Support to transport and environment assessments

Adaptation to Climate Change in the Transport Sector

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Executive summary

This technical paper has been produced as a part of the 2013 working programme of the European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC/CCA) of the European Environment Agency (EEA). It is a first step in an effort to establish a map of current actions in EEA countries for adapting the transport system ([1]) to climate change, and to identify opportunities for further action at the European level in the next years. For doing so, the ETC/CCA team conducted a review of existing research and policy initiatives, and analysed the material collected through a questionnaire sent to member countries, and an experts' workshop organised by EEA.

The literature available on the challenges of adaptation to climate change of transport systems across EEA member countries remains limited, but has expanded in the last years. Two EEA reports are particularly worth mentioning, both focusing on transport infrastructure. The EEA Report No 12/2012 'Climate change, impacts and vulnerability in Europe' (EEA, 2012b) provides an initial assessment for the transport sector (chapter 4.6), based on the results of a few research projects financed by the European Union (EU) 7th Framework Programme for Research and Development. The EEA Report No 3/2013 'Adaptation in Europe' (EEA, 2013), provides policymakers with information to support their adaptation planning and implementation efforts, and highlights the need for coherent, flexible and participatory approaches.

These EEA efforts are to be put in the context of the European Commission's attempts to develop a more systematic approach to adaptation within its climate change policy. The European Commission's White Paper 'Adapting to climate change: Towards a European framework for action' (COM(2009) 147) can be considered as the first significant move in this direction. This White Paper announced the preparation of an adaptation strategy which should go hand-in-hand with the development of national climate adaptation strategies and actions. Following this announcement, the European Commission issued its proposal in April 2013: 'An EU strategy on adaptation to climate change' (COM(2013)216). One of the rationales of this strategy is that "by prioritising coherent, flexible and participatory approaches, it is cheaper to take early, planned adaptation action than to pay the price of not adapting". The strategy contends that, although adaptation measures need to be taken from local to regional and national levels, "there is also a role for the European Union to fill both knowledge and action gaps".

The communication of the European Commission includes a number of actions for mainstreaming adaptation into EU policies and programmes, particularly in transport. It acknowledges that uncertainty "remains a challenge for policy making in this area", but contends that "uncertainty cannot be seen as a reason for inaction. It notably calls for a strong emphasis on incorporating win-win, low-cost and no-regret adaptation actions".

Concerning the transport sector, the strategy considers that "adaptation has already been mainstreamed in legislation in such sectors as... transport". It cites as an evidence for that the legislative proposal for a Regulation on Union guidelines for the development of the trans-European transport network (COM(2011)650/2 final), which includes a mandate to Member States and other project promoters to "give due consideration to the risk assessments and adaptation measures adequately improving the resilience to climate change" (article 41) ([2]). This is just an example of still on-going efforts and efforts to come to include adaptation to climate change in every relevant piece of EU legislation, in transport and other sectors. The EU adaptation strategy also stresses that it is important "to analyse to what extent standards, technical specifications, codes and safety provisions for physical infrastructure should be strengthened". This would be addressed through a mandate for

([1]) Transport system refers to the infrastructure, equipment, regulatory framework and management practices which sustain transport operations. In the report, the first one will be referred to as "transport infrastructure", and the others as "transport services".

([2]) An agreement between the Commission, the Council and the Parliament was reached on 30 May 2013, concerning this legislative proposal: http://europa.eu/rapid/press-release_IP-13-478_en.htm.

European standardisation organisations to start "identifying standards to be revised for better inclusion of adaptation considerations" (action 7: ensuring more resilient infrastructure).

The review of existing literature and policy initiatives showed that adaptation in transport is becoming a familiar topic to an expanding number of stakeholders, who are increasingly integrating the adaptation dimension within their strategies. This increasing interest has to deal with the still significant uncertainties about the expected impacts of climate change on transport in the medium and long term. As some stakeholders point out in their strategies, changes in climate may be influential in modifying land use and activity patterns and transport demand, making necessary a revision of traditional assumptions and practices in European transport planning and policy. In short, it seems that the "resilience" concept ([3]) should be applied to policy decision-making and not only to infrastructure management and transport operations.

With a view to gather information, a questionnaire on actions and experiences for adapting the transport system to climate change was prepared and circulated among the National Reference Centres (NRC) on transport. The NRCs for climate change impacts and adaptation and the National Focal Points (NFP) were also informed about this activity and encouraged to provide support, as needed ([4]). The questionnaire was answered by 23 countries. It was structured into five blocks:

- Block A referred to the relevant national strategies, plans and actions on adaptation to climate change at the national level, and asked for information on whether and how the transport sector was included in these. It also asked for the influence that adaptation may be having in the preparation or revision of emergency protocols. There was also a request for identifying transport-related plans, programmes and initiatives which could have considered adaptation to climate change as a relevant issue.

  The picture that emerges from this part of the questionnaire is that climate change adaptation is gaining momentum in national policy agendas, and that local (and eventually regional) authorities will need to play a central role. Notwithstanding the initiatives in some countries, the transport sector does not seem to be generally identified as a critical one in these initial adaptation efforts. Furthermore, transport planning and decision making do not seem close to mainstreaming either climate change adaptation or risk management within their current practices.

  As climate-change related hazards are likely to have a local character, national and local governments seem to be better suited to identify, monitor and lead the adaptation process. However, there is a strong need for developing adequate guidelines, methodologies and procedures for dealing with information collection, action development and decision making; in this dimension, a European-driven effort, including stronger cooperation among governments, would be necessary. There is a need for cross-boundary and both intra- and cross-sector information exchange and sharing of best practices and lessons learned. This exchange, through dedicated platforms such as Climate-ADAPT and through focused networks and groups, also helps to reduce costs and avoid duplication of work.

- The information base was the main topic of attention under block B. It included specific studies, national programmes funding research projects on adaptation and extreme events, the relevance given to transport in those initiatives, and the channels used to make the information and the knowledge produced available to stakeholders and the public, through national adaptation platforms, similar to the European "Climate-ADAPT" model.

([3]) "Resilience" is defined by the IPCC as "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change." (IPCC, 2007, p.880).

([4]) National Reference Centres (NRC) are nominated by member and cooperating countries. They are nationally funded experts or groups of experts in organisations which are regular collectors or suppliers of environmental data at the national level and/or possess relevant knowledge of specific environmental issues, monitoring or modelling. National Focal Points (NFP) are the main contact points for the EEA in the member and cooperating countries. They are in charge of cooperation with the EEA and the European Topic Centres and organise national coordination of activities related to the EEA Strategy (five-year work programme). See http://www.eionet.europa.eu/partners for further details.

The answers stated a still limited effort in data and information collection and in expanding the knowledge base, probably due to the low priority that many national (and subnational) governments and stakeholders still give to adaptation in the transport sector. This represents a significant barrier for any sound, fact-based progress in this topic, which needs expanding information systems on extreme weather events and their impacts on transport. A stronger empirical basis remains critical for developing more accurate (and possibly less costly) adaptation strategies for the transport system.

- Block C asked for information on the governance and institutional arrangements for adapting the transport sector to climate changes and extreme weather events. It aimed at identifying the leading players and the role of the different stakeholders in the sector as a whole and in the various transport modes.

  Overall, it seems that a majority of the responders do not expect that most infrastructure managers and transport operators will adopt a proactive approach in this field: these actors would rather expect national governments (through their ministries of transport) to take the lead. In the future, it would be interesting to monitor whether climate change is perceived by any of those actors as a business risk deserving more pro-active action.

  Surprisingly, there seems to be no specific relationships among transport and climate change authorities with those agencies in charge of risk management for natural hazards. The respective roles of infrastructure managers, service providers and governments for analysing and assessing the challenges of climate change probably deserve some discussion at the national and eventually also at the European level; some of the more active countries (like Switzerland and the United Kingdom for road and rail or Austria for rail) seem to have addressed this question, and they now rely heavily on the action of infrastructure road and rail managers, as well as rail operators. Furthermore, the identification of the appropriate management changes and additional financial resources should be based on a clearer distinction between already existing climate adaptation responsibilities and new, emerging, additional needs. This would also provide a solid ground for setting up collaborative structures involving other governance levels (mainly local authorities), necessary for moving ahead.

- Under Block D, NRCs were asked to assess the relevance of nine different barriers to adaptation in the transport sector. This was coupled with a request for rating the efficiency of eleven EU initiatives aimed at supporting adaptation in their countries. The answers highlighted significant difficulties at both the political and technical levels, which make it difficult to take further action at this stage for adapting transport systems to climate change. This can be seen as an interconnected situation: as long as technical knowledge does not become able to reduce uncertainty about which changes are likely to occur, it seems difficult for decision makers to take further action in adaptation.

  To cope with this, it would be necessary on the one hand to improve the current level of technical knowledge, and on the other hand to adapt decision making in the transport sector to higher levels of uncertainty. From both perspectives, there would be a need for technical and other developments to manage uncertainty, as well as reduce it. If it is not clear how to manage uncertainty, there could be a tendency to underestimate the consequences of climate change impacts, in the confidence that the transport sector has a good record in coping with extreme weather events in the past. At any rate, it should be stressed that uncertainty should not serve as a justification for favouring business-as-usual practices, but rather to undertake a detailed scrutiny of such practices.

- Block E was an open question for NRCs to suggest how the EEA could better address this exploratory task for analysing the state of the art of transport adaptation to climate change at the national level and to identify potential follow-up initiatives. Four main issues were raised by respondents:

  - The need for clarification of what should actually be regarded as *adaptation* of the transport system to climate change. Two different topics for further exploration were raised here. On the one hand, changes in climate may result in a variety of

socioeconomic impacts, which on their turn, would have an influence on transport demand patterns. On the other hand, disaster risks may vary as a result of changes in climate, and this is likely to require a review of prevention and management plans, within which transport usually plays a key role. In accordance with these concerns, it seems that adaptation actions in transport should not be limited to the revision of current design, operation and maintenance practices, and should be expanded to develop a vision of the contribution of transport to a climate resilient society.

- The need to identify the "climate signals" or "early warning signals", which may be relevant for transport and will require major adaptation decisions.
- A need to strengthen exchanges among countries, and to encourage them to further interact with those who are already active.
- A recommendation for decision-makers and stakeholders in the transport sector to undertake a revision of their procedures in order to accommodate the uncertainty associated to climate change in a transparent and fair way.

The general problems identified by the EU adaptation strategy are also relevant for the transport system: knowledge gaps, need for action at the national level, and still limited action at the EU level. However, in the case of transport, these problems interact with a policy sector facing particular social, environmental and economic challenges. Transport is under increasing scrutiny to improve its energetic and environmental performance, to deliver social and economic benefits aligned with the public and private resources dedicated to it and to accommodate to the changing demand patterns of a rapidly evolving society and economy. Within this framework, the emerging needs for adapting to climate change, and the responses to them, can be seen as a way either to facilitate radical reform or to further consolidate business as usual attitudes. These issues could be better addressed through a revision of the four areas that have emerged as particularly problematic during this study:

- The boundaries of adaptation in transport. Current uncertainty about future changes in climate, at the scale relevant for the transport system, makes it difficult to reach technical consensus on the reasonable boundaries for adaptation. The uncertainty of existing models for identifying key climate change trends at the scale required by transport systems implies, on the one hand, that there are significant research needs in this field; on the other hand, that policy makers should be cautious about general, European-wide conclusions, and should try to develop their own studies at the appropriate regional or local scale. Additionally, this would justify an improved collection of information on disruptive events and the development of monitoring systems, as a means for improving the empirical ground for decisions in the absence of more reliable models.
- The objectives and the actions for adaptation in transport. In the absence of more detailed objectives, and in the context of significant uncertainty and knowledge gaps, it is not surprising that most experts recommend the identification and implementation of so-called soft or no-regret measures: actions that have been identified as necessary within existing transport policies, and which also contribute to increasing the resilience of the transport system. This applies for example to sound maintenance practices for transport infrastructure, integration of transport systems (providing more alternatives to users), revision of already obsolete (or non-existent) design standards, or improved monitoring of vulnerable parts of the system. The identification of further actions would be linked to progress in reducing the current knowledge gap and to the definition of more concrete adaptation objectives for the transport sector. The prevalent perspective here is that it is essential to introduce adaptation as an integral component of on-going infrastructure and operational improvements, as a way for reducing both costs and damage in the longer term. The challenge is to convince relevant parties to take action now against a risk which may still seem intangible to many; therefore no-regret measures, which provide other benefits, are an essential part of mainstreaming climate adaptation. For this, it would be useful to identify tools which could clearly demonstrate the benefits of early actions and the risks of delayed action.
- The stakeholders and the governance regimes. Effective adaptation to climate change would require appropriate governance structures, better suited to anticipate future challenges and

opportunities and to build fair and transparent consensus among stakeholders. The need to adapt to climate change is an opportunity to reflect upon more radical reform in transport governance in order to make decision making procedures better suited to deal with uncertainty and with increasingly integrated, complex transport systems.

- The key paradigms of transport policy. Thus far, the traditional paradigm of providing ever cheaper, faster means for transport, with increasing capacity, has not been challenged([5]), but there would be a need to assess whether this paradigm remains consistent with the still uncertain adaptation needs.

The EEA in cooperation with other key stakeholders (including the European Commission, countries, and key agents within the transport sector) has several options in order to play a catalytic role with some short-term initiatives. They relate to the four broad areas described above: the boundaries of adaptation, adaptation objectives, governance and the revision of transport planning paradigms:

- Reducing uncertainty and better linking climate modelling to the needs of transport planners and policy makers is a medium-term goal, which will mainly rely on research, and knowledge expansion, with greater interaction between both fields. The EEA and partners could promote a dialogue among researchers in the areas of climate modelling and transport planning and policy, as a support to the EU adaptation strategy. This supporting action could highlight the prospects for climate modelling developments better aligned with needs in the transport sector, and explore how they could provide a basis for revised design methods and standards.

- The EEA could encourage quick progress and better comparability for monitoring extreme-weather events with an impact on transport systems. For example, the Transport and Environment Reporting Mechanism (TERM) ([6]) (EEA, 2012a) could include some additional indicators for categorisation of extreme events (region and population affected, main circumstances…) and their effects on the transport system (days of disrupted or suspended services, number of people affected, costs of restoration…). These indicators would offer valuable factual information at a broader scale, facilitating a more solid basis for the revision of maintenance strategies, design standards and contingency plans. Data analyses of disruptive events could then be developed into resilience performance indicators, to facilitate proactive and event-appropriate operational responses. This may be mode-specific or cross-modal and would serve to quantify the base level of network resilience and the corresponding impact of a disruptive event. It would also facilitate more proactive reactions to disruptive weather by identifying an event-specific performance goal which is aligned with mode or network capacity management and safety requirements.

- A revision of current methodologies for the consideration of transport within contingency plans would clarify how adaptation could be addressed at a more general level in the future. In particular, it would be necessary to promote closer cooperation among researchers and practitioners in the transport and the river basin management sectors, as flooding has emerged as one particular area of interest for climate adaptation in transport.

- How climate changes can impact on activity location patterns, population flows and mobility behaviour largely remains an open issue in need of further research and monitoring. These impacts should be considered from a broader perspective on how spatial development patterns may be affected by changes in climate.

- The EEA could also foster the exchange of views and experiences on governance practices promoting flexible and forward looking planning, better suited for decision making under uncertainty, and to further involve a broader set of stakeholders, and particularly transport service operators, within the adaptation debate. Climate change and its related uncertainties only

([5]) The 2011 White Paper on Transport states that "curbing mobility is not an option": transport policy relies on providing more efficient ways of carrying increasing freight and passenger flows.

([6]) http://www.eea.europa.eu/themes/transport/term.

provide further arguments for stressing the need for more flexible and transparent planning and decision making frameworks.

- Whereas adaptation needs have focused thus far on the vulnerabilities of transport infrastructure, comparatively little attention has been given to transport service operators. However, these stakeholders are instrumental for providing passenger and freight transport services under extreme weather conditions, and should play a more central role for adapting the transport system to climate change. In fact, operators could facilitate the adaptation of transport systems to the integration of the needs of vulnerable end-users, from SMEs to low-income citizens or less developed regions, based upon their proximity to them.
- Climate-ADAPT could play a crucial supporting role, providing the necessary information to facilitate discussion on modelling needs, prevention and contingency plans at the national and modal levels, changes in location patterns, and innovative governance practices, among others. It would be necessary to expand the existing information on the transport contents of national and subnational action plans within the Climate-ADAPT platform.

1 Background and scope of the technical paper

The European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC/CCA) has been asked to support the European Environment Agency (EEA) in reviewing current initiatives of adaption of transport to climate change and exploring needs for future action. This task included contributing to a workshop with experts, in order to identify potential recommendations for further action at the EEA level, the review of existing actions at the national level (based on the answers provided by European Environment Information and Observation Network (EIONET) national reference centres on transport (NRC) to a questionnaire prepared by the ETC/CCA, and the preparation of a final report.

The climate is changing at global scale and changes in global and regional temperatures are already modifying weather patterns, causing a number of impacts and increasing the vulnerability of regions, economic sectors and communities. Even if greenhouse gas emissions were to stop today, past emissions mean that climate change will continue for decades. Adapting to the changes is necessary, in combination with global and European mitigation policies, as stated in the EEA's report 'Climate change, impacts and vulnerability in Europe 2012' ([7]).

Adaptation ([8]) consists of actions responding to current and future climate change impacts and vulnerabilities within the context of on-going and expected societal change. It means not only protecting against negative impacts of climate change, but also building resilience and taking advantage of any benefits it may bring.

In short, adaptation manages the unavoidable climate change impacts. Adaptation thus complements climate change mitigation ([9]) efforts, such as reducing greenhouse gas emissions.

There are a number of reasons to justify early action on this issue at the European level. For example, cooperation at the European level can help to identify efficient adaptation responses in the case of climatic regions that do not follow national boundaries. Furthermore, as transport has played a significant role in European integration in the past, through the facilitation of the mobility of goods and citizens, it can be argued that attaining a resilient, climate adapted transport system across Europe is crucial for supporting current economic integration paths. It can also be expected that early responses to emerging climate change-related challenges may be more economically efficient than later efforts, as they allow all players in the transport sector to steadily adapt through time and minimise the risks for harmful effects. Last but not least, the exchange and expansion of knowledge, including technological developments, could greatly benefit from European cooperation.

There is limited information available on the current state of adaptation to climate change of transport infrastructure and services across the EEA member countries and about the perceived challenges. The EEA report 12/2012 'Climate change, impacts and vulnerability in Europe 2012', provides in chapter 4.6 an initial assessment for Europe on the basis of a few recent FP7 projects. It focuses on impacts, less on actions. For further interlinking European and national adaptation policies in the transport sector, we need to better understand national/regional approaches to adaptation of the transport system.

The recent communication of the European Commission, 'An EU Strategy on adaptation to climate change' (COM(2013)216), includes a number of actions for mainstreaming adaptation measures into EU policies and programmes, including transport. In particular, action 7 within the EU strategy calls for "European standardisation organisations to start mapping industry-relevant standards", *inter alia*

([7]) EEA Report No 12/2012. *Climate change, impacts and vulnerability in Europe 2012.* http://www.eea.europa.eu/publications/climate-impacts-and-vulnerability-2012.

([8]) Adaptation is defined as the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". (IPCC, 2007).

([9]) Mitigation is defined as "an anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks.". (IPCC, 2007).

in the area of transport. The new EEA report 3/2013, 'Adaptation in Europe' ([10]), provides policymakers with information to support their adaptation planning and implementation efforts, and highlights the need for coherent, flexible and participatory approaches.

Action at the European level should be further interlinked with national adaptation policies in the transport sector. In fact, as the effects of climate change are mostly felt at the local level, it is necessary to ground action at the European level with a thorough understanding of current national and regional approaches to adaptation of the transport system.

This technical paper has been produced as a part of the 2013 working programme of the European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC/CCA) of the European Environment Agency (EEA). It is a first step in an effort to establish an overview of current actions in EEA countries for adapting the transport system to climate change, and to identify opportunities for further action in the next years.

A clarified picture is emerging from this exercise: adaptation in transport is becoming a familiar topic to an expanding number of stakeholders, and is increasingly being integrated within their strategies to gain attention and resources from decision makers at the European, national and local levels. This increasing interest has to deal with the still significant uncertainties in the expected impacts of climate change on transport in the medium and long term. In fact, changes in climate may be influential in modifying land use and activity patterns and transport demand, making a revision of traditional assumptions and practices in European transport planning and policy necessary. In a nutshell, it seems that the "resilience" concept ([11]) should be applied to policy decision-making and not only to infrastructure management and transport operations.

In short, this technical paper aims at exploring those developments that are likely to emerge in the near future within the transport sector in Europe, and how they may (or may not) increase its climate resilience. It is based on information collected from:

- An extensive review of relevant research (chapter 2).
- A comparative analysis of international cooperative initiatives (chapter 3), including the recent publication by the European Commission of the EU strategy on adaptation to climate change, as well as some key initiatives from various transport stakeholders at the international level.
- A review of national practices in EEA member countries, based on the answers provided by NRCs to a questionnaire prepared by the ETC/CCA. This review considers the different approaches that have been identified: countries focusing on the improvement of management and maintenance practices; countries aiming at making a comprehensive assessment of the vulnerability of their transport systems; countries aiming at identifying particular areas for technical action (chapter 4).
- Six key policy-relevant challenges are discussed, including proposals for possible follow-up actions concerning (chapter 5):
    - The meaning, scope and significance of the varied calls for "integration" in the transport sector as an adaptation strategy.
    - The contribution and limits of existing models for identifying key climate change trends at the appropriate scale for transport systems.
    - The optimal balance between reactive and proactive actions while designing a climate change adaptation action plan for the transport sector at the European and national level.

([10]) EEA Report No 3/2013. *Adaptation in Europe: Addressing risks and opportunities from climate change in the context of socio-economic developments.* http://www.eea.europa.eu/publications/adaptation-in-europe.

([11]) In accordance with EEA Report No 3/2013 (page 18) resilience describes the stability of a system. In social systems, resilience is also affected by the capacity of humans to anticipate and plan for the future. In economics, resilience also refers to the inherent and adaptive responses to hazards that enable individuals and communities to avoid potential losses. See also the IPCC's definition of resilience (footnote 3).

- The respective roles and responsibilities of the various transport stakeholders to adapt to climate change and the need for further collaboration among them: infrastructure providers, operators, equipment providers and users.

- The role of contingency plans, disaster prevention and civil protection agencies.

- The relevance of cultural differences (of the various transport modes, and of different countries and regions within Europe) while addressing climate change adaptation.

2 Recent research results and other contributions

2.1 The review approach

This review aims at identifying recent research, studies and developments in adaptation of the transport sector. It is focused on recent documents, produced since 2010, on the impacts of climate on transport systems. Three main sources of information have been reviewed: research papers and European research projects; stakeholders' documents and position papers; and papers from international organisations.

Adapting transport systems to climate change is a fast-growing concern. The increased attention that is paid to climate adaptation is apparent in both policy and academic publishing. The review has covered five main topics:

- research on climate change scenarios for 2030, 2050 and beyond;
- research on the expected and projected changes in climate, which have an impact on transport;
- research on the geography of adaptation in the transport system (i.e. differences on adaptation needs in accordance with geographical conditions throughout Europe);
- potential changes in long-term trends in transport demand;
- potential challenges to transport supply activities: transport operators' practices, infrastructure managers' actions and industrial strategies of equipment suppliers.

A particular focus on the contributions and follow-up activities of the research projects financed within FP7. Three projects (ECCONET, WEATHER and EWENT) have been completed and one more (MOWE-IT) is in progress. These projects have been influential in gathering the limited information available and making some initial estimates of potential impacts of climate changes in the transport sector.

2.2 A review of early studies: reports and literature prior to 2010

The IPCC 1997 report "*The regional impacts of climate change: an assessment of the vulnerabilities*" (Watson et al. 1997) can be considered as a milestone in the study of adaptation to climate change. Since then, an increasing number of studies and reports have been published, although a reduced number of few refer to the transport sector.

In the USA, one of the first systematic reviews of the consequences of climate change for transport infrastructure and operations was issued in 2008 by the National Research Council (NRC, 2008). It reported that addressing climate change requires an examination of future scenarios, long-term perspective, the capacity to deal with uncertain and changing phenomena, and the identification of concrete responsive actions. The report built upon the previous literature review made by five studies which explored different aspects of the potential impacts of climate change on transport: identification of climate factors of greatest relevance for transportation (Peterson et al. 2006); the role of transport design standards (Meyer, 2006); operational strategies for addressing climate change (Lockwood and Brinckerhoff, 2008); a review of case studies on the vulnerabilities and strengths of various transport modes (Grenzeback and Lukmann, 2007); and decision making under uncertainty (Dewar and Wachs, 2008).

A similar report was made in New Zealand, making a literature review of climate change adaptation of transport networks (Gardiner et al. 2009). This report identified the need for climate change adaptation to be considered within long-term capital improvements programs. Building upon the revision of international literature, Gardiner et al. came to the following conclusions:

- climate change factors should be progressively integrated within infrastructure design and maintenance;
- risk analysis tools would help to reduce uncertainty when including climate-related factors within the decision making process;
- some recommendations have already been made by many international studies to calculate the cost of climate change effects;
- prior contingency planning should be developed, in order to facilitate a quick recovery of transport systems in case of breakdown due to extreme weather effects;
- warning systems are important for minimizing the damage and disruption to transport systems.

Regmi and Hanaoka (2009) found a limited number of contributions within the Asian region. They highlighted the need for further research in the area of transport and climate change, and stressed the need to strengthen institutional capacity to initiate policy guidelines and implementation of adaptation programs.

In Europe, the European Commission and EEA stressed already some years ago the need to pay more attention to climate adaptation (EC 2007; EEA 2008), although the first documents did not pay much specific attention to the transport sector. However, the vulnerability of transport infrastructure and networks to climate change received prompt attention in some European countries, such as the United Kingdom (i.e. Arkell and Darch, 2006), the Netherlands (Nillesen and van Ireland, 2006), Finland (Carter, 2007), and Sweden (SOU, 2007; Lindgren et al. 2009).

Two early reviews of the state-of-the-art in this topic are particularly worth mentioning. The first one (Reckien et al, 2008) mainly focused on the actors involved in adaptation, providing a comprehensive review in accordance with the following criteria: studies dealing with climate change adaptation, with a focus or a specific section on transport; and with an explicit consideration of adaptation. From this review it can be concluded that, at the end of 2008, the adaptation actions in transport were still at a stage of infancy, although awareness and interest were increasing. The significant gap between problem awareness and implementation actions was mainly justified by the complexity of the relationships among the actors involved.

The second extensive literature review is made by Koetse and Rietveld (2009). These authors find that most studies focus on short term impacts and that the transport sector has not received proper attention yet. Furthermore, it stated that the empirical evidence available remained scarce, many studies have significant drawbacks, and most of the studies were focusing on current weather conditions, without analysing long term effects. The authors concluded that more detailed research would be needed to obtain the necessary insight into both, transport infrastructure impacts and behavioural responses to changes in climate.

2.3 Long-term scenarios on climate change

Climate change impacts on natural and human systems are being observed globally and regionally. Scenarios of possible futures indicate than these impacts may increase. Climate modelling is crucial for forecasting changes in climate as a basis for developing mitigation and adaptation strategies.

The evolution of research into climate change has been deeply influenced by the reports of the Intergovernmental Panel on Climate Change (IPCC). The IPCC Working Group II assesses the vulnerability of socio-economic and natural systems to climate change. Assessment reports have produced regularly in 1990, 1996, 2001 and 2007. The Stern Review "*The Economics of the Climate Change*", published also in 2007, also includes a chapter examining the scientific evidence on climate change (Stern, 2007). The Fifth Assessment Report is currently under discussion, and should be published by the end of 2014. The second volume of the Fourth Assessment Report, published in 2007 with the title "*Climate change 2007: Impacts, adaptation and vulnerability*", provides a comprehensive assessment of the climate change literature on these three topics (IPCC, 2007). The report reviews observed changes in climate and forecasts future ones, including sea-level rise, for 2050 and beyond. It provides a complete new assessment of the impacts of climate change on major

regions (including Europe), identifies the key vulnerabilities to climate change, and estimates potential damage levels.

In the EU, scenario building for climate change assessment has become a resource-intensive research activity, with several institutes involved with a global and regional perspective. Reports on future climate change scenarios for 2030, 2050 and beyond in the EU have been produced, in particular, in the context of some European research projects within the sixth and seventh Framework Programmes (FP6 and FP7).

The FP6 ENSEMBLES project (2004-2009) ([12]) provides a good basis for reducing the uncertainties and develop future climate change scenarios, with a focus on future changes of average and extreme values over Europe (van der Linden and Mitchell, 2009). The ENSEMBLES project includes a modelling system for the prediction of climate change and its impacts, with significant progress in the model performance at the seasonal to decadal timescales. It provides a link among global and regional climate change models, statistical downscaling methods and climate change impact models. The outputs of the ENSEMBLES project include a range of future predictions with an assessment of their probability of occurrence. These should be useful for policy makers to assess future strategies for addressing climate change.

The FP7 CLIMATECOST project (2008-2011) ([13]) also produced consistent scenarios for estimating the full costs of climate change impacts in Europe. The FP7 EURO4M project (2010-2014) ([14]) is focusing on weather extreme events in Europe. The project should expand the European capacity to systematically monitor climate variability and change on a range of space and time scales (Klein Tank, 2010). EURO4M will provide high-resolution datasets which will enable observed high-impact weather and extreme events to be put into a long-term historical context.

2.4 Research on the general impacts of climate change on transport

There are a good number of studies with a focus on one particular transport mode, particularly on roads: out of the 60 documents reviewed, only less than one third (29%) refers to climate impacts on the transport system in general, whereas 20% of them are focusing on roads, and the rests is distributed among the other transport modes.

At the European level, Nemry and Demirel (2012) provide an assessment of the future vulnerability of transport to climate change, with a focus on road and rail infrastructure, in the framework of the Joint Research Centre's (JRC) PESETA II project (JRC, 2013). They provide a review summary of previous research, including the main climate change effects, and their possible impacts on transport, providing an insight on the climate change scenarios for the different regions considered within Europe.

Jarosweski et al. (2010) provided a review of previous studies made on the impacts of weather events such as rain, high temperatures, ice and snow on road, rail and waterborne transport in the United Kigdom. Andersson and Chapman (2011) investigated the impact of changing winter weather on road maintenance and traffic accidents in the same country.

Trinks et al. (2012a) analysed the links between extreme weather events and adverse effects on road and rail transport in Germany. In France, the vulnerability or rail and road networks to sea level rise was assessed at the national and regional level in 2009; the study identified that a significant length of both networks would be affected (Groupe de travail interministériel sur les coûts de l'adaptation, 2009).

Taylor and Philp (2010) considered the increased frequency and intensity of extreme weather events (including temperature extremes, decrease precipitation, sea level rise, and coastal winds) as a

([12])ENSEMBLES Climate change and its impacts at seasonal, decadal and centennial timescales http://www.ensembles-eu.org/

([13]) ClimateCost: The full costs of climate change. http://www.climatecost.cc/home.html

([14]) Reanalysis and Observations for Monitoring http://www.euro4m.eu/

significant risk for transport infrastructure in Australia. In the Pacific, Baker et al. (2011) reviewed the expected changes in climate, which could have an impact on infrastructure, including transport, and provided a summary of expected impacts on road (with a focus on bridges), airports and waterborne transport. Friedrich and Timol (2011) have made a study in South Africa, for the metropolitan area of Durban (eThekwini Municipality), identifying those roads more vulnerable to sea level rise.

As an illustration of the studies made in the USA, it is worth mentioning the analysis of the impacts of sea level rise on the transport network of the metropolitan area of Miami made by Lu and Peng (2011). Walker et al. (2011) have outlined a method to assess the vulnerability of multimodal transport systems, and applied it to the city of Portland (Oregon, USA).

These studies have provided a basis for developing more general reviews and strategies at the national level. The US Global Change Research Program (USGCRP, 2009) published a report on climate-related impacts on various societal and environmental sectors, considering the differences among regions across the whole country, with a specific section on transport. Among the various strategies at the state level, it is worth mentioning "Climate Change Adaptation Report" prepared by the Oregon Department of Transportation, which included an assessment of climate change impacts on the state transport assets and system operations (ODOT, 2012). This report pointed out that climate impacts would not be uniformly spread across the region.

In the United Kingdom, the Department for Environment, Food and Rural Affairs (DEFRA) has published a Government Report for "Adaptation to Climate Change: helping key sectors to adapt to climate change" (DEFRA, 2012). In the report, the adaptation needs and the main climate risks for aviation, road, rail, and ports are identified.

2.5 Research on the geography of adaptation in the transport system

Hurlimann and March (2012) have assessed climate change impacts from a spatial planning perspective. Rannow et al. (2010) have also proposed an assessment framework for exploring the impacts of climate change in the context of spatial planning. The framework was applied at a regional level for Germany, and an indicator-based model was developed assessing eleven potential impacts with relevance for the German spatial planning system. The assessment provides new information on the spatial distribution of different potential impacts of climate change in Germany. Regions with cumulative impacts of climate change are identified as hot spot areas, needing urgent adaptation action. Lung et al. (2013) presented a climate change impact assessment framework for the regions of the European Union (NUTS-2 level) and quantified potential regional changes in weather-related hazards, founding that these would not be uniform: for example, the risk for flooding would significantly vary in sign and magnitude across regions, whereas heat stress would generally increase. Therefore, a spatial-sensitive assessment would provide a basis for mainstreaming climate change adaptation within regional development policies in the EU, and for revising current priorities.

In fact, it should be expected that geography would receive an increasing attention from transport adaptation research, as climate change impacts are highly related to the regional context. For example, Berrang-Ford et al. (2011) developed a literature review methodology and applied it to track adaptation action globally, offering some valuable insights on how adaptation is taking place in different geographical regions. Eisenack et al. (2012) review literature that explicitly considers adaptation to climate change in the transport sector, identifying 245 adaptation actions in 63 contributing sources over 5 years from 2005 to 2009. Koetse and Rietveld (2012) also reviewed the literature on climate change adaptation measures in the transport sector in different regions.

Altvater et al. (2011) proposed key adaptation measures for further assessment in the infrastructure and transport sector in Europe, although with no distinction between different regions, and estimated the total costs of the measures. Biesbroek et al. (2010) reviewed national adaptation strategies that were either formally adopted or under development by seven EU member states at the end of 2008. Transport was one of the various sectors addressed in the National Adaptation Strategies reviewed

([15]). The study noted that the role of national adaptation strategies in the wider governance of adaptation differed among countries, but in all cases a new political commitment to adaptation at the national level was emerging. The authors highlighted the significant barriers associated to the institutional framework, the multi-level governance structures and the on-going policy integration processes.

In the US, Schwartz (2010) included a list of some adaptation actions to climate change impacts on transport, with a view to incorporate climate change into the regular transport planning process. The NRC review (2011) focused on transport adaptation practices that had actually been implemented. Meyer et al. (2012) provided a review on how governments (at the national, regional and local levels) are approaching climate adaptation and how they are prepared to respond to extreme weather events.

Haire et al. (2010) compared the strategies undertaken in Canada and the US for adapting transport infrastructure to the consequences of climate change, and provided a summary table with key adaptation initiatives in both countries. The concluded that at the national level, the Canadian government had addressed adaptation on a variety of fronts, whereas the attention devoted to transport issues at the provincial and municipal level had been significantly lower. In the US, although the role of federal institutions in adaptation had been rather limited, the transport sector has been an exception, where these institutions had been more active and provided some leadership.

The National Transportation Policy Project (NTPP) and the National Commission on Energy Policy (NCEP) published a white paper in 2009 to identify the policy options available to support adaptation measures for transport in the US (NTPP, 2009). Taking a sample of 12 states, the document provided a summary of activities to illustrate those areas within the transport sector where states were beginning to take adaptation actions, and included a set of recommendations for short-term action and policy direction. Lindquist and Wendt (2012) prepared a synthesis and literature review of climate change adaptation and mitigation in transport, including information on strategies in some US states and local agencies; the concluded that adaptation strategies were providing recommendations to state and local transport agencies in a variety of fields, including planning procedures, design for pavement and bridges, asset management, and other transport system management activities ([16]).

Regmi and Hanaoka (2011) described a survey made on the state of climate change adaptation in the transport sector in Asia. They identified different policy guidelines which are needed to tackle climate change impacts on transport in Asia. The adaptation strategies and policy measures for the transport sector in Asia included realignment or relocation of sections, and review of design standards and planning procedures for road, rail and other transport infrastructure. These would be needed mainly to cope with future changes in temperature and precipitation patterns.

In Africa most of the resources and research on climate adaptation have focused on sectors other than transport (Berrang-Ford et al. 2011).

2.6 Potential changes in transport demand patterns

This section identifies some recent studies which assess potential long-term modifications in current transport demand patterns as a consequence of climate change. Two topics receive particular attention: changes in daily mobility behaviour and changes in travel flows associated to tourism.

Cochran (2009) highlighted the financial consequences of changes in transport demand flows for both, daily and occasional travel, as they would affect the use and profitability of infrastructures. Sumalee et al. (2011) have developed a multi-modal transport network assignment model including the uncertainties from both, the demand and supply sides. Their proposed stochastic model includes

([15]) http://www.pianc.org/downloads/climate%20change/Biesbrock%202010%20GEC%20Europe%20adapts%20to%20climate%20change.pdf.

([16]) Following a Federal mandate, the US DoT has now published a climate adaptation plan: http://www.dot.gov/sites/dot.dev/files/docs/DOT%20Adaptation%20Plan.pdf .

a representation of day-to-day demand variability and supply uncertainty due to adverse weather conditions and to random degradation of the capacity of the network. For road transport, Cools et al. (2010) focus on the impacts of weather events on the intensity of road traffic flows, and analyse whether weather conditions alter daily traffic intensity in Belgium. They concluded that traffic management strategies to minimize weather-related impacts on traffic operations must take into account local usage and the flexibility of drivers to respond to weather conditions. Datla and Sharma (2010) investigated highway traffic variations under severe winter weather conditions, taking a Canadian highway as a case study.

Concerning the impacts of weather extremes in travel behaviour and daily mobility, Taylor and Philp (2010) reviewed the implications of climate change impacts for transport systems, including changes in user behaviour in Australia. Clifton et al. (2011) included weather factors within a cluster analysis of daily mobility in Sydney (Australia). Saneinejad et al. (2012) explored the relationship between weather and home-based work trips within the City of Toronto, showing a significant impact of weather conditions on active modes (walking and cycling).

Dijst et al. (2013) highlighted that most studies on travel behaviour are located in northwest Europe, North America and Australia, and that they are mainly focused on the analysis of exposure to actual weather conditions instead of making use of future weather forecasts. Böcker et al. (2013a) have assessed the potential effects of climate change on modal choice and travelled distances, in the Randstad region (Netherlands), concluding that climate change would be particularly relevant for switches between active (walking and cycling) and motorized (private car and public transport) modes. Cools and Creemers (2013) assessed how weather forecasts could induce changes in travel behaviour in Flanders; they suggested that future research efforts should focus on the integration of weather changes into travel demand modelling frameworks. Following the same line, Böcker et al. (2013b) included a literature review of the studies which have centred on the impact of weather conditions on daily travel activities; their main conclusion is that existing studies present an incomplete picture of the impact of weather on travel behaviour.

Recent studies on the effects of extreme weather conditions on tourism travel include Dawson et al. (2010), Hübner and Gössling (2012), Nilsson and Gössling (2012), and Scott et al. (2012). Some studies have reviewed the existing literature concerning the impacts of climate change on tourist behaviour and demand; this is the case of Gössling et al. (2012) who reviewed existing studies on tourists' responses to climate change. They highlighted the increasing body of literature on the impacts of climate change on tourist behaviour and demand, making a distinction between short-term and long-term changes in travel behaviour. Kaján and Saarinen (2013) include a literature review of the tourism and adaptation studies prior to 2012.

Rossello (2011) analysed the links between climate and international air travel using a traditional international air travel demand model. The results were consistent with the view that meteorological and climate conditions can act as pull and push factors influencing tourists' decisions. The EUROCONTROL 20-year forecast of flight movements in Europe up to 2035 (EUROCONTROL, 2013b) is based on a model of economic and industry developments, and takes into account a number of factors influencing future demand patterns. The impact of the economic downturn is apparent, compared to the previous forecasts made in 2010, and it would result in lower traffic growth rates. Four prospective scenarios for air transport in Europe were considered, labelled as "global growth", "regulated growth", "happy localism" and "fragmenting world". In all of them, air traffic growth would not be uniform across Europe, and it would be concentrated in some regions compared to others. These scenarios have been taken up in the report 'Challenges of Growth' (EUROCONTROL, 2013a), which also provides several in-depth case studies, including the Mediterranean region, where it is concluded that a reduction in aviation demand could be induced by changes in climate and their impact on tourism flows.

2.7 Potential challenges to transport supply activities

This section reviews literature dealing with adaptation challenges from the transport supply side, including the design, construction, operation and maintenance of infrastructure, the technological

systems based on Information and Communication Technologies (ICT), and the actions of transport operators for adapting to climate change.

In the US, Venner and Zamurs (2012) provide an initial scanning of extreme events and their impacts on the activity of the state Departments of Transport. The study concluded with recommendations to DOTs' maintenance and operation managers to better cope with the challenges associated to extreme weather events. In the United Kingdom, the *Engineering the Future* (2011) report identified ways to ensure infrastructure resilience, covering the engineering aspect of adaptation, as well as the regulatory and social responses.

The research produced in the framework of the European ERANET-Road programme mainly deals with road drainage and adaptation management. Larsen and Pihl (2010) presented a systematic approach to preparing the road network for floods. Their methodology served to identify weak spots, and they proposed some guidelines for reducing the risk and impact of flooding at local sites. Hellman et al. (2010) developed a systematic approach to the identification and design of drainage systems in locations that are vulnerable to road flooding. Kalantari and Folkeson (2013) conducted a survey with professionals working in Sweden and tried to identify problems on road drainage associated to climate change, and to gather suggestions for adaptation measures; they described current practices in the field, and analysed the needs for revision of the current planning, construction, operation, maintenance and monitoring procedures for road drainage. Finally, the ROADEX "Implementing Accessibility" project (2009-2012) (Hudecz et al, 2012) provided a summary of the results of research in adaptation measures to cope with the effects of climate change on low volume roads in the Northern Periphery (Sweden, Norway, Finland, Iceland, Scotland, Ireland, Greenland, Alaska and Canada).

The potential effects of climate change on road pavement performance and design were analysed in Li et al. (2011). They developed a tool for integrating climate change effects within current mechanistic-empirical pavement design models. The World Road Association (PIARC) has produced a report with guidance on how to assess the vulnerability of road pavements to the direct impacts of climate change. The report also prioritised possible adaptation measures for road pavements, which could be either applied immediately or phased in over time. It also included the answers provided by 21 countries to a questionnaire prepared to assess the level of awareness in the road sector (PIARC, 2012).

The use of information and communication technologies (ICTs) for adapting the transport system to climate change seems to be a recent area of interest: only two documents have been found on this topic. The first one (Seitz et al, 2012) is based on the ECCONET research project ([17]) and focused on the contribution of ICTs to cope with the adaptation and modernisation needs of vessels used in inland waterborne transport. The second one refers to the use of route information under severe weather conditions (Ho et al, 2012); it aimed at improving road network reliability under heavy precipitation through the use of advanced route information, taking as a case study the road network of Jiaxian in Taiwan.

Only a few sources have been found on adaptation of transport operators to climate change, and they refer to infrastructure managers, not to transport service operators. Some interesting results are obtained by Ryghaug and Solli (2012). They investigated the understanding and approach of Norwegian road managers towards climate change issues. They reviewed the strategies prepared with respect to road infrastructure across Norway, how road managers perceived the reliability of scientific results and what they perceived as relevant for their planning and strategy developments. The research was based on interviews to road managers at the national, regional and local levels. The interviews revealed that a road sector's response to climate change is only starting now to emerge, and that road managers keep expecting that central authorities will set the path by updating existing handbooks and regulations. In the United Kingdom, the PWC report (2010) provided recommendations to the different stakeholders for adaptation of transport (and other) infrastructure.

[17] http://www.tmleuven.be/project/ecconet/home.htm

2.8 Future research prospects on transport adaptation

Adaptation to climate change in the transport sector is receiving increasing attention from researchers since the end of the last decade. Research activities are mobilizing both, transport and climate change specialists, although the level of interaction among them seems still to be reduced. Early research efforts have focused on gathering information from practitioners, identifying case studies and good practices, and developing recommendations to key institutional stakeholders. These activities have been followed by research efforts focusing on particular aspects within the transport system, such as changes in daily and occasional passenger mobility patterns and the spatial impacts of climate change (including, but not limited to transport as a key component of regional socio-economic systems). Another promising area for researchers is the revision of current maintenance and management practices, with a focus on transport infrastructure. Comparatively, transport operations are not receiving a similar level of attention, although some research activities have been identified in inland waterborne, urban and air transport.

Cooperation between transport researchers and climate and weather specialists has been growing as a key component of research projects, particularly at the EU level. This cooperation is vital for transport researchers aiming at integrating climate change uncertainties within the variety of transport models they use for planning and management purposes, particularly for urban and metropolitan networks.

Although climate-related research publications have been identified in all transport modes, a comparatively higher level of activity has been found in the urban, road, and air transport areas, compared to rail and waterborne transport. In this latter mode, inland waterways seem to have received much more attention than sea transport, at least in Europe.

3 Recent developments at the international and EU level

3.1 The EU strategy on adaptation to climate change

In 2009, the European Commission issued the White Paper "Adapting to climate change: Towards a European framework for action" (COM(2009) 147 final). The main policy objectives stated in this document were to have a more resilient Europe at national, regional and local level and to facilitate the exchange of good practices and co-ordination. The objective was also to strengthen the knowledge base on climate change impacts, vulnerability and adaptation and to mainstream adaptation into policies, strategies and programmes at EU level (and develop dedicated adaptation action where needed). The EU aimed at an integrated approach with mainstreaming adaptation in EU sectoral policies together with activities building adaptive capacity and implementing actions. The White Paper announced the preparation of an adaptation strategy, which should go hand-in-hand with the development of national adaptation strategies and actions.

Following this announcement, the European Commission issued its proposal for an EU Adaptation Strategy in April 2013. One of the rationales of this strategy is that "by prioritising coherent, flexible and participatory approaches, it is cheaper to take early, planned adaptation action than to pay the price of not adapting". The strategy contends that, although adaptation measures need to be taken from local to regional and national levels, "there is also a role for the European Union to fill both, knowledge and action gaps".

The strategy acknowledges that uncertainty "remains a challenge for policy making in this area", but contends that "uncertainty cannot be seen as a reason for inaction". On the contrary, uncertainty "calls for a strong emphasis in incorporating win-win, low-cost and no-regret adaptation actions".

Concerning the transport sector, the strategy considers that "adaptation has already been mainstreamed in legislation in such sectors as... transport", and that a legislative proposal has already been produced for integrating adaptation in the transport sector (COM(2011) 650/2 final). It also stresses the importance "to analyse to what extent standards, technical specifications, codes and safety provisions for physical infrastructure should be strengthened". This would be addressed through a mandate for European standardisation organisations to start "identifying standards to be revised for better inclusion of adaptation considerations" (action 7: ensuring more resilient infrastructure).

The EU adaptation strategy is accompanied by an impact assessment and several staff working documents, including one on Adapting infrastructure to climate change (SWD(2013)137). The document elaborates on the conclusions of the WEATHER and EWENT projects, as well as a report of the Joint Research Centre (JRC), prepared in the framework of the PESETA II project. It highlights that "the consequences of climate change are both negative and positive for transport infrastructure such as for rail, road, shipping and aviation, but will differ from region to region". The document points out that "Environmental Impact Assessment (EIA) and the Strategic Environmental Assessment (SEA) can be appropriate instruments to mainstream adaptation, helping to improve the climate resilience of infrastructure". Guidance to include climate change adaptation into EIA and SEA has been developed by the European Commission to support its Member States ([18]).

The 2009 White Paper "Adapting to climate change" and the 2013 EU Adaptation Strategy have shown that exchange of knowledge and good practices is of high importance in this relatively new policy area. An overview of the different country activities would enable EEA Member States to learn from each other and reveal gaps where further supportive action from a national or European

([18]) Available for EIA at http://ec.europa.eu/environment/eia/pdf/EIA%20Guidance.pdf and for SEA at http://ec.europa.eu/environment/eia/pdf/SEA%20Guidance.pdf.

level may be needed. Transport is also a cross-border challenge and each Member State could benefit from an overview that provides relevant information on their neighbours' approach.

3.2 Other international initiatives

3.2.1 OECD/ITF

The Joint Transport Research Centre of the International Transport Forum and the OECD has set up a task force on this topic, and a report is expected by the end of 2013. The OECD Working Party on Climate, Investment and Development is also working on climate change adaptation (comparing tools for cost-benefit analysis and on monitoring and evaluation looking at various OECD and developing countries). An OECD paper on "National Adaptation Planning: Lessons from OECD Countries" is in preparation.

3.2.2 UNECE

United Nations Economic Commission for Europe (UNECE) and United Nations Conference on Trade and Development (UNCTAD) organised a joint Workshop on “Climate Change Impacts on International Transport Networks” in September 2010 to raise awareness about the important challenges that climate change impacts and adaptation requirements present for international transport networks. Subsequently, UNECE established in 2011 a Group of Experts on climate change impacts and adaptation for international transport networks. To further explore complex interrelation between climate change and transport infrastructures, UNECE organised an international conference on Adaptation of Transport Networks to Climate Change in 2012, hosted by the Greek Government. In order to carry out an in depth study, the Group of Expert distributed a questionnaire to UNECE member countries, which was answered by 26 governments and 7 international transport stakeholders. The report was finalised by the expert group in August 2013, and will be submitted to the UNECE Inland Transport Committee. The draft report states that two thirds of the respondents to the questionnaire view climate change as a serious challenge and 80 % as a challenge for the next 30 years. There would be a need for a primarily "top-down" approach, with stronger cooperation among governments and among the various governance layers. Amendments to existing international agreements could play a role to promote and facilitate adaptation. Further research and study on climate change risks and impacts, and effective warning and adaptation measures were considered as highly necessary at this stage.

3.3 International stakeholders in the transport sector

The main stakeholders within the rail sector have been the International Union of Railways (UIC), with the ARISCC project, conducted between 2010 and 2012) and the Community of European Railways (CER), through a number of workshops, which have supported the preparation of a position paper focusing on the issue of standardisation. In both cases, the focus remains on improving the resilience of the sector in the long-term while keeping the current central role of rail in the European transport policy.

The more relevant contributions from the road sector are due to the CEDR (European Council of Road Directors) and to the ERANET-Road programme, closely related to CEDR. CEDR established a working group on climate change and conducted a survey among European road administrations and ERANET-Road funded in 2008-2010 four research projects on this topic, under the programme "Road Owners Getting to Grips with Climate Change", dealing with winter maintenance, impacts on road pavements, risk assessment and flooding. As a result, it seems that the road sector puts a lot of attention on the improvement of their maintenance practices.

Within the air transport and aeronautics sector, EUROCONTROL first addressed the challenges of climate change in its 2008 "Challenges of Growth" report (EUROCONTROL, 2008). The commentaries to the report, published in June 2011 (EUROCONTROL, 2011), highlighted the significant implications that climate changes could have on both mobility and the global economy. This fresh vision underlined the fact that climate change could significantly impact on current transport demand patterns for passengers and freight. Other risks that are also analysed by

EUROCONTROL are the eventual loss of some airports or runways, due to sea-level rise (there could be up to 30 airports under threat) and disturbances in the most congested air corridors due to severe weather events. These topics have been further developed in the recently issued "Challenges of Growth" 2013 report (EUROCONTROL, 2013a). The preparation of this report included a stakeholder consultation to determine whether the industry now considers that measures to increase climate resilience are required and what actions they are taking. The answers indicated a heightened level of awareness compared to the 2008 review. It calls upon the sector to build resilience into the current infrastructure and operations planning, considering that "early action is the key to building resilience at the lowest cost". Many of the questions highlighted by the 2013 report are already addressed within the SESAR project, in particular the eventual loss of capacity (runways) and an increase in disturbances due to severe weather events (Jeandel et al, 2012). However, the strategic research agenda and the roadmap of the European Technological Platform for air transport and aeronautics (ACARE) does not include climate change adaptation as a significant challenge for this transport mode.

For waterborne transport, developments have been quite diverse in maritime transport and inland waterways. The European Technology Platform for this mode (Waterborne TP) has identified climate change adaptation as one on the key challenges, but neither its strategic research agenda (WSRA) ([19]) nor its long-term vision and roadmap document (Vision 2025) ([20]) includes much detail on this topic. The inland waterways sector has made more tangible progress in the context of the action programme NAIADES ([21]), focusing on the adaptation of the fleet to variable water levels, due to climate change. This approach is similar to the one proposed by the research project ECCONET.

The impact of climate change on sea level rise and its consequences on ports have been analysed in different fora, including the United Nations Conference on Trade and Development (UNCTAD) and the International Association of Ports and Harbours (IAPH). Apparently, the European Association of Ports (ESPO) has not undertaken any action in this area yet. IAPH distributed a questionnaire on adaptation to port members in 2011. The answers show that sea level rise is the main concern for many ports, followed by extreme storms. 38% of the ports expect a 0.5 m- 1.0 m sea level rise in the future, and 15%, more than 1.0 m. For 39% of the ports, any rise above 0.5 m could raise problems. Few member ports of IAPH have undertaken physical actions for adapting to climate change, and it is felt that efforts should be developed first in gathering further information and best practices. Another field of interest for the sector is the impact on world traffic routes of the opening of the Northern Sea Route due to global warming. The UNCTAD expert group stated that "although the effects of climate change at a global level are increasingly well known, the limited availability of data at the local and regional level implies that the design of relevant and appropriate response measures needs to take into account high levels of uncertainty".

3.4 Some key lessons emerging from international activities

This review suggests that most of the transport modes in Europe have already paid some attention to the impact of climate change and to the need for an adaptation strategy. A relevant exception seems to be the maritime port community, although they are taking some initial actions at the global level. There are many similarities in the approach, assessment and proposals among the various transport modes:

([19]) At the Waterborne Strategic Research Agenda (Waterborne TP, 2011, p.25), it is mentioned, under the "Technologies for New and Extended Marine Operations" section that "research has begun into concepts for global scale offshore environmental engineering to combat climate change".

([20]) Although the exact impact of climate change is unclear, it is apparent that we can expect more extreme weather events, which will lead to a change in the operational envelopes of vessels and offshore structures. New technologies, modelling and validation methods will be required to determine an appropriate engineering and operational response. Current design codes and Classification Rules will need to be changed accordingly". (Waterborne TP, 2012, p.7).

[21] European Commission (2012). Towards "NAIADES II": Promoting, greening and integrating inland waterway transport in the single EU transport area. Commission Staff Working Document. SWD(2012) 168 final.

- National stakeholders have been surveyed in the context of the ARISCC (rail), CEDR (road) IAPH (maritime), and EUROCONTROL (air) activities.
- The key impacts identified refer to increasing extreme weather events (droughts and floods, heat waves, rain, winds), and to major changes in key weather patterns (mainly wetter winters and warmer summers in Northern Europe).
- There is consensus on the high current uncertainties associated to the expected impacts of climate change on weather conditions, and the need for further research on meteorological forecast modelling, with a focus on developing accurate forecasts at a local level. Weather forecast models (and services) should be better tailored to the transport system's needs. These research developments should provide for a more solid basis for revising the key extreme weather assumptions underlying transport infrastructure design and maintenance practices.
- More detailed databases on extreme weather events and their impacts on transport infrastructure and transport services would also be of great value for transport practitioners. However, this does not necessarily mean that any action should wait until better data and models are developed, so that current uncertainties are significantly reduced.
- Due to the existing high uncertainties, most research projects are recommending to move forward by improving the networks for exchanging expertise and best practices: this would allow for taking stock of the current variety of weather conditions throughout Europe, and the extensive knowledge on transport operations under very different (and sometimes extreme) climate contexts in Europe. As a follow-up to these efforts, it seems reasonable to increase monitoring and data collection efforts and to develop approaches and models better adapted to cope with transport policy needs. Whilst to some extent the challenges will be different for different modes, from a network perspective it is also essential to develop a co-ordinated approach. Moreover, although some of the specific challenges may be different, the general challenges (e.g. ensuring mobility in disruptive conditions) are the same, and the barriers to adaptation are also the same; therefore, there is surely benefit to be gained from a more co-ordinated approach.
- FP7 research projects have also showed the limitations of current assessment and decision making practices in transport to deal with an environment of increasing uncertainty. Conventional cost-benefit analysis (like in the WEATHER and ECCONET projects) and risk management (like in the EWENT project) have difficulties in providing decision makers with an accurate description of the uncertainties linked to their methodological approaches. Resilience indicators could help to tackle operational uncertainties by facilitating proactive and event-appropriate operational responses. This may be mode-specific or cross-modal and would serve to quantify the base level of network resilience and the corresponding impact of a disruptive event in order to facilitate the development of mitigation actions. They would also facilitate more proactive reactions to disruptive weather by identifying an event-specific performance goal which is aligned with mode or network capacity management and safety requirements.
- Maintenance operations, together with infrastructure and traffic management seem to be the privileged area for action in the near future, as these would immediately increase the capacity for incrementally adapting the transport system to more stringent, but difficult to forecast, weather conditions. Accordingly, all existing studies recommend improving information and monitoring systems on actual infrastructure and traffic conditions.

4 Practices in EEA member countries

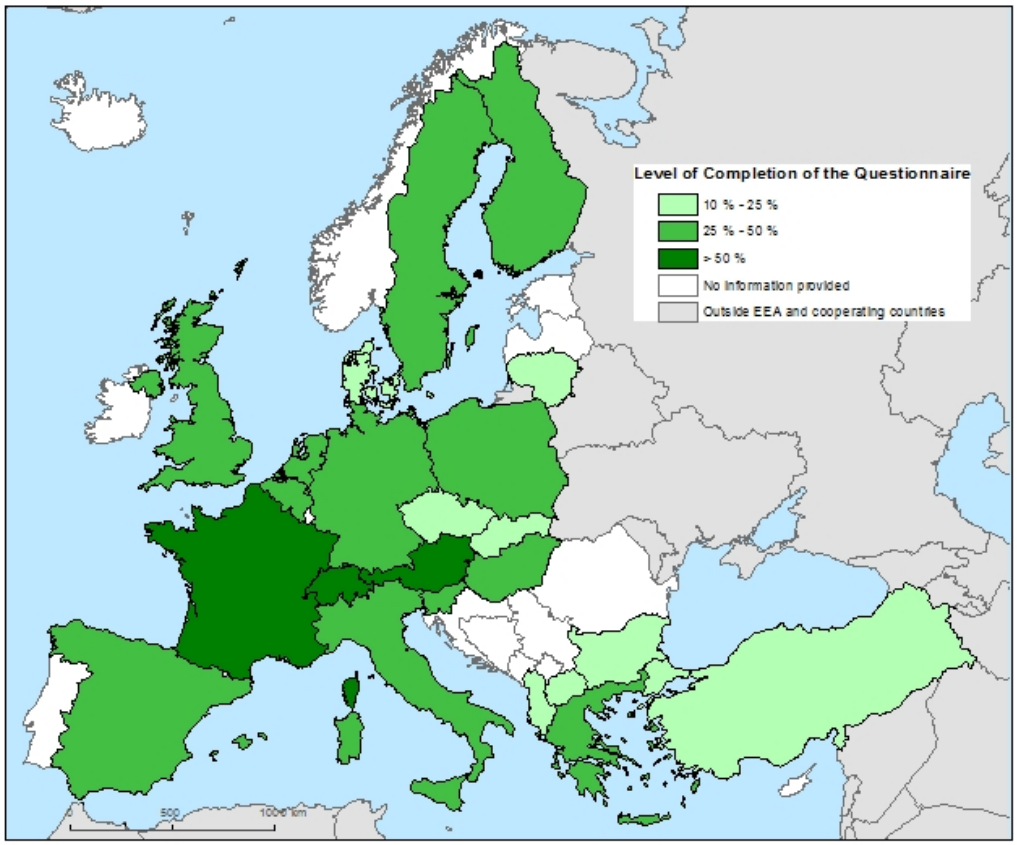
4.1 The questionnaire

Information from EEA members and cooperating countries was collected with the aid of the questionnaire included in Annex 5. The questionnaire was addressed to the EIONET National Reference Centres (NRC) for transport, was distributed on March 8th, 2013 and was closed on April 17th, 2013. A second period for submission was opened between May and June. It was circulated among the National Reference Centres (NRC) on transport, who were asked to coordinate the response in the event that more national stakeholders need to be consulted; the NRCs for climate change impacts and adaptation and the National Focal Points (NFP) were also informed about this activity and encouraged to provide support, as needed.

The questionnaire aimed at gathering a comprehensive overview of the state of transport adaptation actions and climate change in EEA countries and at identifying recent experiences in this area, as conducted by governments (at the national and subnational level) and by infrastructure managers (including all transport modes, public organisations and agencies, as well as organisations managing infrastructure under public private partnership schemes). The questionnaire was initially answered by respondents from 19 countries, and respondents from four additional countries provided information when the questionnaire was reopened in June 2013 (map 4.1). It is worth noticing that the information provided largely relies on the respondents' perspective and background, as adaptation actions in the transport sector within one particular country are typically sprawled among many different actors, and a comprehensive view is not easy to achieve.

The questionnaire also encouraged countries to indicate what type of (other) outcomes would be most relevant for them, so that this task could be developed, and its results could be presented in a more beneficial way. It was structured in 5 complementary blocks:

- Block A referred to the relevant national strategies, plans and actions on adaptation to climate change at the national level, and asked for information on whether and how the transport sector is included in these. It also asked for the influence that adaptation may be having in the preparation or revision of emergency protocols. There was also a request for identifying transport-related plans, programmes and initiatives, which could have considered adaptation to climate change as a relevant issue.
- The information base was the main topic of attention under block B. This information base included specific studies, national programmes funding research projects on adaptation and extreme events, which relevance was given to transport , and how the information gathered and the knowledge produced were made available to stakeholders and the public, through national adaptation platforms, following the European "Climate-ADAPT" model.
- Block C asked for information on the governance and institutional arrangements for adapting the transport sector to climate changes and extreme weather events. It aimed at identifying the leading players and the role of the different stakeholders in the sector as a whole and in the various transport modes.
- Under Block D, NRCs were asked to assess the relevance of 9 different barriers to adaptation in the transport sector. This was coupled with a request for assessing how efficient they considered that 11 different initiatives at the EU level could be, for supporting adaptation initiatives in their countries. The questionnaire also allowed for suggesting further barriers and initiatives, outside the initial lists.
- Block E was an open question for NRCs to suggest how the EEA could better address this exploratory task for analysing the state of the art of transport adaptation to climate change at the national level and to identify potential follow-up initiatives.



Map 4.1 — *Level of completion of the questionnaire* ([22])

It is worth noting that a wide majority of the EEA member countries and cooperating countries provided answers to the questionnaire. However, none of the countries provided answers to all of the questions. This can be considered as an indication that adaptation in the transport sector is still gaining momentum, and that the questionnaire was probably going too far in its request for details, compared to the still limited experience and practice available at the national and subnational level.

The information was completed, wherever this was possible, with additional data from the Climate-ADAPT platform and from the adaptation websites provided by the countries. However, in many countries, adaptation in the transport sector is happening spontaneously, through a predominantly bottom-up approach including many actions taken by local and regional governments and stakeholders, so that it is not possible to get a comprehensive overview of the situation. The analysis made in this section has to be taken cautiously, as a first approach to an extremely dynamic and complex situation.

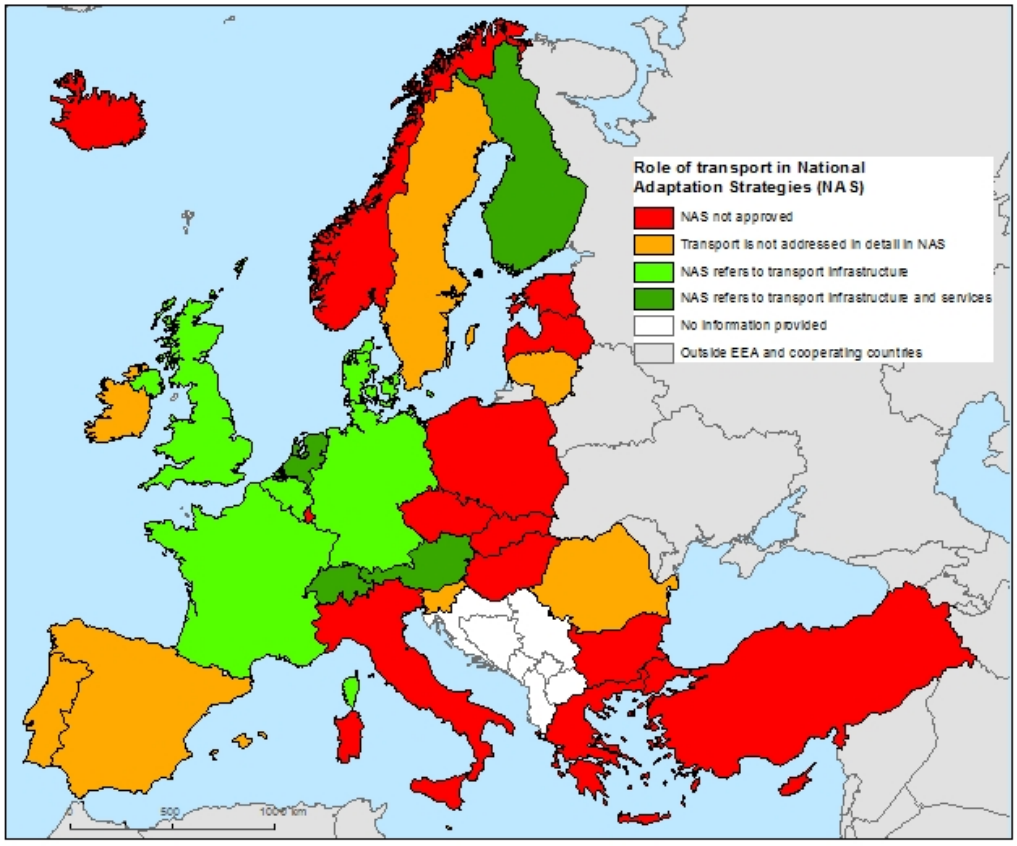
4.2 Question A: Relevant actions at the national level

A review of available information at the European Climate Adaptation Platform (Climate-ADAPT) ([23]) shows that sixteen EEA member countries have developed a national adaptation strategy. Nine additional countries are currently developing such strategies. The transport sector is specifically addressed in many of those strategies (including Austria, Denmark, Finland, France, Germany,

([22]) Answers stating that there is no information available are included in the percentages. If deducted, the percentage of answers of some countries would be reduced, most notably for Turkey (from 64.0% to 31.5%) and the Czech Republic (from 59.0% to 36.5%). For other countries, like Germany, the answers did not include some relevant available information, e.g. at the subnational level, due to lack of time or difficulty in accessing it.

([23]) http://climate-adapt.eea.europa.eu/web/guest/countries.

Ireland, Lithuania and United Kingdom), and with less detail in five additional cases (Malta, Netherlands, Romania, Spain and Switzerland) (Figure 2). Six countries (Austria, Denmark, Finland, France, Germany and Spain) have also developed more detailed adaptation plans, and three others are developing such plans, although the contents and degree of detail of these plans are very different, particularly between those plans approved some years ago (around 2006) and the most recent ones. With the exception of Spain, the plans in the other five countries cover both, transport infrastructures and services. An overview of adaptation strategies of EEA member countries is available at Climate-ADAPT ([24]).



Map 4.2 — *Role of transport in national adaptation strategies (NAS)*

Sources: questionnaire to EEA member and cooperating countries; Climate ADAPT

In the questionnaire, countries were encouraged to complement the initial information already provided to Climate-ADAPT with a listing of other relevant actions, providing links to background documentation and contacts. The answers to the questionnaire show that transport is not generally a central topic within national actions for climate change adaptation, with the exception of a few countries (most notably United Kingdom and, to a lesser extent, Austria, Switzerland or Germany).

Fifteen countries have provided information on the transport contents of their national adaptation strategies (Question A.1). Other countries (such as Hungary and Slovenia) report that their national transport plans include considerations on adaptation to changes in climate and extreme events. Whereas transport infrastructure is generally included in the national adaptation strategies, transport services are considered only by a few countries (Austria, Finland, Netherlands and Switzerland, Map 4.2). Rail, road and urban transport modes are generally considered in national adaptation strategies, as well as inland waterborne transport in those countries for which this mode is relevant. Aviation is also considered in many cases, whereas maritime transport is mentioned only in four cases (Denmark, Finland, Germany and United Kingdom). Although climate change impacts are

([24])http://climate-adapt.eea.europa.eu/en/adaptation-strategies.

addressed, they are linked to the specific conditions of each country. At any rate, there is a strong convergence in most of them: storms, flooding, droughts, ice, snow, and (changes in) temperatures (heat); sea level rise is mentioned by those countries concerned with maritime transport.

The United Kingdom was the first EEA member country where a detailed legal framework was established, including adaptation strategies and programmes: the Climate Change Act (2008), which also includes provisions for their periodic revision. Switzerland has recently updated its CO2 Act (which came into force in May 2000 and originally addressed mitigation), in order to provide also a legal basis for adaptation; this revision came into force on1 January, 2013.

Three of the countries reporting on national adaptation action plans (Question A.2) are addressing both, transport infrastructure and services (Austria, Denmark, Germany), whereas two of them (Finland and France) are covering only infrastructure and two of them (Spain and United Kingdom) provide no details. Only Denmark reported that maritime transport is considered within its national adaptation action plan. Further details on the transport contents within the French adaptation action plan are provided in Annex 4.

In most cases, these plans are within the responsibility of national environmental authorities (Ministries of Environment). In Switzerland and in the United Kingdom, the responsibilities are similarly distributed: the sectoral ministries (Departments in the UK and Federal Offices in Switzerland) are responsible for adaption in their respective sectors, and they develop sectoral sub-strategies and adaptation measures, whereas the ministries in charge of the environment (DEFRA in the UK, FOEN in Switzerland) have the overall responsibility for developing the national adaptation strategies and action plan.

Five countries report on the existence or preparation of adaptation plans at the subnational level (Question A.3). This is the case for the Belgian regions, for the Autonomous Communities in Spain and for some Swiss cantons (such as Bern and Uri). France approved regional frameworks in 2012, and the local plans are now being prepared. The United Kingdom has focused on the development of action plans at the local level, with different mechanisms providing national support to local governments. These efforts, including the development of Departmental Adaptation Plans by each relevant department within the Central Government, have led to the publication of a National Adaptation Programme in July 2013. Danish local governments have agreed to produce local adaptation plans (not sector-specific) by the end of 2013. Multiple local governments in the Netherlands have already local adaptation plans, but transport is not much of an issue, as those plans usually focus on flood risks and water management. In Finland, a local adaptation strategy was approved for the region of Helsinki in 2012. In accordance with the information in the Climate-ADAPT platform, adaptation plans at the subnational level are also widely extended in Germany: three quarters of the 16 Federal States have presented adaptation strategies and measures, and the number of adaptation strategies at the local level is steadily increasing, supported by different funding programmes, guidelines, the transfer of good examples and exchange of experience.

In general, climate change adaptation is not yet mainstreamed within transport planning and decision-making practices (question A.4). The role of transport authorities in the preparation of adaptation strategies seems to be only relevant in three cases: the Danish (2010) and Finnish (2009) ministries of Transport and the British Department for Transport (2012) have developed their own departmental climate change strategies or programmes.

Only a few experiences are reported on climate change adaptation initiatives for specific transport modes. In Finland there are specific plans covering road infrastructure (2007), rail infrastructure and services (2008) and maritime transport (2009); the Flemish government in Belgium has produced a master plan for inland waterways, and the city of London has developed various documents on urban transport infrastructure. In the United Kingdom, 31 reports have been published by different transport infrastructure organisations (mainly local governments) related to their areas of competence (Questions A.5 and A.6). In Germany, the national adaptation plan includes some specific measures for the transport sector, such as the revision of technical standards in the rail sector, the revision of guidelines on the hazards of forest fires on infrastructure, and the development of scenarios in order to consider adaptation within the environmental impact assessment process.

Four countries report on the preparation of risk management plans including the transport sector. In Austria, this is mainly under the responsibility of the Ministry of Environment or the meteorological services; in Spain, under the responsibility of the Civil Protection Services, and in Switzerland, under the responsibility of the federal road administration (ASTRA/OFROU); in Switzerland a comprehensive study for all transport modes, covering risks and opportunities linked to climate changes, is currently under development. In France, risk management plans for coastal disasters, including rail and road infrastructure and services, are operational since 1995; flash flood management plans have been prepared in 2011, but they do not include the transport sector. (Question A.7).

No relevant initiatives are reported for a systematic revision of the design and operational guidelines and standards for transport infrastructure at the national level. However, some concrete actions could be seen as an initial effort in this direction: for example, the United Kingdom reports some studies for roads, including the document *Maintaining Pavements in a Changing Climate*, published in 2008 by the Department for Transport; in Switzerland, the project to deepen the Rhine waterway between Basel and Birsfelden, in order to enhance reliability of inland navigation during low water conditions, could also be seen as an adaptive action. There are no transport-specific emergency protocols in any countries. France has set different technical groups for identifying the adaptation needs of transport systems, covering infrastructures and services for all modes since 2011 (Questions A.8 and A.9).

Only a reduced number of transport stakeholders seem to be conducting studies on adaptation and extreme events within their respective areas of competence: Railway operators in Austria and Switzerland are addressing changing natural hazard situations. They monitor natural hazards and are aware of changes in intensity and frequency. Further details of the Austrian experience are provided in Annex 2. An assessment of the vulnerability of airports to climate change is under development in France, covering infrastructure and operations. In Italy, one motorway concessionaire is developing a study on flooding-related risks and revising the design criteria for crossing of watercourses. In Germany, the impacts of extreme events on inland waterways and coastal areas have been studied in the context of the KLIWAS project ([25]). These detailed observations and registrations of natural events seem to be a promising way to detect changing trends as early as possible. (Question A.10).

In Austria, national research efforts in this field aim at establishing economic assessment tools for prioritisation of adaptation measures (Adapt2to4), assessing the cost of inaction (COIN) and integrating adaptation goals within the early phase of projects mandatory for Environmental Impact Assessment (EnvisageCC), taking into account the impacts related to a changing climate and the adaptation options available.

Following its National Adaptation Plan, the technical services of the French government are assessing the existing standards for design and maintenance in order to check the current vulnerability of the transport system (Question A.11).

One key issue, as stated in the answers from the French NRC, is to establish adequate climate reference thresholds for the assessment of the vulnerability of existing design standards, including the necessary coherence across transport modes (Question A.12).

([25]) German acronym for the project full title: "Climate change and consequences for water management".

The picture that emerges from this part of the questionnaire is that climate change adaptation is gaining momentum in national policy agendas, and that local (and eventually regional) authorities are called to play a central role. Notwithstanding the initiatives in some countries (including Austria, Germany, Switzerland and the United Kingdom, among others), the transport sector does not seem to be generally identified as a critical one in these initial adaptation efforts. Furthermore, transport planning and decision making seem not to mainstream either climate change adaptation or risk management within their current practices. The experiences in Austria and Switzerland for road and rail could be highlighted as an exception to this: the higher degree of awareness in these two transport modes could be associated to decades of experience in dealing with natural hazards and extreme events in mountainous areas, where risk management is a key issue for safeguarding human systems.

As climate change may increase frequency and intensity of some natural hazards, the impacts are likely to have a local character, and national and local governments seem to be better suited to identify, monitor and lead the adaptation process. However, there is a strong need for developing adequate guidelines, methodologies and procedures for dealing with information collection, action development, knowledge sharing, good practice exchange and decision making; in this dimension, a European-driven effort, including stronger cooperation among governments, will be necessary.

4.3 Question B: The information and knowledge base at the national level

Adaptation of transport systems to climate change and extreme weather events remains an area with few, although increasing, initiatives at the national and subnational levels for improving information and expanding the knowledge base.

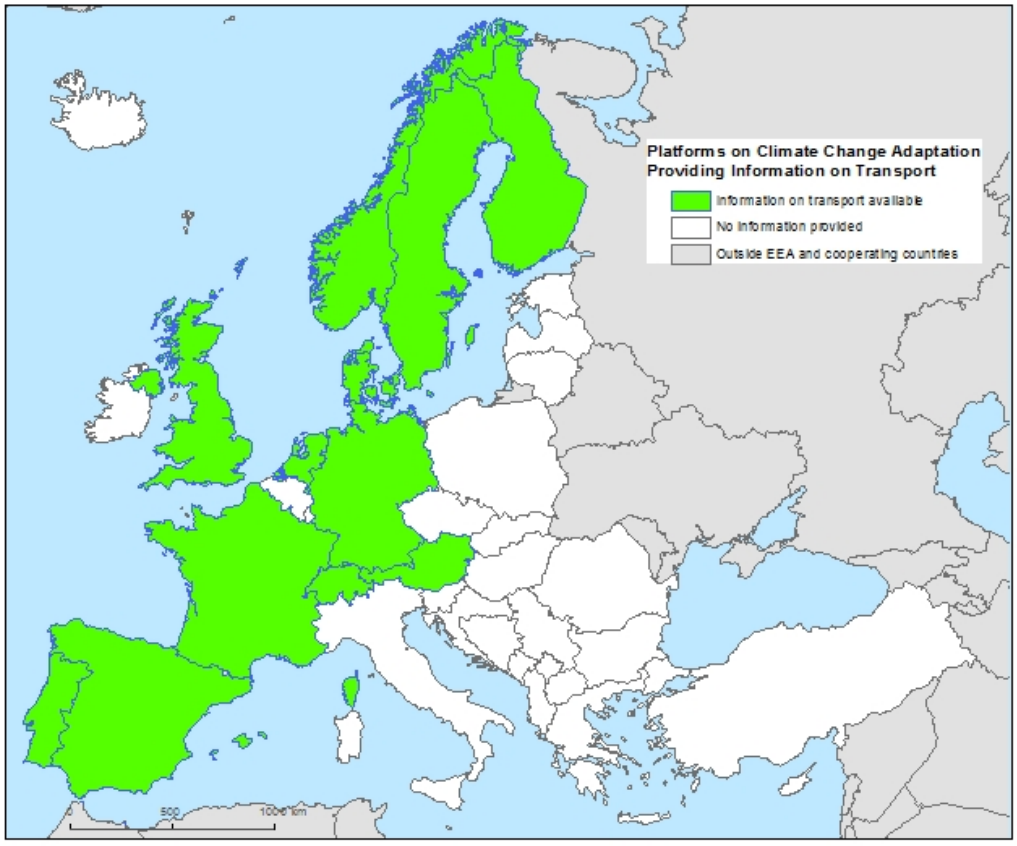
Eleven countries have reported some recent (since 2008) assessments or studies on vulnerability, resilience or adaptation of transport to climate change. These studies have been mainly done by national research institutes or universities or by environment agencies. Both, transport infrastructures and services, are addressed in most of those studies. Whereas most of the studies addressed various transport modes, there are a few focusing on one single transport mode – in Austria (rail), Denmark (maritime), France (airports), Spain (maritime), Switzerland (roads) – or focusing on one particular impact: France (rail and road infrastructure costs due to sea level rise and increased temperatures), Spain (sea level rise, flooding), United Kingdom (ice, snow) (Question B.1). Annex 3 provides further details of the study made by the Spanish government to analyse the climate change adaptation needs for the trunk transport network.

Studies on extreme weather events and their impact on transport are scarcer. Only a few countries are reporting a significant activity: Austria, Bulgaria and the Czech Republic for rail and partly for road; Bulgaria and the Czech Republic also for floods; Greece and Slovakia for general exploratory studies addressing all transport modes and a variety of impacts (Question B.2). In Germany, the impact of extreme weather events on waterborne transport has been addressed within the KLIWAS project.

The Alpine region is particularly well developed in terms of climate change studies with a spatial planning perspective, facilitated by the international cooperation framework for the protection of the Alps. This includes the CIPRA document *Transport in Climate Change Report* in 2010 and the research project Paramount (2007-2013), financed by the European Regional Development Fund.

Five countries are reporting research programmes relevant for adaptation of transport to climate change and extreme weather events. This does not mean that other countries are not developing research activities in this field, but rather than these are probably conducted in the framework of general research programmes, and these activities may be more difficult to identify. The Austrian Climate Research Programme addresses all transport modes and impacts since 2008 in its yearly national call. The Dutch climate change research programme has included a project theme on infrastructure. The French research programme "Gestion des impacts du changement climatique" has been in place since 1999. Germany reports on two wide projects: The first one focuses on inland waterways (KLIWAS); the second one, conducted by the Chameleon Research Group, develops

adaptation measures for companies providing public utility services in the energy and transport sector ([26]). The United Kingdom includes one programme (TRaCCA) financed by the rail industry, and Annex 1 provides further details about British research on adaptation for road and rail transport. (Question B.3). More information would be needed to assess the relevance of adaptation in the transport sector as a research topic within national research programmes; the information provided suggests that some exploratory research has already been conducted, and that it seems likely that research activities will increase in the future. It would be interesting to gain a more comprehensive picture of the research effort in EEA member countries.



Map 4.3 — *Platforms on climate change adaptation providing information on transport*

Sources: questionnaire to EEA member and cooperating countries; Climate ADAPT

The development of information and data sharing platforms at the national level (similar to the EEA's Climate-ADAPT) is making quick progress: Austria, Denmark, Finland, France, Germany, the Netherlands, Norway, Sweden, Switzerland and the United Kingdom have set up such national platforms; Portugal and Spain provide information on adaptation to climate change (including some material about transport) in the webpages of their respective Ministries of Environment, and other countries such as Poland are expected to open their webpages on adaptation soon. Sweden has set up a climate change platform providing information- mainly on its National Adaptation Plan- to all the agents interested in the subject. Platforms in Austria and the Netherlands cover transport infrastructures and services for most modes and impacts, whereas in the United Kingdom a variety of platforms have been developed, each one serving specific purposes and focusing on infrastructure (Map 4.3). Furthermore, only Austria, Switzerland and the United Kingdom report to be collecting data systematically (Questions B.4 and B.5). In the case of Switzerland, cantons must prepare and

([26]) http://www.klima-chamaeleon.de/index.html. The project is running from October 2009 to October 2013.

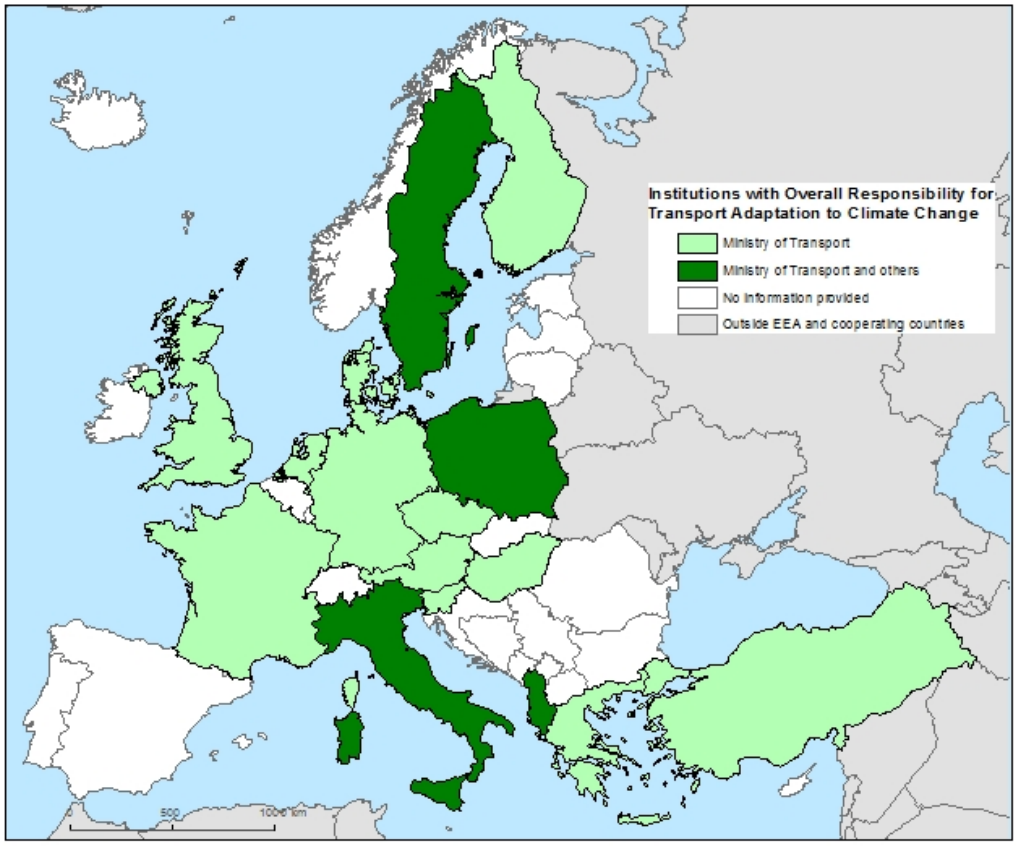
update hazard maps, including transport infrastructure, and a common risk analysis methodology has been produced for national roads.

This still limited effort in data and information collection and in expanding the knowledge base is probably closely related to the low priority that many national (and subnational) governments and stakeholders still pay towards adaptation of the transport system to climate change and extreme weather events. Furthermore, this represents a significant barrier for any sound, fact-based progress in this topic, which needs expanding information systems and related long-term monitoring on extreme weather events and their impacts on transport. A stronger empirical basis remains critical for developing more accurate and affordable adaptation strategies for the transport system.

4.4 Question C: Governance and institutional issues

Not surprisingly, the ministry of transport is identified as the main institution responsible for climate change adaptation of the transport system by all the responding countries, complemented eventually by other public agencies. Only in the case of urban transport, municipalities become the more important stakeholder (in five countries), compared to the ministry of transport (cited by three countries) and to other national agencies (cited by four countries). (Map 4.4, question C.1).

The answers reflect that competencies are clearly identified, and that climate change adaptation is not encouraging a revision of existing governance practices in most countries. However, this conclusion could be premature, as the questionnaire did not include a request for a detailed description of the responsibilities and roles of the ministry of transport and other agencies. This is particularly the case for urban transport, where new schemes of cooperation could be needed in future, in order to find an appropriate framework encouraging local responsibility and leadership and providing adequate support from the national level.



Map 4.4 — *Institutions with overall responsibility for transport adaptation to climate change*

Source: questionnaire to EEA member and cooperating countries

The road sector seems to present a simpler structure of responsibilities, compared to other transport modes. The ministries of transport and the road agencies are mentioned as the key stakeholders by 11 out of 12 countries. In fact, in many countries regional and local authorities are owners and managers of significant parts of the road network, and their potential role for developing adequate responses to climate change also in these parts of the network should be taken into consideration. In fact this situation is highlighted only in the answers received from Austria, but is probably relevant for many other countries.

The situation is more diversified for the rail sector, as the distribution of responsibilities among ministries of transport, rail infrastructure agencies and rail operators is different from country to country. For air and maritime transport, and for inland waterways, the responsibilities are also shared among the ministry of transport and different agencies, in accordance with the governance model in each country. Only a few additional stakeholders are mentioned: different public technical bodies (France: CETE, CETMEF and IFSTTAR), civil protection services (Greece) and the Academy of Sciences (Hungary) (Question C.1).

Only a few countries have provided information on the distribution of responsibilities and interactions among stakeholders (Question C.2). In general, a rather flexible and open situation emerges here. As the answer from the Netherlands states, this may be initially described as a "joint responsibility"([27]), rather than as a field where clear boundaries among institutions can be established from the beginning. However, it should be expected that those responsibilities would be subsequently clarified. France describes a "top-down" approach, in which the government (through the action plan on climate change) or the ministry of transport provide the general mandate and guidelines for stakeholders. In other countries, such as Germany, a federal ministry can delegate tasks or responsibilities to its corresponding federal agencies, institutions or administrations, and interaction among the federal government and the federal states is facilitated through formal conferences of the ministers for transport issues at the national and state level.

Switzerland provides a detailed description of how responsibilities are distributed among partners in the road and rail modes. In this context, no relevant private stakeholders are identified (with the sole exception of railway undertakings, in Austria and Germany) as being active in transport adaptation.

It seems that it could be useful to further explore how stakeholders identify their roles and cooperate, and how the current focus on infrastructure could be expanded, in order to associate also stakeholders dealing primarily with transport services.

Overall, it seems that a majority of the responders do not expect most infrastructure managers and transport operators to adopt a proactive approach in this field: any action should rather be induced by national governments (ministries of transport). The fact is that some of the countries which are being more active (Switzerland and the United Kingdom for road and rail, Austria for rail) seem to rely heavily on the action of infrastructure road and rail managers and railway undertakings. Furthermore, with some exceptions, there seems not to be any specific relationship among transport administrations and those agencies in charge of risk management for natural hazards. The respective roles of infrastructure managers (and eventually service providers) and governments for analysing and assessing the challenges of climate change probably remains an unexplored question, deserving some discussion at the national and eventually also at the European level. Furthermore, defining the boundaries among already existing climate adaptation responsibilities and emerging additional needs is a challenge with clear implications on management and financial needs. Finally, setting up collaborative structures with other governance levels (mainly local authorities) seem to be a key priority for moving ahead.

([27]) This is how it is described in the Dutch National Adaptation Strategy in 2007. However, in the Strategy it was intended that responsibilities would be specified in following years. A recent review report of the Dutch climate change adaptation policies noted that this never materialized and mentioned the lack of clear responsibilities and the lack of coordination as reasons why not all relevant issues relating to climate change adaptation have been covered by policy making yet.

4.5 Question D: Main barriers and areas for EU policy

The questionnaire suggested a list of barriers and asked respondents to rate them as low, medium or high, without establishing any further ranking among them. It must be stressed that the results obtained are necessarily reflecting the subjective perceptions of those in charge of answering the survey. The results are to be read more as provocative material to encourage further analysis and discussion on these barriers than as a factual and objective picture of the prevailing situation in EEA countries. The list included the following nine barriers, and the possibility to name additional ones:

- Lack of awareness.
- Knowledge gaps.
- Data gaps.
- Lack of Training.
- Lack of capacities (e.g. appropriate staff).
- Lack of financial resources.
- Difficult access to funding.
- Lack of coordination or conflicting sectoral policies such as transport-economy-nature protection etc.
- Lack of coordination or conflicting policies between different government levels – between the local, regional, national, EU level.

Table 4.1 — *Perceived relative importance of main barriers to improving adaptation of transport to climate change*

Source: questionnaire to EEA member and cooperating countries

COUNTRY	LACK OF AWARENESS	KNOWLEDGE GAPS	DATA GAPS	LACK OF TRAINING	LACK OF CAPACITIES	LACK OF FINANCIAL RESOURCES	ACCESS TO FUNDING	COORDINATION OF SECTORAL POLICIES	COORDINATION AMONG LEVELS OF GOVERNMENT
AL	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
AT	HIGH	HIGH	MED.	HIGH	MED.	HIGH	HIGH	HIGH	HIGH
BE	HIGH	HIGH	MED.	HIGH	MED.	HIGH	MED.	MED.	MED.
BG	LOW	MED.	MED.	MED.	MED.	HIGH	MED.	MED.	MED.
CZ	HIGH	MED.	MED.	MED.	HIGH	HIGH	MED.	HIGH	MED.
ES	HIGH	LOW	MED.	LOW	MED.	MED.	MED.	MED.	MED.
FR	LOW	HIGH	HIGH	LOW	LOW	MED.	LOW	MED.	MED.
GR	MED.	HIGH	HIGH	LOW	MED.	HIGH	HIGH	HIGH	HIGH
HU	NONE	NONE	LOW	LOW	LOW	HIGH	MED.	LOW	LOW
IT	HIGH	HIGH	MED.	HIGH	MED	HIGH	HIGH	HIGH	HIGH
NL	MED.	MED.	MED.	LOW	MED.	HIGH	MED.	HIGH	HIGH
PL	HIGH	HIGH	MED.	LOW	HIGH	HIGH	HIGH	HIGH	HIGH
SK	HIGH	MED.	MED.	HIGH	LOW	LOW	LOW	NONE	LOW
SI	HIGH	LOW	HIGH	MED.	MED.	HIGH	HIGH	N/A	MED.
CH	LOW	LOW	MED.	LOW	MED.	MED.	MED.	MED.	MED.
TR	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	MED.	MED.	LOW

Most of the answers from respondents in the different countries agree in acknowledging the importance of the various barriers ahead for improving adaptation of transport to climate change (Table 4.1). The respondents of those countries generally awarding higher scores to the barriers include Albania, Austria, Greece, Poland and Turkey. Those awarding lower scores include Hungary, Slovakia and Switzerland.

There is a strong consensus in identifying the lack of financial resources as the most relevant barrier (12 out of 16 answers identify this one as a "high barrier"). The adaptation of transport systems to climate change is generally associated with a higher dedication of resources. This seems to be more a need for additional financial resources, as the access to already existing sources of funding is not such a strong barrier (this is identified as a high barrier by only six countries).

Although still considered as medium-level barriers, lack of training and lack of capacities are the ones with lower average scores. For training needs associated to climate change adaptation, there is a higher deviation in the scores provided by countries, probably as a consequence of a different understanding in what these needs could be; this question would deserve further discussion and exchange of views among countries and experts. Together, the low scores for both barriers could reflect an optimistic perception on how countries (and particularly governmental structures in charge of adaptation in transport) value their technical resources to address adaptation.

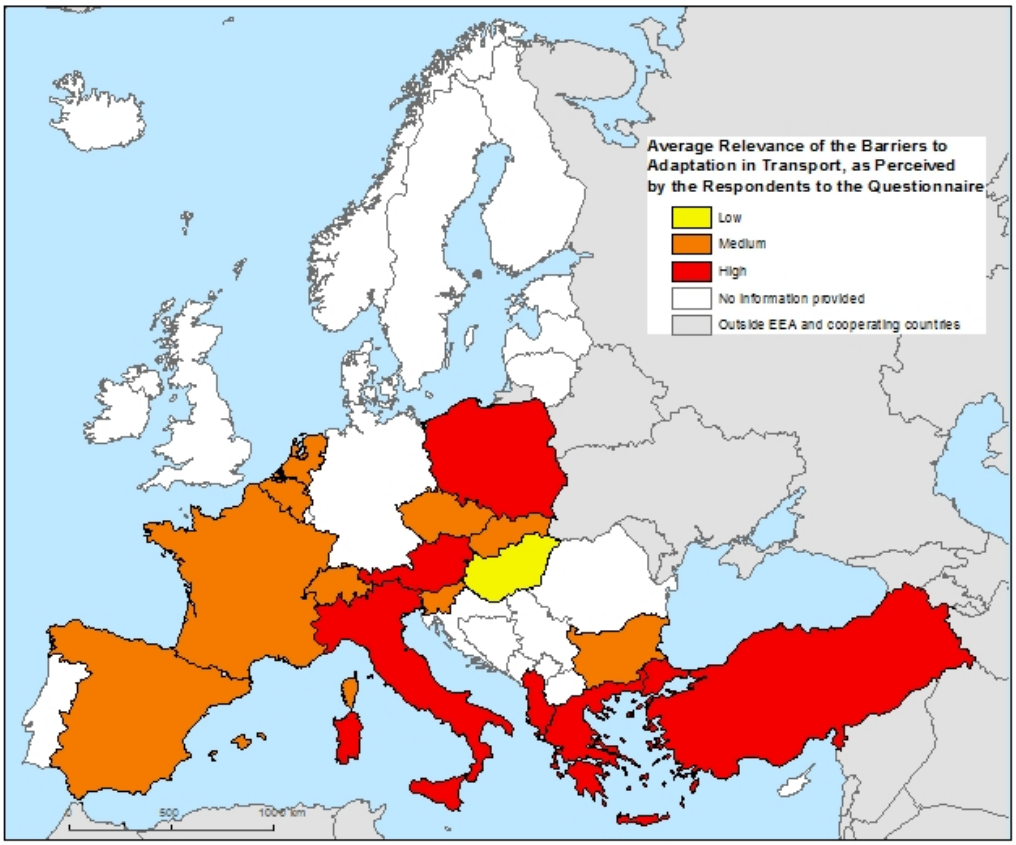
The other barriers mentioned in the questionnaire receive quite similar average scores, although with different degree of variations among countries. Lack of awareness is considered as a high barrier by ten out of sixteen countries. A similar average score is given to the coordination of EU sectoral policies.

Although knowledge gaps and data gaps receive a similar average, countries seem to have more disparate views on the existence of knowledge gaps compared to data gaps: respondents from eight countries consider the former as a "high" barrier, whereas three of them consider it as a "low barrier"; for the latter, most of them (10) agree in valuing it as medium barrier.

Lack of coordination among governments is also considered as a rather medium barrier in average. Together with the "lack of awareness" mentioned previously, this would point out to a certain need for strengthening the governance structures related to adaptation to climate change in the transport sector.

The average scores provided by the respondents are summarized per country in Figure 5. The average has been calculated through association of a numerical value (1, 2 or 3) respectively to the 3 categories (low, medium and high), and giving the same weight to all the barriers considered. The final value is rated as low when below 1.5, medium when between 1.5 and 2.5 and high when above 2.5.

Respondents from five countries have pointed out some additional barriers. Austria and the Netherlands mention the lack of political action, either because adaptation is seen as a long-term issue, not requiring urgent short-term action or because there is no political urgency. Uncertainty is mentioned by Switzerland and Poland as a high or medium barrier (respectively). Austria also states that other, more important challenges are getting the attention of decision-makers. As a low barrier, it is mentioned also by Austria that climate change impacts mostly have a very local dimension. France suggests that technicians and infrastructure managers, particularly in the private sector, could be facing difficulties to include adaptation within their practices and investments due to the lack of reference data on climate change.



Map 4.5 —*Average relevance of the barriers to adaptation in transport, as perceived by the respondents to the questionnaire*

Source: questionnaire to EEA member and cooperating countries

Thirteen countries provide answers on the activities, which the EU could develop in order to support better adaptation of transport systems to climate change in their countries. The questionnaire proposed a list of eleven activities, with the possibility of adding new ones:

- EU adaptation strategy.
- Transport information in the Climate ADAPT platform, e.g. risk maps at the European level, guidelines, tools …
- Facilitating trans-national cooperation.
- Facilitating the cooperation with key stakeholders, bridging the gap among the transport community and climate change scientists.
- Integration of climate change adaptation into other EU policy areas (such as cohesion, transport, social policies, and other policies).
- Funding.
- Revision of design standards.
- Introducing “climate-proof” as a conditionality to support any transport project or policy (e.g. as proposed for EU Structural Funds 2014-2020).
- Development of methodologies, indicators and thresholds on resilience and vulnerabilities.
- Revision of data collection needs and development of new data collection standards.

- Transport research for adaptation to climate change.

Most of the activities suggested in the questionnaire receive a high score (Table 4.2). Transport research, funding and cooperation with stakeholders are the activities getting a higher support.

Table 4.2 —*Perceived Relative Importance of EU activities in support of adaptation of transport to climate change*

Source: questionnaire to EEA member and cooperating countries

COUNTRY	EU ADAPTATION STRATEGY	CLIMATE-ADAPT INFO. PLATFORM	TRANS-NATIONAL COOPERATION	COOPERATION WITH STAKEHOLDERS	INTEGRATION OF CCA IN EU POLICIES	FUNDING	REVISION OF DESIGN STANDARDS	CLIMATE-PROOF OF TRANSPORT PROJECTS	METHODOLOGIES, INDICATORS, THRESHOLDS	DATA COLLECTION	TRANSPORT RESEARCH
AT	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	MED.	MED.	HIGH
BE	MED.	HIGH	HIGH	HIGH	HIGH	HIGH	MED.	HIGH	MED.	MED.	MED.
BG	MED.	HIGH	HIGH	HIGH	MED.	HIGH	MED.	MED.	HIGH	HIGH	HIGH
CZ	MED.	HIGH	MED.	HIGH	HIGH	HIGH	LOW	MED.	MED.	MED.	HIGH
ES	MED.	MED.	MED.	MED.	MED.	MED.	MED.	MED.	HIGH	HIGH	HIGH
FR	HIGH	MED.	MED.	MED.	HIGH	LOW	HIGH	HIGH	HIGH	LOW	HIGH
GR	MED.	HIGH	HIGH	HIGH	MED.	HIGH	HIGH	MED.	HIGH	MED.	HIGH
HU	HIGH	MED.	MED.	LOW	MED.	MED.	LOW	MED.	LOW	LOW	MED.
IT	HIGH	MED.	MED.	HIGH	HIGH	HIGH	HIGH	HIGH	MED.	MED.	MED.
NL	MED.	LOW	MED.	MED	HIGH	MED.	MED.	MED.	HIGH	HIGH	MED.
SK	HIGH	HIGH	MED.	HIGH	MED.	HIGH	NONE	HIGH	HIGH	HIGH	HIGH
SI	HIGH	MED.	N/A	N/A	MED.	HIGH	N/A	N/A	N/A	HIGH	HIGH
TR	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH

Political actions receive a still high, but slightly lower support. Within this group of activities, the higher scores are given to the integration of climate change adaptation within other EU policy areas and to the EU adaptation strategy. The facilitation of trans-national cooperation receives a slightly lower support (five countries consider this as highly relevant and 7 as of medium relevance). All respondents seem to see EU action as relevant and not in contradiction with trans-national cooperation.

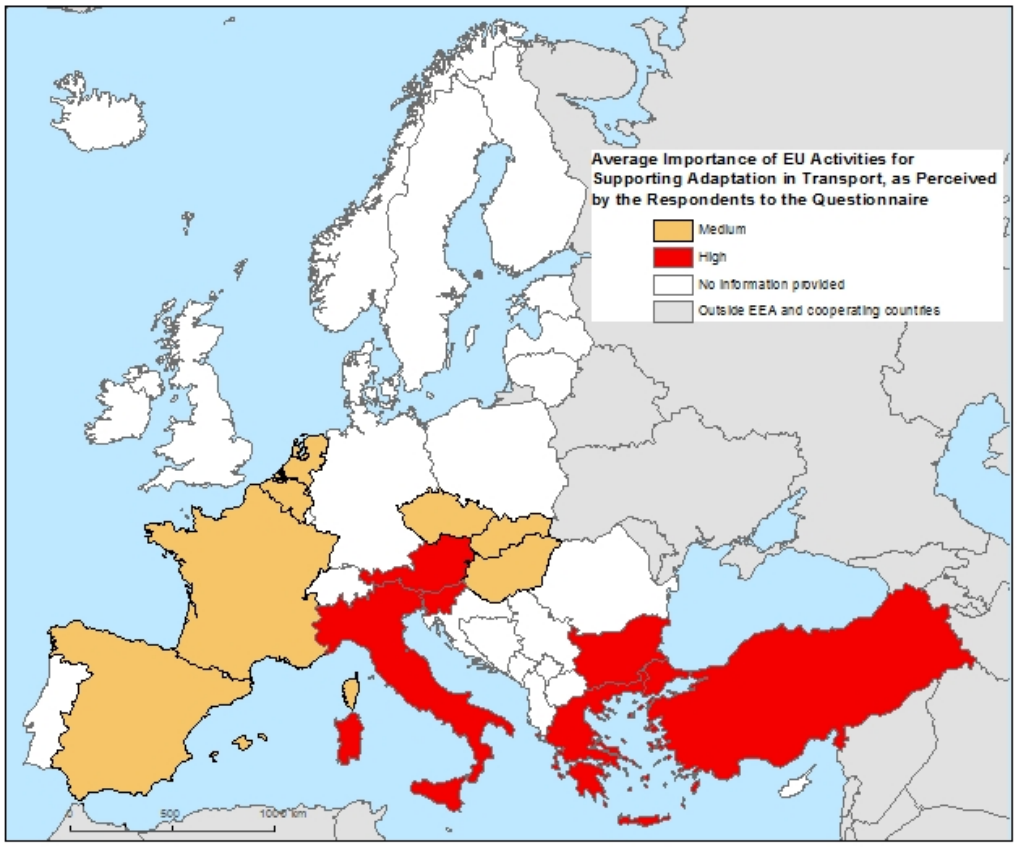
There is also high-to-medium support to those activities referring to the development of technical tools, such as methodologies, indicators and thresholds on resilience and vulnerabilities, the Climate-ADAPT platform and the introduction of "climate-proofing" as a condition to get access to EU funding. Together, these actions could provide a conceptual basis for the revision of current EU procedures applied for selecting the priorities of transport policies.

Data collection receives a lower average score, and with more discrepancies among countries. Data collection could be seen as a way to reduce uncertainty, and from this perspective, it could be interesting to encourage discussion on how the information available could be improved, aiming particularly at decision makers, as suggested by Slovenia.

The revision of design standards for transport systems receives the lowest average support from the countries, although with wide differences among them, probably reflecting disparate national approaches concerning the role of design standards in the transport sector.

The average scores provided by the countries are summarized in Map 4.6. The average has been calculated through association of a numerical value (1, 2 or 3) respectively to the 3 categories (low,

medium and high), and giving the same weight to all the supporting actions considered. The final value is rated as low when below 1.5, medium when between 1.5 and 2.5 and high when above 2.5.



Map 4.6 — *Average importance of EU activities for supporting adaptation in transport perceived by the respondents to the questionnaire*

Source: questionnaire to EEA member and cooperating countries

Some additional activities are mentioned by Austria. These include the development of early warning systems and of disaster risk reduction systems and the possible inclusion of climate change adaptation within environmental impact assessments of transport infrastructure. Slovenia and Italy stress the need to provide reports (particularly from the EEA) with relevant information to raise awareness among decision makers, including questions such as an economic evaluation of climate-related damages in transport infrastructure.

Overall, these answers highlight significant difficulties at both, the political and technical levels, which make it difficult to take further action at this stage for adapting transport systems to climate change. This can be seen as an interconnected situation: as long as technical knowledge does not develop in order to become able to reduce uncertainty about which changes are likely to occur, it seems to be difficult for decision makers to take further action for adaptation. This situation raises two challenges: how to improve the current level of technical knowledge, and how to adapt decision making in the transport sector to apparently unavoidable high levels of uncertainty. As it is not clear whether current levels of uncertainty may increase, there could be a tendency to favour business as usual approaches, and to minimise the consequences of climate change impacts, in the confidence that the transport sector has a good record in coping with extreme weather events in the past.

4.6 Question E: Potential for EEA action and support

The various additional suggestions from countries on how the EEA could better tailor this analysis can be clustered around four major issues (Question E):

- The need for clarification of what should actually be regarded as adaptation of the transport system to climate change. Further discussion would be helpful on two main areas. On the one hand, changes in climate may result in a variety of socioeconomic impacts, which on their turn, would have an influence on transport demand patterns. On the other hand, disaster risks may vary as a result of changes in climate, and this is likely to require a review of prevention and management plans, within which transport usually plays a key role. In accordance with these concerns, it seems that adaptation actions in transport should not be limited to the revision of current design, operation and maintenance practices, and should be expanded to develop a vision of the contribution of transport to a climate resilient society.
- It would be worth to progressively identify and highlight the "climate signals" or "early warning signals", which may be relevant for transport and will require major adaptation decisions.
- As there are significant differences among countries in their current action for adapting transport systems to climate change, there is a need to strengthen exchanges among countries, and to encourage them to further interact with those who are already active, e.g. via exchanging current practices.
- The higher levels of uncertainty associated with climate change impacts, compared to other key challenges of European societies, remain a key barrier for further action at the national level. In the past, the transport sector has been successful in accommodating medium-term uncertainty within its decision-making structures (particularly with EIA and SEA procedures). It seems that decision-makers and stakeholders in the transport sector should undertake a revision of their procedures in order to accommodate in a transparent and fair way the uncertainty associated to climate change.

5 Key policy challenges ahead

5.1 Transport in the framework of the EU adaptation strategy

The EU adaptation strategy is founded on the identification of three key specific problems or gaps that require additional action (SWD(2013)132, Part 1, p.14-25):

- Gaps in knowledge and in access to information. This problem is linked to the uncertainty regarding the future impacts of climate change and to the barriers for making knowledge generally available through adequate dissemination channels, like Climate-ADAPT. There is also a need to identify specific data outputs and indicators relevant for transport sector but that are not always available in current climate change databases, such as the number and length of freezing days, the number of days beyond a certain temperature, etc.
- Gaps in adaptation action at sub-EU level. The EU adaptation strategy states that "one of the greatest challenges for cost-effective adaptation measures is to achieve coordination and coherence at the various levels of planning and management", and recalls that "the recommended instrument at global level, under the UN Framework Convention on Climate Change (UNFCCC), is national adaptation strategies". In fact, the Cancun Adaptation Framework adopted under the UNFCCC ([28]) recommends for adaptation action to "*follow a country-driven, gender-sensitive, participatory and fully transparent approach, taking into consideration vulnerable groups, communities and ecosystems"*. Not surprisingly the first action of the EU adaptation strategy refers to "encourage all Member States to adopt comprehensive adaptation strategies" and recalls that the Commission is providing guidelines for formulating adaptation strategies.

  This approach requires action focused on the national and local levels, based on adaptation strategies and action plans collaboratively adopted by national and local stakeholders, as appropriate. Furthermore, the quality of the strategies and plans thus far adopted is quite disparate, which can be a logical consequence of the remaining gaps in knowledge, of the lack of more precise technical and scientific guidelines, and also of the resources that different countries may be dedicating to this area.
- Gaps in adaptation uptake in key sectors. The EU approach is mainstreaming adaptation within all EU policies, including transport, but additional efforts are needed. There is a particular attention to infrastructure, due to its long life spans and its great economic value, so that climate resilience has been included within the legislative proposal for the revision of the guidelines for the Trans-European Transport Network ([29]). However, there is no general framework for including climate resilience either within project assessment or within project design. Furthermore, climate change will affect areas such as supply chains and logistics, with an impact on companies' profits and consumers' prices. Many economic agents, and particularly SMEs, may have difficulties in adapting to a changing environment, particularly when changes are poorly identified and visible only in the long run. As stated by the European Commission Staff Working Document for the EU adaptation strategy (SWD(2013)132, part I, p.19), "a coherent framework of policies and regulations is necessary for effective decisions on adaptation, providing the right incentives and helping address potential barriers".

Under this general perspective, the EU adaptation strategy is deployed through eight actions:

- Action 1. Encourage all Member States to adopt comprehensive adaptation strategies.
- Action 2. Provide LIFE funding to support capacity building and step up adaptation action in Europe.

([28]) See http://unfccc.int/adaptation/cancun_adaptation_framework/itmes/5852.php

([29]) COM(2011) 650/2 final. See section 3.1 for further details.

- Action 3. Introduce adaptation in the Covenant of Mayors framework.
- Action 4. Bridge the knowledge gap. This includes the identification of relevant tools and methodologies to address these gaps through Horizon 2020, improvement of the information available in Climate-ADAPT and the promotion of EU-wide vulnerability assessments.
- Action 5. Further development of Climate-ADAPT as the "one-stop shop" for adaptation information in Europe.
- Action 6. Facilitate the climate-proofing of the Common Agricultural Policy, the Cohesion Policy and the Common Fisheries Policy.
- Action 7. Ensuring more resilient infrastructure, including a mandate for European standardisation organisations to start mapping industry-relevant standards in the area of energy, transport and buildings, and the provision of guidelines for project developers working on infrastructure and physical assets.
- Action 8. Promote insurance and other financial products for resilient investment and business decisions.

For the transport sector, these actions are aligned with an approach favouring:

- Adaptation, climate-proofing and increased resilience of transport infrastructure of EU relevance, mainly through the revision of standards, and the completion of vulnerability studies.
- European research on climate adaptation of the transport system, in order to "bridge the knowledge gap".
- Encouraging a national approach to adaptation, through national strategies and action plans supported by Climate-ADAPT as a key portal for information and knowledge.

Notwithstanding the general adequacy of this approach, it is necessary to assess whether the particular characteristics of the transport system, which have not been specifically addressed within the preparation of the EU strategy, could justify a more focused approach, and if so, how EEA could support it. This is discussed under the next section, based on the contributions collected during this task, and particularly at the experts' workshop.

5.2 What is specific about the transport system?

The general problems identified by the EU adaptation strategy are also relevant for the transport system: knowledge gaps, need for action at the national level, and still limited action at the EU level. However, these gaps interact in the case of transport with a policy sector facing particular social, environmental and economic challenges. Transport is a sector under increasing scrutiny to improve its energy consumption and environmental performance, to deliver social and economic benefits aligned with the huge public and private resources dedicated to it and to accommodate to the changing demand patterns of a rapidly evolving society and economy.

Within this framework, the emerging needs for adapting to climate change, and the responses to them, can be seen as a way either to facilitate radical reform or to further consolidate business as usual attitudes. This strain can be better identified through a revision of the four areas that have emerged as problematic during this study:

- The boundaries of adaptation in transport.
- The objectives and actions for adaptation in transport.
- The stakeholders and governance regimes.
- The key paradigms of transport policy.

5.2.1 The boundaries of adaptation in transport

Current uncertainty about future changes in climate, at the scale relevant for the transport system, makes it difficult to reach technical consensus on the reasonable boundaries for adaptation. The

uncertainty of existing models for identifying key climate change trends at the appropriate scale required by transport systems implies, on the one hand, that there are significant research needs in this field; on the other hand, that policy makers should be cautious about general, European-wide conclusions, and should try to develop their own studies at the appropriate regional or local scale. Additionally, this would justify the collection of information on disruptive events and the development of monitoring systems, as a means for improving the empirical ground for decisions in the absence of more reliable models.

In fact, the challenge of taking decisions under uncertainty is not new at all for public policies, and in particular for transport. Technical transport practice for dealing with uncertainty has historically been based on the review of data and records of past events. What is questioned now by changing climate patterns is precisely the relevance and validity of that approach, based on historical experience. This situation lies probably at the heart of the current controversy and lack of consensus about the new climate boundaries for the transport system.

Some main lines for action emerged during the discussions of the experts at the EEA workshop held in May 2013, which could help to clarify and define the new boundaries:

- Uncertainty regarding future climate makes it necessary to expand the scope of any prospective studies and to revise the assumptions behind foresight and scenario building exercises, in order to integrate key future climate conditions.
- Increased collaboration among transport experts and meteorological experts for the development of climate models better suited to identify those events, which are more relevant for transport infrastructure design and transport operations. The focus should move to the description of patterns in future extreme weather events, and how they may impact at the local level. Winds and floods seem to be particularly relevant for the transport system.
- Better knowledge of local conditions. A prerequisite for this is the availability of detailed inventories of the transport system, particularly transport infrastructures and their actual performance and characteristics. Furthermore, adequate monitoring of extreme weather events and their impact should serve as a means to assess the system's vulnerability and to develop locally-tailored adaptation measures.
- Linking transport to disaster prevention and management. Transport is crucial within any plan on civil protection and disaster management, whereas any efforts for improving disaster prevention rely on better knowledge of weather hazards and their potential impacts on transport. The need for cooperation seems to be particularly relevant for transport managers and river basin authorities, particularly in mountainous and flood-prone areas. Contingency plans and disaster prevention should become more relevant as areas of cooperation for the transport sector. Civil protection agencies, as key partners, could facilitate a more systematic approach to the assessment of vulnerabilities in the transport system and to identify flexible approaches to cope with them.
- Furthermore, any detailed forecasts on climate changes will be likely to become controversial among transport stakeholders, as new sources of uncertainty, in the same way that current prognosis on social and economic changes are discussed today within the planning and policy decision-making cycle. Dealing with this additional source of controversy will become a part of the future professional practice for helping stakeholders to make a distinction among traditional climate-related impacts, new impacts associated to likely changes in climate, and unlikely impacts, not to be considered.

5.2.2 The objectives and actions for adaptation in transport

The approach of the transport system to climate change adaptation should probably be a mix of reactive and proactive actions. The former are better suited to deal with uncertainty, and should result in the development of more flexible operational practices, and a renewed focus on maintenance and incident management. The latter would be expanded in future, as current uncertainties decrease and as interaction with experts from other fields (meteorology, energy, ICT,

water…) provides a more detailed understanding of the projected changing patterns in climate and their associated impacts.

How and which actions will be selected should probably be a consequence of the approach chosen for adaptation in transport. From the EU perspective, the adaptation strategy only provides a broad reference: "*The overall aim of the EU Adaptation Strategy is to contribute to a more climate-resilient Europe. This means enhancing the preparedness and capacity to respond to the impacts of climate change at local, regional, national and EU levels, developing a coherent approach and improving coordination*" (CE, 2013).

It seems obvious that there are different ways of "*enhancing the preparedness and capacity to respond to the impacts of climate change*" of the transport system. The transport system may adapt to changes in climate by upgrading the resilience of all its components and modes, by expanding in priority those components and modes offering a higher level of resilience already now in a core network, by multiplying alternatives for users, or by increasing its capacity to deliver adequate alternative mobility under disruptive emergency situations, to cite only a few possible trends. These alternative approaches respond to different underlying objectives, and would result in adopting different actions. Furthermore, the objectives to be chosen are largely dependent on the general long-term vision for the transport system in the EU ([30]).

In the absence of more detailed objectives, and in a context of significant uncertainty and knowledge gaps, it is not surprising that most experts recommend the identification and implementation of so-called soft or no-regret measures: actions that have been identified as necessary within existing transport policies, and which also contribute to increase the resilience of the transport system. Some of these measures can also provide synergies between mitigation and adaptation policies. This applies for example to sound maintenance practices for transport infrastructure, integration of transport systems (providing more alternatives to users), revision of already obsolete design standards (or development of such standards if they do not exist), or improved monitoring of vulnerable parts of the system. Performance indicators could be used to monitor the resilience of the system. The identification of further actions would be linked to progress in reducing the current knowledge gap and to the definition of more concrete adaptation objectives for the transport sector.

5.2.3 The fragmentation of stakeholders, cultures and governance regimes

Transport is a fragmented sector in Europe as elsewhere, with many different, well-consolidated and long-established technical cultures and management practices specific to particular countries and to particular transport modes. There is a tendency for these practices to react autonomously to the challenges of climate change, eventually with a potential to further broaden the differences among transport modes or European regions.

It can be argued that there are significant differences in the challenges that climate change could raise to the various transport modes, and to different countries and regions within Europe, and that a high degree of autonomy for national and modal stakeholders would be the most adequate response. However, this autonomy should at least be compatible with some strengthening of the exchange of information and with the development and use of common methodological tools. In other words, current knowledge gaps should be reduced by a cooperative, integrated approach across transport modes and European regions, while respecting the specificities of sectoral organisations and approaches.

Furthermore, adaptation would need stronger collaboration among the various transport stakeholders, particularly among infrastructure managers, transport operators and vehicle and equipment manufacturers. Thus far, most if not all of the attention has been given to infrastructure providers and managers. In fact, the interest mentioned above for soft, non-regret measures, and the relevance of transport for social and economic activities would suggest that operators could become the crucial actors for adaptation in the transport sector: Operators are in an excellent position to identify

([30]) This vision is partially described in the 2011 White Paper on Transport (COM(2011)144) *Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system.* However, this 2050 vision focuses on energy consumption and emissions, without much focus on future adaptation needs.

vulnerabilities and threats to the transport services they provide, to look for adequate alternatives and to establish contingency plans in case of disruption.

Integration is often mentioned as a key trait of the transport systems of the future. Integration makes reference to many dimensions: the integration of the different transport modes (multimodality), technical integration among national infrastructure networks, in order to make seamless mobility possible across borders, operational integration, in order to be able to provide door-to-door transport services to users combining various operators and modes. More relevant seems to be the integration of key horizontal policies and objectives within transport policies and decision making, including a coherent approach to climate change.

From this perspective, effective adaptation to climate change would require appropriate governance structures, better suited to anticipate future challenges and opportunities and to build fair and transparent consensus among stakeholders as a way to move forward. The need of adapting to climate change is an opportunity to reflect upon a more radical reform in transport governance in order to make decision making procedures better suited to deal with uncertainty and with increasingly integrated, complex transport systems.

5.2.4 The key paradigms of transport policy

The drivers of transport demand can be substantially affected by changes in climate. These could result in relocation of activities, variations in agricultural output in regions, migration of population within Europe or changes in tourism patterns, among others. These changes, within Europe and at a global scale, could result in substantial modifications of current and expected transport flows. Furthermore, transport remains as one of the major sources of GHG, so that the relevance and impact of climate change will probably be instrumental for defining objectives in transport policy in the future: significant changes in climate will probably result in more stringent transport policies, whereas low or negligible changes in climate should allow for more conservative, business-as-usual policies.

Climate change is likely to be influential in how the key paradigms of transport policy will evolve in the future. Thus far, the traditional paradigm of providing ever cheaper, faster means for transport, with increasing capacity, has not been challenged ([31]), but there would be a need to assess whether this paradigm remains consistent with the still uncertain adaptation needs.

The consolidation of the paradigm of multimodality in Europe, if finally materialised, could be crucial for defining the adaptation strategy in the future, as increased integration among transport modes and services would expand the number of alternatives and options to users and result in a less vulnerable transport system, in which critical nodes and system management could become as relevant as infrastructure.

5.3 Prospects for international cooperation

This final section explores a number of short-term initiatives in support of the integration of adaptation issues within transport policies, in which the European Commission, EEA and member countries could play a valuable role. They relate to the four broad areas described above: the boundaries of adaptation, adaptation objectives, the revision of transport planning paradigms and the governance of transport. Further discussion among these stakeholders and the key agents within the transport sector would be needed to explore these proposals, but it seems that, at any rate, the EEA would have a crucial role to play, through the promotion of knowledge sharing, data gathering and analysis and coordination.

Reducing uncertainty and better linking climate models to the needs of transport planners and policy makers is a medium-term goal, which will mainly rely on research, and knowledge expansion, with greater interaction among researchers, and practitioners, from both fields. The EEA could promote such a dialogue, as a support to action 7 of the EU adaptation strategy. Following this action, the

([31]) The 2011 White Paper on Transport states that "curbing mobility is not an option": transport policy relies on providing more efficient ways of carrying increasing freight and passenger flows.

Commission is expected to launch a mandate for European standardisation organisations to start mapping standards in the area of transport (among others), identifying standards to be revised for better inclusion of adaptation considerations. This supporting action could highlight the prospects for climate model developments better aligned with needs in the transport sector, and how they could provide a basis for revised design methods and standards.

Better tailored modelling is a part of the approach. Improved monitoring of extreme-weather events, based on good practice available, with an impact in transport systems is another. The EEA could encourage quick progress and better comparability in this field by including some additional indicators within its Transport and Environment Reporting Mechanism (TERM) (EEA, 2012b). These indicators could provide a categorisation of extreme events (region and population affected, main circumstances) and their effects on the transport system (days of disrupted or suspended services, number of people affected, costs of restoration…). If provided by EEA member countries, these indicators would offer valuable factual information at a broader scale, facilitating a more solid basis for the revision of maintenance strategies, design standards and contingency plans.

In fact, the consideration of transport within disaster prevention and contingency plans is another area with significant potential, as a means to clarify the objectives of adaptation and to launch concrete measures with a short- to medium-term perspective. Transport plays a crucial role within contingency plans, for providing the necessary access of assistance services to the affected area. A revision of current methodologies for the consideration of transport within contingency plans would clarify how adaptation could be addressed at a more general level in the future. Furthermore, it would be necessary to promote closer cooperation among researchers and practitioners in the transport and the river basin management sectors, as flooding has emerged as one particular area of interest for climate adaptation in transport.

How climate changes can impact on activity location patterns, population flows and mobility behaviour largely remains as an open issue in need of further research and monitoring. These impacts fall beyond the boundaries of the transport sector, and should rather be considered within a wider consideration on how spatial development patterns may be affected by changes in climate. It is within this broader framework that a revision of current transport paradigms may be undertaken.

The EEA could also foster the exchange of views and experiences on governance practices promoting flexible and forward looking planning, better suited for decision making under uncertainty, and to further involve a broader set of stakeholders, and particularly transport service operators, within the adaptation debate. In fact, current transport planning and decision-making have been the object of substantial discussion for quite some time at all levels and particularly at the EU one, from a sustainability perspective (e.g. the strategies developed since 1998 at the EU and national levels to integrate environmental and sustainable development objectives within transport policy). Climate change and its related uncertainties only provide further arguments supporting the need for more flexible and transparent planning and decision making frameworks. For example, the EU FP7 project MEDIATION provided some ideas on how decision making in public policies can be better adjusted to the uncertainties linked to adaptation ([32]). Additionally, the CIRCLE-2 Joint Initiative on Climate Uncertainties will provide a sound guidance on “How dealing with uncertainties in climate change impacts, vulnerability and adaptation” ([33]).

Whereas adaptation needs have focused thus far on the vulnerabilities of transport infrastructure, comparatively little attention has been given to transport service operators. However, these stakeholders are instrumental in providing services for transport of passengers and freight under extreme weather conditions, and should play a more central role for adapting the transport system to climate change. In fact, operators could facilitate the adaptation of transport systems to the needs of

([32]) The MEDIATION (Methodology for Effective Decision-making on Impactts and AdaptaTION) project can be accessed at http://mediation-project.eu and http://mediation-project.eu/output/downloads/d4.1-report-on-uncertainty-methods-updated-v2.pdf.There is a general presentation of the project's proposal at the EEA Report No 3/2013 *Adaptation in Europe*. http://www.eea.europa.eu/publications/adaptation-in-europe.

([33]) http://www.circle-era.eu/np4/P_UNCERT.html.

vulnerable end-users, from SMEs to low-income citizens or less developed regions, based upon their proximity to them.

Climate-ADAPT could play a crucial supporting role, providing the necessary information to facilitate discussion on modelling needs, prevention and contingency plans ([34]) at the national and modal level, changes in location patterns, and innovative governance practices, among others. More precisely, it would be necessary to expand the currently existing information within the Climate-ADAPT platform on the transport contents of national and subnational action plans, and to make sure that Climate-ADAPT is able to cope with the different perspectives and needs of the various stakeholders in the transport sector. Some cooperation at the European level with those transport stakeholders more active in adaptation issues could facilitate the identification of information to be provided by the platform.

5.4 The way forward

This technical paper has made a first attempt to provide an overview of adaptation initiatives in the transport sector in EEA countries. This objective proved to be more difficult to achieve than initially expected, as in many countries adaptation of transport is happening not only through initiatives led by national governments, but often through bottom-up initiatives of regional and local governments and other stakeholders. As a result, further efforts will be needed for getting a comprehensive overview of such a dynamic situation.

As the number of adaptation initiatives increases throughout Europe, there is a growing need for facilitating the networking and exchange of experiences among stakeholders at the local, regional, national and European levels. There is certainly a wide area for further action from the EEA, with the support of its European Topic Centre on climate change impacts, vulnerability and adaptation, to continue collecting information, including more practical cases, and to deepen the analysis of the expanding activity in this field, increasing the information provided by Climate ADAPT for the transport sector.

([34]) There are already several information platforms for the disaster risk reduction (DRR) community in Europe. The prevention web platform offers extensive information, such as http://www.preventionweb.net/english/professional/contacts/profile.php?id=8679 for the European Forum for Disaster Risk Reduction (EFDRR) and http://www.preventionweb.net/english/countries/europe/ for information on national platforms.

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7 Annex 1: Case study: United Kingdom

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Legal framework for climate change issues in United Kingdom: the UK Climate Change Act 2008

In 2008, the Climate Change Act was passed, making the United Kingdom the first country in the world to have a legally binding commitment to reduce its carbon emissions (specifically, to reduce emissions by at least 80% in 2050 from 1990 levels) ([35]).

As a result of the Act, the Committee on Climate Change (CCC) was set up, to advise the Government on emissions targets, and to report to Parliament regarding progress to reduce the United Kingdom's greenhouse gas emissions. The CCC includes the Adaptation Sub-Committee (ASC) which examines, and advises on, the Government's climate change adaptation programme.

The Act established a framework to promote UK adaptation action ([36]) consisting of:

- The UK Adaptation Reporting Power.
- The UK Climate Change Risk Assessment (CCRA): a five-yearly assessment of the major risks and opportunities from climate change in the United Kingdom.
- The National Adaptation Programme (NAP): the Government's long term strategy to address the main risks and opportunities identified in the CCRA.

UK Adaptation Reporting Power ([37])

This framework grants the Secretary of State the power to require public service organisations to produce reports on their activities with respect to climate change adaptation. The first round of reporting yielded responses from around 90 organisations, including transport organisations such as Network Rail, Highways Agency, Associated British Ports, UK airports, Office of Rail Regulation, etc.

Climate Change Risk Assessment (CCRA) ([38])

The first UK CCRA was completed in 2012. Around 700 separate risks were identified and over 100 of these were analysed in detail. Eleven sector reports ([39]) were produced, including one covering transport risks. The main transport risks assessed in the first CCRA were:

- Flood disruption / delay to road traffic.
- Landslide impacting the road network.
- Cost of carriageway repairs.
- Rail buckling risk.
- Road and rail bridge failures due to scour.

([35]) http://www.theccc.org.uk/tackling-climate-change/the-legal-landscape/global-action-on-climate-change/

([36]) http://www.theccc.org.uk/tackling-climate-change/preparing-for-climate-change/uk-adaptation-policy/

([37]) https://www.gov.uk/government/policies/adapting-to-climate-change/supporting-pages/adaptation-reporting-power

([38]) https://www.gov.uk/government/publications/uk-climate-change-risk-assessment-government-report

([39]) http://ccra.hrwallingford.com/CCRAReports/reportviewer.html?sector=intro&link=LinkTarget_1

- Roads and rail at significant likelihood of flooding.
- Shipping routes: navigable days for the north-west and north-east passages per annum.
- Major UK airports and the national air navigation service provider also had to submit adaptation reports.

National Adaptation Programme (NAP) ([40])

The first UK NAP report was published on 1st July 2013. It will be reviewed every five years and is divided into the following chapters:

- Built environment.
- Infrastructure.
- Healthy and resilient communities.
- Agriculture and forestry.
- Natural environment.
- Business and local government.

The NAP aligns risks identified in the CCRA to actions being (or to be) undertaken, and the timescales for these actions, according to each theme.

Devolved administrations

The Parliament of the United Kingdom has devolved aspects of government to the "devolved administrations" (DAs) in Northern Ireland, Scotland and Wales. Certain issues related to climate change legislation are affected by this:

- The 80% reduction target by 2050, as specified in the UK Climate Change Act, includes contributions from the DAs (about 20% of the UK's total emissions currently) ([41]).
- The DAs have their own climate change policies in addition to being covered by the UK Climate Change Act:
    - The Scottish Parliament passed the Climate Change (Scotland) Act ([42]) in 2009. This commits Scotland to an interim target of a 42% reduction in emissions by 2020 (as well as the 80% target specified in the UK Act), and also to annual targets between 2010 and 2050.
    - The Minister of the Environment for Northern Ireland is developing plans for a Northern Ireland Climate Change Act ([43]).
    - Wales does not yet have its own specific legislation regarding climate change, but the CCC recently advised the Welsh Government on possible options for climate change legislation ([44]).

([40]) https://www.gov.uk/government/policies/adapting-to-climate-change/supporting-pages/national-adaptation-programme

([41]) http://www.theccc.org.uk/tackling-climate-change/the-legal-landscape/global-action-on-climate-change/

([42]) http://www.scotland.gov.uk/Topics/Environment/climatechange/scotlands-action/climatechangeact

([43]) http://www.doeni.gov.uk/ni_climate_change_bill.htm

([44]) http://www.theccc.org.uk/tackling-climate-change/the-legal-landscape/global-action-on-climate-change/

Case study: the impact of climate change on the railway network of Great Britain ([45])

Context

The mainline railway network of Great Britain (GB) is among the oldest in the world and in its current form is owned and operated by a variety of different stakeholders:

- Network Rail own and operate the railway infrastructure (rail tracks, signalling, bridges, tunnels, level crossings, viaducts and 17 key stations).
- Passenger train services, and other stations, are operated by Train Operating Companies (TOCs).
- Freight train services are operated by Freight Operating Companies (FOCs).

Other relevant stakeholders include:

- UK Government Department for Transport (DfT), which sets the UK's overall transport policy.
- Office of Rail Regulation (ORR), the UK's regulatory body for railways.
- Rail Safety and Standards Board (RSSB).

Approach

In 2010-11 an assessment of possible climate change impacts on the GB railway network was undertaken by the Met Office for Network Rail, as part of "Tomorrow's Railway and Climate Change Adaptation" (TRaCCA research project, RSSB reference T925 ([46])), a rail industry project supported by the industry's Technical Strategy Leadership Group (TSLG) and funded by DfT through the 'Rail Industry Strategic Research Programme' managed by RSSB.

The study involved close collaboration between the Met Office and Network Rail, to develop a novel methodology combining the weather and climate expertise of the Met Office with the deep industry knowledge of Network Rail. *Phase 1* of the work consisted of a series of joint Met Office / rail sector workshops with the aim of identifying the weather sensitivities of the GB railway network. Around 60 sensitivities were identified.

In *Phase 2* of the work, the 60 sensitivities were prioritised, to produce a list of the 16 most important sensitivities ("priority risks"). A high-level assessment of the priority risks was carried out for one major railway route, in order to support Network Rail in fulfilling their obligations under the Adaptation Reporting Power. *Phase 3* of the work revisited the priority risks, reviewed and modified aspects of the methodology and applied it to the whole GB railway network.

Treatment of uncertainties

Future projections of the climate are subject to particular uncertainties, including those related to climate model formulation ("model uncertainty"), choice of emissions scenario ("forcing uncertainty") and natural climate variability. The methodology used data from the Met Office Hadley Centre's regional climate model (RCM), at 25km spatial resolution. Data from eleven separate realisations of the RCM ("RCM variants"), with slightly different input parameters, were used. Future time periods examined were the 2020s (2010-2039), 2030s (2020-2049) and 2040s

([45]) Note that "Great Britain" comprises England, Scotland and Wales, whereas the "United Kingdom" comprises England, Scotland, Wales and Northern Ireland; the railway in Northern Ireland did not form part of this study.

([46]) http://www.rssb.co.uk/RESEARCH/Lists/DispForm_Custom.aspx?ID=888

(2030-2059), relative to a baseline of 1971-2000. All RCM variants were run under the Medium (SRES A1B) ([47]) emissions scenario. The extent to which different uncertainties were included in this assessment is therefore:

- Inclusion of some aspects of model uncertainty (eleven different versions of the Met Office RCM, but no consideration of climate models from other centres).
- No consideration of forcing uncertainty (but under time horizons out to ~2040s there is little difference between projections under different scenarios).
- Some consideration of natural variability, by the use of thirty-year time periods, and the inclusion of three different future time periods.

Uncertainty was presented by calculating the average response across the eleven RCM variants and also including the minimum and maximum responses across the variants.

Example

Rail buckling was identified as one priority risk, where the relevant climatic variable is temperature. Discussions with Network Rail revealed that a series of actions are taken at particular critical rail temperatures, where the temperatures depend on the track condition:

- deployment of heat watchmen to monitor the track condition in situ
- imposition of 30/60mph speed restrictions (30mph freight, 60mph passenger services)
- imposition of blanket 20mph speed restrictions

An empirical relationship ([48]) exists between the rail temperature and the ambient air temperature:

$$T_{\text{rail}} = \frac{3}{2} T_{\text{air}}$$

This relationship was used in conjunction with the information about critical rail temperature actions to determine the corresponding critical air temperatures. The future occurrence of conditions requiring track buckling management actions was then modelled via threshold exceedance analysis of summertime (May-Sep) daily maximum temperature data from the RCM.

A projected increase in occurrence of conditions requiring track buckling management actions was found, for all track conditions except those with the highest critical rail temperatures. For the latter, present-day occurrence of these conditions is either rare or absent, and may remain so in future ([49]).

Presentation of research outcomes

As well as presenting research outcomes via a report, a web application was also created for visual dissemination of results (see screenshot in Figure A.1.1). Users can select a priority risk of interest and then explore projected changes to this between baseline and future periods, together with a

([47]) Nakicenovic N. and R. Swart (2000). Special Report on Emissions Scenarios. A special report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK. Available from http://www.ipcc.ch.

([48]) Hunt, G.A. (1994) An analysis of track buckling risk. British Railways Internal Report RRTM013.

([49]) Palin, E.J., Thornton, H.E., Mathison, C.T., McCarthy, R.E., Clark, R.T. and Dora, J. (2013) Future projections of temperature-related climate change impacts on the railway network of Great Britain. *Climatic Change*, doi:10.1007/s10584-013-0810-8

measure of the uncertainty in the results (via the minimum, average and maximum modelled response).

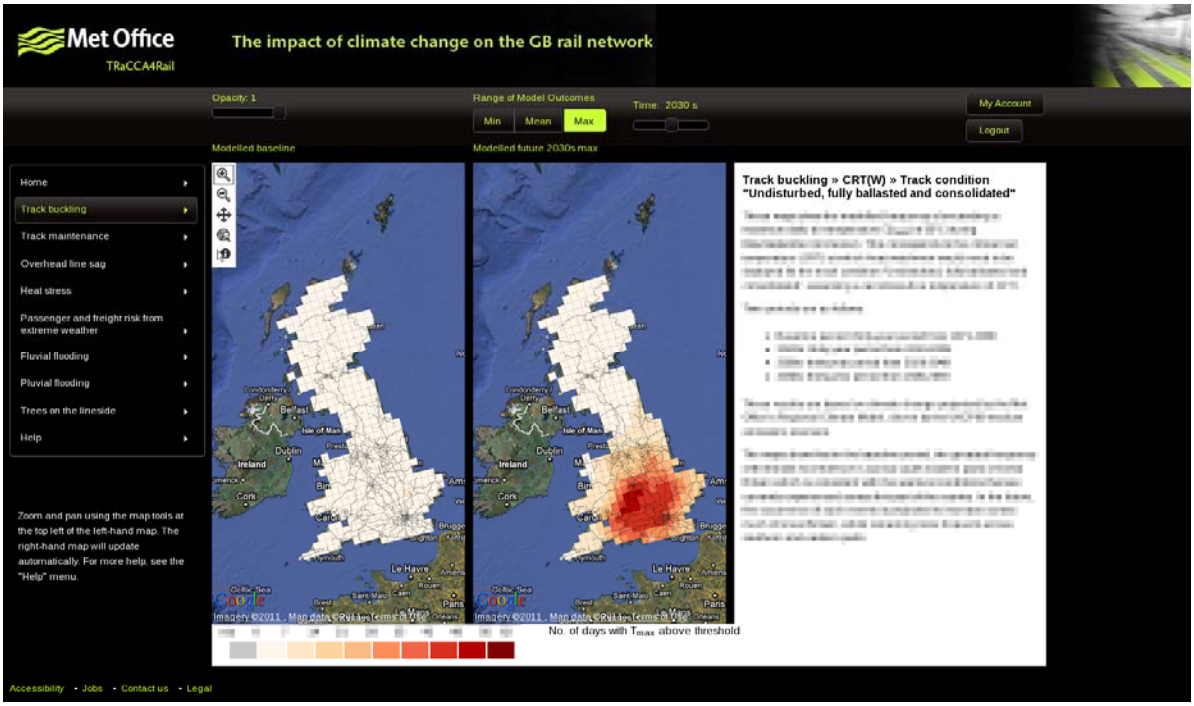


Figure A.1.1 - *Screenshot of the TRaCCA web application, showing (for a particular track condition) the modelled baseline (left) and projected (right) changes in conditions requiring track buckling management actions. Here, the user has chosen to display the maximum future model response for the 2030s*

Summary and outlook

A major outcome of this work has been to acknowledge and set in motion work to address the gap between scientific capability and the requirements of decision-makers. To this end, close collaboration with industry partners has yielded novel ways to link the knowledge of rail sector experts with the results of state-of-the-art climate projections, in order to supply decision-makers with information which is both scientifically robust and appropriately communicated.

Since the completion of T925 a further programme of research (RSSB reference T1009 ([50]), "Further research into adapting to climate change") is now in progress, to deliver step changes in climate science, knowledge of climate change vulnerabilities, and the development of support tools, to increase the weather and climate resilience of the GB railway.

GB Road Management (National/Local)

The road network in the England is managed by both national and regional authorities. The major "trunk" roads in England, including the Motorway network, are managed by the Highways Agency; the network of smaller local and urban roads are managed by local government authorities, mostly county councils and unitary councils covering some larger, mainly urban areas. In Scotland and Wales there are separate but similar structures of national and local management. This case study focuses on the trunk road network in Great Britain.

([50]) http://www.rssb.co.uk/RESEARCH/Lists/DispForm_Custom.aspx?ID=1138

The case study illustrates the development of a Vehicle Over-turning (VOT) Module for a Hazard Impact Model (HIM) developed under the Natural Hazards Partnership (NHP). The NHP is a collaboration of a number of UK, mainly Government, agencies and departments with expertise or stakeholder interests in aspects of natural hazards. Key customers of the NHP are the Cabinet Office, Scottish Government and Welsh Government who have responsibility for managing national risks involving public safety and national infrastructure. The HIM is a framework for the development of modelling capabilities to estimate elements of risk for the NHP. Risk is here defined following the conventions of the UNISDR (United Nations International Strategy for Disaster Reduction), (see UNISDR, 2009) as the product of probability of hazard and the level of impact which depends on the vulnerability and exposure of society or assets at risk. In addition to the VOT, other HIM modules are being developed within the NHP to consider risks related to landslides and surface water flooding hazards.

The HIM Vehicle Overturning Module

The VOT Model was developed as a first demonstration of the concept of the HIM, using previous research on the wind-speed thresholds required to over-turn various types of vehicles. The model attempts to use forecasts of maximum gust wind-speeds (the hazard) to estimate the overall risk of disruption to the operation of the road network, taking account of the vulnerability of different segments of the road network and the exposure which depends on the numbers of people and businesses impacted by the disruption caused by a vehicle over-turning incident. This chain of risk, from hazard probability, through vulnerability and exposure to overall risk is common to any implementation of the HIM concept. The precise definitions of vulnerability and exposure used will depend on the interests of the key stakeholders and the aspects of the impact of the hazard which they are most interested in.

Implementation of the HIM concept for the VOT module is illustrated in Figure A.1.2. The hazard forecast is taken as the probability of exceeding four defined thresholds identified for different vehicle types: unloaded heavy goods vehicles (HGVs), unloaded light goods vehicles, cars and loaded HGVs. The forecast winds are related to the road network to determine which 2km segments of road are liable to experience gusts exceeding the thresholds in directions relative to the road liable to cause over-turning, and the probability of an incident determined taking account also of the vulnerability of the road segment which depends on its location, surrounding terrain and vegetation, so for example a road on a high mountain pass with little vegetation might have a vulnerability of 1.0 while one passing through a sheltered valley may have a vulnerability of 0.1. Finally the exposure element depends on the volume of traffic on road segments, which may depend on the time of day/week/year, which determines the numbers of people and businesses impacted by the disruption caused by any vehicle over-turning incident.

The VOT module has been implemented at the Met Office as a tool to aid forecasters in issuing risk-based severe weather warnings as part of the UK National Severe Weather Warning Service. It takes wind gust forecasts from the Met Office high resolution forecast model. An example of its use is illustrated in Figure A.1.3. Warnings are issued according to a “traffic-light” colour based on a risk matrix taking account of probability and impact as illustrated in Figure A.1.3c. Figure A.1.3a (left) shows a first-guess warning provided to the forecaster from the latest high-resolution probabilistic forecast system in use in the Met Office, which uses a standard range of wind thresholds to represent different levels of overall impact, which suggests a Yellow warning over parts of SE England, SW England and Wales. In addition the forecaster requested a run of the VOT model which was run from a single high-resolution model run and indicated some risks on the road network further to the NW, towards East Anglia and the Wash (Figure A.1.3b, centre). As a result the forecaster issued a warning which extended the first-guess area further in this direction (Figure A.1.3c, right).

The VOT module, as noted above, currently runs using wind forecasts from the latest high-resolution weather forecast model run. The Met Office has recently introduced a probabilistic forecast system based on an ensemble technique where the model is run multiple times with small differences to assess the confidence and uncertainty in the forecast. In order to improve probability

aspect of the risk assessment, the VOT will soon be implemented to run from this ensemble forecast. In conjunction with this change, it is planned to start running the module on a daily basis as a standard part of the forecast production process.

Further Planned Enhancements

Further research is on-going towards improving the VOT module and the related services. In particular:

i) Bridges – large bridges over rivers and river estuaries can be particularly vulnerable to strong winds causing closures and traffic restrictions, to prevent vehicles being over-turned. The model is currently being enhanced to include specific forecasts for such bridges, with investigation of ways to model to the resulting impact on network traffic flows.

ii) Incident-based modelling – Research is also being undertaken to determine whether alternative approaches to estimating wind impacts on the road network can improve on the physical modelling approach described above. Datasets of reported wind-related incidents are being analysed in relation to observed and analysed wind speeds to develop a probability of disruption conditional on the forecast wind-speed.

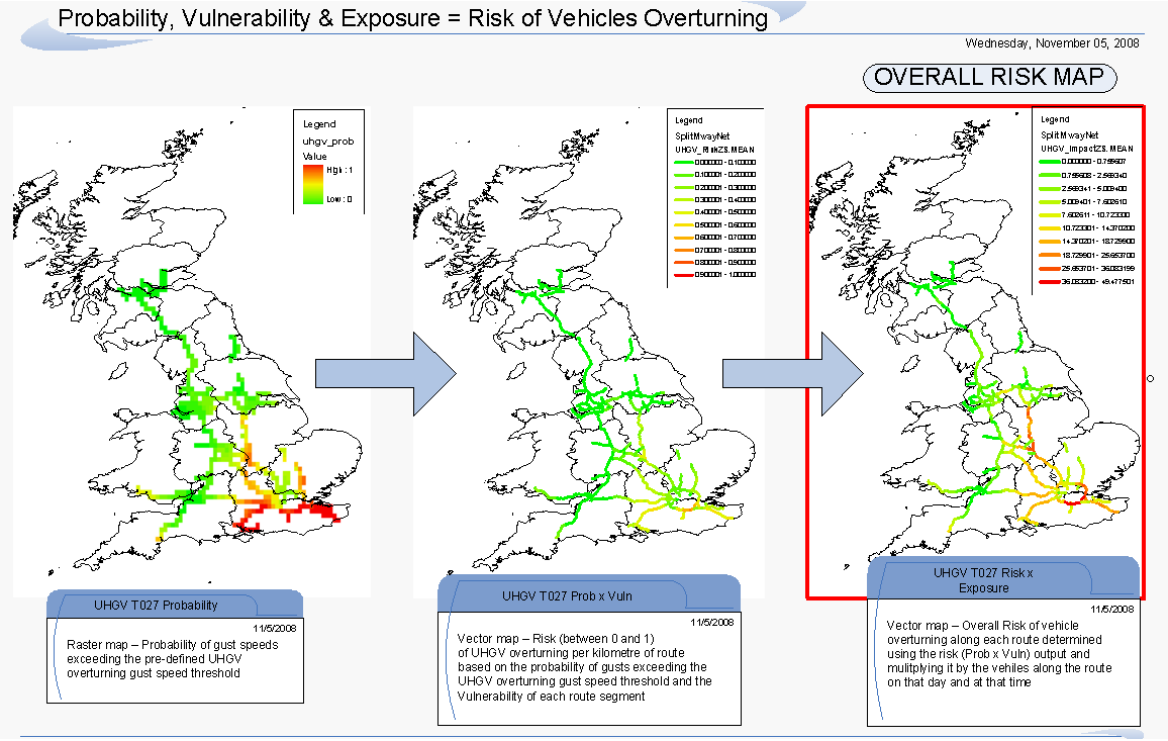
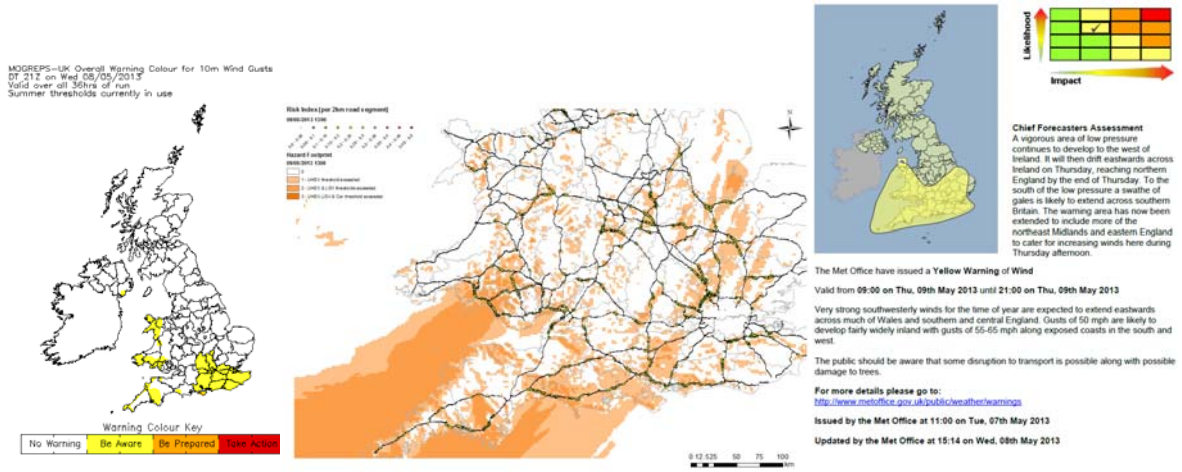


Figure A.1.2 - *Illustration of the risk chain from Hazard Probability (left) through Vulnerability (centre) to Risk (right) for the vehicle over-turning model applied to the GB trunk road network*



a) b) c)

Figure A.1.3 - *Example of the vehicle over-turning model applied to a severe weather warning. a) First-guess warning from high-resolution probabilistic forecast system. b) Vehicle-overturning model output. c) Issued warning including the impact matrix used for the warnings service*

References

UNISDR. 2009. Terminology on Disaster Risk Reduction. UNISDR (United Nations International Strategy for Disaster Reduction), Geneva, May 2009.

Met Office Barometer on line. *Natural Hazards Partnership: A defining partnership*. http://www.metoffice.gov.uk/barometer/features/2013-07/a-defining-partnership

8 Annex 2: Case study: Austria

Authors: Markus Leitner, Andrea Prutsch (Environment Agency Austria)

Example of the Austrian Federal Rails – Infrastructure and Climate Change

The **Austrian Federal Railways** (ÖBB - Österreichische Bundesbahnen) runs the national railway system of Austria. It is entirely owned by the Republic of Austria and is divided into several separate businesses that manage the infrastructure and operate passenger and freight services. Since 2003 it has also run Austria's largest bus company with its intercity networks.

The ÖBB is a significant organisation, carrying about 450 million passengers a year, and for some time has been conscious of climate change when making decisions. It has about 4,800 km of route network and more than 1,000 railway stations. Given the long life-span of up to 100 years in investments in major transport routes, bridges, tunnels etc. it is important to properly consider changes in future climate. After all, the company knows only too well that there is little tolerance towards the late running of trains.

Figure A.2.1 – *Railways*
© EAA/ Maria Deweis

Climate Change and rail infrastructure - Like many other transport modes, also rail is affected by a changing climate. Extreme weather events like heavy precipitation, hail, storms, snow and heat-waves can impact the rail-infrastructure negatively. It is expected that the frequency and intensity of such extremes will be different in the light of a changing climate. Therefore it seems even more important for the Austrian Federal Rails to start to deal with and manage such possible negative impacts. Due to pro-active tackling of climate change and the implementation of related adaptation measures, the Austrian Federal Rails are early movers in the European context.

Project KLIMA - In 2010, the Austrian Federal Rails contracted the Environment Agency Austria (EAA) and the Institute of Meteorology, University of Applied Life Sciences (BOKU) to help identify potential climate change impacts on rail infrastructure and develop recommendations for adaptation. The aim was to investigate as many meteorological variables and climatic changes as possible that might have an impact on the company's infrastructure and security of service.

The first step was to produce an overview table on observed climate impacts for railway infrastructure and some operational issues. Therefore company-internal data from damaging events of the existing time-period 1990-2011 were analysed and, with the help of weather map archives and other weather chronicle, judged on its meteorological source.

Senior executives and company experts in the fields of research and innovation, natural hazards and sustainability were incorporated into a steering group and included in every step of the project. Such continuous involvement of company members in the project was seen as critical to its success.

Based on the analysis - tailor-made for the Austrian Federal Railways - recommendations for adaptation were formulated. In a nutshell, now it is time for the company to take up these recommendations and implement them in the long-term. So far, the early warning systems have been adapted. Additional adaptation measures are being planned.

Example of standards and standards for construction

- **Impacts:** due to the expected increase of heat days and heat periods, a stronger heating of material and thermal stress for construction material are anticipated. Also rail buckling can occur more often. During heavy precipitation events, the drainage system might be overloaded, thus the risk of flooding of rails or tunnels increases.

- **Recommended Measure:** current construction standards shall take into account higher loads of construction in future. A systemic and continuous review of current construction standards is thus an important measure. The Austrian Federal Railways has in the meantime already adapted its directive of civil engineering constructive work.

References

http://botany.uibk.ac.at/neophyten/download/09_OeBB_Rachoy_KLIWA.pdf

http://www.oebb.at/infrastruktur/__resources/llShowDoc.jsp?nodeId=29841913

9 Annex 3: Case study: Spain

Author: Albert Compte (CEDEX)

In September 2012, the Spanish ministries in charge of transport and the environment set up a working group with a mandate to analyse the climate change adaptation needs for the trunk transport network in Spain.

The figure below summarises the approach adopted by the working group. The first phase of the analysis (from October 2012 to March 2013) was focused on the identification of the main impacts and risks of climate change on the trunk network, and their categorisation in accordance with the perceived urgency in taking action for adapting the network to those impacts. During the second phase (from April to July 2013) the working group discussed which adaptation measures should be taken as a priority. During the whole process, the working group got the support of four modal specific groups of experts, one per transport mode (roads, railways, ports and airports). These modal groups included experts from the national road administration, ADIF and RENFE (railways infrastructure manager and operator respectively), Puertos del Estado (national ports agency) and AENA Aeropuertos (national airports manager), among others.

At the beginning of the process, the experts from each transport mode identified the scope of the analysis, by defining which infrastructures should be included under the concept of "t*runk network*", and the assets to be considered in the analysis.

In order to identify and prioritise the potential climate change impacts and risks, the working group requested the support of meteorological and climatic experts, who provided information on the climate change forecasts in Spain. The general information was supplied by the national meteorological agency (Agencia Estatal de Meteorología), and additional specific information on maritime conditions, on coastal areas and on hydrological regimes was provided by the national ports agency (Puertos del Estado), the Spanish office for climate change (Oficina Española de Cambio Climático) and the national research centre CEDEX, respectively. The identification of the key meteorological information and parameters to be provided by these organizations was made by the modal groups of experts for each transport mode, on the basis of a review of the parameters considered as more influential for the design of each asset of the trunk network, and the analysis of actual vulnerability to weather events.

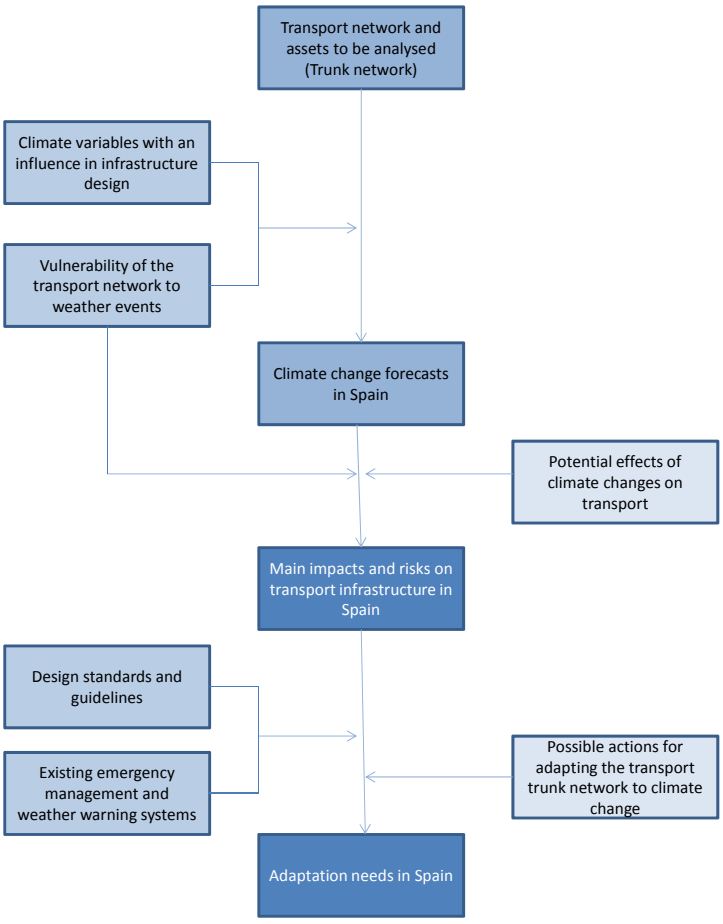


Figure A.3.1 - *Methodological approach adopted by the working group*

The identification and categorization of the potential climate change impacts by the modal groups was also supported

by a review of the state of the art on the possible effects of climate change in the transport sector identified in other countries, and by researchers and international organisations.

The second phase of the analysis started with a systematic collection of information by the modal groups on transport infrastructure design standards, guidelines and technical recommendations, in which those meteorological variables considered as more sensitive to changes in climate are influential. Additional information was gathered concerning the scope and limitations of existing emergency/incident management systems and of existing meteorological warning systems for extreme weather events. These were completed with a literature and research review of actions proposed or implemented in other countries for adapting the transport system to climate change. With this background, each modal group prepared a proposal of adaptation measures specific for Spain, which was consolidated afterwards by the Working Group in a final proposal of actions for the entire trunk network.

The Spanish office for climate change is currently preparing the Third Work Programme 2014-20 of the National Adaptation Plan, and the results of this analysis should provide further baseline information, and contribute to identify the priorities of action to be developed under this framework within the transport sector.

Reference

Grupo de Trabajo para el análisis de las Necesidades de adaptación al cambio climático, 2013, *Necesidades de adaptación al cambio climático de la red troncal de infraestructuras de transporte en España*. CEDEX, Madrid.

10 Annex 4: Case study: France

Author: Ángel Aparicio (UPM) based on information provided by Bertrand Reysset (Observatoire national sur les effets du réchauffement climatique, ONERC)

The French national action plan, approved in 2011, points out that the "transport infrastructure" chapter is led by the general directorate for infrastructures and transport systems. Even if the whole plan is coordinated by the Ministry of environment, the responsibility for action implementation is shared by different Ministries and general directorates. Thus, the French NAP is close to the UK approach.

As a part of the NAP, France has started to review its transport infrastructure standards (rail, road, air and inland waters). This work is led since 2011 by the general directorate for infrastructures and transport. The review is currently identifying those standards which are sensitive to climate change. The next step will be to update sensitive standards, if so required.

Various measures in the area of transport infrastructure have been identified within the NAP. They provide climate change impact analytical means, prevent vulnerabilities of transport systems and prepare the improvement of resistance and resilience of infrastructure, existing and future, to ensure continuity and security of the services transporting people and goods.

Action 1: To review and adapt the technical references for construction, maintenance and operation of transport systems (infrastructure and equipment).

This is to ensure that transport infrastructures meet adequately the evolutions expected as a result of changes in average and extreme climate conditions. This is relevant, as those infrastructures although built for a long period of service life (some up to a century or more), have followed the technical specifications, sometimes old, available at their time of design. A similar challenge is faced by transport equipment. For new transport projects, an adequate correspondence match between the revised hazards and national, European and international technical references is essential.

Action 2: Research on the impact of climate change on transport demand and its effects on the reorientation of transport supply.

Climate change could alter medium and long term travel demand patterns: origins and destinations related to the temporal distribution of flows and the geographic distribution of population and activities, the attractiveness of tourist destinations... A prospective light should be put on possible developments in passenger and freight mobility and their impact on transport supply. The impact of urban morphology changes will also be studied.

This action regarding the evolution of the modal, geographic and temporal transport split is developed in four directions:

- For long distance, by fostering research on the evolution of location choices of population and activities, as well as tourist destinations.
- For cities, by studying the changing links between planning policy and transport in cities.
- For air transport, through further analysis of air traffic trends in the framework of ICAO.
- For freight, by studying the evolution of the location of economic activities and major corridors.

Action 3: To develop a harmonized methodology in order to achieve a diagnosis of the vulnerability of infrastructure and transport systems for land, sea and air transport.

Methods of analysis of the climate change vulnerability of transport networks are underdeveloped, as this topic has been addressed only recently. Risk analysis have been developed, although limited to some specific parts of the transport networks. Further methodological tools should be provided through scientific and technical research, in order to provide guidance to network operators on how to undertake local vulnerability studies for each network, and to allow for comparison on the basis of "criticality indices". Two steps are envisaged for this action:

- To develop a methodological framework adapted to transport networks for vulnerability analysis.
- To develop a methodology for vulnerability analysis adapted to networks and singular points (bridges, tunnels...)

Action 4: To establish a state of vulnerability of land, sea and air transport networks in France, including both, the mainland and overseas territories; to prepare response strategies, progressive and tailored to the impacts caused by climate change, both globally and regionally.

This action will undertake a risk analysis for all transport infrastructures (road, rail, inland waterways, ports and airports) in relation to climatic hazards for their designed lifetime. Overseas regions or areas that are far away from the mainland (islands, mountains, valley bottom...) and have limited or no access alternatives (airport, port, bridge, etc.) seem to be particularly vulnerable. The change in average climate conditions and the increase in the frequency, duration and extend of extreme events raise new questions about liability and arbitration in choosing an adaptation strategy (retrenchment, construction, acceptance of a temporary unavailability and report towards other means of transport ...), the level of acceptable risk, the timing to invest and implement adaptation strategies. This action involves two measures:

- The completion of vulnerability studies.
- The facilitation and set-up of a network of correspondents to build on the experiences and provide methodological support to infrastructure managers and transport operators.

References

Ministry of ecology, sustainable development, transport and housing, 2011, Infrastructures and transport systems action sheet, in *National Climate Change Adaptation Plan 2011-2015*, p.40-41. http://www.developpement-durable.gouv.fr/IMG/pdf/ONERC_PNACC_Eng_part_1.pdf

11 Annex 5: Questionnaire

With the questionnaire we ask you to answer five questions:

A How is the transport sector adapting to climate change in your country?

B What is the information base in your country on climate change impacts on transport sector?

C How is adaptation in the transport sector organised in your country?

D What do you consider as barriers to better adaptation of transport to climate change impacts and are there areas where EU policy could help to overcome these?

E How could the EEA tailor the analysis to better fit your needs?

We ask you to provide your answers in the online form, which will be accessible from 8 March 2013. Until then, you can already collect the material and consult additional experts if needed. Below we list the type of information we request per question.

General notes to assist with completing the questionnaire:

- We ask explicitly for adaptation activities. Adaptation efforts serve to manage unavoidable climate change impacts. Adaptation thus complements climate change mitigation efforts, such as reducing greenhouse gas emissions, which focus on reducing climate change impacts.
- We would prefer information on action at the national level. Yet, and depending on the situation per country, subnational action may also be of relevance as it could support or even substitute national action. In this respect please provide such information where relevant.

A How is the transport sector adapting to climate change in your country?

Depending on the availability in your country, we ask you to provide information listed below. Note, that some initial information you will already find in **Climate ADAPT** or the Overview on national adaptation strategies and plans and the consideration of the transport sector

- National adaptation strategies
- National adaptation action plan
- Subnational adaptation strategy or action plans
- National (eventually subnational) transport strategy or transport plans, which considers adaptation to climate change or extreme events
- Transport sector plans (e.g road, rail, etc.), which consider adaptation to climate change or extreme events
- Action plans from infrastructure managers or service providers, which focus on adaptation to climate change or extreme events
- Risk management plans, which consider adaptation to climate change or extreme events
- National transport standards or guidelines for design and operation, which consider adaptation to climate change or extreme weather events
- Emergency protocols, which consider adaptation to climate change or extreme events or

- Any other plan, strategy, programme, guidelines, initiative, etc. that directly or indirectly considers transport adaptation and that you consider relevant in the context of this questionnaire.

Per entry we ask (tick boxes or short text fields) for

  - Status (Approved, in planning, not available)
  - Title
  - English title
  - Year
  - Part(s) of the transport system considered (transport infrastructure, transport services)
  - Transport mode(s) considered (Road, Rail, Aviation, Inland water shipping, Maritime shipping, Urban transport)
  - Climate change/extreme weather impact(s) considered for transport ((Extreme) Temperatures, Flooding, Sea Level Rise, Storms, Ice and Snow, Water Scarcity and Droughts)
  - Responsible organization
  - Link (if available)

If available, please add information on the state of implementation of adaptation measures for the transport sector: To what level is the current transport infrastructure already adapted to climate change? Have transport services already undergone procedural change? Have adaptation measures in the transport sector been implemented or are they still in the planning phase?

B What is the information base in your country on climate change impacts on transport sector?

Depending on the availability in your country, we ask you to provide information on

- Any major recent (since 2008) assessments or study in your country on vulnerability, resilience or adaptation of transport to climate change at the national (or subnational level).
- Any major recent (since 2008) assessments or study in your country on the vulnerability, resilience or adaptation of transport to extreme weather events only at the national (or subnational) level. (note: Here we ask for relevant additional studies which only consider extreme events but not climate change , for example, disaster risk management.)
- Any relevant national (or subnational) research programme important for the adaptation of transport to climate change or to extreme weather events. Note: We are looking for broader (institutional) research programmes, not for specific research projects.
- Any relevant national (or subnational) knowledge and information initiative, platform or similar initiatives important for the adaptation of transport to climate change or to extreme weather events (e.g. Climate ADAPT at the European level:)
- Any systematically collected data that is relevant for assessing the impacts of climate change or extreme weather events on transport, disruption of transport operations, extraordinary infrastructure reconstruction costs, etc.

Per entry we ask (tick boxes or short text fields) for

- Title
- Language
- Year
- Part(s) of the transport system considered (transport infrastructure, transport services)
- Transport mode(s) considered (Road, Rail, Aviation, Inland water shipping, Maritime shipping, Urban transport)
- Climate change/extreme weather impact(s) considered for transport ((Extreme) Temperatures, Flooding, Sea Level Rise, Storms, Ice and Snow, Water Scarcity and Droughts)
- Organization and/or Author
- Contact (email, phone) and/or homepage
- Link(s) to the document(s)

Optional: Are you aware of interesting cases in your country on the vulnerability of a critical part of the transport system (bridge, coastal road section…) to extreme weather events, which could be relevant to climate change adaptation?
If yes, please provide some further information. We might want to explore this as case studies:

C How is adaptation in the transport sector organised in your country?

Which institutions are responsible for climate change adaptation in the transport sector? You may, depending on your country, name more than one per category. Think also about institutions responsible for disaster risk management. Provide name and website

a. Overall transport system
b. Roads
c. Railways
d. Air transport
e. Inland Waterborne transport
f. Maritime transport
g. Urban transport
h. Other

Describe briefly how these bodies might interact, e.g. how are responsibilities distributed, how are they inter-dependant, what interaction takes place with other bodies at subnational levels, etc.

Are there any private stakeholders in your country (transport companies, unions, NGOs, etc.) which are particular active regarding transport adaptation? These private stakeholders could be an additional source of information to be consulted by EEA. Please provide

- Name,
- Short information of type of activity, transport mode, etc.,

- Part(s) of the transport system considered (transport infrastructure, transport services)
- Transport mode(s) considered (Road, Rail, Aviation, Inland water shipping, Maritime shipping, Urban transport)
- Website and / or contact

D What do you consider as barriers to better adaptation of transport to climate change impacts and are there areas where EU policy could help to overcome these?

What do you consider as barriers to better adaptation of transport to climate change? (Tick relevance (None – low – medium – high – don't know) and provide explanation if needed)

- Lack of awareness
- Knowledge gaps
- Data gaps
- Lack of Training
- Lack of capacities (e.g. appropriate staff)
- Lack of financial resources
- Difficult access to funding
- Lack of coordination or conflicting sectoral policies such as transport-economy-nature protection etc.
- Lack of coordination or conflicting policies between different government levels – between the local, regional, national, EU level
- Other

Which EU activities could support a better adaptation of transport in your country? Tick relevance (None – low – medium – high – don't know) and provide explanation if needed)

- EU adaptation strategy
- Transport information in the Climate ADAPT platform, e.g. risk maps at the European level, guidelines, tools …
- Facilitating trans-national cooperation
- Facilitating the cooperation with key stakeholders, bridging the gap among the transport community and climate change scientists
- Integration of climate change adaptation into other EU policy areas (such as cohesion, transport social, and other policies)
- Funding
- Revision of design standards
- Introducing "climate-proof" as a conditionality to support any transport project or policy (e.g. as proposed for EU Structural Funds 2014-2020)
- Development of methodologies, indicators and thresholds on resilience and vulnerabilities
- Revision of data collection needs and development of new data collection standards
- Transport research for adaptation to climate change
- Other

E How could the EEA tailor the analysis to better fit your needs?

In this section you have the opportunity to provide us ideas on how we should prepare the results of this survey, which areas we should further explore, what we should focus on in the future, etc. This will enable us to better tailor our activities on adaptation and transport and to provide additional benefits for EEA member states.

If there are additional professionals in your country who you would recommend us to contact, please provide their contact details and area of expertise