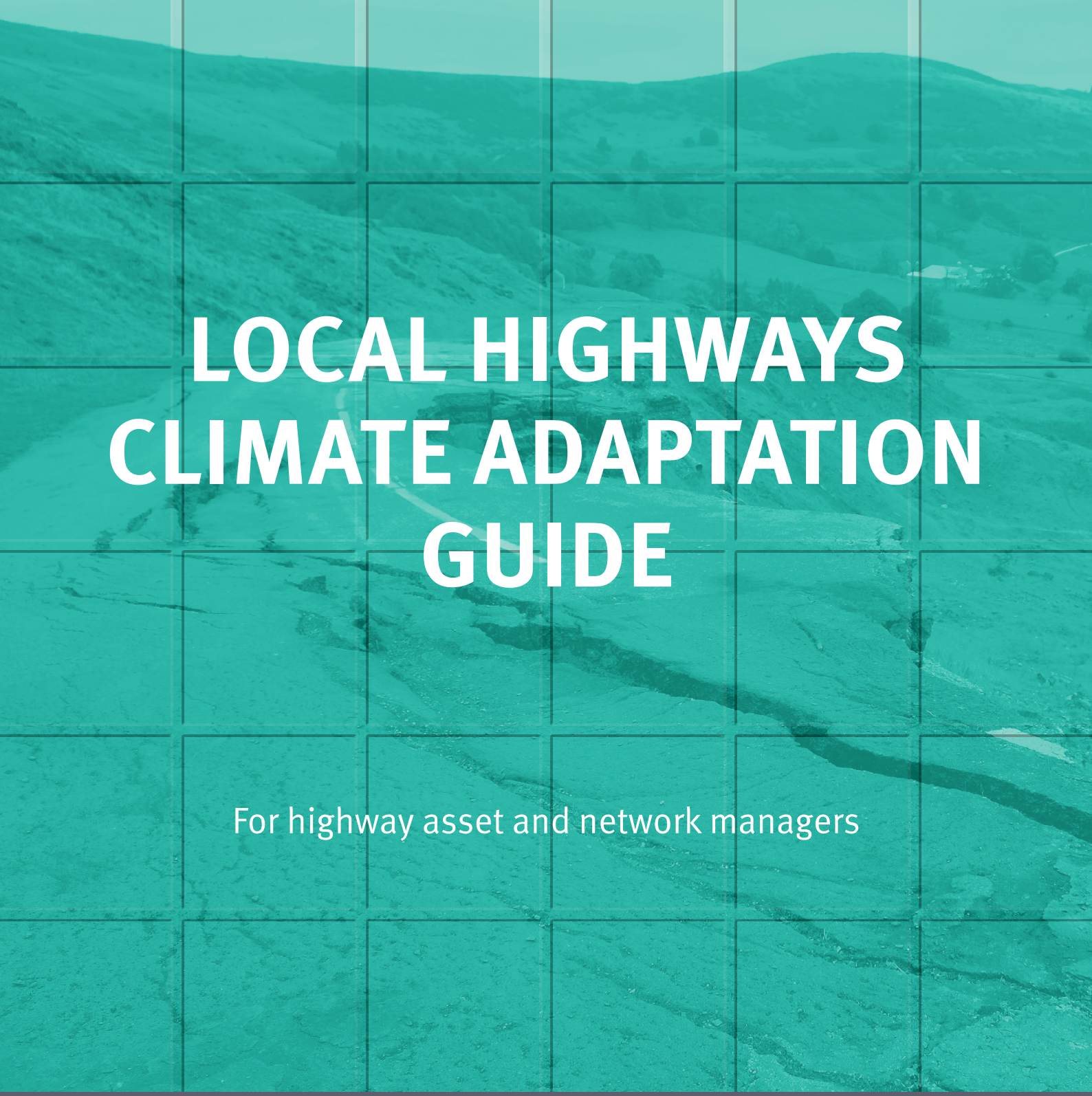


LOCAL HIGHWAYS CLIMATE ADAPTATION GUIDE

For highway asset and network managers

ADEPT

The Association of Directors of Environment, Economy, Planning & Transport

CONTENTS




1. FOREWORD

Climate change

We have known for some time that our climate is changing, as forecast by the Met Office's UK Climate Projections.

These projections provide updated observations and climate change projections up to the year 2100. The data indicates that by the end of the 21st century:

- All areas of the UK are projected to be warmer.
- Summers will be, on average, hotter and drier.
- Winters will be, on average, milder and wetter.
- Extreme weather will become more common.
- Lying snow will disappear almost entirely.
- Sea levels will rise, and the increase will be greater in the south and east.

The effects of climate change are already being felt. Observed changes to our climate to date include an increased frequency of hot weather spells and heatwaves, an overall increase in rainfall and a growing frequency of severe weather events - most visibly in the form of Met Office named storms.

Scope of this guide

In recent years, the UK has experienced a notable increase in severe weather events, including both individual storms and clusters of storms in short succession. Many local authorities are reviewing how prepared they are for severe weather events, including response and recovery. Often highway asset and network managers work in conjunction with their Local Resilience Forum.

In 2025, ADEPT, in collaboration with the Environment Agency, published the Rapid Adaptation Pathways Assessment (RAPA) toolkit. The toolkit focuses on flood and coastal erosion risks and is aimed at local authorities, allowing them to undertake a basic rapid adaptation pathways assessment approach in their places and partnerships. This Local Highways Climate Adaptation Guide is intended to be read alongside the RAPA toolkit, ensuring consistency across local adaptation assessments.

Similarly, ADEPT Live Labs 2, Decarbonising Local Roads in the UK - the three-year, UK-wide £30 million programme funded by the Department for Transport that aims to decarbonise the local highway network - has developed a range of innovative approaches to reducing carbon emissions. This guidance is intended to be considered alongside that work, so that climate adaptation measures are aligned with current decarbonisation evidence, trials and findings.

This guidance, however, focuses specifically on the implications of climate change for the management and maintenance of highway infrastructure assets.

This document provides guidance on climate adaptation for highway asset and network managers and contains three practical guides: Guide 1 on how to update a resilient route network, Guide 2 on how to undertake a local risk assessment and Guide 3 on how to update an asset management plan for climate adaptation.

Context

The Climate Change Act 2008 is the legislative framework which shapes the approach to climate change in the UK. National Adaptation Programmes are the statutory requirements through which much of the UK climate adaptation response is driven.

The third National Adaptation Programme was published in 2023, and this sets out the government's plans to adapt to climate change over five years from 2023 to 2028. This includes protecting the natural environment, supporting business in adapting to climate change and adapting infrastructure. The Climate Change Committee's recent independent advice report (which informed the Climate Change Risk Assessment 3) found that, in the transport sector, more action was needed to achieve the level of resilience defined in the adaptation programmes.

The starting point for local highway authorities is to understand the changing risk to our highway assets. Often a local risk assessment is needed to understand how those changing risks will affect our policies and strategies in managing and maintaining our highway assets.

This guidance sets out how to assess the risks that climate change poses to highway infrastructure assets, forming part of both a wider climate adaptation assessment and a transport asset management plan.

The ISO 14090:2019, PAS 3090 on Adaptation Pathways, and the National Highways GG103 process may also be useful reference documents in developing a local risk assessment.

2. SCALE OF ADAPTATION FOR LOCAL HIGHWAYS

In this guidance document, the following broad definitions are used to describe local climate impacts - this is solely for the purpose of describing the different types of climate adaptation that may be needed.

a) Severe weather events

Usually, this refers to weather events such as storms, which have a significant impact over several HOURS.

In most cases, it will be neither feasible, nor cost effective to adapt existing highway infrastructure alone to mitigate the impact of such events.

Local highway authorities often support and collaborate with their Local Resilience Forum to prepare appropriate response and recovery plans for severe weather events - this guidance encourages this approach.

Plans for mobilising additional highway maintenance resources to support response and recovery from a severe weather event should be developed in partnership with local resilience forums and emergency management teams.

Another consideration is whether standard highway response teams are adequately equipped to respond to severe weather events, or if additional equipment should be provided.

While it is usual for highway response teams to be trained in local risk assessment to manage health, safety and wellbeing for each specific response, this can be enhanced using severe weather response procedure cards. These provide additional guidance: for example, how to assess and respond to deep water, the risk of falling trees etc.

When considering the adaptation of highway assets to mitigate the impact of severe weather events, the first step should be a review of the resilient route network.

Following a severe weather event, a review of the condition of highway infrastructure assets should be undertaken. This should include all key asset categories, including structures (such as bridges and retaining walls), pavements, highway drainage systems, street lighting and technology assets.

Where significant deterioration is identified, this may also prompt a refresh of the Asset Management Strategy, to plan for the recovery of appropriate asset condition levels over time.



GUIDE 1: HOW TO UPDATE YOUR RESILIENT NETWORK

Most local highway authorities define a network hierarchy within their transport asset management plans. A resilient route network further defines the priority routes for maintenance and investment to improve their resilience to climate and other impacts.

Adaptation of the resilient route network means increasing the network's ability to withstand and recover from disruptive events with minimal impact on essential transport functions. Identifying at-risk assets and locations along the resilient network is an essential first step, allowing adaptation planning to take place, including consideration of third-party assets, such as public sewers.

The resilient route network is identified through risk assessment, consultation with stakeholders - including emergency services, utility providers and public transport operators - and analysis of socioeconomic priorities. The primary purpose of this is to ensure the continued functioning of vital infrastructure and services under stress or threat. This can be broken down into several key objectives:

i. Protection of critical connectivity

Essential services access: maintains access to hospitals, schools, utility hubs and other vital community assets (as determined locally).

Public transport continuity supports priority bus, rail and freight movements, including access to depots, that underpin the local economy.

ii. Minimisation of disruption

Rapid recovery: enables swift restoration of transport links after incidents, reducing downtime and cascading impacts on local communities

Planned diversion routes: contingency plans to keep people moving.

iii. Strategic investment and maintenance (adaptation)

Targeted resource allocation: focuses limited budgets on the most critical roads, optimising maintenance and upgrading for resilience.

Lifecycle planning: incorporates resilience considerations into asset management strategies and infrastructure renewal programs.

iv. Community safety and wellbeing

Equitable access: ensures that vulnerable groups retain access to essential services during emergencies.

When identifying a resilient route network, it must be remembered that most routes provide an important function for residents and local business. However, the resilient route network is often restricted in scale to provide affordable prioritisation.

While the resilient route network will often overlap with parts of the winter service network, it should be defined independently, not simply duplicated.

b) Extreme weather events

Extreme weather typically refers to weather events such as heatwaves and prolonged rainfall, which have a widescale impact over several DAYS. A series of storms in close succession may also create an extreme weather event.

Some localised areas may experience significant impact and where this occurs, the response and recovery measures detailed in the Severe Weather section above will apply.

In this section, the wider highway asset impact is considered. Typical impacts include:

- Pavement failure from prolonged high temperatures (heatwave).
- Bridge element failures from prolonged high temperatures (heatwave).
- Pavement failure from prolonged rainfall.
- Slope and retaining wall failures from prolonged rainfall.
- Drainage capacity/outfall operation exceeding capacity from prolonged rainfall.
- Pavement and geotechnical failure from drought.

In most cases, adapting existing highway infrastructure to mitigate the impact of such events will be neither feasible nor cost effective.

Highways authorities are advised to carry out local risk assessments to identify locations and assets most at risk from extreme weather events, based on historic data and network hierarchy.

The outcome of local risk assessments should support greater preparedness for responding to extreme weather events, on the basis that such events are becoming more likely and that forecasting capabilities continue to improve. For example, it is increasingly likely that a prolonged rainfall event will occur. A planned response, established through local risk assessment, could include measures such as:

- Deploying flood warning signs to known flooding locations.
- Increased monitoring of known vulnerable assets, such as structures and retaining walls, particularly those in critical locations or where failure could have a potentially severe impact.
- Pre-emptive cleaning of highway and other drainage systems.

The same approach applies to heatwave, drought and other extreme weather events. It should be assumed that weather events which adversely affect highway assets and the highway network will become more frequent and more extreme over time. Further detail on local risk assessments is provided later in this guidance.

However, the following is given as an example:

	Risk factor	Response	Adaptation
Pavement in heatwave conditions	Evolved roads with multiple surface dressing on south facing slopes	Spreading of grit stone before or during heatwave ideally on a pre-determined route	Resurfacing
Bridges in heatwave conditions	Older metal bridges with exposed structure, insufficient movement capacity to bearings and joints	Monitoring of at-risk structures.	Replacement of at-risk bearings and joints
Pavement in prolonged rainfall	Thin surface course systems	Repair and renewal	Preventative maintenance treatments
Retaining wall in prolonged rainfall	Inadequate/blocked back of wall drainage leading to increase in lateral loads on back of wall	Cleaning of back of wall drainage	Inspection and maintenance of back of wall drainage. Consider slowing of run off on retained ground i.e. planting, permeable paving/carrier drains

This table is provided as guidance and is not definitive. For example, scour risk remains the highest risk for bridges however, many authorities have implemented measures to manage these risks.

c) Gradual climate change

Gradual climate change refers to shifts in the climate, measured over YEARS that cumulatively result in a widespread impact on the highway network.

Typical impacts include:

- Longer growing seasons (soft estate).
- Changes in the timing of the growing season (soft estate).
- Increasing network disruption due to flooding.
- Subsidence and heave on the highway due to more intense rainfall.
- Reduced disruption from snow and ice due to warmer winters.
- Increased land drainage runoff.
- Greater risk of landslips from more prolonged and intense rainfall.

Early planning by local highway authorities will enable effective adaptation to gradual climate change, in many cases at little or no additional cost.

Adaptation to gradual climate change should be supported by a local risk assessment.

Adaptation strategies may include:

- Changes to asset management strategies.
- Changes to maintenance management plans.
- Changes to maintenance contracts.
- Managing customer expectations directly, for example through published changes to service levels.
- Managing customer expectations indirectly, for example through permanent flood risk signage.
- Increased monitoring of at-risk assets such as structures and slopes.

When developing asset management strategies, consideration should be given to current standards and specifications that are being updated, to reflect the changing impact of weather on highway assets.

Some examples are (with Design manual for Roads and Bridges references):

- CD227: Design for pavement maintenance, with supporting information in MCHW.
- HD32: Maintenance of concrete roads.
- HD38: Concrete surfacing and materials.
- CD529: Design of outfall and culvert details, which requires culverts conveying a public watercourse to be discussed and agreed with the Environment Agency.
- CG501: Design of highway drainage assets, which focuses on reducing risk through increasing drainage capacity, and this now requires a climate change allowance of 20% in design with a sensitivity test to 40%.
- LA113: Road drainage and water environment. This requires that all new schemes are supported by a Flood Risk Assessment to assess flood risk to and from the scheme, including the latest allowances for climate change.
- CD522: Drainage of runoff from natural catchments includes references to climate allowances.
- CS641: Managing the maintenance of highways geotechnical assets, which includes a risk-based approach to asset management and maintenance, encompassing a range of factors including flood risk; and
- CD356: Design of highway structures for hydraulic action, which includes scour assessment requirements and guidance including requirements to apply climate change allowances.

Note: this is not an exhaustive list.

d) Adaptation timelines

The table below provides an indication of adaptation timelines - i.e. how soon adaptation should be considered- drawn from the Met Office Climate Projection probabilistic data (high scenario):

	Baseline	By 2039	By 2069
Heatwave	0	5	8
Dry spells	1	1	3
Prolonged rain	1.4	8.5	15.2

3. LOCAL RISK ASSESSMENT

a. Key climate and asset risks for local roads

Based on experience of operating and maintaining highway networks, an initial assessment of climate resilience risks for highway infrastructure assets is summarised in the table below.

Local risk assessments will determine the current impact of climate change on each asset type and inform their expected performance under different climate scenarios. These risk assessments will also identify the most vulnerable assets and locations, forming the basis of an adaptation programme. This should be guided by the principles of adaptation pathways: the phased implementation of adaptation measures, aligned to progressive climate impacts to provide optimal cost benefit.

Pavement

Key climate risks:

- Rainfall (prolonged) leading to early life pavement failure.
- Rainfall (intense) leading to flooding and accelerated deterioration (potholes, joint failures).
- Heat leading to deformation.

Structures

Key climate risks:

- Rainfall (intense) leading to flooding and scour.
- Heat leading to deformation (joints).

Drainage

Key climate risks:

- Rainfall (intense) leading to flooding and blockage.

Lighting

Minimal climate risks:

- Interdependency with resilience of energy network.

VRS

Minimal climate risks:

- Heat leading to deformation (steel & wire VRS systems).

Geotechnical

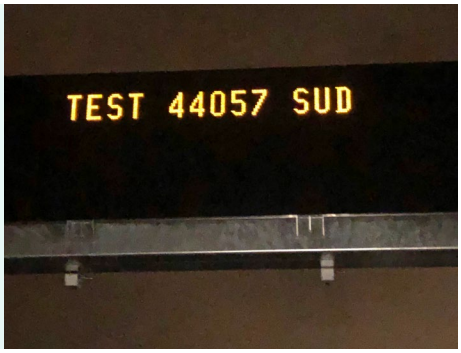
Key climate risks:

- Rainfall (prolonged) leading to landslip type failures.
- Rainfall (intense) leading landslip type failures.
- Rainfall/heat leading to shrinking or swelling of clay.

Technology

Minimal climate risks:

- Interdependency with resilience of energy network.



Soft Estate

Minimal climate risks:

- Rainfall (intense) leading to flooding (often no permanent damage).
- Change to growing season (affecting maintenance resource management).

Ancillary assets

Minimal climate risks:

- Reduced maintenance due to resilience risk cost of other assets.

b. Hierarchy of adaptation

Adaptation to improve the resilience of highway infrastructure can take many forms. The following hierarchy is suggested to ensure that low or no cost options are considered ahead of renewal, placement or improvement of assets.

no adaptation needed

adaptation through change to future highways contracts

adaptation through change to agreed service levels

adaptation through change to existing highways contracts

adaptation through re-prioritisation of existing interventions

adaptation through new interventions

reactive response

plan, warn, inform, reactive response

adaptation

c. Risk assessment

The following assessment process aligns with the ADEPT / Environment Agency RAPA toolkit approach and outlines the key steps and considerations for adapting local highways to the impact of climate change. It provides a systematic framework to support adaptation planning and implementation.

This risk assessment process is intended to support the review of highway asset management and maintenance plans. For guidance on preparing to respond and recover from severe weather events, please refer to the RAPA toolkit directly. The two approaches are complementary and are intended to be used alongside one another.

This structured risk assessment process enables highway authorities to proactively manage climate risks, safeguard public assets and support sustainable mobility for future generations.




GUIDE 2: HOW TO UNDERTAKE A LOCAL RISK ASSESSMENT

1. Planning

Planning the risk assessment and establishing its context is an important first step. This should include engaging with other teams in the local authority responsible for climate change, flood risk management and emergency planning. Agreement should be reached on the scope for this review, and the outcomes sought, including any updates required to transport asset management plans, strategies and any associated maintenance management plans.

Briefing key stakeholders and participants at an early stage is also recommended, to reassure them that this will be based on what is currently needed to improve resilience of the highway network and to agree a proportionate approach to managing future risks.

It is equally important to clearly define the scope of the risk assessment. This guide focuses specifically on highway infrastructure assets and improving their long-term resilience through updated asset management plans and strategies.

2. Understand the risks and opportunities from current climate

This step focuses on clearly defining the changing risks posed by climate change to local highway infrastructure assets. It should be informed by local operational and asset management experience, historical weather data and the guidance set out in the previous section.

This stage involves gathering data on existing conditions, such as drainage capacity, pavement materials, and the frequency of weather-related disruptions. Data sources including asset condition surveys, historical weather records and traffic impact analyses should be used to quantify current risks.

For example, roads known to be prone to flooding and older bridges with central piers are more susceptible to scour during heavy rainfall events. GIS mapping and asset inventories can also help highlight assets at risk.

Assessing the vulnerability of highway assets in this way helps prioritise adaptation within the asset management strategy and establishes a baseline against which future changes can be measured.

3. Understand the risks and opportunities from future climate

This step builds on the current risk assessment by incorporating projected climate scenarios, such as increased rainfall intensity, higher average temperatures and sea level rise. Using climate models and scenario planning, or by assuming that current weather trends will continue in line with these projections, the assessment estimates how risks to highways may evolve over the coming years.

For example, a road that is currently flood-prone may face greater inundation risk as rainfall patterns intensify. This forward-looking analysis helps prioritise adaptation within the asset management strategy.

Spatial data analysis may also be useful to supplement historic network performance and local knowledge. For example, to determine which roads, bridges, and culverts are situated in floodplains, wildfire-rich areas, or regions likely to experience higher temperatures or other climate related hazards.

Consideration of the underlying geology can also be useful. Overlaying hazard maps with highway networks enables planners to focus resources on the most exposed assets. This will form the basis for a targeted adaptation strategy within an updated highway asset management plan.

Objectives should focus on maintaining connectivity, ensuring public safety, reducing long-term maintenance costs, and supporting sustainable transport. Engaging stakeholders - including elected members, emergency services and

the public - helps ensure that the objectives are aligned with community needs and regulatory requirements and should inform updates to the asset management policy objectives.

4. Consider adaptation options

Having assessed current and future climate risks, a range of adaptation measures should be identified and evaluated for their effectiveness, feasibility, and cost.

Options to consider include:

- Greater focus of maintenance programmes on the Resilient Network.
- Identifying pavements susceptible to heat damage and developing a targeted asset management strategy for them.
- Reviewing the pavement asset management strategy to mitigate the impact of prolonged wet weather.
- Reviewing the asset management strategy for drainage systems.
- Identifying bridges at risk of scour or heatwave and developing a targeted asset management strategy.
- Reviewing local geology to assess landslip risk to the network.

Each option should be assessed against criteria such as cost-benefit ratio, technical complexity, environmental impact and social acceptability. It is essential that selected options align with the updated highway asset management plan strategy to ensure they meet broader community and policy objectives.

Adaptation pathways should be considered, as these outline the short, medium, and long-term actions required. This approach recognises that adaptation is a dynamic process requiring flexibility as both knowledge and conditions change. For example, immediate actions might include regular culvert maintenance, while longer-term plans could involve culvert replacement or new construction techniques.

Implementation plans should clearly set out roles, responsibilities, timelines and funding mechanisms to ensure adaptation measures are delivered in a systematic and accountable way.

Continuous monitoring is essential to track the effectiveness of adaptation measures and respond to unforeseen challenges. Key performance indicators could lead to reductions in weather related road closures, lower maintenance costs and improved user safety.

Findings from asset management systems and stakeholder feedback should inform ongoing learning and improvement. The adaptation pathway should be reviewed and updated regularly in response to monitoring data, emerging risks and technological developments, ensuring that local highway networks remain resilient in the face of climate change.

5. Identify and evaluate interdependencies

The results of this risk assessment should be used to update the transport asset management plan. This will clarify how different elements of highway management are connected, and how highways management supports wider corporate goals.

As established in the planning stage, engagement with outside bodies will help understand:

- Things the service depends on such as fuel, energy and communications.
- Areas requiring collaboration with others, for example: highway drainage, water company services and land drainage.
- People who use the roads, including public transport operators.

4. ASSET MANAGEMENT STRATEGIES

Transport asset management plans must take account of climate change to make sure roads are kept in good condition and looked after in ways which are safe and offer value for money.

UKRLG guidance is that transport asset management plans should include risk assessment, adaptation measures and continuous review.

The highway assets most at risk include pavements, bridges, drainage and soil/rock stability. Managing those risks effectively requires alignment of the adaptation programme with the current operations, maintenance and asset renewal programmes.

The following guide sets out some key steps in updating transport asset management plans to consider climate adaptation.

GUIDE 3: HOW TO UPDATE AN ASSET MANAGEMENT PLAN FOR CLIMATE ADAPTATION

a. Highway infrastructure asset data

Local risk assessments will require inventory and ideally condition data for those assets which face significant risks, including pavements, bridges, drainage, structures and geotechnical assets.

Many local authorities do not have the information relating to assets such as embankments, retaining walls, smaller culverts and underground drainage. It may be necessary to review how much information is available and the opportunity to gather the relevant data.

Asset inventory data

The asset inventory should include where the asset is, what type of asset it is (for example which form of pavement construction), and totals for each type of asset. Information about sub-surface drainage assets may be limited.

Asset condition data

- For pavements, standard surface condition monitoring information about the condition of the components of structures (for example deck, joints, bearings) should be recorded.
- Information about drainage and soil and rock condition may be limited.
- Current weather-related impacts should also be recorded (for example location, duration, frequency and impact of flooding).

b. Understanding risks and impacts

Asset managers should assess the climate-related risk to roads and relevant infrastructure by considering:

- Previous incidents.
- Local climate projections.
- The condition of roads and infrastructure.
- This guidance.

c. Integration into strategic planning

Adaptation should be part of the strategy for transport asset management. For example, policy alignment should be developed through ensuring asset management policies reference climate resilience as a core objective.

For example, some Climate Emergency declarations include preparedness for heat, flooding and storms. Consideration should also be given to alignment with corporate policies relating to resilience of service delivery.

Asset managers should also consider linking their policies with corporate policies designed to ensure service delivery is resilient.

- Objective Setting:
  Set clear, measurable objectives relating to climate adaptation (for example reducing flood-related disruptions).
- Lifecycle Planning:
  Incorporate climate risks into lifecycle planning, including maintenance and renewal.

By integrating adaptation into these objectives' highway authorities can proactively manage climate risks rather than reactively responding to incidents.

d. Risk assessment and prioritisation

The UKRLG guidance recommends a systematic approach to risk assessment:

- Asset register and data collection:
  Update and maintain asset inventories which show the location of assets which are most at risk.
- Vulnerability assessments:
  Use this guidance to focus on climate changes affecting highway infrastructure, and the assets that will be affected, supported by a local risk assessment to estimate their vulnerability. Greater detail may be provided through tools such as the UK Climate Projections (UKCP).
- Prioritisation:
  Rank risks based on likelihood and consequence to inform investment decisions and maintenance priorities.
  Keep the resilience of the road network under review to ensure local priorities are up to date.

A suggested approach to local risk assessment for climate impact on highway infrastructure is provided in this guidance. This enables interventions where they are most needed to make the best use of resources.

e. Adaptation actions

Suggested climate adaptation measures include:

- Design standards:
  Update design specifications to reflect future climate conditions (for example higher capacity drainage).
  Many national standards (for example DMRB) already have updated specifications in response to climate change.
- Maintenance regimes:
  Increase inspection and maintenance frequencies (including contracts).
- Customer, policy and standards:
  Adjust policies and service levels and manage customer expectations.

Nature based solutions:

Consider sustainable drainage systems and green infrastructure such as tree planting to reduce flood risk and the counter rising temperatures in cities and towns.

f. Collaboration and continuous improvement

Effective adaptation requires collaboration across departments, with stakeholders and neighbouring authorities. Sharing information, best practice and lessons learned will make roads and other assets more resilient.

Asset management plans should be treated as living documents, regularly reviewed and updated to incorporate new evidence, technologies, and climate projections.

g. Monitoring and reporting

Establish key performance indicators (KPI) for adaptation, such as:

- Reduction in weather-related incidents.
- Keeping roads and highways assets in better condition.
- Progress against adaptation objectives.

Regular monitoring and transparent reporting will support accountability and help improve performance.

5. CUSTOMERS

a. Customer focus

When updating asset management strategies to take account of climate change and adaptation, consideration should be given to customer communication through both direct and indirect channels.

Direct communication involves consultation on specific events, polices and strategies, for example a recent flood or changes to when and how often grass verges are cut. Given the trend towards more severe weather events, it should be made clear that proposals are often designed to reduce rather than prevent harm.

Indirect communication will be used to manage customer expectations about the effects of climate change. For example, installing permanent flood warning signs, or signs showing how often a road which is at risk of flooding is likely to be closed.

b. Consultation

Local authorities often have established processes to consult on new and updated policies and strategies.

These are likely to be suitable when consulting on asset management strategies which have been changed to include climate change adaptation.

c. Survey

Many local authorities use surveys to monitor customer satisfaction with either a range of local services or specifically on highways, for example the National Highways and Transportation survey.

Taking part in a national survey allows local authorities to see how well they are doing compared to other local authorities. This can be used to improve public perception and satisfaction scores.

Surveys do not necessarily need to ask climate related questions, but responses should be considered in the context of climate change. Sometimes the results of surveys may indicate a need to change policies, strategies or investment plans. But in some cases, a change in messaging and communication is needed.

d. Engagement and communications

- Alternative methods of gathering feedback from residents should be considered, including pop up surveys targeting groups of people who have not always been successfully engaged with.
- Online engagement tools.

e. Benchmarking

Many local authorities are members of benchmarking clubs such as the Future Highways Research Group (FHRG).

This enables both the sharing of best practice and the assessment of the value for money of highway services.

6. DEFINITION OF CLIMATE ADAPTATION

In this guidance, the following definitions have been adopted.

- Decarbonisation. This aims to reduce greenhouse gas emissions by decreasing our reliance on fossil fuels. In 2019 as part of the Paris Agreement[1], the UK government committed to reaching net zero greenhouse gas emissions by 2050, based on 1990 levels.

- Adaptation refers to actions or processes that adjust a system so it can cope with the expected impacts of climate change[2]. Adaptation measures are specific actions taken to minimise and avoid the harmful effects of climate change. It is a local, context-dependent process to reduce vulnerabilities.

- Resilience describes a system's capacity to absorb, adapt to and recover from disruptive events effectively. It involves anticipating and coping with shocks from hazardous climate events and recovering from their impacts efficiently[3]. Resilience builds resistance and recovery capability over time to cope with impacts and reduce risks, such as the ones associated with climate change, while adaptation is just one of the processes that helps improve resilience[4]. Building resilience is an ongoing process that enhances the ability to respond flexibly to extreme events and can only be fully understood within the specific local context.

For further information on decarbonisation, please refer to ADEPT Live Labs 2.

For further information on resilience, please refer to ADEPT / Environment Agency RAPA toolkit.

Adaptation will include:

i. Risk assessment.

ii. Updated asset management and maintenance strategies.

iii. Update of resilient network.

iv. Update of diversion routes.

v. Monitoring.

vi. Planned adaptation intervention.

1 *The Paris Agreement | UNFCCC*

2 *Intergovernmental Panel on Climate Change (IPCC) SYRAR5-Glossary_en.pdf (ipcc.ch)*

3 *What is the difference between climate change adaptation and resilience? - Grantham Research Institute on climate change and the environment (lse.ac.uk)*

4 *Cañavera- Herrera, 2019, Roads to adaptation: Understanding adaptation planning of urban road infrastructure*

CASE STUDIES

The following case studies have kindly been provided by local highway authorities:

a. Pavement heat damage (various).

b. Pavement rainfall damage (various).

c. Pavement heave management (Lincolnshire and Norfolk).

Case Study: Pavement heat damage

(various local authorities)

Heat damaged roads

1. Asset data collection and quality

A local risk assessment using information about previous sites where heat has caused damage and listing places where problems may arise in the future. Identification of potentially vulnerable sites by analysis of existing texture depth data from SCANNER/DVI and identifying south facing slopes of roads.

2. Vulnerability assessment

Pavements are particularly vulnerable where roads have been repeatedly surface dressed including those which have been surface dressed using older techniques. Air temperatures exceeding 30° for 3 consecutive days (commonly defined as a heatwave in weather forecasts) lead to a softening of the pavement surface, with aggregate sinking and bitumen rising. This leads to a sticky surface which may result in potholes. The greater risk is when the pavement cools and loses its texture depth it will become very slippery.

3. Prioritisation

These roads are unlikely to form part of the principal road network or the resilient road network. However, heat damage can cause vehicles to lose control and leave the road. The correct approach to maintenance will depend on how serious the problem is, and the customer's expectations.

4. Maintenance response

One way of dealing with heat damaged roads is to use a gritter to spread grit stone. It is better to grit before the road is damaged if possible.

5. Adaptation response

The normal practice is to add at least 40mm of conventional surface course. However, in some cases excess bitumen "bleeds through". Suppliers are developing a more heat-resistant surface dressing which may help in the future.

6. Reference documents:

- ADEPT Guidance on resilience of surfacing materials
- ADEPT Climate Change and Evolved pavements

Case Study: Pavement rainfall damage

(various local authorities)

Rainfall damage roads

1. Asset data collection and quality

A local risk assessment using data from roads and highways assets which have had problems in the past and listing sites which may be vulnerable in the future. Identification of potential sites by analysis of information about the condition of roads and assets from SCANNER or DVI or similar records of type of surface course.

2. Vulnerability assessment

Thin Surface Course System pavements which are more than 15 years old can be vulnerable where the number of days of rain has increased. More rain may also affect other types of surface course pavement resulting in potholes mainly through surface (top down) crack development and surface joint failure.

3. Prioritisation

Busier roads are expected to deteriorate more rapidly and this will determine which routes are prioritised. When prioritising, consideration should be given to routes with Thin Surface Course Systems and similar materials.

4. Maintenance response

Preventative maintenance techniques will usually reduce the permeability of the road surface and mitigate this risk. These techniques include all forms of surface dressing, slurry sealing and micro-asphalt. In some cases, preservation and rejuvenation treatments should be considered to seal very small cracks in the pavement. Timely joint sealing and repair is also recommended.

5. Adaptation response

A review of the asset management plan and maintenance management plan in respect of the pavement surface course treatments and their whole life costs and carbon, taking account of the different pavement service requirements in different locations will provide a useful adaptation response. Updating plans to take account of how pavements are best maintained in all locations and understanding the carbon emissions associated the work is an important response to climate change.

6. Reference documents:

- ADEPT Guidance on resilience of surfacing materials
- ADEPT Climate Change and evolved pavements

Case Study: Pavement heave management

(Lincolnshire and Norfolk)

1. Asset data collection and quality

Lincolnshire County Council and the BGS shared their knowledge to show a direct relationship between unclassified/evolved road residual life (RL) and structural condition, as well as how much the ground under the road can compact under pressure.

2. Vulnerability assessment

Roads in the south of Lincolnshire are affected by ground movement. This results from the geology, vegetation, road maintenance and drainage practices. The superficial peat, tidal flat deposits and alluvium can all compact under pressure when loaded or due to loss of water because of drought or the effects of drainage and irrigation. The shallow foundations of the county's evolved roads increase their vulnerability to ground movement which often causes damage. This includes longitudinal cracking and edge failure, and uneven long-section profiles due to localised failures.

3. Prioritisation

This will involve collaboration between geotechnical asset managers and engineering geologists to make decisions about maintenance and repair based on an understanding of geological properties and processes, and how these may change in future.

4. Maintenance response

The council usually repairs these roads by using sprays and overlays to add a new surface on top of the of the road, but this adds weight which can cause more damage over time. Increased traffic including heavier farm vehicles and lorries has added to the problem. New drainage practices which have become necessary due to climate change have led to lower water levels in dykes managed by the Internal Drainage Board. Hotter drier summers, and warmer wetter winters lead to naturally higher annual SMDs. These are projected to increase leading to the need to prevent or reduce the likely damage.

5. Adaptation response

Monitoring with remote sensing and regular condition surveys would show how well new repairs are working and the effects of climate change.

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