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Adaptation to Climate Change – Task Group under CEDR

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Abstract

Conference of European Road Directors, CEDR, initiated work on studying the effects of climate change on roads. The work belongs to Strategic Plan 2 (2009-2013), Thematic Domain Operation and is organised as twin tasks dealing with adaptation on one hand (task 16) and mitigation of climate change on the other hand (task 17). This paper describes the work within task group 16 on adaptation to climate change, from the initiation of the work to the publishing of the report to CEDR, October 2011. The mandate of the adaptation group can be summarised as follows: Show the consequences of climate change for infrastructures, and propose actions towards adapting the road network and management procedures to climate change. The work started by performing two surveys in road administrations in the participating countries: a survey of risks related to climate change, and a survey of ongoing adaptation work.

The report to CEDR consists of a summary of the results of the surveys, and is followed by a more detailed examination of the effects of climate change on the road network. Suggestions for adaptation work are offered and criteria for prioritising possible actions are proposed. A thematic collection of examples demonstrating adaptation work in the participating countries is integrated in the report. Some of the examples refer to R&D programmes. Others describe current practice in one country that may be useful and relevant for application in another country. The report also suggests topics for future research, including opportunities for trans-European joint research programmes.

Keywords: Climate change adaptation; National Road Administration; national policies; risk assessment; road planning; road maintenance

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1. Introduction

Conference of European Road Directors, CEDR, initiated work on studying the effects of climate change on roads. The work belongs to Strategic Plan 2 (2009-2013), Thematic Domain Operation and is organised as twin tasks dealing with adaptation to climate change (task 16) and mitigation of climate change (task 17).

The goal of the report written for CEDR was, in accordance with the mandate, to outline the main consequences of climate change for road infrastructures and to propose actions for adapting the road network to climate change. This paper describes the work within task group 16 on adaptation to climate change, from the initiation of the work in May 2009, to the publishing of the report to CEDR, October 2011.

2. The Climate in Europe

Climate in Europe will change during the 21st century. Model predictions indicate that the mean annual temperature will rise by 1° to 5.5°. While the annual precipitation is likely to increase in the north and decrease in the south, the intensity of daily precipitation and the probability of extreme precipitation intensities can increase in all regions. Mean annual wind speeds are expected to increase in the northern regions as well, while they might decrease in the Mediterranean regions. Extreme wind speeds can increase in western and central Europe and in the North Sea area. As a consequence of climate change, the sea level in some areas is likely to rise by up to 0.9 m by the end of the century.

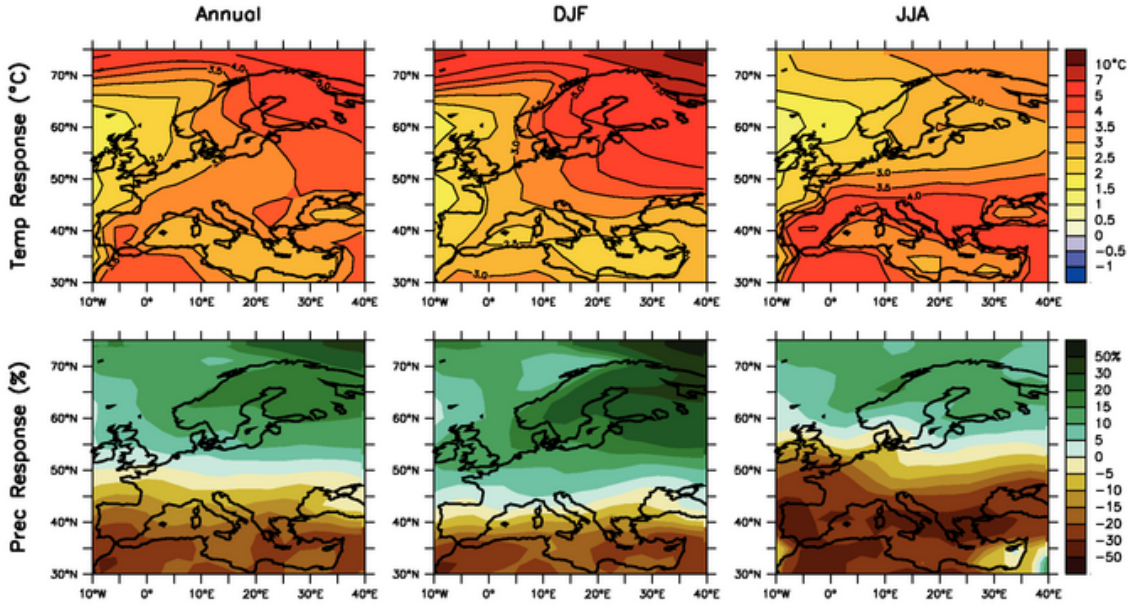

Fig. 1. IPCC's Physical Science Basis section of the 2007 report, Figure 11-5:
(a) Annual mean, winter (DJF) and summer (JJA) temperature change between late 20th and late 21st century.
(b) Annual mean, winter (DJF) and summer (JJA) change in precipitation between late 20th and late 21st century

Europe can roughly be divided in two main regions, see Fig. 1: northern and eastern Europe, where warmer and wetter winter seasons will impose the main challenges, vs. southern, western and central Europe, where climate change challenge will be dominated by warmer and dryer summers.

Climate change will modify the actual risk levels and therefore challenge design rules and procedures for the operation and maintenance of the road infrastructure. There will be an increase in unusual climatic events with significant impacts on infrastructures, operations and the economy at large. For road owners, adaptation to climate change should be included in current and future procedures covering all aspects of road planning, design, maintenance and operation.

3. The challenges to the national road administrations (NRAs)

Two important surveys were performed among the NRA-members of the task group. The aim of the first survey was to map the awareness of the NRAs about climate change issues: Which specific problems are already observed? Are the NRAs prepared to deal with them? The second survey was performed to obtain an overview of ongoing work concerning adaptation to climate change.

3.1. Risks related to climate change

In northern and eastern Europe the expected increase in winter temperatures could lead to more frequent freeze/thaw cycles in areas with stable winter conditions today. This may lead to frequently reduced road friction, and increased use of de-icing chemicals. This may also yield frost heave damages and require more frequent pavement renewal. This is a concern that is referred to by the northernmost countries. Other issues pointed out, though as less severe, are a possible increase in frequency of rock fall, and the loss of permafrost as an important load-bearing capacity factor, for example in Sweden, causing increased road deterioration and problems for heavy goods transport.

In southern, western and central Europe main risks are related to a higher frequency of days with extreme maximum temperatures and generally warm summer months. These changes affect negatively mainly pavement conditions and durability of pavements/surfaces. Higher winter temperatures in central Europe could lower the demand for snow clearing, but at the same time increase the need for de-icing, where rainfall on cold road surfaces reduces friction.

A probable increase of winter precipitation in western, northern and central Europe could generally lead to higher operational costs (snow clearing and salting) and require improved emergency plans, winter maintenance guidelines and traffic safety measures. Increased snow fall (both amount and intensity) raises the risk for avalanches and may yield higher investments in protective installations. Norway and other member countries point out the need to develop landslide and avalanche risk models, better tools for predicting avalanches and avalanche alert systems.

A substantial decrease of summer precipitation, combined with an increase of temperature, in southern and central Europe will directly lead to more severe and prolonged drought periods, possibly introducing a risk of more frequent wildfires in new areas.

In the whole of Europe, and especially in some regions in northern Europe, there is a risk of increase in the intensity of daily precipitation and the probability of extreme precipitation events. This may cause more frequent flooding in existing drainage systems due to insufficient capacity. It may also cause erosion and landslides, a risk pointed out by all member countries. Adaptation of guidelines for the design of appropriate culverts, drains, bridges, erosion and landslide protections will be necessary. Problems due to stronger winds or storms are by the member states of this task group generally not considered as very severe.

Roads in coastal areas are at risk from anticipated changes in sea level. Especially Sweden, Norway, Denmark and France report concern for existing low-lying road sections, ferry berths and sub-sea tunnel portals. Besides the need for a better analysis of probable sea levels, design guidelines for sea defences against wave erosion will have to be adapted and implemented.

3.2. Ongoing work in the NRAs

Work on adaptation to climate change has started in almost all of the member countries. However, differences are large concerning the type of work, approach and anchoring to political initiative.

In some of the member countries a political initiative towards climate change adaptation has been taken in the form of a national policy. Depending on the level of detail, these policies can be thematic, identifying transport infrastructure as an important subject for adaptation. Regardless of that, most of the participating NRA's have acknowledged adaptation as an important task in the long term strategic planning. However the development of formal adaptation strategies varies between the countries.

The Finnish Transport Agency has published a long term plan Liikenneolosuhteet 2035 (Transport conditions 2035), which is an appraisal by an expert of what the transport sector will be in 2035 and how to get there. It includes guidelines for transportation system work and road management. It visions a sustained level of service even if flooding, wind, more intensified rainfall and zero-temperatures become more frequent.

The Norwegian National Transport Plan contains the Ministry of Transport and Communications' recommendations for the government's transport policy and a strategic plan for development of the overall state infrastructure for transport by road, rail, air and sea. Although adaptation to climate change has been the subject thematic reports that two consecutive plans have been based on, a separate adaptation strategy has not yet been formulated, neither for the road administration or the transport sector as whole.

In May 2011 the United Kingdom Government published Climate Resilient Infrastructure: Preparing for a Changing Climate, which sets out the Government's view on adapting infrastructure in the energy, ICT, transport and water sectors to the impacts of climate change. The Highways Agency's response to the challenge of climate change must involve both mitigation and adaptation. The Highways Agency's commitment is to assess the potential risks that climatic changes pose to the ongoing management, maintenance, improvement, and operation of the strategic road network, and develop appropriate management and mitigation solutions to remove or reduce these risks. The Highways Agency developed the Highways Agency Climate Change Adaptation Strategy and Framework in 2009.

Many of the participating NRA's are involved in collaborative national projects driven by other domestic institutions. In many cases research projects and programs on climate change have been initiated by the NRA's themselves. Some examples of recent research work are; the Swedish programme "Natural events with negative consequences for society of today and tomorrow's climate", the Norwegian project "Climate and Transport", and the Finnish research project ILMATIE.

Last but not least, it should be mentioned that many of the participating NRA's have contributed to the collaborative research programme "Road Owners Getting to Grips with Climate Change" that was initiated by ERA Net Road. The programme was launched to exploit synergies and minimize double costs in developing common knowledge, adaptation tools and strategies. The programme resulted in four successful research projects covering some of the most important topics shared by European NRA's.

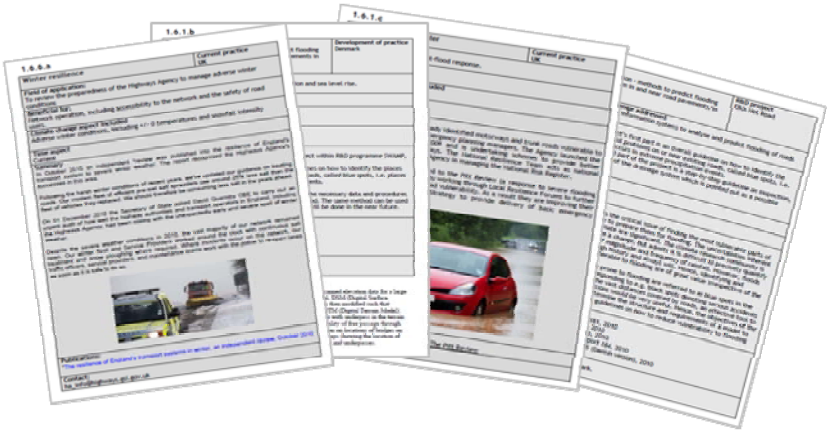

Fig. 2. Report for CEDR contains a thematic collection of examples demonstrating adaptation work in the participating countries: research and development programmes specially dealing with adaptation to climate change or current practice relevant for adaptation work.

4. Effects of climate change on the road network

Climate change, as described by the projections from global and regional models, will bring about a number of challenges for the road network in Europe. In most cases this will be today's challenges, but on a larger scale, occurring more frequently and at other locations than expected. In addition, we may experience more of unusual weather combinations, e.g. winter floods. In some cases climate change may be beneficial for the road owners, e.g. in places where less snow can be expected.

The most important issues to address are:

- More flood and erosion – a challenge for drainage systems, erosion protection and for the design and maintenance of culverts and bridges,
- Landslides and avalanches: occurring more frequently, at new locations and with a higher share of "wet" landslide types, such as slush avalanches and debris flow,
- Droughts and high summer temperatures may impose problems for the asphalt surfacing, due to softening, but also for runoff conditions, due to lower permeability. Risk of wildfires may also increase in the southernmost regions.
- Deterioration of roads and pavements – i.e. increased rutting and reduced service life, mostly in cases where the drainage is insufficient,
- Effects of sea level rise on coastal stability and importance of ensuring sufficient elevation for roads, quays, and bridges, as well as sub-sea tunnel portals,
- Heavy snowfall in mountain areas of northern Europe, causing trouble for winter maintenance and operation,
- Risk management and efficient procedures for initiating remedial actions after an unwanted event occurs – due to the fact that present protective measures may not be sufficient and that the planning of remedial measures requires time.

All of these effects can be recognised in all phases of road management: planning, design, construction, maintenance and operation. The challenges should be addressed as soon as possible. Some

problems in the operation phase can be avoided by adequate planning or design. These issues will be addressed in Chapter 5.

On the other hand, repair and reconstruction does not necessarily have to be done as soon as the problem occurs. Adaptive measures should be incorporated in planned maintenance and reconstruction, dependent on the detrimental climate parameter and the remaining service life. These issues are the subject of Chapter 6.

5. Adaptation to a changing climate according to working operations

5.1. Planning

By considering the effects of climate change already in the planning phase of a project, difficulties in the operation phase can be avoided. Some examples are:

- Vertical alignment of the road, ensuring sufficient elevation with respect to flooding and sea level. Horizontal alignment, avoiding landslide risk zones, or coastal erosion, and minimising the consequences of crossing waterways.
- Planning of water management: drainage systems ensuring efficient run-off and pollution control, sub-surface drainage, extended use of retention ponds, planning flood ways and alternative waterways.
- Considering the needs in maintenance and operation already in the planning phase.

5.2. Design and construction

Climate change will require adaptation of design rules in order to ensure sufficient drainage capacity and erosion protection, define adequate quality requirements for road construction materials, manage landslide risks and implement measures to ensure protection of the environment.

Ensuring sufficient capacity of drainage systems is one of the most important adaptation measures. Adaptation of design standards is already taking place in several countries. Maintenance of existing drainage structures should be carried out with respect to future needs, and if possible as a part of planned regular replacement of old systems.

Bridges need good erosion protection and robust foundation. This concerns the choice of sufficiently robust type of foundation and erosion protection, and the choice of adequate design flood values. In addition, requirements for free height above the water level and the effect of drifting ice should be revised.

Landslide protection should probably be more robust in in a wetter climate. In could also be expected that landslides occur at new places. The main issues are: description of risk related to weather parameters, planning and prioritising protection measures. Improved prediction models and risk assessment methods are needed for optimising preventive actions. The risk of “wet” landslide types, such as debris flow and slush avalanches, should be assessed.

Road structure and pavements should be designed to withstand high summer temperatures or difficult friction conditions around 0-temperatures. Remedial actions to be taken in cooperation with the contractor are: use of stiffer binders suitable for higher pavement temperatures, design of asphalt resilient to freeze-thaw effect and salting, hydrophobic pavements which reduce the slipperiness in exposed areas, and hydrophobic structure treatment, which can keep the water away from the structure and reduces frost-heave problems.

Environment protection will be even more important in a wetter climate. The design and placement of sedimentation basins should be done in a way that they can be used for retention of flood water as well.

Ensuring corridors for wildlife in new conditions in a future climate is an important part of the design. Maintenance of green surroundings for providing visibility may require more attention due to better growth conditions.

Signs and lighting along the road network can give higher safety and better mobility in a wilder climate.

Contracts that are composed for a longer contract period (for example if construction and maintenance are included) must take into consideration climate change.

Fig. 3. Debris flow, such as over E6 in Rosten, Norway, may occur more often in a wetter climate (foto: Niklas Eriksson, NPRA)

5.3. Maintenance and operation

Maintenance and operation of the existing road network is probably the arena where most of the adaptation work needs to be done. This includes risk assessment, through identifying potential risks and vulnerable assets, and risk management related to unwanted events, including both preventive measures and emergency plans. Risk assessment and risk management can be seen as tools in almost every working procedure. Therefore there should be common principles for how to use them, at least at the national level.

Inventory of vulnerable assets is good basis for adaptation. It is an investigation of the actual capacity of the road network to withstand more severe conditions than designed for. Since available funds in general are sparse, there is a need to provide information which helps in assigning priorities. Developing guidelines for better inventory of assets along the road network implies developing good risk- and susceptibility analyses, which should contain: criteria for identifying especially exposed or vulnerable assets, procedures for calculating their effective capacity, plans for improved (e.g. more frequent)

inspection and better maintenance procedures (e.g. proactive measures in response to unfavourable weather forecast), and plan for repair. Adaptation measures should preferably be undertaken together with planned maintenance or repair.

Inspections should be more detailed and/or more frequent in a harsher climate, especially if the asset it not designed to withstand today's climate.

Winter maintenance is mainly an everyday operation in which the operation models can be changed rather quickly in order to suit the working environment. Planning should be done with a perspective of 5 to 10 years. There seems to be a need to refine the operation models of winter maintenance in the near future, to optimize the resources, working methods and level of service for more intense snowfall. More attention has to be paid to the environmental hazards of salt.

Maintenance backlog is a usual problem on road networks. The level of practically feasible maintenance is closely connected to the technical standard of the roads. Eliminating the backlog and ensuring proper maintenance would by far mean adapting to climate change.

Preparedness and emergency plans are even more important in a challenging climate. It is impossible to avoid all negative effects of climate change. We need to be prepared for the consequences. We have to have operation models on how to react to risks. Emergency plans are needed to ensure operation and avoid losses. The operations are mainly on regional levels or on local levels, but it is necessary to set some principles on the national level. The main parts of incident management are prediction models, and planning of the operation models for unexpected situations. It is also important to have a plan for cooperation in emergency cases. All operators should know their roles and must act accordingly. Some of the most severe effects of the climate change should also be rehearsed in advance.

Traffic management in challenging conditions or after unwanted events on the road is an important tool for avoiding further accidents or traffic jams, or other harm to the road users. This includes use of good monitoring systems for traffic control, rerouting, improving road user information systems, efficient communication of risks or danger to the road users etc.

Self-monitoring structures**:** For the most vulnerable assets there might be a need to use more complex monitoring systems which also utilise information collected from road users and communicate the risk.

Contracts for operation should be formulated bearing in mind that climate change can affect the working conditions. The contracts should state how the risk will be divided between the procurer and the contractor. It is necessary to reconsider and redefine the standard conditions, which are the basis for a contact, as opposed to the unexpected conditions, which do not have to be covered by the contractor. An operational model for unexpected situations (i.e. situations requiring more equipment than available) has to be provided.

6. Knowledge base, now and in the future

Adaptation to climate change is dependent on a good and always developing knowledge base, not only in the field of work of the road administrations but also from other professional fields, especially meteorology, hydrology and geology. Interpretation of climate research for practical use is a precondition for adaptation. The most important parameters are: rain intensity, projections of flood values, wind, storm frequency and sea level rise. Improved monitoring of climate parameters, documentation of the condition of assets, and registration of events on the road network improve the knowledge basis for adaptation already 20 or 30 years from now and ensure more reliable adaptation measures in the future. Finally, good interface solutions are necessary, such as web portals for weather and road data. We need functional databanks for landslide data, improved documentation of landslide and avalanche events in every-day operations.

The effect of climate change on roads is an endless source of topics for necessary research, e.g.:

- the relation between climate parameters and landslides, avalanches, “wet” landslide types,
- effects of weather combinations: heavy rain on frozen ground including melted snow,
- combined effects of sea-level rise, storm surge and coastal waves,
- improving models for simulating the effects of climate on pavements and road sub-bases, integrating regional climate and hydrological models.

Coordination of research and education activities enhances adaptation work: dissemination, knowledge transfer and implementation of research results, trans-European joint programming, raising awareness of the general public and politicians, ensuring that academic education includes adaptation issues.

More effort should be put into the calculation of costs related to climate change. It is a difficult task due to many uncertainties in the future situation. However, it is necessary for better prioritising of remedial actions.

7. Criteria for choosing and prioritising adaptation measures

Climate projections will always be uncertain. Managing uncertainty will therefore be an important part of adaptation work. The CEDR task group advises the NRAs to act now, despite uncertainties in climate projections. The available knowledge is sufficient for formulating adaptation measures. However, these measures have to be chosen rationally. Throughout the service life of a structure, sufficient safety has to be achieved for available resources.

Required safety levels (or corresponding levels of acceptable risk) are difficult to define in general terms. However, a required safety level can and should be recognised in each particular case, and should be a part of the basis for making decisions concerning adaptation measures. The design life of a new structure (or the remaining design life of an existing structure being assessed) must be seen in relation to the time aspect of climate change. It is not necessary to take into account climate aspects that will not be fully developed during the service life of a structure. The time aspect should also always be seen in relation to the projected development in the most detrimental climate parameter: e.g. precipitation intensity for drainage capacity, sea level rise for planning of sub-sea tunnels etc.

For existing structures it is preferable to perform adaptation measures as a part of planned maintenance or repair. When performing repair, one should design the measures based on design values that will be valid for the remaining service life of the structure.

- In some cases it may be better to accept a certain level of damage (and cost of repair) than to avoid damage altogether. Cost-benefit analyses provide a good basis for decisions;
- If the acceptable level of disturbance is already exceeded, one cannot wait. In addition, waiting is advisable only if it is followed up by monitoring the condition of the structure and the development in the most important climate factors;
- In formulating contracts for maintenance and operation more effort will be required for defining the “normal” or standard situation, and for deciding how risks and consequences of unfavourable weather should be divided between the authority and the contractor;
- Experience from finalised contracts should benefit new contracts. Performing the most necessary repair of the road before a contract period provides better possibilities for good maintenance. Climate change makes this relation even more important!

Regardless of the national administrative and climatic differences, there are some actions with a beneficial effect, or no-regret actions, which can be carried out immediately:

- The maintenance backlog and keeping up the planned maintenance is a challenge on almost all road networks. It is, however, a crucial element for adaptation to climate change. The maintenance backlog

increases the vulnerability to climate effects, which in the next round further increases the damage and repair needs.

- Improving the knowledge base through collaboration with research environments in meteorology, hydrology, geology etc. and communication of needs is important for reducing uncertainties in the future. Improving documentation of events on the road network, and performed maintenance or repair, data on "small" assets such as culverts will provide the NRAs with a better starting point for climate adaptation.
- Improving preparedness can prevent the loss of life and reduce damage and costs, already today.
- Contracts for maintenance which include better information about risks, improved monitoring, inventory and emergency plans are beneficial for management, both today and in the future climate.

8. Conclusions

The following effects of climate change are most important to address: flood and erosion, landslide, rock fall and avalanches, droughts and high temperatures, effects leading to increased deterioration of roads, effects of sea level rise, winter operation, risk assessment and management, and the calculation of costs.

All implications of climate change should be addressed at as an early stage as possible.

Planning: alignment of roads avoiding excessive exposure, comprehensive plans for management of runoff water, early considering implications on maintenance;

Design and construction: ensuring sufficient drainage capacity and sufficient erosion protection, revising design rules for adaptation to higher climate loads, developing models for more analytical risk assessment for landslides, designing robust pavements resistant to high temperatures, taking care of environmental issues: pollution control, fauna etc, considering implications of road design on maintenance, taking care of climate issues in construction contracts;

Maintenance and operation: risk assessment in all phases, at all levels (identifying the most vulnerable assets according to predicted climate change, mitigating damage, prioritising needs), risk management related to unwanted events (preventive measures following forecast, preparedness and emergency plans for managing situations after unwanted events), taking care of maintenance backlog – a drawback for road management in general, preparing for more demanding conditions for winter operation (by good contracts, emergency plans etc.), efficient traffic management (communication of risks under unwanted events and rerouting, use of good monitoring systems for traffic control), improved contracts (better definition of standard vs. exceptional condition, methods for sharing risk, robust requirements for inspection routines and documentation).

The knowledge base for adaptation should be developed by improved monitoring, mapping, and documentation of events on the road network. Further research is necessary for obtaining more knowledge on the effects of climate change on the road network, developing ways of defining acceptable risk and risk-based specifications. Raising awareness of stakeholders and the general public on the importance of adaptation is also important.

Prioritising: Adaptation to climate change should begin already in the planning phase of a road project and should be included in all other working procedures. For existing infrastructure, adaptation measures should be carried out as a part of planned maintenance or repair. The measures have to be chosen in a way that sufficient safety is achieved during the (remaining) service life of the structure. Postponing action is advisable only if it is followed up by monitoring the condition of the structure and the development of the most important climate factors. In some cases, accepting damage and the costs of repair may be the best solution.

However, defining the acceptable level of risk is a difficult task. It is also difficult to define the standard or "normal" climate valid for the service life of a structure or for the duration of a maintenance contract. This accentuates the need for good contact with expert offices in meteorology and hydrology and for good contracts for maintenance and operation.

The following no-regret actions are pointed out: reducing the maintenance backlog; improving the knowledge base through research, communication of needs, documentation of events and performed maintenance or repair; improving preparedness; and formulating maintenance and operation contracts which include better information about risks, improved monitoring, inventory and emergency plans..

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This paper is a short version of the report "Adaptation to climate change - Task 16" of October 2011. For the complete list of references, please see the full report, available from the CEDR website: www.cedr.fr.