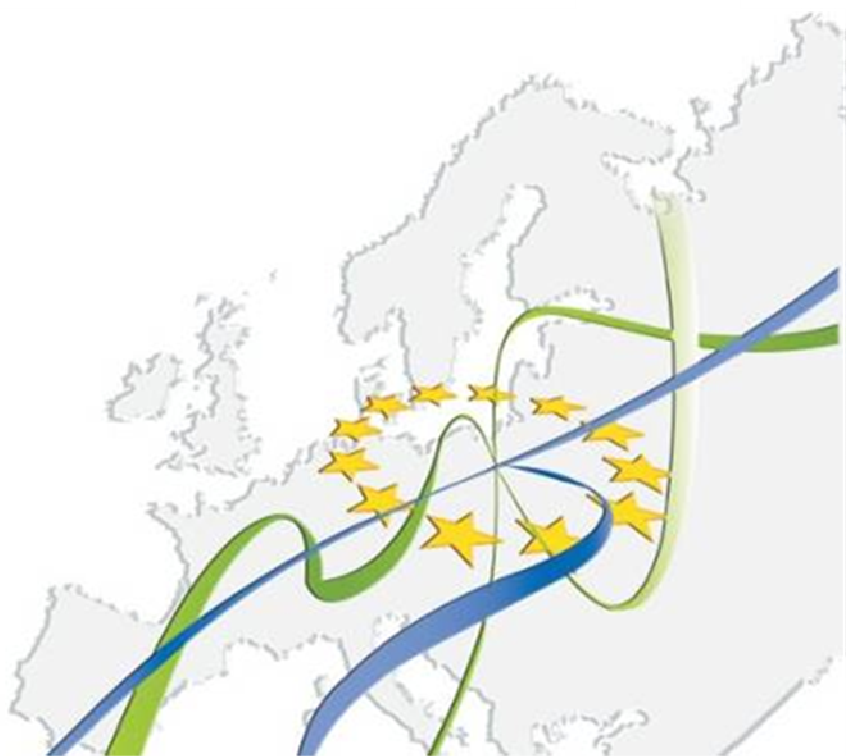




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European Roadmap **Climate Resilient Road Transport**

Version May 20, 2011



- A reliable transport system is essential to the functioning European society
- The financial external cost of network interruption from extreme weather events is significant
- Climate change will increase the severity and frequency of extreme weather events and thereby lower the reliability of the transport system
- Given the long life cycle time of infrastructure, action is needed urgently
- The following headline actions are proposed:
 - Assess climate change models
 - Identify vulnerabilities on the key European transport networks
 - Establish future service levels
 - Identify technologies for climate change adaption
 - Identify key high risk points on the network
- The R&D funding for to achieve a European Climate Change resilient transport networks will be relatively low, but will increase significantly once Full Scale Field Operation Tests are under construction

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Terms used¹

Mitigation means taking action to tackle the causes of climate change, that is reducing concentrations of greenhouse gases in the atmosphere.

Adaptation means taking action to deal with the consequences of a changing climate, resulting from increased levels of greenhouse gases. This document will concentrate almost entirely on adaptation.

¹ Adapting to climate change – UK Climate Projections 2009. UK Department for Environment, Food and Rural Affairs - www.defra.gov.uk/environment/climate/documents/interim2/climate-uk-projections.pdf

Executive Summary

An efficient and reliable transport system is essential for the society, for the transport of goods, for employment and for leisure. Currently, Europe's transport systems struggle to cope with extreme weather events, and climate change is predicted to increase the frequency and severity of certain weather events. Additionally, traffic prognoses show that freight volume transported on roads will increase by approx. 70% until 2030 (prognosis for German motorways).

The entire transport infrastructure (road, rail, sea and inland waters) will be significantly impacted by climate change, affecting the way Europe's transportation sector plan, design, construct and maintain infrastructure in the future.

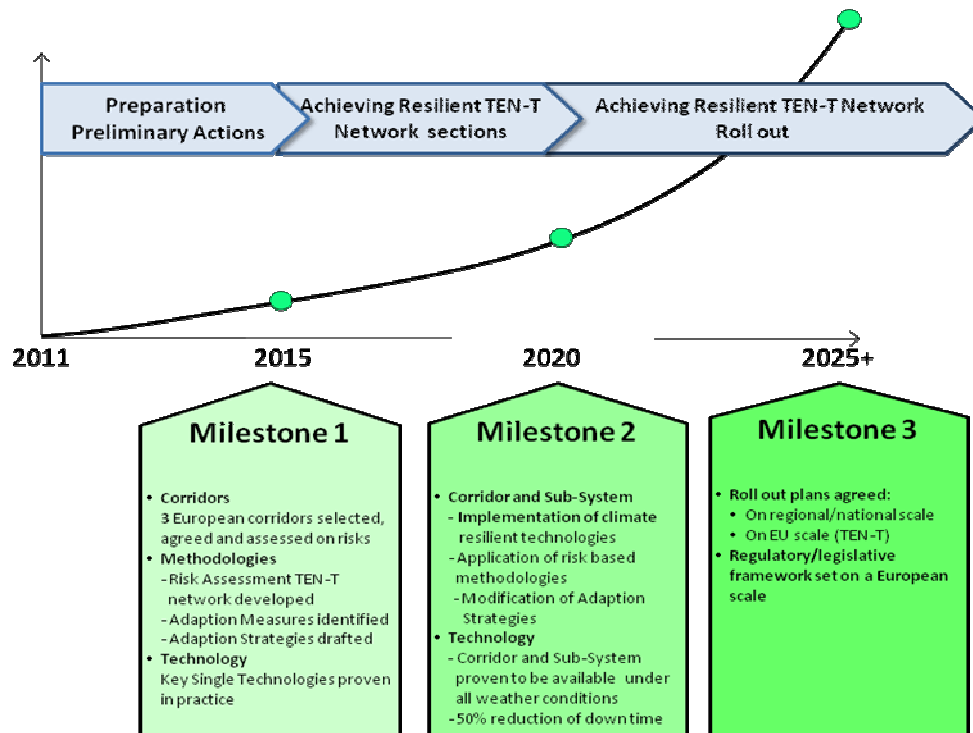
On the basis that there will be significant impact from climate change, and considering that all eventualities cannot be catered for, this roadmap aims to determine how road transport infrastructure shall adapt to the inevitable changes.

Facing this situation road authorities need to be supported with appropriate strategies to ensure reliability, availability, maintainability and safety (RAMS approach) of road infrastructure.

Whilst there are many initiatives that will look to mitigate the effects of climate change through the adoption of low carbon technology, some impacts are inevitable, and this roadmap sets out the steps required to maintain, and ideally improve the resilience of the three key transport networks (road, rail and inland waterways) to extreme weather events, and specifically the key TEN-T European transport networks. The key guiding objective to which the milestones will relate is as follows:

A climate resilient transport network will ensure that key corridors will be available to the user in all weather conditions.

The following figure outlines the key steps and timescales that have been proposed.



The 'headline' tasks proposed are:

- Selection of 3 European corridors
- Identification and modelling of climate change effects.
- Risk based vulnerability assessment for TEN-T Network.
- Adaption Technology identification, proving, integration and roll out.
- Development of adaptation strategies and their implementation for existing infrastructure.

Extreme weather events currently cause significant disruption to transport networks and Climate Change may amplify this. As such the potential impacts of Climate Change cut across many of the other roadmaps including; Sustainable Long Distance Freight Transport, Urban Mobility and Road Transport

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1. Introduction

There is widespread scientific consensus that climate change due to human activities is real, and that regardless of the international response, some effects are inevitable. Notwithstanding the uncertainties, significant warming is predicted (greater in northern Europe in the winter, and greater in southern and central Europe in summer), mean annual precipitation is forecast to increase in the North and decrease in the South, whilst flooding events and droughts will become more common. Coastal regions will be at greater risk of flooding from increased storm events and sea level rise.

Safe and efficient transport systems are essential in the functioning of business and society; the disruption caused by extreme weather events such as snow, flooding or heat are evident. This will have implications for all travel modes.

The consequence of increasing weather extremities due to climate change could be a related loss of network availability and subsequent reduction of transport reliability and accessibility to urban and economic areas, as well as increased accident frequency and severity. Climate change can also manifest itself by gradual changes in climate parameters. Unlike extreme weather events, gradual changes can go unnoticed but still have effect on the durability and functioning of road infrastructure, like steady increases in temperature, sunshine (UV exposure), seawater-level and changing groundwater-levels.

The economic costs of current extreme weather events are significant, even for relatively limited losses of availability, as the recent examples below show²:

- The Belgian road haulage association, FEBETRA calculated that the 5 days during which some 30,000 trucks were blocked in Belgium cost the sector and the economy some 99 million Euros.
- The French road haulage association FNTR calculated that winter conditions in France in December 2010 cost a loss in turnover of about 150 million.

2. Scope and Approach

Climate change is real and impacts all aspects of road transport. Currently, the transport network struggles with extreme weather events, and these are likely to increase in frequency and severity. Additionally, traffic prognoses show that freight volume transported on roads will increase by approx. 70% until 2030 (prognosis for German motorways).

On the basis that there will be significant impact from climate change, and considering that all eventualities cannot be catered for, this roadmap aims to determine how road transport infrastructure shall adapt to the inevitable changes. This will affect design, construction, maintenance and operation of new and existing road infrastructure.

Facing this situation road authorities need to be supported with appropriate strategies to ensure reliability, availability, maintainability and safety (RAMS approach) of road infrastructure.

This roadmap aims to support road authorities using a stepwise approach. The first step consists of an analysis of regional climate projections. On the basis of this projections road relevance scenarios are to be developed. Using these scenarios holistic vulnerability analyses can be conducted.

² Written communication from Marc Billiet, Head EU Goods Transport, International Road Transport Union (IRU). January 21st 2011.

Finally, risk based approach and economic assessments can be used for the identification of sustainable adaption measures.

3. Transport System Vulnerability to Climate Change

Some uncertainty exists about the potential impacts that climate change may cause, not least because of uncertainty as to the international response in reducing greenhouse gas emissions (mitigation). Nonetheless, it is generally accepted that there has been an impact on climate patterns, and this will continue to a greater or lesser extent. The purpose of this roadmap is not to go into scientific details of climate change, but to examine what potential impacts there might be, what impact that might have on the transport infrastructure, and what adaptation measures might be required. The predicted impacts and resulting vulnerabilities are considered below.

Potential temperature and rainfall patterns across Europe are presented below, showing a general increase in temperature across Europe, but particularly in the far south Mediterranean areas, in Eastern and the far north of Europe and in mountainous regions. This generally corresponds with a decrease in precipitation in southern Europe and an increase in northern Europe, although this is unlikely to be uniform. The United Kingdom and northern France show virtually no change, however it is possible that the summers will be drier, whilst winters will be wetter.

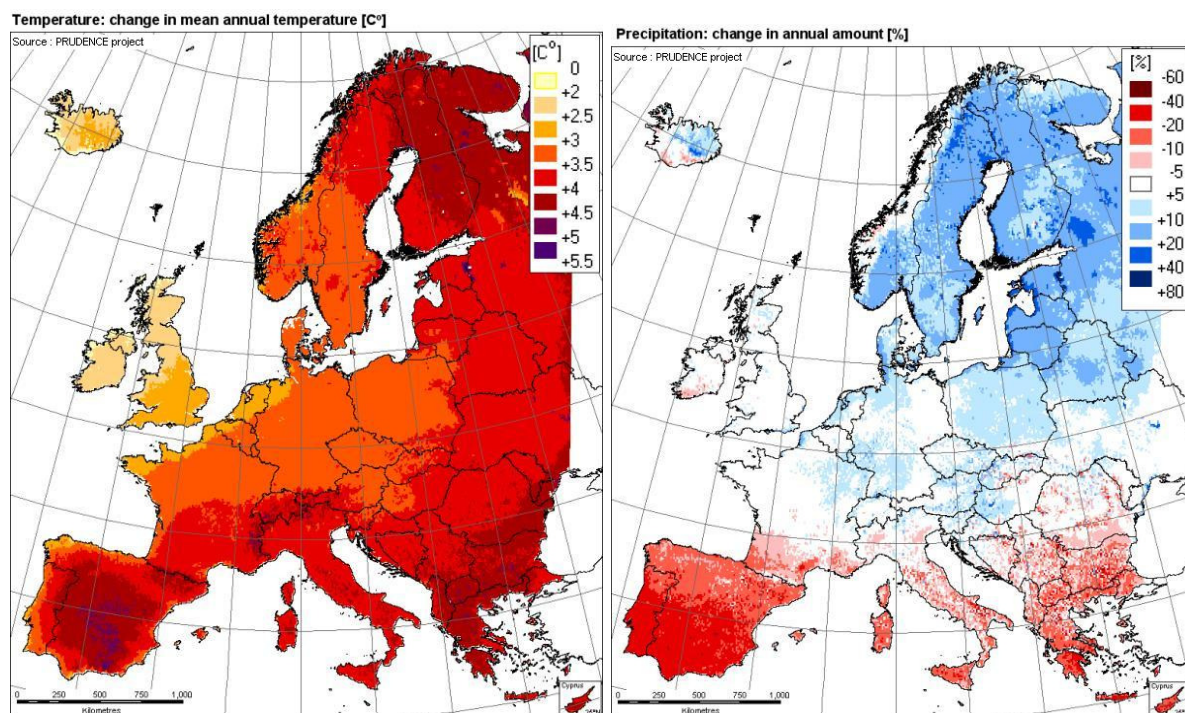


Figure 1 Change in mean annual temperature³ (left) and mean annual precipitation⁴ by the end of this century (taken from <http://peseta.jrc.ec.europa.eu/docs/ClimateModel.html>)

³ Absolute change in mean annual temperature between control period 1961-1990 and 2071-2100, under the IPCC SRES scenario A2. Data from EC-funded project Prudence (HadCM3 global circulation model, and HIRHAM regional climate model in 12km resolution), map elaboration by EC JRC/IES.

⁴ Relative change in mean annual precipitation between control period 1961-1990 and 2071-2100, under the IPCC SRES scenario A2. Data from EC-funded project Prudence (HadCM3 global circulation model, and HIRHAM regional climate model in 12km resolution), map elaboration by EC JRC/IES.

As the climate changes, extreme weather events like heat waves, droughts heavy rain and snow, storms and floods are becoming more frequent, more intense and longer lasting. Vulnerability to climate change varies widely across regions:

- Generally, it is rainfall that would cause changes in groundwater levels. This can cause problems for relatively low lying countries with islands and extensive coastlines. For example, changes in groundwater levels have been reported to have an impact in Denmark, causing 'blue spots' where sea level change will affect land drainage causing groundwater to reach the surface temporarily or permanently, causing road closures⁵.
- In Europe the Mediterranean area is becoming drier, making it even more vulnerable to drought and wildfires.
- Northern Europe, meanwhile, is getting significantly wetter, and winter floods could become common.
- Europe's far north, the Arctic and Outermost regions (due to increased global warming).
- the Alps (due to rapid melting of snow and ice)

4. The European Ten-T Network

In considering strategies to deal with the impacts of climate change on the European transport network, it is likely that a staged approach will be implemented. There are key road, rail, inland waterways, ports and airports across European Member States whose continued efficient function is vital to maintain European economic competitiveness. It is these transnational assets that will require the immediate focus, followed by national, regional and local transport networks.

The Ten-T European network represents the key trans-national assets of road, rail and inland waterway / ports. In addition to these, key airport terminals such as London Heathrow, Paris Charles de Gaulle, Frankfurt and Schiphol could be added. The continent has significant coverage of roads, and similar network of rail links, although a smaller network of high speed links. The inland waterway network is largely concentrated around northern and central Europe, with key seaports in northern France, Belgium, the Netherlands and Germany, with many of these representing modal hubs. For example, from Europe's largest port of Rotterdam, goods can be transported by road, train or inland waterway. The protection of these assets against possible effects of climate change is imperative.

5. Transport Service Levels

In recognising that climate change will have various impacts in various regions of Europe, and that there is a critical network of transport modes that require protection, an obvious starting point would seem to be to determine, firstly, the key infrastructure assets that might be at significant risk, and to agree service levels for various tiers of infrastructure.

For example, for the Tier 1, Ten-T networks that are key European transport corridors, it might be required that they operate at 99.99% availability, whereas local roads might be assigned a lower availability level based on the cost-benefit of keeping operational. The point at which the service levels are set will have a significant bearing on the required adaptation measures.

The transport system in Europe is made up of the road, rail and inland waterway systems. As the dominant sector in terms of passenger and freight movements across Europe, the road sector is one which offers the greatest flexibility in terms of re-routing opportunities. In order to determine the

⁵ Kristiansen, J R: 2010. Rising groundwater levels can cause permanent flooding of roads. Transport Research Arena Europe. Brussels.

roadmap and the milestones, the first step is to determine what is envisaged by a climate resilient road; i.e. once a target is defined, the steps to achieve that target can be identified.

It will not be possible to make a road, or transport system totally resilient to climatic events, and certainly not at an acceptable economic cost. The ultimate milestone (with a realistic target for 2050) would be that:

In 2050 a blocked route will not affect the capacity / performance of the network'

In the 2025 to 2030 timeframe the following specific targets are considered appropriate:

- Only the core network (TEN-T) can be made resilient
- Service levels should be set, specifically with a target for a reduction in downtime of 50%; this will cover all aspects of downtime, and not just that related to weather events.
- Several corridors will be resilient, with downtime reduced by 50%.
- For reconstruction and new building the roads should be designed to be resilient, and vulnerabilities should be accounted for and/or avoided. This requires 'Intelligent Road Design'.
- There is a challenge in competence and skills shortage currently which should be addressed.
- Maintenance and management cost effects and long term (life cycle) effects should be accounted for.

The proposed target for 2025 is shown below, and the milestones presented in this document will be geared towards this target.

In 2025 a climate resilient transport network as a whole will ensure that key routes are available to the user in all expected weather and climate conditions.

Effectively this means the network service might be limited for an acceptable period of time, but the transport routes that are key to the European economy and society may not be blocked. Selection of key routes will be subject to a cost-benefit evaluation over the corridors/routes involved.

6. Research and Innovation Themes

The current transport system cannot grow with demand and so there is a balance to be made in ensuring that the future transport system is accessible, can satisfy the requirements for sustainable economic prosperity, and yet which will be resilient to climatic impacts. This requires a holistic solution which will cover development and implementation of technologies and methodologies, management and adaption strategies as well as specification and introduction of technical regulations.

The research and innovation activities focus on a broad range of themes. The key fields are highlighted below:

Development and implementation of methodologies

1. Development of a tool for risk-based methodologies assessing vulnerabilities of the road network. Analysis of vulnerability of road network and detection of potential affected road network elements inclusive making out climate effect vulnerability maps.
2. Estimation of economic costs of adaption measures and development of risk based procedures to consider the cost of disruption due to extreme weather events versus the cost of adaption

Development and application of technologies

1. Resilient drainage systems, soil strengthening and rock stabilization techniques, and early warning systems
2. Resilient asphalt and concrete pavements (mixture and pavement design, paving technologies) and methods of increasing skid resistance.
3. Resilient, long life and low maintenance new bridges and adaption measures for increasing resilience of existing bridges including foundations, pre-emptive protection systems for tunnel structures against flooding and solutions for conservation of groundwater reserve during tunnel construction and operation.
4. Rapid and automated inspection and survey methods as well as sustainable maintenance measures and techniques.

Development and introduction of management and adaption strategies

1. Models to predict weather events, congestion, other relevant factors and real time management systems to provide early warning of trigger events and instigate intelligent re-routing and modal shift. Development of guidelines to cope with restricted flow during extreme weather events.
2. Development and implementation of adaption strategies, measures and techniques for new and existing road network infrastructure.

7. Roadmaps and Milestones

The roadmap will provide proven solutions that are ready to implement by the National, regional and local infrastructure authorities. The generic build up is from single technology trials from around 2013 towards full systems proving on a network scale around 2020. From 2020 the roadmap will be concerned with supporting and facilitating the roll-out activities by the authorities. It is in this stage that the Climate Change Resilient Transport will be implemented.

Milestones are proposed for 2015, 2020 and 2025 for short, medium and longer term implementation respectively, and are outlined in Figure 2, below.

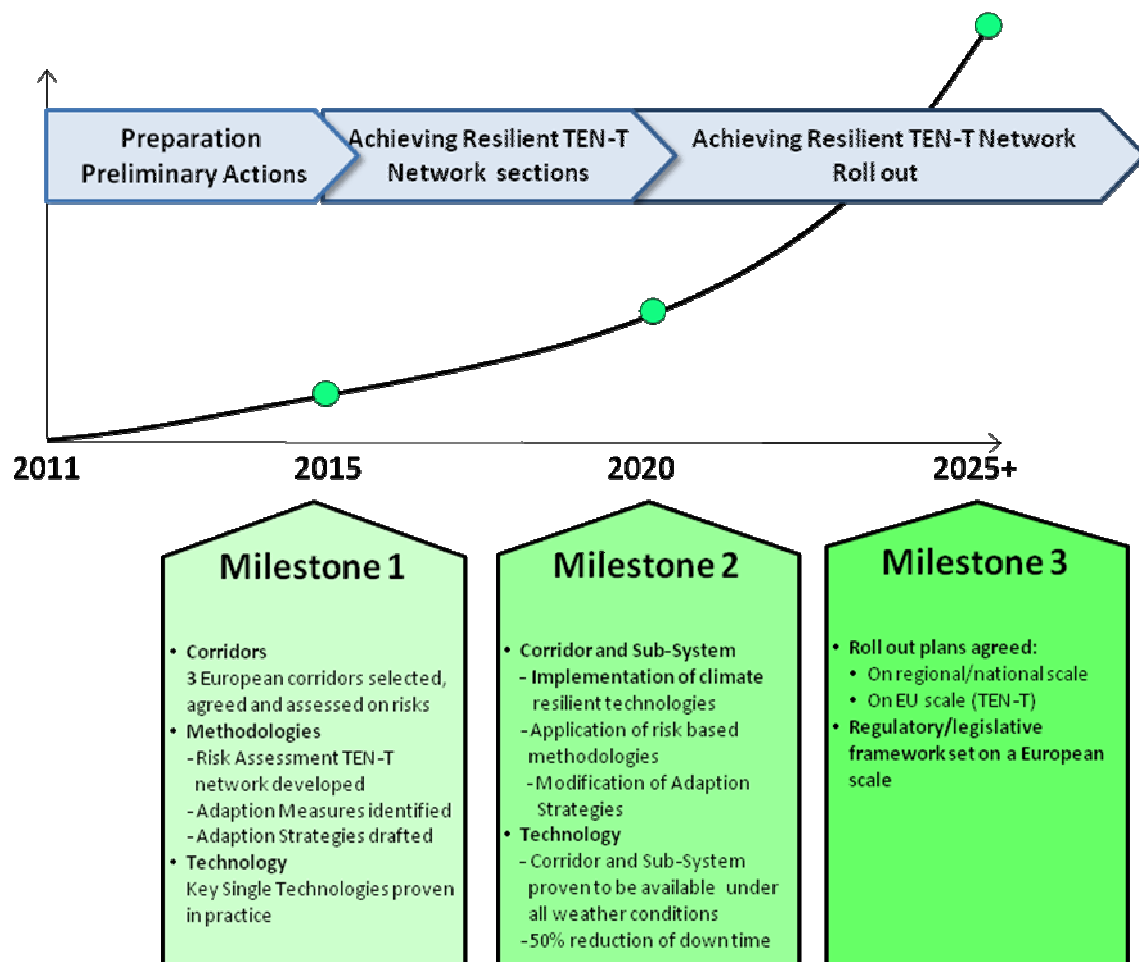


Figure 2: Outline Milestones for Climate Change Resilient Transport

Milestone 1: Preparation and preliminary actions (2015)

The main topics of Milestone 1 are the selection of 3 TEN-T Pilot Corridors, collection of background information and implementation of a unified database on transport related climate change effects/scenarios and the application of single technologies on selected infrastructure elements.

Corridor selection

- Selection of 3 TEN-T Pilot Corridors.
- Preliminary assessment of weaknesses based on currently available methodologies (RIMAROCC, SWAMP and already available national tools).
- Encourage road authorities to carry out pilot projects for eliminating identified weaknesses.

Methodologies

- Review, analyze and assess existing regional climate projections regarding European Transport needs.
- Further development of the regional climate projections (where necessary).
- Fusion on regional climate projections with the aim to gain a unified knowledge data base specific for European Transport (TEN-T).
- Development of risk based methodologies for assessing the vulnerabilities of transport infrastructure.
- Identification of adaption measures with regard to the possible vulnerabilities.
- Development of adaption strategies and their implementation for existing infrastructure.

Technology proving

- Optimization of identified adaption measures and further development to enable deployment.
- Selection of infrastructure elements for pilot applications.
- Single technology proving of selected adaption measures/technology.
- Validation of technologies based on the results of pilot projects.

Milestone 2: Achieving resilient sections of the TEN-T network (2020)

By 2015, validated information on adaption technologies available can be provided. Unified information on regional climate change effects as well as scenarios relevant for transport infrastructures will be available. Validated methodologies for the identification of vulnerabilities will have been proven. Key elements are:

Corridor and Sub-System Proving

- 3 TEN-T Pilot Corridors and sub-systems like city rings and transport interfaces to implement climate resilient technologies.
- Agreement on common specifications for identified routes.
- Application of risk based methodologies for assessing the vulnerabilities of the 3 selected corridors/sub-systems (identification of hot spots; modification of adaption strategies).

Technology proving

- Ongoing research on additional potential technical solutions.
- Real time traffic management systems that monitor traffic and environmental conditions and provide an early warning of trigger events.
- Improved weather and traffic prediction models.

- Enabled technology on a systems level (i.e. integrated over materials and components, management strategies and policy and governing principles).
- Feed forward to optimise supply chain. The business case would state the % reduction in down time.
- Methodologies for Cost-Benefit analyses; evaluation on sub-system level.
- Allied to the technical tasks should be the development of new nation level management and governance processes.

Milestone 3: Achieving resilient TEN-T network (2025)

It is expected that all technical solutions have been tested and validated on sub-system level; cost-benefit analyses have been carried out. Key task of milestone 3 is implementation of all technologies on system level (3 TEN-T Pilot Corridors).

By 2025 all technologies for resilience should have been proven on a European scale, incl. sub-systems identified by 2020. At this stage, there will be a requirement to take best practice from the three routes, to learn and improve and to continue to deploy solutions more widely across the TEN-T network. At this stage, technologies, operational strategies and governing principles will be fully integrated.

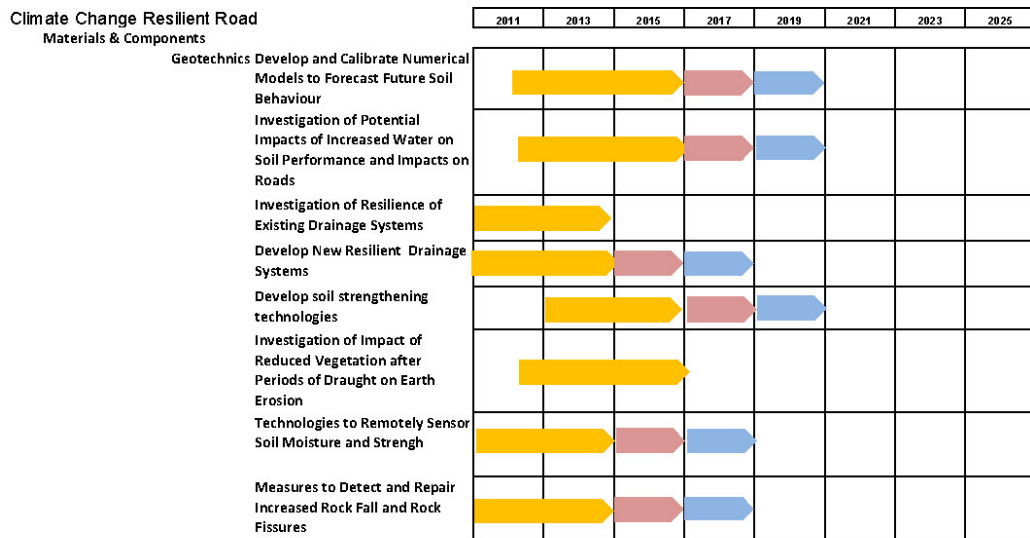
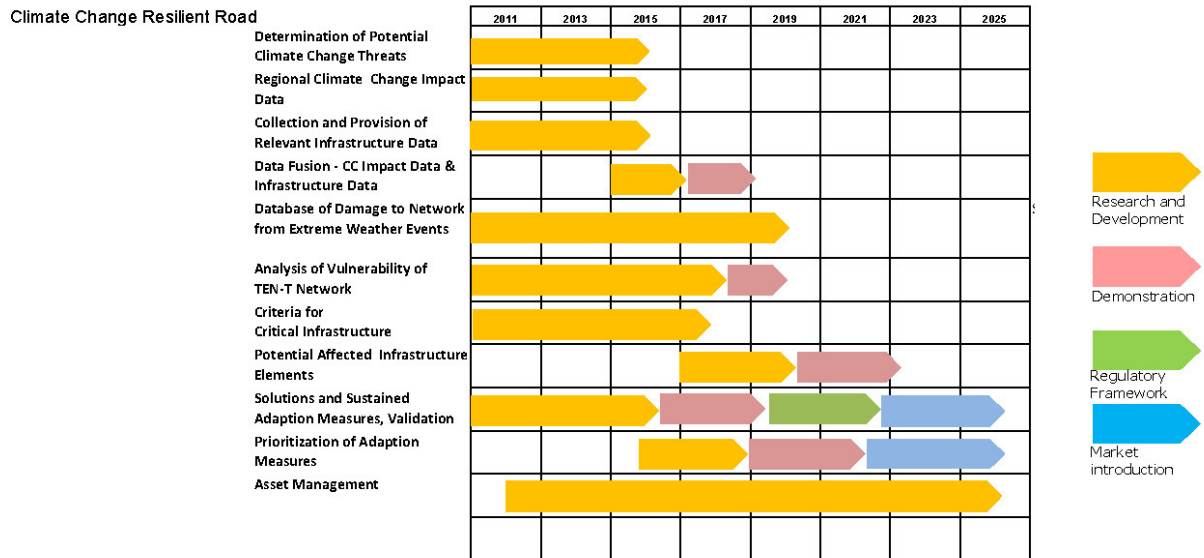
Underpinning this will be the development of Governance and Management Systems with an overview at a European Union level; these will be based on risk-based asset and accessibility management. Allied to this will be Transport and Asset Management strategies, at a European level with affiliates in Member States.

Roll out: 2025 and beyond

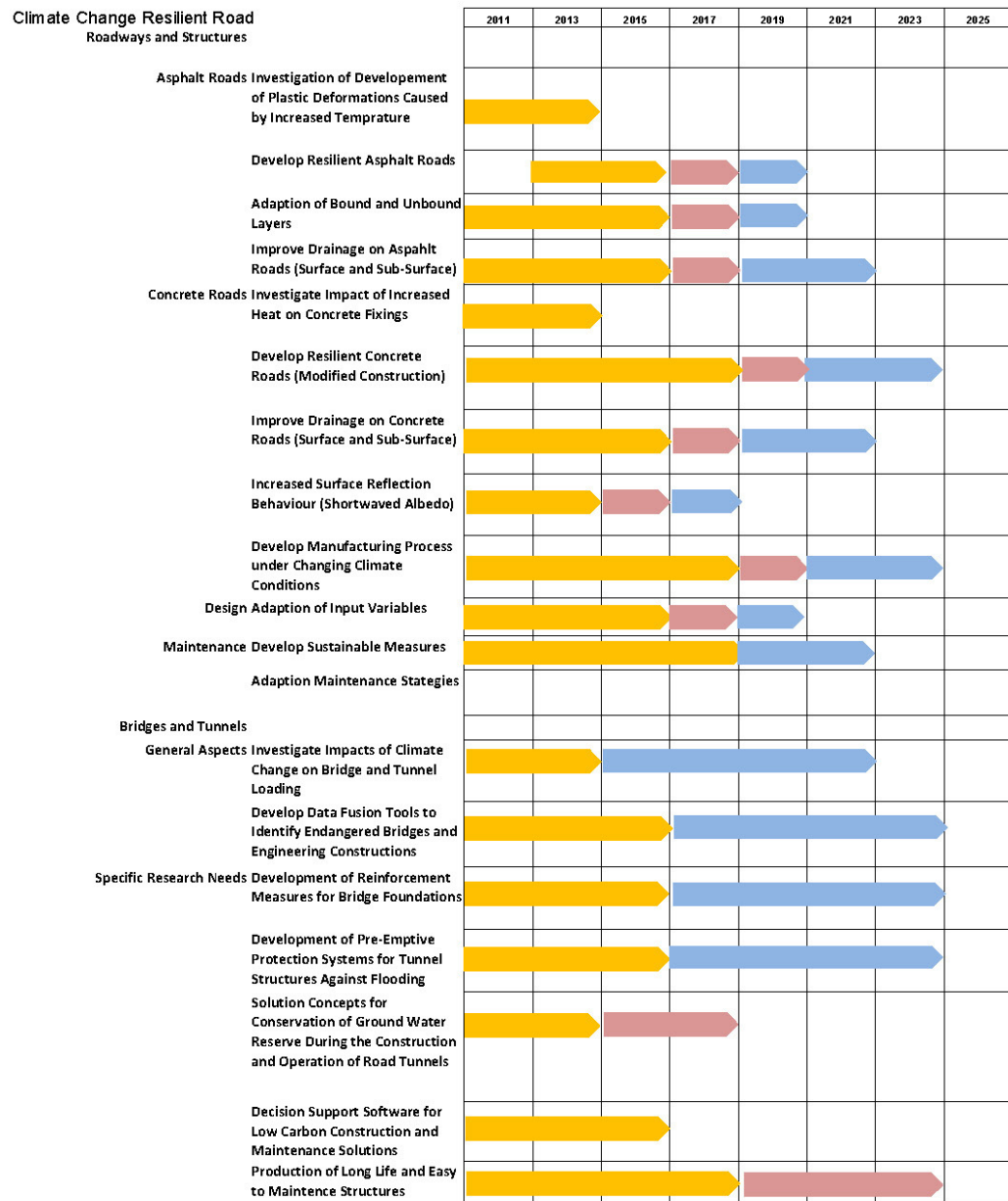
Following milestone 3 all methodologies and technologies for resilience can be handed over to European Road owners/operators for direct implementation.

8. Proposed Research Topics

Presented below are more detailed proposed research topics that could potentially be developed into work packages, and an indicated timeline.



ERTRAC Research and Innovation Roadmaps



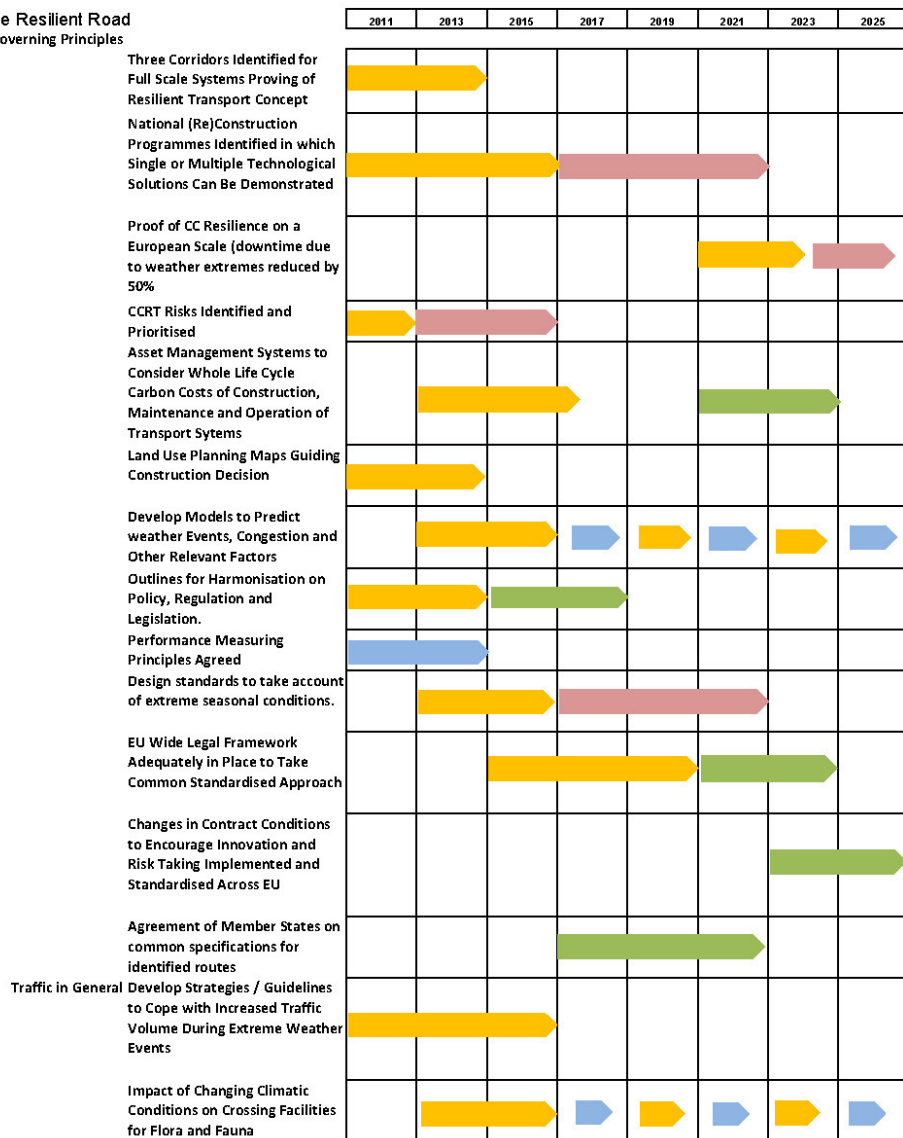
ERTRAC Research and Innovation Roadmaps

Climate Change Resilient Road Management Strategies



ERTRAC Research and Innovation Roadmaps

Climate Change Resilient Road Governing Principles



9. Links to other roadmaps

Extreme weather events currently cause significant disruption to transport networks and Climate Change may amplify this. As such the potential impacts of Climate Change cut across many of the other roadmaps including; Sustainable Long Distance Freight Transport, Urban Mobility and Road Transport Safety.

Future long distance transport requires highly available infrastructure (green corridors). This will require roads to be designed to meet demands for longer and heavier vehicles, which will exert significantly higher loading. Additionally, infrastructure for green corridors have to fully take into account more frequent, intense and longer lasting weather events and their impact on planning, design and operation. The recommended research in this roadmap will help ensure that these requirements are met.

Future urban mobility will aim for significantly improved integration of freight delivery requirements in urban planning. The demand for delivery of goods and services will increase, and the urban road infrastructure has to meet these challenges. Additionally, the predicted more frequent, more intense and longer lasting weather events, especially heat waves, can have a significant impact on the urban microclimate. The design of new, and the upgrading of existing urban road infrastructure, including the use of ITS applications will have to take account of both the climate predictions and freight requirements.

The roadmap “Climate Resilient Road Transport” will also support the need for safety and security in road transport and provide the necessary level of protection, and will contribute to ERTRAC’s ambitious target of reducing by 60% fatalities and severe injuries by 2030 (baseline 2010).