

The Appropriation of the Climate Change Problem among Road Managers: fighting in the trenches of the real world

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Abstract

This paper investigates how transportation sector managers perceive and utilize climate science, and subsequently, how they appropriate the climate change problem. The analysis focuses on which devices they qualify as useful for translating between knowledge, policy and practice concluding with a discussion of what this suggests in the development of efficient climate adaptation strategies. The paper demonstrates that although transportation sector managers accept the findings of climate science knowledge presented to them, their understanding of the climate change problem and the range of qualifying anchoring devices used in the development of climate adaptation strategies are differentiated according to where they are located in the institutional context. For transportation sector managers on the regional and district level, the climate problem is largely perceived through the occurrence of extreme weather rather than through climate science. However, this knowledge basis is not considered sufficient to support ‘knowing how to act’ and has resulted in waiting for the authorities to make standards and regulations that would translate climate change knowledge into methods

of practice. We argue that the development of standards and regulations might be underestimated in relation to user demands in climate adaptation work that involves reconciling scientific information.

Keywords

Climate adaptation strategies, weather experiences, road management, domestication, boundary organizations, anchoring devices

The Appropriation of the Climate Change Problem among Road Managers: fighting in the trenches of the real world

On the 24th of August 2008 what the local population in the valley of Sunndal feared the most happened: stone blocks of a hundred kilos hit the main road and one person was severely hurt. The section of the road that was hit by the rockslide was well known as a high risk area. In fact, anticipation of future rock falls had already led worried parents, anxious of the transportation of their children to school, to ask the local council for the provision of two school buses instead of one in order to spread the risk, if an accident occurred. The largest national daily newspaper reported that there was increased danger of rockslides in this segment of the road due to climate change, evidenced by a greater variation in local temperatures and swift transitions between freezing point, snow and rain¹.

Climate scientists have been reluctant to interpret specific extreme weather incidents, as being caused by climate change, since such a relationship is difficult to prove statistically. However, there is no doubt that temperature increase is widespread over the globe and that some extreme weather events have changed in frequency and/or intensity over the last 50 years (IPCC 2007). It is likely that the frequency of heavy precipitation events (or proportion of total rainfall from heavy events) has increased over most areas and that natural systems related to snow, ice and frozen ground are affected increasing ground instability in permafrost regions and rock avalanches in mountainous regions such as Norway. The IPCC report identifies pressures on urban and rural infrastructures (e.g. loss of property and increased risk of death and injuries, disruption of settlements, commerce, transport and societies) as possible impacts of climate change linked by heavy precipitation consistent with projections for the mid- to late 21st century. This suggests that even though scientifically challenging to establish a relationship between climate change and what is commonly referred to as an “extreme”

¹ In the news paper Verdens Gang, 25.08.2008

weather incident on a very local scale, this interaction is established as a matter of concern in the mass media and also in sectors of society experienced to be especially vulnerable to consequences of climate change, like the road sector which is of primary concern in this article.

Climate change adaptation in the road sector is an issue that will affect future planning of road infrastructure, practices of maintenance, and emergency planning increasingly over the years to come. Thus, our climate policies should not only be designed for mitigation, but also reflect that we have to adapt to the unavoidable (Schneider, 2009). The question of climate change adaptation raises challenges about how risks should be handled and how policy decisions concerning how to organize future road infrastructure could be shaped. In order to make climate adaptation governable, there needs to be an awareness of how the climate change problem is understood or appropriated among actors in the road sector.

It is not yet clear whether current scientific knowledge about climate change is perceived in such a manner that it will have any real impact on the way the transportation infrastructure is planned and managed. This raises important questions about the way knowledge concerning climate problems and risks are being appropriated such as how scientific knowledge about climate change is perceived and used by transportation professionals on the ground. How does the management of the public road system understand climate change issues? What strategies are prepared for the impact of climate changes with respect to road infrastructure across Norway? How do road managers perceive the reliability of scientific results, and do they think this is relevant for their planning and strategy developments? These core questions concerning the appropriation of scientific climate change discourses by road managers are to be addressed in this article.

There is abundant knowledge, both nationally and internationally, about how the transportation sector may contribute to climate change through emissions (e.g. IPCC 2000,

OECD/IEA 2000, TRB 2008). Less attention has been given to the potential impact of climate change, or extreme weather events, on *transportation systems*. Of existing studies, some focus on emergency evacuation (Church and Cova 2000; Pisano et al. 2002), while others address the effect of weather on the frequency of road accidents (Edwards 1999) or the effects of flooding events on the system-wide performance of transportation networks (Suarez et al. 2005). Even fewer studies have been devoted to the question of how one should handle the potential impacts of climate change and extreme weather events on transportation infrastructure. Consequently, there is a need to look deeper into the consequences of climate change in context of the transport infrastructure and the way such concerns are managed. This article investigates how important groups of actors linked to the Norwegian road sector appropriate the climate change problem. Thus, we are not just dealing with the professional everyday reaction of road managers to the issue of climate change, but also with possible organisational adaptation and learning processes within the road management system.

In the next section we will examine the literature on the relationship between scientific knowledge and practise related to climate change adaptation. Then we go on to examine how climate change has been appropriated more generally among road managers and their adaptation strategies both on the institutional level and the more day to day local level.

Climate change adaptation: Between sense making devices and instrumental action

The literature on climate change adaptation has grown substantially during the last few years, as it has become more and more clear that the Earth will inevitably be subject to climate changes of considerable impact. However, a less studied approach to the problem of how climate knowledge is appropriated uses insights from the public understanding of science literature (e.g. Wynne 1995) that has been concerned with scientists and lay people's relative expertise, exploring lay local knowledge and the rationality of people's engagement with

science. For example Martin (1994) has shown how the perceived logic of everyday life in a given context is a main feature of the way scientific knowledge is understood and accounted. The members of the public, and this also applies certainly to public servants, are not passive recipients excluded from the production and validation of knowledge. They consider, validate, supplement, and adapt the knowledge that is communicated to them. In line with this approach, we will analyse sense-making with respect to climate change by drawing on the generic concept of domestication.

To analyze domestication of knowledge or information means to study the development of practices such as the construction of meaning and learning with respect to a given area of concern like global warming (Sørensen et al. 2000; Sørensen, 2006). A main advantage of this perspective is that it reminds us that sense-making is not just about making meaning, but that there are also cognitive and practical aspects that need to be assessed. Phrased differently, knowledge about human-made global warming needs to be enacted in everyday life including work related practices, and this enactment involves articulation of positions with respect to truth and falseness of knowledge claims, but also considerations about how to act on the perceived challenges. Moreover, domestication may result in rejection as well as acceptance of climate science knowledge, in addition to a variety of transformations of this knowledge. Thus, the main aim of the paper will be to study how road managers domesticate climate science. The domestication perspective allows us to not only identify whether road managers use climate science, but also explore their existing experience-based knowledge practices when making sense of the climate problem.

In order to address the impacts of climate change it has been pointed out that decision makers need more accurate and precise assessments of future impacts in order to adapt successfully (e.g. Füssel 2007). However, as emphasized by various scholars, decision-making related to adaptation is not only a question of providing more knowledge (Tribbia &

Moser 2008), more reliable foresights about future climate conditions (Adger et al. 2009) or more accurate and precise climate predictions (Dessai et al. 2009; Dessai & Hulme 2004; Pielke & Sarewitz 2005). In order to provide knowledge of greater relevance, there must also be a focus on the shaping of institutional processes that can mediate useful knowledge for different decision-making contexts (Nie 2007). One lesson so far has been that providing better knowledge is not going to do the work alone. What are needed are institutions that reconcile knowledge producers and users.

The ways that professionals, like road managers, appropriate the climate change problem are of course connected to how transport management institutions develop their climate strategies and are governed to react to such perceived new challenges. Earlier studies of the relationship between the appropriation of the climate change problem and the development of climate adaptation practices have been focused on the potential beneficial role of 'boundary organizations' to institutionalize interaction between information producers and users (Cash et al 2003, Tribbia & Moser 2008; Vogel et al. 2007). Guston identifies how boundary organizations need the approval of science for the credibility of their knowledge claims, as well as, the approval of political institutions for the legitimacy of their policy orientations. In this way, boundary organizations will need to have the overall dual purpose of protecting, but also transcending the divide between science and practice. In this context, translation is put forward as being one of the "functions" that boundary organisations are assumed to perform in order to assure that information and resources are comprehensible for co-operating individuals and organizations (Tribbia & Moser 2008:317). Thus, one hypothesis would be that road managers rely on boundary organizations to translate climate science into usable and relevant knowledge for making climate change adaptation practices in the road sector. In other words, the existence of boundary organizations may facilitate the

domestication of climate science. This hypothesis will be scrutinized in the following analysis.

In addition, we think it will be fruitful to supplement the focus on mediating boundary institutions that can facilitate the domestication process with a focus on more pragmatic 'anchoring devices' (van der Sluij et al 1998). Anchoring devices are tools or mechanisms that "seem to function as a means of managing uncertainty in that they limit 'drifting' in the primary scientific sense, and that serve to constrain the discourse and implying a more vertical set of social interactions" (van der Sluij et al 1998: 312). Here, the concept of anchoring device may be useful for describing how the existence or non-existence of such stable knowledge constructs assists the development of climate adaptation strategies in practice.

Thus, our second hypothesis is that road managers use developed devices that anchor climate change knowledge to adaptation practices. In the next section we will look further into the institutional context in which climate adaptation strategies are developed. We will also look deeper into what existing institutional bodies could potentially function as boundary organizations and anchoring devices aiding the domestication process, before going on to analyse how scientific knowledge about climate change is perceived and used (i.e. domesticated) by road managers placed in central management institutions and among transport professionals on the ground.

The institutional context: The organization of the Norwegian public road sector

The Norwegian Public Roads Administration (NPRA) is under the leadership of the Directorate of Public Roads (DPR), which is an autonomous agency subordinated the Ministry of Transport and Communication. The DPR ensures that the NPRA manages its resources and reaches the objectives set by the Norwegian National Assembly (Stortinget) and

the Government. The DPR manages this task through the strategic planning of budgeting, supervision and resource allocation as well as through the National Transportation Plan (NTP), which is the primary long-term planning document in the road sector (see figure 1 for an overview of the institutional system). The NTP is produced every four years and sets the priorities of the transport sector over the next ten years and addresses both policy and resources. The aim of the NTP is to provide both a superordinate and technical basis on which to make decisions. Thus, the NTP is an important part of the broader socio-technical system of road management and may therefore be seen as a potential anchoring device that needs to be in place in order to get the work going. The latest NTP from 2009 generally expresses the importance of mobility, welfare and regional development as crucial values in the transport policy. Climate change is reflected in the latest NTP in the form of mitigation strategies, but not as adaptation strategies.

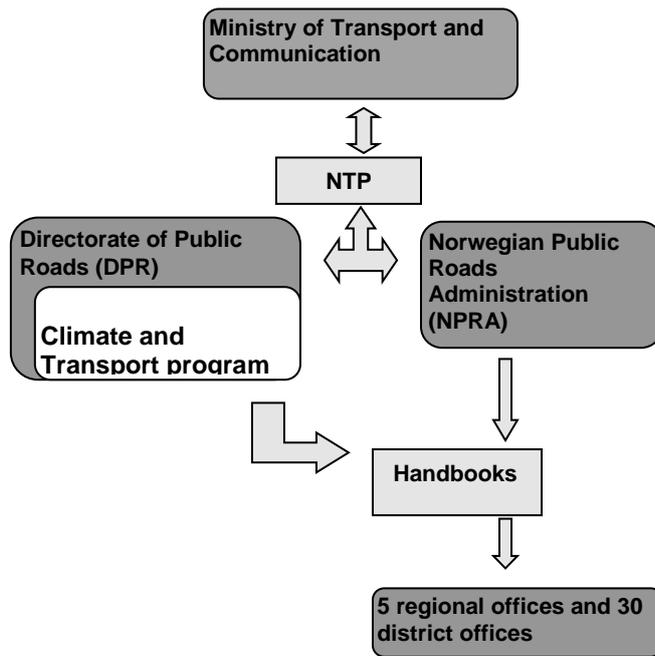
The NPRA is responsible for the planning, construction and operation of the national and county road networks. In 2003 the production activities of the NPRA was separated into the government-owned public company, Mesta. The NPRA is divided into five regions and thirty districts. Regional road offices are responsible for strategic planning, allocation of resources between districts, and between regional road offices and districts, as well as, governing and follow up on districts.

In 2007 the DPR launched a four year research and design program led by its technology department in order to meet future climate changes. The main objective of the Climate and Transport program was to evaluate the effects of climate change on the road network and recommend remedial action concerning design, construction and maintenance of the system. Subprojects were initiated covering different tasks that included: 1) a literature survey on climate change and its effect on road transportation, 2) data collection on varying topics ranging from flood and erosion prevention, avalanches (e.g. snow, soil), flooding,

slides, rock fall and bearing capacity of roads, as well as, 3) assessing the consequences of winter operation, emergency plans and susceptibility. These projects were supposed to produce information that could serve as input to policy documents like the NTP and to new or updated versions of guidelines and standards.

Other institutional documents contributing to the establishment of a kind of internal infrastructure of professional communication among the five regional offices and 30 district offices of the NPRA are the “handbooks”. The handbooks serve as the knowledge basis for decision making on the local level and could possibly function as anchoring devices that constrain a ‘drifting’ of scientific knowledge, serving to limit the adaptation discourse and implying a more vertical set of social interactions. The handbooks are differentiated into two types of official documents. The first type (e.g. “the blue series”) consists of normative textbooks, and the second type (e.g. “the yellow series”) are standards approved by the DPR. The normative textbooks typically function as the first official document where new knowledge is initially included and discussed in a professional context, before this knowledge can be included in standards or serve as a basis for rewriting standards. The handbooks are updated on an irregular basis. The handbook on construction of roads was last updated in 2005 with a new version planned published in 2011, and the handbook on maintenance of roads was last updated in 2003.

Diagram 1 Key governmental road managing institutions (dark grey) and documents (light grey)



Before we move on to the analysis section, a brief note on the data material and methods is needed. The data material consists of interviews of employees in the NPRA. We have interviewed 25 managers and section leaders (from a total population of 30) from all five regions and all 30 district managers. In each of the five region offices we interviewed leaders of the 1) strategy staff, who are responsible for work on National Transportation Plan and governing objectives and results, 2) the road and traffic department, which is responsible for the administration of the national and county road network and safety issues and 3) the department responsible for developing the road network. As the district offices are the executive link of the operative tasks of the NPRA, it was vital to learn what they saw as consequences of climate change for their work, and how they responded to these challenges. We interviewed all district managers who in most cases handle the contact with the public and municipalities, local traffic safety, control of the road network, as well as, planning and owner responsibilities for management and maintenance. These interviews were all conducted as a telephone survey with an open questionnaire² during February and March 2008. The

² See electronic supplementary material

interviews lasted about 30 minutes. We conducted in-depth interviews lasting around one hour with five employees of the DPR who all were members of the Climate and Transport program during September to October 2007.

All interviews were taped and transcribed. We translated the quotations used in this paper from Norwegian and have tried to retain their oral qualities. The strategy of analysis was inspired by grounded theory (Strauss and Corbin, 1998). We began by examining the transcribed interviews for salient categories, which were given a label or a code. We then grouped these codes to find related subcategories that might be linked to more comprehensive categories. In this process, quotations were selected to represent the various categories and positions as accurately as possible. In the final stage, we tried to integrate categories. In doing so, we made use of the generic properties of domestication theory as a basis for making storylines. As categories developed and became richer we returned to the interview material to search for more examples and to look for perspectives or observations that we might have overlooked in the first rounds.

Analysis: Making sense of the climate problem

In the next sections we look more deeply into the way road managers domesticate climate science, or in other words perceive and utilize climate science in relation to climate adaptation work. We will first look at how these processes are managed among the centrally placed officials and how the knowledge is used in developing potential anchoring devices like the handbooks described previously. Then we move on to assess domestication processes as we find them among professionals on the ground and see whether they identify the Climate and Transport program as a boundary organization or any anchoring devices that facilitates translation from science into practice.

Domestication of climate science among centrally placed officials of the Directorate of public roads

The interviews with key representatives of the Directorate of public roads and members of the Climate and Transport program to a large extent expressed a basic trust in the results from climate research. They stated to be closely following climate science and being attentive to the IPCC reports relevant for Norway. The centrally located road managers however gained their knowledge mostly from reports in the mass media and through the metrological institute and geological research centres (Norwegian Geological Institute and Norwegian Geological Assessments), institutions with which they shared a long history of professional cooperation. They described a procedure where they collaborated with the Norwegian Meteorological Institute on picking scenarios from the scientific results, which they found to be most realistic for Norway. A usual account of the procedure was as follows:

“When it comes to information from climate science, we are just receptors, ..[and] from the research guidelines, we must determine our departure point. It is the Norwegian meteorological institute that acts as an intermediary, breaking down the data at an international level to a level relevant for Norway.”

All of the centrally placed officials placed great trust in the ability of their own organizations to evaluate what knowledge was relevant for them. Centrally positioned employees of the Public Roads Administration involved in the Climate and Transport program emphasized that the process of “bringing science to policy” was weakened due to unclear political priorities and unclear political aims that limited the road management system’s institutional and organizational ability to use existing knowledge in the development of climate adaptation strategies. Thus, there existed a somewhat unclear situation regarding what kind of adaptation possibilities existed and the degree to which scientific knowledge about possible strategies would be given the political and institutional backing needed to translate it into practise.

The domestication of climate change knowledge into anchoring devices also met more practical challenges. One of the distinguished experts on road planning, employed by the

NPRA who was engaged as a member of the Climate and Transport program to write a textbook for the blue series of handbooks said:

“So far there is one little passage in a handbook on drainage where it says that one should calculate 25 % more run-off. I think that is the only formulation where climate knowledge is included in standards [...] It is a hard and challenging job to get new knowledge into the standards”

Essentially, up until this point the handbooks had not been written to function as anchoring devices in the development of climate adaptation strategies, in the sense of communicating and transporting stable knowledge constructs in this area. According to the expert quoted above, this was because climate adaptation strategies currently in development should focus on how to improve the adaptation design towards the climate conditions *of today*, emphasizing the handling of weather-related incidents that already had been experienced on Norwegian roads, rather than to future climate changes.

In line with this, the leader of the Climate and Transport program stressed the importance of underlining the distinction between climate science and adaptation, motivated by what she saw as a need to emphasize the status of the existing body of practical knowledge which new climate adaptation knowledge should be incorporated:

“Climate knowledge needs to adapt to the existing base of knowledge. ...there is a difference between climate science and climate adaptation, as climate science is often focused on uncertainties, while climate adaptation strives to hold on to the little certainties that exist in order to construct, to maintain and run operations.”

This quotation from the leader of the program illustrated that although there was a general trust in climate science and its results among the key persons within the organization, the focus of their work was to get a grip on the existing body of practical knowledge, i.e. collecting and systemizing knowledge on conditions that initiated different types of slides and avalanches.

Summing up, there was little evidence of the development of tools or mechanisms for managing uncertainty about climate knowledge or ongoing standardization work using the two most important potential anchoring devices within the sector: the National Transportation Plan and the handbooks, which could enable the domestication of climate science. However, given that downscaled climate impacts are still very uncertain, it might be premature to expect the inclusion of it in the handbooks, particularly in the yellow series. Generally, it might be unrealistic to expect many specific discussions in the handbooks, partly since that seems to have been the intention of the Climate and Transport program.

Domestication through experiences of extreme weather among local and regional road managers

The interviews with the local and regional road managers indicated that there are very few doubts on the reliability of climate research. However, they have not yet appropriated results actively and in such a way that it has led to many reflections on the relevance of the results for their planning and strategy development. Typical accounts were clear about the need for more local climate change forecasts, but simultaneously were unclear about what kind of data that exist today that would be relevant:

“One must have a [...] climate model [...] that says something about the amount of precipitation expected and how often one may expect different types of extreme weather situations. One needs climate data that can see a bit into the future. I don't know if these data exists. What we know is more general knowledge like the expectation to have more intense precipitation in northern part of Norway, especially in autumn”.

In spite of uncertainties about the applicability of the existing scientific knowledge, the road managers seemed to take the basic results for granted. This was most of all represented through numerous and detailed accounts of how the consequences of climate change have real effects on the management of roads. When road managers were asked if they thought climate changes would influence their activities, almost all of our respondents said that they thought

they would. Fifty of the fifty-five road managers also said that they already saw signs that they themselves interpreted as evidences of climate change. These accounts were presented differently from person to person and from one region to another, but the interviews showed evidence of four general types of experiences that shaped how the climate problem was conceptualized in practise: (1) heavier fall of rain and snow, (2) different types of slides, (3) flooding, and (4) difficult road conditions around zero degrees Celsius temperature.

One example of the first type of mediated climate change related to *heavier rainfall* is exemplified in this quotation, where we asked the road managers whether they thought climate changes would influence their activities.

“Yes, no doubt about that. We think we already have experienced it [...] The last 2-3 years in autumn, we have experienced quite heavy rain fall generating a new type of landslides and rock fall that we earlier have not had in such extent. We have also seen that the rainfall is more intense. The autumn of 2006 resulted in destruction of three bridges within a few weeks.”

The interviews revealed that the experiences of significantly heavier rainfall were linked to the perception of climate changes in multiple ways. On one side, it was perceived as a phenomenon to reflect upon and which provided a basis for doing comparisons to historical data. Data on precipitation has been made publicly available through an internet news portal by The Norwegian Meteorological Institute and The Norwegian Water Resources and Energy Directorate (NVE) which is Norway’s national centre of expertise for hydrology. The road managers used these data in their everyday work and the database constituted a basis of knowledge that served to reflect the consequences of climate change.

Alternatively, the witnessing of heavier showers and snowfall were linked to the second perception that was identified in the interviews as experiences of different new types of slides. Most road managers related the second type of experiences - new types of slides – directly to climate changes. These slides were seen as new in two ways: they contained less snow and more rocks and earth, and as emphasized by the district leader, from the northern

region in Norway, “It has become more difficult to really predict where they come because they come where we least expect them.”

Additionally, witnessing heavier rainfalls also led to the recognition of a third kind: *experiences with flooding*. A typical account was one like this, where we asked if climate changes were thought to influence one’s activities and the respondent answered:

“Yes, we can almost say that we know that it does. We have had some instances where we see the result of climate change. We had increased rainfall and rain intensity, leading to flooding and in some cases landslides. And secondly, we have had a couple of instances, like last weekend, with spring tide.”

Thus, increased incidents of flooding were one of the perceived consequences of climate change. The fourth type of experience that the road managers associated with climate change was the ‘zero-degree road condition issue’ related to *increased occurrence of difficult road conditions* around zero degrees Celsius temperature which typically was described as follows:

“We experience considerably bigger challenges with mild winter conditions...[such as] wet snow and slush, which freezes, [and] then we get tracks. Then we salt and we gravel, ..[and] it begins to rain and all this gets washed away. Then, suddenly, we get under-cooled rain again. And these very sudden transitions are getting almost too challenging for maintenance.”

The experience related to more sudden transitions of the road environment was obvious to the road managers in particular, since this had immediate and vast implications for their work related to keeping up the maintenance standard of the roads. Many of the respondents compared the current situation of yearlong fluctuating temperatures with ‘earlier times’ where two or three periods would occur annually, one in autumn/winter related to the first snowfall and one or two around spring. Essentially, the situation was characterized as one of instability.

The interviews revealed that the understanding of the climate change problem was mediated through the occurrence of extreme weather, rather than climate science and related scientific knowledge. Thus, the occurrences of extreme weather were experiences that shaped the understanding of the climate. Experiences of extreme weather and weather related

incidents were ways of domesticating climate changes, and the main consequence of this was that the road managers felt an urge to do something about the situation. In the next sections we will look more into what kinds of actions were developed among the regionally located road managers as actual responses to climate changes. Did domesticating climate change through experiences of extreme weather influence how adaptation strategies were developed in practice? Were there any boundary organizations that aided the translations? Did the National Transportation Plan and the handbooks function as anchoring devices in the domestication process?

On the road to action

The weather stories outlined above may be seen as vehicles on the road to action. Based on what most road authority managers experienced as evidence of climate changes, there was a strong emphasis that something had to be done in order to adjust the practice according to future climate changes.

We found three typical domestication processes in the road sector's response to climate change. First, there was a kind of awakening process, but which still had not led to any real initiatives in changed practise. Secondly, there developed a tendency to make small incremental changes, and thirdly, a tendency to wait for the central authorities to react to the problem by creating standards and regulations. A very typical example illustrating the first type of response was as follows:

“Well, [climate adaptation] has become an issue in a completely new way in meetings. In particular in relation to new constructions we are more aware of it. We observe that we maybe will have to organize maintenance differently.... So we feel that there probably is a change of attitudes ... For the time being, it has more to do with a raised awareness about the issue than directing new actions and ways to work.”

Road managers in general were more aware of the issue than before as shown above. It was something that had sneaked into their consciousness, but they were still not acting on the

problem, although they saw that they would have to deal with it more concretely in the future. The response to be awakened, but to do nothing applied not only to general planning of future constructions, but also to emergency planning. There was raised awareness, but no pro-active action was taken. One of the reasons for this was lack of resources. So even though the problem was domesticated on a symbolic level, it was not enough to change established practices. This was the most widespread response in our data material. It was however, possible to identify a few responses to the climate change problem that involved developing new practices. For example a small number of respondents reported on making small incremental changes through contracts between the administrators of roads and a competing set of contractors. One of our respondents explained this practice in the following way:

“...our district contracts are awarded every year now, leading to contract changes. The contracts are getting better year by year, allowing for climate change, However, to enter a contract in the middle of a five-year contract and makes changes awfully expensive”.

As indicated in this quotation, the contracts offered opportunities for making changes in the way that responsibilities were specified between the road managers and the entrepreneurs who managed the maintenance work of the roads. One example of this kind of change was to include in the contracts that the dimensions on new culverts, subdrains and service pipes should be increased. In this respect, the contracts ‘allowed for’ considering climate changes. On the other hand, the contracts were long lasting and fixed during the period of the contract, which made it costly to make changes and improvements during the contract period. A small number of road managers anticipated that such material changes, specification of equipment to be used, and the definition of ‘extreme weather’ incidents would become important in the next round of shaping and negotiating contracts. A very small number of road managers reported that they had tried to do some adaptation work by doing incremental changes when entering into contracts with contractors. However, the most common response was that

standards and regulations reflecting climate adaptation needed to be modified from higher levels in the organization in order to be implemented in practice.

We are now tapping into the third and most common response in dealing with future climate change and adaptation, which was to domesticate climate knowledge through translation into standards. Developing adaptation strategies to meet the new weather challenges was to a very large extent perceived as a result of inscribing and translating relevant climate knowledge into *guidelines* and *handbooks*. Essentially, the road managers pictured a kind of regulative-practical domestication process. Even if the experiences in the news weather reports pointed to a lot of diversity and uncertainty regarding future climate changes, the road managers seemed to have great confidence in the standards produced by central authorities. The regional road managers envisioned handbooks as the primary governing tools, both the normative guidelines of the “blue series” and the regulative prescriptions in the “yellow series”. Even if climate knowledge was not yet translated into existing devices, there were articulations of the need to do so. One manager expressed this common view quite clearly stating: “as climate change is high on the agenda in society, climate change has entered our agenda in the way that it has to be included and updated in our handbooks.” This and similar accounts pointed to a need for adapting, and actually updating, existing road regulation practices. Road managers seemed to be prepared to appropriate this knowledge and to turn it into practice.

The uncertainty of how to translate climate science into practice was not the only challenge that the interviews revealed about the practice of climate change adaptation. The road managers also expected considerable costs to be tied to climate adaptation work. Consequently, the majority of road managers in the districts affected found it sensible to wait for adaptation work to be addressed officially, but until then go on with business as usual:

“If we need to upgrade culverts and the whole system that leads the water away, we should wait for the coming of new guidance in road standards and specifications. It is a project in the Directorate of Roads that we are going to look at this now as a basis for adjusting these. So we are waiting for this.”

The Climate and Transport program served as a main point of reference when the road managers were asked to specify sources of information on consequences of climate change that were relevant for their work. The quote above illustrates that the Research and Design program (R&D) was expected to be a kind of boundary organization that could facilitate the translation of climate science into adaptation practice. At this point in time the work of the R&D program had not yet been turned into stable knowledge constructs with means of managing uncertainty in regard to climate adaptation practice. The road managers, however, expected that the project would facilitate action, but perceived standards as the proper means of translation. Connected to the call for standards, a few road managers also uttered a need for more specific climate science, models, weather data, which could make the adaptation easier. However, this was mostly seen as a subordinate concern compared to the need to develop updated standards.

Conclusion: Adaptation through existing regulatory devices?

In this article we have set out to develop a more differentiating understanding of how climate adaptation strategies are shaped in the public road sector and how these strategies depend on specific translations or appropriation of the climate science discourse by the socio-technical system of road managers. The way road managers' perceptions and actions are shaped by scientific discourse, as well as, their institutional context and public opinions about climate change are indeed helpful for shedding light on the practice of climate change adaptation. When we look more deeply into the way different types of road managers (e.g. central

administration vs. regional vs district offices) perceive and utilize climate science, how they use this in the practice of climate change adaptation, as well as which devices they qualify as useful for translating between knowledge, policy and practice, our analysis reveals the following:

1. The road managers on the district level appropriate the climate change problem as a challenge that will alter their practice (climate adaptation). This is mainly based on their own experiences of extreme weather. They perceive that climate science as trustworthy, although it is not perceived as immediately useful for application. Therefore, these professionals wait for the research and development project to transform climate science findings into knowledge that is more application oriented and capable of directing their practice..
2. The Climate and Transport program under the NPRA is a potential boundary organization that is expected to aid the domestication of climate science. The contributors involved in the program are currently in the process of doing this by translating science into adaptation strategies and practice.
3. As for now, there are no anchoring devices or tools that function as stable knowledge constructs that facilitate uncertainty management in regard to climate adaptation practice and makes domestication easier. However the National Transportation Plan and handbooks that articulate standards and regulations have obvious potential as acting as anchoring devices that could be developed in such a way.

The road managers first and foremost perceive climate change on the basis of their own experiences of extreme weather. These experiences, together with the general discourse about climate change and an increased expectation from the public regarding risk management constitutes their ‘knowledge basis’ on the grounds of which they see it as important to engage

in climate adaptation activities. And although this is enough information to make road managers want to act, it is not however considered a sufficient basis from which to know how to act.

This case study may be seen as yet another demonstration of the problem of reconciling the supply and demand of scientific information for decision-making (McNie 2007, Sarewitz & Pielke 2007). The road managers trust the basic results from climate scientists presented to them in IPCC reports and by Norwegian research institutions with which they share a long history of cooperation. None the less, current scientific knowledge about climate change is still not perceived in such a manner or presented in such a form that it has had any real impact on the way the transportation infrastructure has been planned and managed. This has to do with the fact that road managers have not domesticated possible solutions as to how one should deal with the problem practically.

In the climate adaptation literature, as well as in many studies of the relationship between science, policy and society, mediating institutions or boundary organizations are perceived to be beneficial (i.e. rendering scientific knowledge usable in contexts of application) (Cash et al 2003, Guston 2001, Tribbia & Moser 2008, Vogel et al. 2007). The R&D project in the road sector was also perceived by road managers to potentially provide the relevant knowledge. However, our analysis indicates that so far neither this project or other existing institutions has served the role as a boundary organization, despite the preconditions being present. The data material indicates that the R&D project may be such a project when concluded.

In this article we argue that weaknesses concerning the development and implementation of climate adaptation strategies are not effectively addressed in current practice. Even if more institutional connectivity may strengthen the transfer, and potentially the preciseness of knowledge necessary for decision making, there is a need to critically

identify solutions connected to existing tools, objects and devices that are involved in the enactment of climate adaptation policy. Providing relevant knowledge is of course important, however there may also be advantages of looking further into what way climate adaptation strategies may be grafted into to existing professional practices such as through incremental changes via contracts.

The interviews demonstrate that the road managers are currently waiting for the central authorities to act in the form of updating existing handbooks and regulation, since they perceive the translation of knowledge into practice as being too time and resource consuming for them. Handbooks are perceived as the important anchoring device between the boundaries of science, policy and the road society.

On a general note our study of this domestication process illustrates the important point that climate adaptation is in a fundamental way very practical as it is integrated in the daily work of managing the road infrastructure (Solli & Ryghaug 2009). This partly explains why road managers point to changes to the existing apparatus of standards and regulations as a natural way to adapt to changing climate. Centrally, we assert that the development of standards and regulations might have been underestimated in relation to reconciling the supply of scientific information with user demands.

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