992; MacEachren 1994). In recent years we have also seen several applications of geographic visualization to climate change communication (Sheppard 2012; Neset et al. forthcoming). Against this backdrop, the present study sets out to explore the potential of geographic visualization tools to feed into adaptation-related decision making and implementation in the public policy domain.

The study aims to provide a general overview of the key challenges to the implementation of climate change adaptation in the public sector policy domain and to explore the role and potential of geographic visualization for overcoming some of these challenges. To this end, a group of Norwegian stakeholders e.g., civil servants working with climate change adaptation and risk management at local, regional, and national levels were asked to assess two visualization tools: ViewExposed (Opach and Rød 2013) and VisAdapt (Neset et al. 2013). Research questions that guide this study are as follows:

(1) What do stakeholders generally perceive as major challenges to the implementation of climate change adaptation?

(2) What role could geographic visualization tools play in enhancing the implementation of climate change adaptation measures?

Despite the specific focus on the two visualization tools (ViewExposed and VisAdapt), the analysis of stakeholder discussions is of general nature and should be of interest to the wider field of environmental planning and management. We see our primary contribution as being to the discussion on science communication as well as to more general debates on challenges to public policy implementation in the area of climate change adaptation. The paper is structured as follows. Section 2 aims to situate this study within the wider field of implementation and adaptation studies and to provide a brief background to the field of visualization research. First, we briefly introduce the literature on barriers to climate change adaptation as well as the field of implementation research. Thereafter, we review the development from cartography to geographic visualization and the implications that follow for (expected) map user profiles. Section 3 provides information on the case and the methodology of the paper. Section 4 analyzes the results in terms of the major themes and issues that emerged during group discussions and individual interviews. Chapter 5 summarizes and discusses the findings.

2. Background _ previous research

2.1. Implementation research and barriers to adaptation

This study set out to analyze the role of geographic visualization in implementation of climate change adaptation policies and measures. Pressman and Wildavsky (1973), who first introduced the concept of implementation into the field of public administration research, define “implementation” as “to carry out, to accomplish, fulfil, produce, complete” (Pressman and Wildavsky 1973, p. xxxi). For the purpose of this paper, implementation is understood as the realization of adaptive actions, i.e., measures to reduce vulnerability to the negative impacts of climate change.

In previous research, one way of studying the implementation problem has been to conceptualize it as a problem of knowledge transfer from science to practice (Johansson 2010). Therefore, studies in this area have focused on how to make the transfer of knowledge as efficient as possible in order to facilitate the uptake of research findings. However, a major challenge is that barriers to implementation are not solely related to the gap between science and practice but also, as Johansson (2010, p. 110) points out, to “resource allocation, ethics and power.” These problems are more explicitly addressed in research on policy implementation in public administration; which places a greater emphasis on communicative relations and networks of information as important variables in the process of implementation. The departure point for policy implementation research is that implementation is more than a non-political and automatic execution of orders where the intentions of decision makers are carried out as a technical administrative process. Instead, implementation from this perspective is a process with relevance and importance for politics (Löfgren 2012).

Debates on policy implementation have traditionally been divided between top-down and bottom-up approaches. Here, the top-down perspective emphasizes the ability of policy makers to control the process of implementation from formulation to delivery stage, in order “to detect errors in the policy making chain” (Johansson 2010, p. 114). From this perspective, local governments and civil servants are primarily looked upon as executors of orders. The bottom-up perspective, on the other hand, views street-level bureaucrats as “the real policy makers” and pays attention to what happens in the interface between civil servants and the general public (Lipsky 1980).

Traditional textbook examples typically refer to implementation as the last step of a linear public policy-making process as illustrated in Figure 1 (Sabatier 2007).

This linear view of the policy-making chain has received extensive criticism for being too simplistic, in other words, for not considering that the stages in Figure 1 do not normally follow in a sequential order but are mixed up and intertwined in a complex and dynamic policy process (Sabatier 2007). Just as Dannevig et al. 2012, we do recognize limitations of the above categorization, but still consider a separation of the policymaking stages to be of analytical value, in our case for illustrating the different stages where geographic visualization tools may potentially play a role.

More recent developments in social sciences suggest a move from a narrow focus on government as the primary unit of analyses towards a focus on broader systems of governance. This implies that implementation can be studied and understood as a fragmented process taking place through communication in networks rather than as the last stage of a stepwise and linear policy process. (Pierre and Peters 2000).

So far, the literature on climate change adaptation has conceptualized adaptation as a local issue (Preston, Mustelin, and Maloney 2013). In this context, the literature on barriers to adaptation has striven to identify what hampers municipalities’ ability to reduce vulnerability to climate change and how problems may be overcome (Biesbroek et al. 2013). Climate change adaptation in Norway, for instance, is characterized by the absence of a coordinated government adaptation strategy (Aall 2012). Studying implementation of climate change adaptation in a Norwegian context means that municipalities turn out as critical agents not merely implementers, in other words, “executors of national orders,” but also, as Dannevig, Rauken, and Hovelsrud 2012 point out, as “independent policy actors” and agenda setters. This corresponds with previous research on critical challenges to climate change adaptation which include aspects of governance and institutional factors such as the institutionalization of climate change adaptation processes into formal planning procedures, cross-sector communication and cooperation, as well as organizational learning beyond individuals (Storbjörk 2007, 2010; Glaas et al. 2010). In addition, an unclear division of responsibilities between different departments and divisions has been highlighted as a problem for risk management (Hjerpe and Glaas 2012).

Figure 1. Implementation understood as the last step of a linear policy-making process/chain.

Another barrier pointed out in the literature is the challenge of reducing the gap between research results and stakeholder needs and of tailoring research results towards specific user groups (Mastrandrea et al. 2010). In the field of science communication, the argument has been made for a move from a focus on public understanding of science towards public engagement in science (Wibeck 2013). Similarly, this suggests making a shift in problem analyses from an “information deficit model” among laypeople towards an approach that involves the public more actively in processes of knowledge production and policy-making in order to enhance engagement (Wibeck 2013). Along these lines, the Swedish Defence Research Agency (Calsson-Kanyama and Hörnsten-Friberg 2012) suggests that the main challenge to climate adaptation may not only concern the generation of new scientific knowledge but also the communication of knowledge in a more engaging and easily accessible way. The need for knowledge brokers, who are able to bridge the gap between knowledge producers and knowledge users, is being increasingly recognized in several strands of the science-policy domain (Pielke 2007; Meyer 2010). In this context, the visual representation of climate data has emerged as a new and upcoming research field, which moves beyond traditional realms of science communication and strives for data exploration and decision support that meets the demands of different user groups.

2.2. From public communication to private exploration?

The use of diagrams and maps for data communication and exploration has long historical roots. During the period roughly between 1850 and 1900, which has been termed the "Golden Age of Statistical Graphics," there were remarkable innovations in graphical methods and their applications (Friendly 2008). Among the novel examples from this period is Florence Nightingale's use of rose diagrams to make complex data clear to a resistant audience. Nightingale's rhetoric in her use of the rose diagrams is an important example of how visual abstraction of data can help further an argument. With her diagrams, Nightingale was able to capture the whole picture of the disaster caused by the Crimean war, from the high mortality rate to the cause of death to the reasons for the disaster and its solution (Brasseur 2005). Without the convincing power of the drawn rose diagrams politicians would not have implemented the solutions for modernizing sanitary methods as suggested by Nightingale.

The history of cartography contains numerous similar examples of how a map can be designed to communicate a certain message with a given objective; in Harley's words, "[t]here is nothing revolutionary in the idea that cartography is an art of persuasive communication" (Harley 1989, p. 11). Indeed, the decades after the Second World War, cartography developed as a discipline aiming to make maps communicate information effectively (Kol_a_cn_y 1969). The ruling paradigm viewed maps as having "a predefined purpose" (MacEachren 1994). From the early 1990s on, the view of maps as a medium to transfer knowledge was gradually extended with an additional view of maps as devises for knowledge discovery (MacEachren and Kraak 2001). "For cartographic visualization the message is unknown and, therefore, there is no optimal map! The goal is to assist an analyst in discovering patterns and relationships in the data" (MacEachren and Ganter 1990, p. 65). The transition involved potential changes in map use along three dimensions, as illustrated in MacEachren's (1994) map use cube (Figure 2). Once a medium that communicates a predefined message (presenting the known), the map has become a device to explore large data set in order to acquire new knowledge (knowledge discovery). Second, from being a medium for knowledge transfer from a specialist to a wide audience (public domain), the map has moved to become a device for highly personalized exploration (private domain).1 Third, from having a low level of human_computer interaction, the map has moved to become a device equipped with a plethora of interactive functions.

The use of traditional static overview maps is situated in the upper right corner of the map use cube. Exploration, which is situated in the lower left corner, emphasizes the use of interactive map-based tools in a more individual or small group settings in an effort to analyze the data, discover relationships, and generate hypotheses. The level of interactivity is an important feature of geographic visualization tools, where interactivity refers to the ability to both incorporate local knowledge and represent multiple perspectives. Web-based visualization tools can thus serve as basis for the exploration of the potential effects of climate change and be a starting point for debating and

negotiating experts' opinions on vulnerability and adaptation (Rød et al. 2012).
Because the impact of climate change varies geographically (O'Brien, Sygna, and Haugen 2004), climate change adaptation has an inherent spatial dimension. Thus, geographic visualization has the potential to support communication and exploration of future effects of climate change and to support adaptation to anticipated negative effects. For many, the effects of climate change may be described as vague, abstract, and hidden (Lujala, Lein, and Rød forthcoming). However, the representation of scientific data as visual information provides opportunities to communicate with lay audiences, and increase their knowledge and recognition of the impact of climate change (Sheppard 2012; Wibeck, Neset, and Linnér 2013). Multiple examples of visualization-supported web applications have been created over recent years to do this (Neset et al. forthcoming). A number of studies have addressed the challenges and opportunities related to the use of geographic visualization in planning and decision-making processes (e.g., Sheppard 2012; Sheppard et al. 2011; Salter et al. 2009; White et al. 2010). This reflects the methodological challenges that also come with visual applications. As Sheppard (2012, p. 356) points out, visualization is useful for "laypeople and experts alike using the universal language to cross disciplinary, cultural and language barriers," and as such has potential for both communicating complex scientific information and

Figure 2. The map use cube (after MacEachren 1994).

enabling anyone to explore large data sets in order to understand scientific information. However, the powerful and persuasive potential of visual communication calls for awareness of the risks associated with using them and a need for ethical practices in the use of visualizations (Sheppard 2001; Nicholson-Cole 2005; Wibeck, Neset, and Linn_er 2013). This further underlines the need for research on the use of such tools, and for evaluation of the use of geographic visualization for decision support and its impact and potential for supporting implementation.
In this study, we used the map use cube as a theoretical reference to facilitate understanding of differences in design and user profiles of geographic visualization tools used for the implementation of climate change adaptation measures. Because these measures might be linked to different phases of the policy-making processes (see Figure 1), geographic visualization tools might have various purposes and types of users. The map use cube (Figure 2) might help to structure the expectations and reflections of potential users regarding the design, content, and functionality of visualization tools.

3. Methods, materials, and case study description

3.1. The Norwegian context

In order to give the reader a picture of the national setting wherein our study has been situated this section aims to present a little bit of the Norwegian context with regard to climate adaptation and its implementation. Norway is generally considered to be resilient to the negative impacts of climate change (O'Brien, Sygna, and Haugen 2004). There is, nevertheless, a considerable geographical variation between Norwegian municipalities regarding their levels of exposure and vulnerability to extreme events (Holand, Lujala, and Rød 2011; Rød et al. 2012). Since 2009, municipalities in Norway have been obliged to carry out risk and vulnerability assessments. This, however, does not mean these assessments are translated into action since climate change adaptation is not enforced by any particular legislation. Nor is adaptation initiated centrally but, as Dannevig, Rauken, and Hovelsrud (2012) have pointed out, it is more or less a voluntary undertaking. Norway has 428 municipalities (in 2014) and the county governor acts as a connecting node between municipalities and the government and is primarily responsible for coordinating and supporting municipalities' implementation of national policies and decisions. At the national level, climate change adaptation is coordinated by the Norwegian Directorate for Civil Protection (DSB). The DSB acts as a resource with reference to climate change adaptation and facilitates information sharing and cooperation between state departments, research organizations as well as counties and municipalities (www.dsb.no).

3.2. VisAdaptTM and ViewExposed

For the purpose of this study, two prototypes of geographic visualization tools, VisAdaptTM and ViewExposed, were used to gather empirical data on the potential role of geovisualization in climate change adaptation actions. VisAdaptTM (Neset et al. 2013) has been designed and developed as a tool allowing homeowners and insurance professionals to investigate data on climate impacts and projections and to provide practical recommendations on possible adaptation measures. Due to the wide scope of this tool, it is continually tested by sector professionals in physical planning and the insurance sector and by private users. ViewExposed is designed to support urban planners, hazard management officers, and other decision makers, by providing information on where the most exposed and vulnerable locations are and on why these places are exposed and/or vulnerable (Opach and Rød 2013; see also Appendix B Figure B1). Although the tools' information scopes and expected target audiences differ significantly, VisAdaptTM and ViewExposed have several common features. They are both web-based geographic visualization tools whose content is relevant for climate change adaptation. They are both designed with a functionality to support decision making related to identifying local vulnerability or where and how to carry out climate change adaptation. These tools were selected to provide the contrasting types of geographic visualization that are frequent in climate change information and to spur the discussion into what types of functionality and information might be most relevant for their work.

At the time of the empirical study, five different views comprised the VisAdaptTM prototype's interface (Figure 3, left; see also Appendix B Table B1): two synchronized map displays showing climate impacts (A) and climate projections (B), the street view (C), the house view (D) with recommendations for adaptation, and finally, the graph view (E) showing climate model data. There are many interactive functions in the prototype used in the research. The user can type in an address and the street view pops up (C); the two map views and the graph view are adjusted according to the coordinates of the address. The user can navigate in the map view (A) and select different map layers with climate impacts. In selecting a county from the map, the user triggers an event that updates the graph view (E) where the data of the currently selected climate variable could be investigated more thoroughly.

The ViewExposed tool has a range of functionalities, which are provided by three views (Figure 3, right; see also Appendix B Table B2): map (A), parallel coordinates plot (B), and data table (C). Using color scales (choropleth method) facilitates the identification of the most exposed and/or vulnerable places either at the municipal or ward (sub-municipal) level (as for today the ward level data have been uploaded only for municipalities in Trøndelag in central Norway). Initially, the municipal level is shown, but after users select a municipality (E), they can run the application on a sub-municipal level (wards). The map identifies the most vulnerable places, and the plot provides more information on why these places are particularly vulnerable. Each polyline corresponds to a geographic unit (municipality or ward) on the map. Thus, the position of a polyline indicates whether the corresponding geographic unit scores high or low on the vulnerability indices. The white polyline represents the national mean. Using the data table view (C), users can sort the geographic units according to how they score on exposure and vulnerability indices and gain the same information as provided by the map. The table also provide a polyline for each geographic unit (D) displaying the level of exposure or vulnerability.

Figure 3. The graphical user interface of the VisAdapt's prototype (left) and of ViewExposed (right) as discussed in the workshop. Source: the authors.

The role of maps is essential for both VisAdapt and ViewExposed, but the tools' "positions" in the map use cube (Figure 4) are slightly different. Both tools represent a novel and interactive way of addressing climate vulnerability and adaptation, although the test version of VisAdapt allowed for significantly less interactivity compared to ViewExposed, which provided not only the possibility to select indicators, but also to explore the data by means of parallel coordinate plot and a data table. Furthermore, in terms of knowledge, ViewExposed enables the user to explore large data set in order to acquire new knowledge, while VisAdapt had a stronger tendency to present the known (i.e., predefined maps). While both target specific user profiles, potential users might come from other groups and make different demands on these tools.
Both tools were intended to support exploratory knowledge acquisition, relevant for climate change adaptation and/or assessments of exposure and vulnerability. VisAdapt can be used by private property owners to obtain information on adaptation measures to make their houses more robust. Since the type of climatic exposure varies geographically, some homeowners may be advised to secure their roof against strong winds whereas another may be advised to secure their basement towards possible flooding. ViewExposed is targeted towards planners who need to acquire knowledge on the location of the most exposed and vulnerable places and why they are vulnerable. A county risk manager may for instance use the tool to identify which municipality has the highest integrated vulnerability and to explore what factors lies behind; are there one or more exposure indices and/or are there particular challenges regarding socio-economic, demographic, or build environmental characteristics? ViewExposed will provide answer to such questions and thus serve as a tool facilitating knowledge discovery and is intended for specialized (private) users while VisAdapt (Figure 4) is intended for general (public) user.

3.3. Research context and methodology

In an effort to apply an actor-oriented approach (Klein and Juhola 2014), the research for this study was carried out in close collaboration with the intended users of the research results. Data collection was carried out at a workshop on climate change adaptation and integrated vulnerability assessment, held in Trondheim in February 2013 at the
Figure 4. VisAdapt and ViewExposed situated in MacEachren's map used cube (1994).
The workshop provided an opportunity to interact with stakeholders and gain better insights into three main areas. First, the seminar provided us with an understanding of the general challenges stakeholders experienced in regard to climate change adaptation. Second, we received more general feedback on the role geographic visualization tools may play in facilitating the implementation of adaptive actions. Third, we received concrete suggestions on how we could further develop VisAdapt and ViewExposed to better respond to their needs. Initially, only a small group of participants from the Trondheim county administration and municipality were invited. But after the integrated vulnerability assessment maps received considerable media attention before the workshop, in total 11 stakeholders

signed up for the workshop. The participants included civil servants from the DSB (national level), emergency managers in two counties in mid-Norway (regional level), and urban planners and emergency planners from four different municipalities (local level). Some of these participants also had responsibilities related to mapping and geographical information systems. The group, thus, consisted of well-informed stakeholders.

The workshop was structured as outlined in Appendix A Table A1. It started with a plenary discussion on general issues related to climate change adaptation and vulnerability assessments. Thereafter, the participants circulated among three tables and for 15-20 minutes discussed the more concrete content and functionality of ViewExposed and VisAdapt, in groups. They also assessed the usefulness of these tools for decision support which was of particular interest to this study.
After the workshop, all participants were asked for follow-up interviews, which provided an opportunity delve deeper into the concerns and perspectives of each participant. Two of the 11 participants asked to be interviewed together and one referred to a colleague as being more informed. Accordingly, nine interviews were conducted with 10 participants. All participants allowed us to audio record the workshop and the interviews. All the recordings except one, where sound quality was too poor, have been transcribed. Transcripts from group discussions were analyzed and thematically categorized in a table to provide a better overview. This was used to discern general patterns and relationships. In some cases individual statements have been quoted in the text because they illustrated important empirical points in relation to our research questions. We will describe our findings in Section 4.

3.4. Limitations of the study

An obvious challenge to workshops that aim to both interact with stakeholders and test specific applications is the time limitations, which sets constraints for how much participants can familiarize themselves with the content and functionality of the tools. A longer session would have allowed for more in-depth knowledge and a better understanding both from a stakeholder and a researcher point of view. Here a balance had to be made between the researchers' desire to collect information and participants' willingness and ability to attend the seminar.
Furthermore, at the time of the workshop the VisAdaptTM tool was still under development, and hence an early prototype was tested with participants. This had to be kept in mind as data were analyzed since it had potential implications for the usability, functionality, and relevance of the selected data that were assessed during the workshop. Furthermore, the maps generated by the ViewExposed tool had been publicly available in the Norwegian media prior to the event, whereas during this workshop participants

interacted for the first time with VisAdaptTM. This difference in familiarity became noticeable in the emphasis on the vulnerability index presented in ViewExposed, when the participants discussed the data content of the tools. Therefore, a clear bias towards the vulnerability index can be found in the section discussing empirical data from our workshop.

4. Results

This section aims to discuss the recurrent themes and issues that emerged from the plenary discussions, the group discussions, and individual follow-up interviews. Section 4.1 provides an account of the topics discussed in relation to general challenges to climate change adaptation including question related to knowledge gaps, division of responsibilities and communication. Section 4.2 focuses on the two geographic visualization tools and how they could potentially ease implementation-related challenges. Questions discussed in Section 4.2 concerned data relevance and data quality, interactivity features of the tool and also the role of geographic visualization as communication support versus decision support.

4.1. Implementation challenges for climate change adaptation

Concerns over climate data measures were a recurrent theme in individual interviews and group discussions. Generally, local actors felt they needed more specific data to take action; for example, in addition to having a mean value for increases in precipitation, they also wished to know where it would rain, and how much. Of special interest were extreme events (variability) such as intense cloud bursts, which may last for just a couple of minutes but still cause significant damage. Municipal actors generally wished to have higher spatial data resolution and in some situations practical guidelines as for how to act on this information, for example, how to dimension drainage and sewage pipes.

On a more general level, a dividing line was found between those who asked for more clear guidelines from government (primarily municipal actors) and national actors who argued that municipalities themselves possess the real expert knowledge. Here, municipal actors maintained that they do not have the information they need to take action. This applies, in particular, to extreme events where they feel insecure regarding how much (which level of uncertainty) they should plan for. They demanded concrete guidance from the government to relate to in their planning procedures. Representatives from the DSB, on the other hand, argue that the municipalities are the experts since they have long been considering the influence of climatic factors in their respective areas and are the possessors of local experience and knowledge. The representatives saw a great pedagogical challenge in making municipalities understand that “they are the experts,” that they have always adapted hence what they are doing they argued, is really nothing new.

Representatives from the national directorate were also puzzled by how discussions, from their perspective, seemed to over focus on data insecurity. Climate projections, they argued, are some of the most predictable trends we have whereas other trends in society are less so. As a national stakeholder puts it:

Many seem to be pacified by the uncertainties associated with climate change and climate projections; however, it is almost the most robust knowledge basis we have in relation to how the future will look like . . . Societal structures are much harder to plot into plans; however, it seems they are not so concerned about that. . .

In this vein, national actors raised the question of why wait for national authorities to provide exact figures for sea-level rise, how to dimension water and sewerage infrastructure, when everyone basically know which direction the country is heading and the knowledge and experience mostly lies with local actors.

Embedded in this discussion is also a discussion on expectations, roles, and responsibilities of local versus national players. As discussed by Storbjörk (2007) and others, both national and local actors seem unwilling to take responsibility for the decisions taken as climate predictions remain inexact. According to the workshop participants, uncertainties are perceived as a special challenge since they frequently serve as an excuse for inaction and aggravate the process of gaining support for adaptive action.

Some participants (primarily municipal actors) said that they face challenges in communicating the risks associated with the impacts of climate change while trying to make other actors pay attention and take this into account. These concerns relate to contacts with private entrepreneurs such as contractors and developers, communication with politicians and intra-municipal dialogues. In this context, it was also argued that having a “third party” to relate to, such as scientifically supported advice or a legislative decision would provide some weight to the argument and hence speed up adaptive action. A frequently mentioned example related to cases where municipalities wish to impose stronger constraints in building regulations than the constraints stipulated in the national building code.

Governance challenges raised by municipal representatives also related to issues of cooperation and communication between different societal actors. In this context, it was suggested that small municipalities could gain a lot from inter-municipal cooperation by sharing and learning from each other’s experiences. In this context, some kind of knowledge basis and common ground for facilitating internal municipal and external dialogues was called for.

4.2. Strengths and limitations with VisAdapt and ViewExposed

Some of the shortcomings discussed by the participants related to the content of the tools. The participants were especially interested in the selection of variables that had been included in the Integrated Vulnerability Index in ViewExposed. The elements at risk represented in the index are buildings only. Here, it was argued that, it would be relevant to use roads and other critical infrastructure as additional elements at risks.

It was also argued that by focusing on exposure to natural hazards and socio-economic indicators, one misses out on the role of the institutions in charge of adaptive action. Moreover, vulnerability also depends on local institutional environments and local knowledge. This component, argued several participants, is not captured by the vulnerability index. Another discussion concerned the more general question of the ability of any index to capture the importance of social capital and local institutional capacity to manage or reduce vulnerability to climate change.

Similarly, the seriousness of events was not indicated in the landslide mappings in either of the tools, which participants considered important to have to reach a better understanding of risks in the region. Furthermore, the question of whether historical data or projected data have a greater value to planners and decision makers was an issue of discussion. Arguments covered the uncertainty in future projections as well as the incompleteness of historical databases on natural hazards.

Nevertheless, the value of such tools was emphasized for collecting data, and several participants highlighted the request for a more interactive data exchange, implying that a tool might be linked to their own databases or specific regional information. This would allow for individual and tailor-made analysis for specific purposes. Furthermore, they suggested that the user should be able to select and explore specific variables that are relevant for a certain context.

A central topic of discussion was to what extent a user should rely on “ready-to-use” tools for guidance, including practical recommendations on actions regarding climate change adaptation. This theme partly relates to the level of interactivity especially related to the ViewExposed tool and indices based on multiple parameters.

A number of comments (relating to ViewExposed) indicated that the participants wanted to interact more directly with the data, to select, combine, and compare parameters in their own way. Referring to the map use cube as a theoretical reference, the participants wished to have more explorative functions available in the tools where they could experiment and discover new knowledge rather than having a “black-boxed” index delivering a vulnerability ranking. Many also wished to compliment and expand the content of the tools with their own data to include other relevant parameters for individual use or to link to existing local databases. This would allow users to do more investigative efforts in terms of risk planning and management and offer the opportunity of tailoring the analyses to more individual needs.

Relating to the theme of relying on “ready-to-use” tools, the participants wanted to explore the basis on which a special ranking in the vulnerability index had been set and to be able to unfold individual parameters for a specific municipality. This would allow for assumptions and premises to be more transparent than those offered by a closed index.

Several participants discussed the calculated index presented by ViewExposed and one of their main questions was whether the background data could be accessible. They wondered, if, for example, the 31 variables that form the social vulnerability index could be explored one by one.

It would have been interesting here to turn the 31 variables on and off _ as you like. As such we could add the population over 67 years old, to overlay with flooding. That would say something about where I would need to aim my evaluation efforts. . . .

Participants also argued that it is important to remember that these tools do not give a complete picture of reality, but do feed into the discussion and spur the debate about climate change adaptation.

Throughout the discussions, several participants emphasized the engaging and motivating potential of geographic visualization tools. They saw the tools as beneficial for mobilizing support for adaptive action and for getting the issue established on the policy agenda. In this context, it was argued that using external sources such as scientifically backed up visualization tools adds weight to their argument. Thus, presenting scientific information in an easy-to-understand way was perceived as instrumental to creating awareness of the need for adaptation, among the general public and decision makers. The visualization tools’ communicative functions thus could help municipal planners to justify their arguments.

As one workshop participant put it:

So I thought: “Yes! This is it; we need arguments when we work with societal planning. To have something concrete to say is important for us working as local authorities. To have something that can provide us with facts, that we can show the politicians and say, look here, this is something that is derived from research. That is something that creates opportunities for breakthroughs in halted or pending risk and vulnerability assessments. Such maps give us the possibility to push our planning one step further.

Participants also saw a great potential in the tools because they gather a lot of information in one place, which creates a common platform that facilitates discussions. Discussions at the workshop itself were lively and seemingly spurred by the two visualization tools demonstrated to the participants. Generally the tools were seen as “dialogue starters,” which spur engagement and encourage debates and which could help those wishing to push the issue of climate change adaptation higher on the agenda.

5. Communication support or decision support for implementing climate change adaptation?

This study set out to provide insights into local challenges for climate change adaptation and the role geographic visualization tools could play in overcoming some of these challenges and in supporting the implementation process. In doing this, the study touched on three research fields: (1) implementation studies; (2) science communication; and (3) geographic visualization research.

First, as discussed, some research has studied implementation challenges as an issue of knowledge transfer from science to practice (Johansson 2010). Within the field of public administration research, however, implementation is conceptualized as the realization of public policy and the problems studied relate to “the complexity of joint action” (Pressman and Wildavsky 1973). This paper has striven to integrate these perspectives into the analyses because we see both as relevant to the problem under study. Second, in line with current trends in science communication literature, the empirical results of this study emphasize the importance of enhancing engagement rather than addressing an information deficit per se. Third, the map use cube has provided us with a theoretical reference for understanding the shifting roles, expectations, and needs of our stakeholders and how these relate to implementation challenges in the context of climate change adaptation.

The analysis of multiple discussions and interviews pointed towards the conclusion that rather than the key potential of the two geographical visualization tools being the ability to address the problems derived from information deficits, it may be in enhancing engagement as they facilitate discussions around vulnerability assessments and adaptation efforts. The participating stakeholders maintained that such tools may serve to create awareness and facilitate dialogue but their content and functionality is probably too generic to be useful for informing specific operations in specific places.

The participants pointed towards the need to increase awareness of the issues in order to put climate change adaptation actions on the agenda (i.e., agenda setting, Figure 1). Furthermore, they wished to use the maps for communication rather than as an explorative tool for analysis. This implies that geographic visualization tools could enhance implementation of climate change adaptation by facilitating communication, spurring debate, and promoting engagement.

Our empirical material indicates that stakeholders have multiple roles in the climate change adaptation planning and implementation processes. This is reflected in their description of challenges in climate change adaptation work in general and the potential role of geographic visualization tools in particular. The participants expressed concerns directly related to information deficits, e.g., gaps particularly in local, contextual, and more precise data to be a critical challenge to implementation. However, in their role as policy actors and agenda setters, they also see the need for tools that could provide a common ground for discussions, facilitate communicative processes (ease the complexity of joint action in public administration), and help raise climate change adaptation concerns on the public and political agenda (i.e., increase public engagement).

This again is a reflection of their own multifaceted user profiles, which range from that of expert users in their role as planners and implementers to public users in their role as agenda setters and policy actors. Similarly, the knowledge dimension (see Figure 2) of geographic visualization tools corresponds to demands to enable the user in communicating the known information to a wider audience, for example, in presenting a final map of risk zones. It also corresponds to demands to facilitate the exploration of the unknown among colleagues, for example, allowing the user to create hypotheses and correlate selected parameters for local analysis.

While the paramount aim of many map-based tools is to provide highly interactive functionality to facilitate information exploration and knowledge construction in a private domain, what stakeholders found useful was being able to present the known to a wider public. There interaction is less important (see Figure 2). The functionality offered in these tools was not considered as important primarily for decision support, but for providing information on maps, diagrams, table views and so on that could be used to initiate or to enforce a debate or dialogue as part of an implementation process. This conclusion should, however, not be considered an either-or situation. Rather, as also proposed by MacEachren (1994), user requirements are a continuum ranging from a need to use maps to communicate a message to using them to explore an area to enhance understanding, for instance, of why a certain municipality is vulnerable to the negative effects of climate change. The role of geographic visualization for adaptive action can be multidimensional and, thus, flexible tools are required for the different purposes of the policy-making process.

In summary, the results of this study confirm that a major challenge for climate change adaptation lies in science communication, and here geographic visualization can play a significant role. The communicative benefits of the visualization tools may help to facilitate dialogue and thereby overcome challenges related to “the complexity of joint action” (Pressman and Wildavsky 1973). As science communication has moved from a focus on information transfer to seeking to enhance public engagement, this raises associated questions about the role scientists play in knowledge communication. A potential conflict between the goal of information transfer and efforts to enhance engagement is pending. The critical challenge for scientists is to keep the difficult balance between ethical aspects of science communication (Sheppard 2012) and the call for societally relevant research.

Local stakeholders often express the need for more precise and more contextualized data to support their efforts to enhance implementation of climate change adaptation measures. In addition, they frequently ask for clear directives on how to act upon the data provided. This, as argued, may partly relate to the question of accountability and a general unwillingness to take responsibility for decisions taken when climate scenarios remain inexact. However, from the perspective of our stakeholders, another need was just as important, that for having support in communicating the need for adaptive action to a wider audience of decision makers in order to enhance political support and public engagement. This need springs from the challenges that follow from new roles and responsibilities related to this policy area because, in the field of climate change adaptation, civil servants (i.e., traditional executors of orders) have turned out to be critical agents for agenda setting. They need tools as reference material and as a joint platform for facilitating multi-stakeholder dialogues. This need for support, we argue, also reflects larger trends relating to the transition from a focus on government to one on governance (Pierre and Peters 2000); the climate change adaptation policy area serves as an example of this trend.

Scientific visualization has been recognized for its engaging and social learning potential; however, as Klein and Juhola (2014, p. 9) state, “the effectiveness for decision making is an under researched area.” Our study confirms that visualization tools are helpful for creating engagement and can facilitate social learning. According to our stakeholders, this may also be precisely what is needed to improve decision-making processes and speed up implementation. This follows from the recognition of decision making and implementation as being more than a value-neutral and a technical administrative process. Instead, it involves several actors with competing views and agendas. As this study has shown, decision making is also about making one’s voice heard, and here visualization tools provide powerful instruments for communication. Therein, we argue, lies the primary contribution of geographic visualization for narrowing the implementation gap in climate change adaptation.

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Notes
1. Public vs Private can also be interpreted as expert vs layman
2. A position as well as a Norwegian Government agency (www.fylkesmannen.no/eng).

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Appendix 1:

Table 1: Overview of the type of discussion/interview and questions posed to the participants during the workshop in Trondheim

Type	Number	Questions
Plenary discussion	n:1	Major challenges to climate change adaptation. What is needed to increase robustness/reduce vulnerability?
Group discussion 1: Content and Information	n:3	What kind of information do you need when working on issues related to climate change and extreme natural events? Can **ViewExposed/VisAdapt** support your practical work in any way? If so, in what way? How could it be improved? What information would you like to add?
Group discussion 2: Functionality and design	n:3	Do you think that **ViewExposed** and **VisAdapt** are well equipped with interactive functions? What additional tools (features) not in **ViewExposed** or **VisAdapt** would enhance/facilitate your work? What additional functions would you like to add?
Group discussion 3: Decision support	n:3	Potential for such tools to be used in the participant’s everyday professional work. Strengths and limitations of these tools in this regard? How would you describe the potential for (these kind of) visualization tools in general for your purposes?
Individual follow-up interviews	n:9	Major challenges to climate change adaptation? What is needed to increase robustness? Strengths and limitations with VisAdapt and ViewExposed? What is desired from the research community in general?

Figure 1. Implementation understood as the last step of a linear policy-making process/chain.

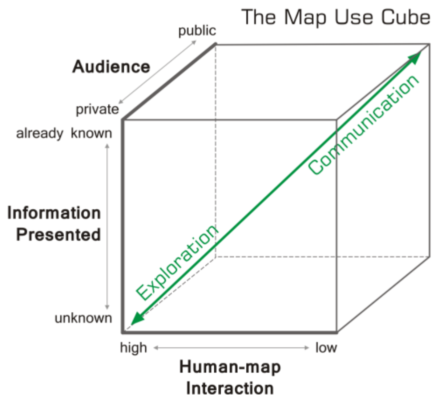

Figure 2. The map used cube (after MacEachren 1994).

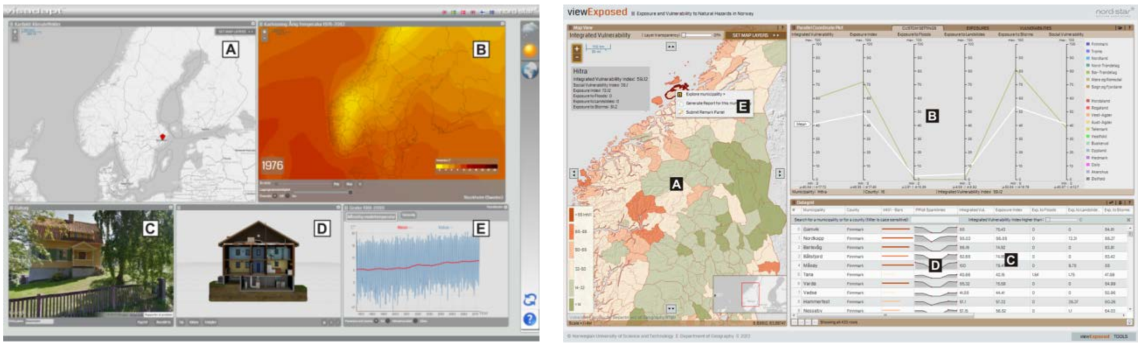

Figure 3: The graphical user interface of the VisAdapt's prototype (left) and of ViewExposed (right) as discussed in the workshop (left)

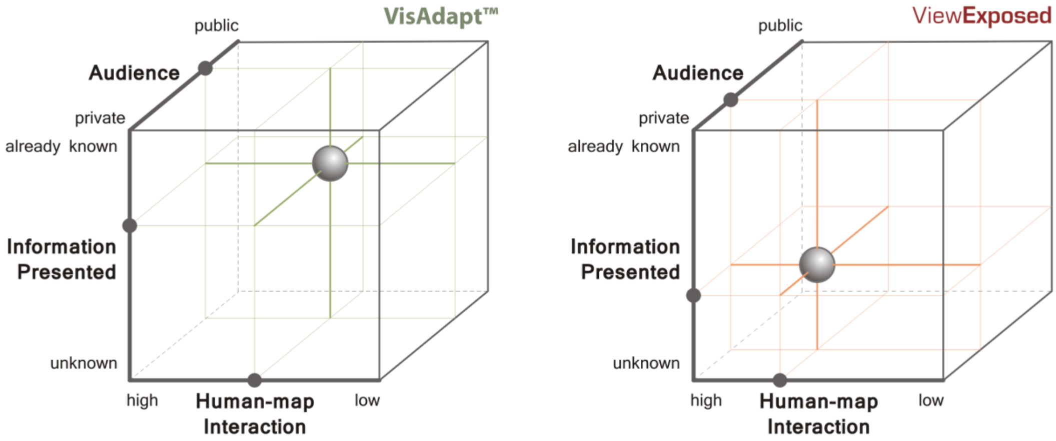

Figure 4. VisAdapt and ViewExposed situated in MacEachren's map used cube (1994)