An Roinn Iompair
Department of Transport

Climate Adaptation Strategy for Regional & Local Roads

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Contents

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Executive Summary

The Regional and Local road network in Ireland provides crucial social and economic functions for both urban and rural communities. However, the assets which make up this network vary greatly in terms of their type, age, and condition. While the asset stock constructed in recent years complies with current standards, many legacy roads were constructed prior to the existence of design standards. As a result, Regional and Local road assets are particularly susceptible to the impacts of climate change due to a combination of their age, condition, and the design approach used at the time of construction.

According to the New Climate Projections 2020[1] published by the Environmental Protection Agency, significant climate changes are predicted to occur in Ireland by mid-century. These include more summer heatwaves; ~50% less days with frost/ice; fewer snowfall events; substantially more dry periods and heavy rainfall events; lower mean wind speeds; and ~ 10% fewer storms.

In order to address the susceptibility of the Regional and Local road network to the predicted changes in climate, the Climate Action Plan 2021 includes an action to develop guidance relating to the climate adaptation of Regional and Local roads.

Therefore, in response to Action 297 of the Annex of Actions to the Climate Action Plan 2021, this document has been developed to define a climate adaptation strategy for Local Authorities in Ireland which will improve the resilience of assets on the Regional and Local road network to the impacts of climate change.

The development of this strategy has been informed by research which was undertaken to determine the approach taken in other jurisdictions internationally to the climate adaptation of road assets. This identified a number of recurring themes that form the basis of other climate adaptation strategies, such as:

- Preventative maintenance as part of normal asset management activities is one of the most effective ways of improving the climate resilience of road assets.
- The approach to be used should be informed by real climate related failures that have occurred in the past. This ensures that the approach developed is tailored to the climate risks which are specific to the relevant jurisdiction.
- When assets do fail, a 'Build Back Better' policy should be adopted by designing and constructing replacement assets in accordance with current standards which already include appropriate factors of safety for climate change. Works which are not designed to latest standards are often unsustainable and costly in the long term which results in less funding for other climate adaptation schemes.
- In some cases, the 'Do Nothing' option should be considered where the cost of making the asset more climate resilient is not justified. A cost-benefit approach should be used to prioritise funding allocations and to identify any poor value schemes.
- Residual lifespan of the asset is an important consideration. Where the remaining expected life of the asset is low, it may be better to apply minimal solutions in the short term and plan a full asset replacement in line with latest design standards at the end of life of the asset.

[1] The New Climate Projections 2020 are based on 'Research 339: High-resolution Climate Projections for Ireland – A Multi-model Ensemble Approach' published by the Environmental Protection Agency (EPA) and supported by Met Éireann and the Marine Institute https://www.met.ie/epa-climate-projections-2020 .

In line with the approach taken in other jurisdictions, this strategy is based on real climate related failures that are currently occurring on the Regional and Local road network in Ireland. These Common Failure Types were identified during a number of workshops with representatives from the Local Authority sector and the actions developed under this strategy are focused primarily on these Common Failure Types.

While the focus of this strategy is climate adaptation, it is nevertheless important that this should be delivered in a sustainable manner and that the actions taken as a result of this report do not lead to an increase in activities which are contributors to climate change. The most effective way to ensure this is to prevent failures before they occur and to design replacements/repairs in accordance with latest design standards which already take account of increased demands on assets due to expected changes in climate.

While one of the main themes of climate adaptation is to prevent failures before they occur, it is not practical to do this in all cases. Where climate related failures do occur, Organisational Resilience will help ensure that these are dealt with in a planned manner in order to maintain road functionality or mitigate the impacts of road closures. Local Authorities already have significant planning and resources in place in this regard. In order to supplement these, a methodology for the identification of Critical Infrastructure Routes has been developed in parallel with this strategy. This defines a process for identifying sections of the Regional and Local road network which service certain strategic facilities such as fire stations, health facilities, power stations, and Local Authority maintenance depots etc. This will aid Local Authorities in their existing emergency planning arrangements and will support the process to prioritise funding for climate adaptation schemes. The methodology for identifying these Critical Infrastructure Routes is set out in Technical Annex 1 to this document.

This strategy identifies a number of actions which are now required to improve the climate resilience of assets on Regional and Local roads in Ireland as described below.

- Update Existing Guidance Documents: The existing suite of asset management guidance documents should be updated to include additional inspection and preventative maintenance requirements to address the Common Failure Types identified. This should be done by providing a Climate Adaptation Addendum to the Guidelines for Road Drainage (2nd Edition, March 2022), the Pavement Asset Management Guidance (Version 1.0, December 2014), and the Bridge Asset Management System (September 2019) documents. As there is currently no guidance in place which is specific to geotechnical assets, a new guidance document should be developed to cover this area which will deal with asset management requirements in general and also the inspection and preventative maintenance requirements for the Common Failure Types identified. A number of guiding principles for sustainability have been identified in this strategy document; these should be taken into account when updating the above guidance documents to ensure that the adaptation actions that are put in place are delivered in a sustainable manner.
- Update MapRoad: The existing asset management software system (MapRoad) supports the use of a range of existing asset management documents including the three guidance documents listed above. Once these documents have been updated as described, the MapRoad system will also need to be updated to reflect these changes.

- Produce Vulnerability Mapping: Vulnerability mapping should be produced to identify specific areas of the network which are most vulnerable to relevant Common Failure Types. Vulnerability mapping will not be suitable for every case but where it is practical to categorise the network in terms of risk of failures on a national basis, this will be useful both in terms of identifying issues before they occur and for prioritising funding. Any vulnerability mapping produced should be stored in MapRoad.
- Identify Critical Infrastructure Routes: Each Local Authority should identify the Critical Infrastructure Routes within their respective areas using the methodology defined in Technical Annex 1 to this report. The resulting Critical Infrastructure Routes should be stored in MapRoad.
- Works Prioritisation Methodology: The Works Prioritisation Methodology as described in Technical Annex 2 is currently in spreadsheet format. This format should be used to finalise any changes that are required to the approach. Enabling the collection of relevant data via MapRoad would ensure better control over the data generated and, in the long term, would allow the prioritisation process to take better account of other related data such as historical climate failures, vulnerability mapping and Critical Infrastructure Routes.
- Annual Review: Once the above measures have been put in place, the overall approach should be subject to a review on a yearly basis until the systems are well established to ensure effectiveness and identify areas for improvement.

This document also contains a number of Technical Annexes that address specific issues which are related to this strategy. These include topics such as the identification of Critical Infrastructure Routes and guidance for Local Authorities on the Works Prioritisation Methodology. It is expected that the number of Technical Annexes will grow over time as knowledge and techniques in this area develop.

Implementing this strategy requires input from the Local Authority sector as a whole and therefore this document is addressed at Local Authorities (both at management and operational level), the Department of Transport, and supporting organisations such as the Road Management Office and the Climate Action Regional Offices.

Background

Background

The Regional and Local road network in Ireland consists of approximately 96,000 kms of roads ranging in type from minor roads serving a small number of isolated dwellings in rural settings, to busy inter-urban routes connecting large provincial towns. In total, the network carries almost 55% of all road traffic nationally and it therefore serves critical social and economic functions for citizens and the economy.

Primary responsibility for the maintenance and improvement of the network rests with Local Authorities with state grants and oversight being provided by the Department of Transport.

The Regional and Local road network is made up of a large variety of asset types such as bridges, pavements, cuttings, embankments, drainage systems, signs, barriers, and fencing; and each of these can vary greatly in terms of their age, condition, design standards to which they were constructed, and the performance demands which are placed on them.

Managing the wide array of assets which make up Regional and Local roads in order to deliver a safe and efficient transport network is a complex and challenging task and Local Authorities manage this by means of an asset management system that comprises a series of guidance documents and the MapRoad software system.

However, there is growing evidence in recent years that climate related failures such as road flooding, slope stability, bridge undermining and bitumen melting are becoming more frequent and more severe. As these failure types are relatively new, the existing asset management approach is not focused on identifying, measuring and preventing these types of climate related failures.

In summary, the variability in age, condition, and historical design requirements of road assets which make up the Regional and Local road network is such that these assets are particularly susceptible to climate change. The established approach to the management of these assets is focused on the existing maintenance issues that have occurred regularly for many years now; but this approach should be adapted to include greater emphasis on climate related failures which are starting to become more common in recent years or are at risk of developing in the future.

In response to this situation, the Climate Action Regional Office (Atlantic Seaboard South) initiated a project on behalf of the Department of Transport in 2020 to provide guidance to the Local Authority sector on developing the climate adaptation of the Regional and Local road network. The aim of this guidance was to:

- inform staff of the importance of appropriate planning for climate change and implementation of climate adaptation procedures, and
- develop a range of design, maintenance and rehabilitation strategies and approaches to adapt the Irish Regional and Local road network for climate events and reduce the risk of damage and loss of function.

Phase 1 of this project was a scoping exercise which was undertaken by the Climate Action Regional Office (Atlantic Seaboard South) between June 2020 and January 2021. This involved:

- a review of all 31 Local Authority Climate Adaptation Strategies,
- a survey of all Local Authorities on their current practices and future requirements,
- a review of international best practice and guidance, and
- an assessment of existing road asset management guidance and systems.

This scoping exercise identified four key requirements for integrating climate adaptation into the management of the Regional and Local road network:

i. A roads adaptation guidance document.
ii. A methodology for the identification and recording of vulnerable locations.
iii. Mapping of vulnerable locations.
iv. A prioritisation methodology for adaptation interventions.

The Climate Action and Low Carbon Development (Amendment) Act 2021 committed Ireland to reducing overall greenhouse gas emissions by 51% no later than 2030, which puts Ireland on a path to reach net-zero emissions by 2050.

The Climate Action Plan 2021 was produced as a result of the above Act and provides a detailed plan for the actions required to achieve these targets. The overall aims of the plan are to reduce emissions in order to create a cleaner greener economy and society which is more sustainable and better protected from the potentially grave consequences of climate change.

The Climate Action Plan 2021 lists a large number of actions across a range of areas including Policy; Governance; Ensuring a Just Transition; Citizen Engagement; Public Sector Leading by Example; Carbon Pricing and Cross Cutting Policies; Electricity; Enterprise; Built Environment; the National Retrofit Plan; Transport; Agriculture; Land Use, Land Use Change, Forestry, and the Marine; The Circular Economy; Ireland's International Action on Climate Breakdown; and Adaptation.

The plan sets indicative ranges of emissions reductions for each sector of the economy and it will be updated annually to ensure alignment with legally binding economy-wide carbon budgets and sectoral ceilings.

This strategy document has been developed on foot of Action 297 of the Annex of Actions to the Climate Action Plan 2021 which commits that the Climate Action Regional Offices shall:

'Develop guidance on climate adaptation on regional and local roads.'

The purpose of this document is therefore to define a climate adaptation strategy for Local Authorities in Ireland which will improve the resilience of assets on the Regional and Local road network to the impacts of climate change.

Implementing this strategy will require change across the Local Authority sector as a whole and therefore this document includes actions for practitioners & management within Local Authorities; entities which provide a supporting role to Local Authorities such as the Road Management Office and the Climate Action Regional Offices; and funding organisations such as the Department of Transport.

Predicted Climate Change

Predicted Climate Change

In order to develop a strategy for ensuring road assets are more resilient to climate change, it is necessary to make an objective assessment as to which failures are likely to become more prevalent and more severe due to the expected changes in climate in the future.

In order to do this, the New Climate Projections 2020[2] for Ireland have been used in the development of this strategy to quantify the predicted rate and extent of those climate changes which will impact road assets.

Climate modelling is based on greenhouse gas concentrations in the atmosphere in the future, but these are difficult to predict in the long-term as they are based on factors which are uncertain, such as economic growth and the extent to which climate mitigation is successful. For this reason, the Intergovernmental Panel on Climate Change (IPCC) has developed a number of plausible scenarios for the trajectory of greenhouse gas concentrations in the future.

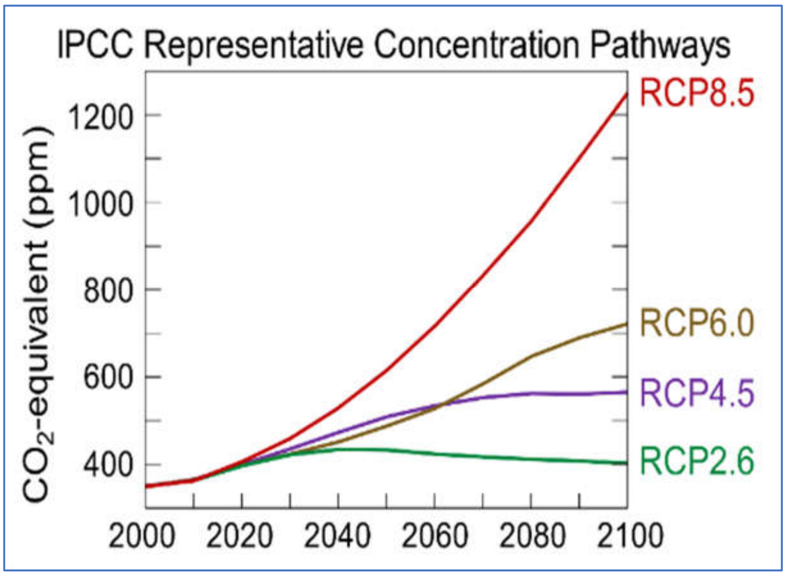

Figure 1 – IPCC Representative Concentration Pathways

Each of these scenarios is known as a Representative Concentration Pathway or RCP[3].

The model used in the New Climate Projections 2020 for Ireland is based on two scenarios; RCP 4.5 is used to represent the intermediate scenario and RCP 8.5 for the potential worst-case scenario.

The model predicts that the following changes will occur between the baseline period (1981-2000) and mid-century (2041-2060) based on a combination of both the scenarios mentioned above.

- Temperature
    - Temperatures are projected to increase by 1 – 1.6°C compared with the baseline period, with the largest increases occurring in the east of the country.
    - Temperature increases will be greatest at the extremes, with summer daytime and winter night-time temperatures projected to increase by 1 – 2.4°C.
    - Summer heatwave events are expected to occur more frequently.

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[2] The New Climate Projections 2020 are based on 'Research 339: High-resolution Climate Projections for Ireland – A Multi-model Ensemble Approach' published by the Environmental Protection Agency (EPA) and supported by Met Éireann and the Marine Institute https://www.met.ie/epa-climate-projections-2020 .

[3] Figure 1: All forcing agents' atmospheric CO2-equivalent concentrations (in parts-per-million-by-volume (ppmv)) according to the four RCPs used by the fifth IPCC Assessment Report (Efbrazil, 2020).

- Precipitation
    - Precipitation is expected to become more variable, with substantially more periods of prolonged dry weather and heavy precipitation events predicted.
    - The number of days with frost and ice will decrease by approximately 50%.
    - Snowfall is projected to decrease substantially across the country.
- Wind
    - Mean 10-metre wind speeds[4] are projected to decrease for all seasons and the energy content of the 120-metre wind[5] is projected to decrease.
    - The numbers of storms affecting Ireland is expected to decrease by approximately 10%.
- Specific humidity[6] is projected to increase substantially, while relative humidity[7] is projected to increase slightly for all seasons except summer.
- The length of the growing season is predicted to increase by between 12% and 16%.
- A small decrease is expected in the available solar energy for photovoltaic (PV) power production.

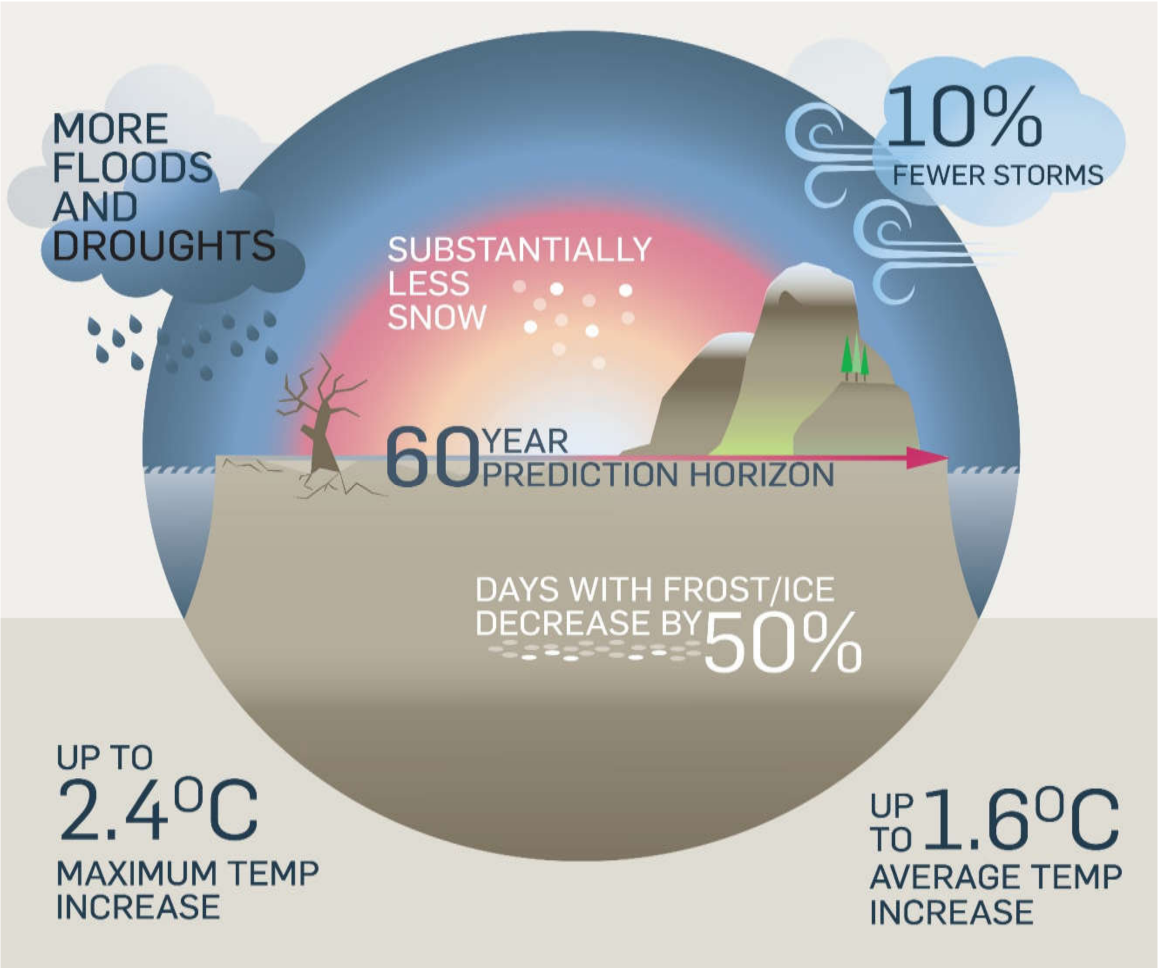

Figure 2 – Predicted Climate Changes

4 10-metre wind speed is the wind speed at a height of 10m above ground level.
5 120-metre wind speed is the wind speed at a height of 120m above ground level.
6 Specific humidity is the mass of water vapour in a mass of air.
7 Relative humidity is how much water vapour there is in air compared to the maximum amount that the air could hold at a given temperature.

Literature Review

Literature Review

Prior to developing this strategy, a review of existing literature was undertaken to determine the approach that is being taken in other jurisdictions to the climate adaptation of road assets.

The target scope of this literature review was to identify and review documents with the following characteristics:

- documents which related to 'climate adaptation' or 'climate resilience';
- and which had been published by local government, government, or road authority organisations;
- and which related primarily to England, Scotland, or New Zealand, but other jurisdictions were to be included if a document was identified which was particularly relevant;
- and which had been published in the last circa 10 years, but earlier documents were to be included if particularly relevant.

In addition to the document types described above, the scope also included the review of any relevant documents already published in Ireland to ensure that the strategy to be developed would be consistent with existing publications.

Note that in any literature review, it is not possible to consider every document that meets the criteria. The aim is to find a sufficient sample of documents which represent the general approach which is commonly taken in other jurisdictions.

While the number of documents will vary, most literature reviews will typically include the review of 3 – 10 documents depending on the type of project. This is on the basis that even the simplest projects will benefit from the examination of more than one approach; and that ten suitable reference documents will in most cases provide a good sample of all the possible approaches for larger more complex projects.

In this case, it proved difficult to find reference documents which are relevant to the climate adaptation of Regional and Local road assets and as a result, the review process was extended in a further effort to identify such documents. As a result, the final number of reference documents reviewed as part of the literature review was 47.

These documents were published by a variety of sources from a range of sectors including the following organisations:

- The World Bank;
- The Organisation for Economic Co-operation and Development;
- The New Zealand Government;
- The European Road Transport Research Advisory Council;
- The Conference of European Directors of Roads;
- Climate Adapt;
- Highways England;
- Transport Scotland;
- Wiltshire Council in the UK;
- The Government of Ireland including the Department of Transport and various other state departments; and
- Met Éireann.

As a result of the literature review, it was evident that there is no single universal approach that can be applied to climate adaptation of road assets. However, a number of recurring themes were present in many of the reference documents which are transferable to the Irish Regional and Local road context, as listed in Table 1 below.

Literature Review Recurring Themes
Areas for Guidance Climate adaptation should be developed based on real problems which have occurred in the past over all phases of the asset lifecycle (i.e. design, construction, maintenance, and renewal). This should include examination of issues which occur both suddenly (such as flooding events) and gradually (such as a longer growing season); and should include issues which originate both inside the road corridor (such as asphalt melting) and outside the road corridor (such as landslides). In addition to looking at challenges which may arise due to expected climate change, it is also important to consider opportunities (such as a shorter winter treatment season) in climate adaptation planning.
Asset Management Climate adaptation should be implemented as an enhancement to whatever asset management approach is already in place. Asset management is the best way to deliver climate resilience of road assets and even simple asset management systems, such as effective procedures to ensure adequate maintenance, are very effective climate adaptation measures. Preventative measures are more effective than reactive maintenance. Climate adaptation should be built on the same data-led approach which is central to all asset management systems.
Structured Approach The implementation of climate adaptation for road assets should follow a structured approach. For example, the following steps are commonly found in many of the climate adaptation documents reviewed: • Identify future demands that are expected of the road network e.g. expected growth in traffic levels. • Identify the relevant expected climate changes from modelling e.g. in rainfall, temperature, and wind. • Undertake a wide area risk assessment / vulnerability mapping exercise to identify areas where the product of probability and impact is highest. • Develop climate adaptation solutions for highest risk areas. • Cost these solutions and prioritise them based on an economic assessment such as cost-benefit analysis or multi-criteria analysis. • Implement the prioritised solutions. • Monitor and review the effectiveness of the solutions which have been implemented – this will allow robust knowledge to be built iteratively over time. • Continuously improve the approach based on a growing knowledge base. • Ensure that Emergency Planning procedures are sufficient to deal with those failures that occur in spite of climate adaptation measures.

Literature Review Recurring Themes
Build Back Better Even the most robust measures for climate adaptation will not prevent all failures before they occur. When assets do fail, a 'Build Back Better' approach should be adopted using latest design standards. Applying solutions with little design input which are excessively conservative are poor value for money and unsustainable. The best approach is to design solutions using latest standards to ensure an evidence-based consistent approach which takes account of climate risks without being excessive.
Consider the 'Do Nothing' option It is not possible to make all road assets completely resilient to all climate change impacts and, in many cases, the 'Do Nothing' option is a preferable choice where the costs of managing the issue are less than the adaptation costs.
Dealing with Uncertainty Climate adaptation involves developing solutions to impacts which may occur to some unknown extent at an unknown time in the future depending on climate changes which are difficult to predict accurately. As a result of this inherent uncertainty, there is a significant risk that the solutions chosen will transpire in time to be either excessive or insufficient; both of which outcomes will result in wasteful and unsustainable practice which redirects funds away from worthwhile projects. Therefore, climate adaptation practice should be based on robust research supported by objective data in order to ensure value for money and effective solutions. Solutions which are based on shorter term climate predictions will involve less uncertainty and therefore a lower degree of risk.
Residual Asset Lifespan Where the expected remaining lifespan of an asset is short, these assets are less worthy of climate adaptation for two reasons. Firstly, less climate change is expected in the short term than over the long term and therefore assets which are near end of life are less impacted by climate change. Secondly, adapting assets which are close to end of life means that the benefits of such investment will be felt for a shorter time which will reduce the benefit to cost ratio. While the primary aim is to use preventative maintenance to extend the asset lifespan as far as is optimal, all assets will eventually reach end of life. When residual lifespan is short, it may be better to apply minimal adaptation solutions and plan a full asset replacement to latest design standards at end of life of the asset.

Table 1

Common Failure Types

Common Failure Types

As identified in the Literature Review, adapting road assets to the challenges of a changing climate is best done based on the actual climate related failures that are already occurring. This approach will ensure that the adaptation measures which are put in place will be tailored to the type, condition and variety of assets which exist on the Irish Regional and Local road network.

During the development of this strategy, these Common Failure Types were identified during a series of structured workshops with representatives from the Local Authority sector. Each of these workshops was focused on a different discipline (structures, pavement and geotechnical) but a number of Common Failure Types were also identified in other areas, or which spanned more than one discipline.

The purpose of these workshops was to identify failures which commonly occur, and which are caused entirely or in large part by the climate change impacts in the Predicted Climate Change section above.

Each Common Failure Type was also examined under the following three headings to see if the most likely cause of the failure was known:

- Is the failure due to a weakness in the design standards that were in effect at the time that the asset was constructed?
- Is the failure due to an issue with the way that the design standards were interpreted or applied during construction or reconstruction of the asset?
- Is the failure due to an issue with the inspection, maintenance, or ongoing repair of the asset?

In the majority of cases, the contributors to the workshops felt that the Common Failure Types are not due to any shortcoming in the current design standards which already contain measures to allow for expected climate change. The main causes of climate failures are legacy assets which were constructed to design standards which are now out of date; and issues relating to inspection and maintenance.

Following the workshops, high-level adaptation actions were developed for each Common Failure Type to address the causes identified; and a preliminary risk assessment was carried out using Table 2 opposite to identify the most frequent and most problematic failures at a national level[8].

Impact / Probability	High	Medium	Low
High	High	High	Medium
Medium	High	Medium	Low
Low	Medium	Low	Low

Table 2 – Overall Risk

A list of the Common Failure Types identified together with the relevant details described above is summarised in Table 3 below. The actions developed under this strategy are focused primarily on developing an approach which will prevent the occurrence of these specific Common Failure Types.

[8] Note that this is a high-level risk assessment which considers the overall operational impact of Common Failure Types across the country as whole. The initial assessments in this document are based on the data collected by the Department of Transport for prioritising and funding climate adaptation projects to date. These assessments should be updated in future when more data is available on climate adaptation projects.

Table 3 – Summary of Common Failure Types

Ref	Discipline	Common Failure Type	Predicted Climate Change	Description	Probability	Impact	Overall Risk	Adaptation Action	Notes
1	Pavement	Softening of Hot Rolled Asphalt (HRA) surface course due to bitumen melting.	Increased temperatures and more frequent summer heatwaves.	The road surface becomes soft due to higher temperatures resulting in damage to the road surface in the wheel track zone.	Low	Medium	Low	Vulnerability mapping based on records of historical occurrences. Inlay / overlay the surface course with a material which is more resilient to higher temperatures.	Note the risk that materials with an improved resilience to higher temperatures may have other performance characteristics which are reduced e.g. winter performance. Need to balance this risk.
2	Pavement	Softening of surface dressing due to melting of the binder.	Increased temperatures and more frequent summer heatwaves.	The road surface becomes soft due to higher temperatures resulting in damage to the road surface in the wheel track zone.	Low	Medium	Low	Vulnerability mapping based on records of historical occurrences. Replace the surface course with a material which is more resilient to higher temperatures.	Note the risk that materials with an improved resilience to higher temperatures may have other performance characteristics which are reduced e.g. winter performance. Need to balance this risk.

Ref	Discipline	Common Failure Type	Predicted Climate Change	Description	Probability	Impact	Overall Risk	Adaptation Action	Notes
3	Pavement	Damage to cycle tracks due to bitumen melting.	Increased temperatures and more frequent summer heatwaves.	The cycle track surface becomes soft due to higher temperatures. Soft binder may stick to the wheels of bicycles which are using the cycle track.	Medium	Low	Low	Vulnerability assessment to determine if areas shaded from midday sun by trees / buildings are impacted less. The most efficient preventative measures might be to simply consider the use of materials which are more resistant to melting during initial construction.	Note the risk that materials with an improved resilience to higher temperatures may have other performance characteristics which are reduced e.g. winter performance. Need to balance this risk.
4	Pavement / Drainage	Road flooding due to blocked drainage.	More variable precipitation patterns with substantially more frequent heavy rainfall events.	Drains which have operated well with minimal maintenance in the past are now a cause of flooding due to more frequent / severe heavy rainfall events.	Medium	Medium	Medium	Repair any damage caused by previous flooding events. Adopt a preventative approach to maintenance which is based on records of historical flooding.	

Ref	Discipline	Common Failure Type	Predicted Climate Change	Description	Probability	Impact	Overall Risk	Adaptation Action	Notes
5	Pavement / Drainage	Road flooding due to inadequate drainage or no drainage system.	More variable precipitation patterns with substantially more frequent heavy rainfall events.	Capacity of the original drainage system has been gradually overtaken by increasing rainfall intensities due to climate change.	Medium	Medium	Medium	Identify sections of the network which are vulnerable to flooding based on records of historical occurrences. Develop schemes for new or improved drainage systems in these areas which are designed to current standards.	
6	Pavement / Drainage	Coastal flooding due to high tides and storm surges.	More variable precipitation patterns with substantially more frequent heavy rainfall events. Sea level rises.	High tide levels combine with strong onshore winds to create abnormally high sea levels. This leads to flooding of low-lying areas close to the coast, particularly during / after periods of heavy rainfall.	Low	High	Medium	Identify sections of the network which are vulnerable to coastal flooding based on records of historical occurrences. Develop schemes for new / improved sea defences / drainage systems designed to current standards.	Note that this failure type may be less common in future given that the numbers of storms affecting Ireland is expected to decrease by ~ 10%. This effect may be balanced to some extent by increasing sea levels.

Ref	Discipline	Common Failure Type	Predicted Climate Change	Description	Probability	Impact	Overall Risk	Adaptation Action	Notes
7	Pavement / Drainage	Groundwater flooding in karst areas.	More variable precipitation patterns with substantially more frequent heavy rainfall events.	Sustained rainfall over a prolonged period can lead to increased water levels in turloughs which in turn can flood adjacent roads. This can lead to lengthy road closures and road damage.	Low	High	Medium	Vulnerability mapping based on records of historical occurrences. Develop schemes such as road-raising schemes in at-risk areas which are designed to current standards.	Note that this failure type may not be significantly more common / severe in future as current predictions are uncertain as to whether average rainfall levels will increase due to climate change.
8	Structures	Damage to bridges due to scour action.	More variable precipitation patterns with substantially more frequent heavy rainfall events.	An increase in the frequency / severity of heavy rainfall events can lead to greater discharge levels in rivers which can accelerate scour at unprotected bridges.	Medium	Medium	Medium	Vulnerability mapping based on records of historical occurrences. Put in place a regime of Scour Inspections at the at-risk locations. Develop scour protection schemes which are designed to current standards.	Note that while scour damage is not exclusively due to climate change, increasing frequency and severity of heavy rainfall events could exacerbate this failure type significantly.

Ref	Discipline	Common Failure Type	Predicted Climate Change	Description	Probability	Impact	Overall Risk	Adaptation Action	Notes
9	Structures / Drainage	Mortar wash-out on masonry arch bridges due to poor drainage.	More variable precipitation patterns with substantially more frequent heavy rainfall events.	Water build-up in the fill material can lead to wash-out of jointing resulting in a loss of structural integrity of the arch, abutments, supports or wing-walls which can in turn damage or collapse the structure.	Medium	Medium	Medium	Enhance the existing bridge inspection regime to include inspection for this specific issue. Develop schemes to improve waterproofing and drainage which are designed to current standards.	Note that while mortar wash-out is not exclusively due to climate change, increasing frequency and severity of heavy rainfall events could exacerbate this failure type significantly.
10	Structures	Damage to structures, signs, or trees due to high winds.	Note that this failure type may be less common in future given that the number of storms affecting Ireland is expected to decrease by ~ 10%.	High wind events cause damage to mature trees or to older signs / structures which are not designed to current standards.	Medium	Low	Low	Climate change is likely to be a limited contributor to these types of failure. For this reason, no adaptation actions are proposed other than normal inspection and maintenance of these assets.	It may be beneficial to introduce measures to ensure that existing signposts are not overloaded by the erection of additional signs over time.

Ref	Discipline	Common Failure Type	Predicted Climate Change	Description	Probability	Impact	Overall Risk	Adaptation Action	Notes
11	Geotechnical / Drainage	Slope failure in a cutting due to high groundwater levels.	More variable precipitation patterns with substantially more frequent heavy rainfall events.	Absent, insufficient, or blocked drainage in cuttings can lead to high groundwater levels and weakening of the slope face which in turn can cause cracking or slippage failures.	Low	Medium - High	Medium	Put in place a regime of inspections to check for this specific issue at the at-risk locations. Develop schemes for improved slope drainage in these areas which are designed to current standards.	Note that while slope stability issues are not exclusively due to climate change, increasing frequency and severity of heavy rainfall events could exacerbate this failure type significantly.
12	Geotechnical / Drainage	Slope failure in a cutting due to heavy rainfall and insufficient or blocked crest drainage.	More variable precipitation patterns with substantially more frequent heavy rainfall events.	Surface water flowing from adjacent lands and down the face of the cutting can lead to erosion / weakening of the slope which can lead to slope failure.	Low	Medium - High	Medium	Put in place a regime of inspections to check for this specific issue. Develop schemes for improved crest drainage in these areas which are designed to current standards.	Note that while slope stability issues are not exclusively due to climate change, increasing frequency and severity of heavy rainfall events could exacerbate this failure type significantly.

Ref	Discipline	Common Failure Type	Predicted Climate Change	Description	Probability	Impact	Overall Risk	Adaptation Action	Notes
13	Geotechnical / Drainage	Slope failure on an embankment due to heavy rainfall and no formal drainage system.	More variable precipitation patterns with substantially more frequent heavy rainfall events.	Surface water flowing from the road surface and down the embankment face can erode / weaken the slope. This can lead to slope instability or even failure.	Low	Medium – High	Medium	Put in place a regime of inspections to check for this specific issue. Develop schemes for improved slope drainage in at-risk areas which are designed to current standards.	Note that while slope stability issues are not exclusively due to climate change, increasing frequency and severity of heavy rainfall events could exacerbate this failure type significantly.
14	Geotechnical	Slope failure on legacy embankments and cuttings due to excessive slope gradient.	More variable precipitation patterns with substantially more frequent heavy rainfall events. Increased temperatures and more frequent summer heatwaves.	Slopes constructed with a steep gradient prior to current design standards, which have performed well in the past, begin to fail due to increases in rainfall, or deterioration in vegetation health.	Low	Medium – High	Medium	Put in place a regime of inspections to check for this specific issue. Develop schemes for retaining structures or slope reconstruction in the at-risk locations which are designed to current standards.	Note that while slope stability issues are not exclusively due to climate change, increasing frequency and severity of heavy rainfall events and summer heatwaves could exacerbate this failure type significantly.

Ref	Discipline	Common Failure Type	Predicted Climate Change	Description	Probability	Impact	Overall Risk	Adaptation Action	Notes
15	Geotechnical	Failure of a retaining wall due to unintended overloading over time e.g. due to development works etc.	More variable precipitation patterns with substantially more frequent heavy rainfall events.	This occurs when additional loading is placed on the retained ground behind the retaining wall structure.	Low	Medium	Low	Carry out a desk-based risk assessment of each retaining wall. Inspect these progressively based on the risk assessment. Develop schemes for strengthening or reduction of retained loads which are designed to current standards.	Note that the predominant cause of this failure type is not related to climate change. However, increasing frequency and severity of heavy rainfall events could exacerbate this failure type.
16	Geotechnical / Drainage	Failure of a retaining wall due to blocked back-of-wall drainage.	More variable precipitation patterns with substantially more frequent heavy rainfall events.	Blocked cross drains on the retained side of the retaining wall can lead to a build-up of groundwater pressure behind the retaining wall, which in turn can cause movement / failure.	Low	Medium - High	Medium	Carry out a desk-based risk assessment of each retaining wall. Inspect/maintain these progressively based on the risk assessment.	While this failure type is not exclusively due to climate change, increasing frequency and severity of heavy rainfall events could exacerbate this failure type significantly.

Ref	Discipline	Common Failure Type	Predicted Climate Change	Description	Probability	Impact	Overall Risk	Adaptation Action	Notes
17	Geotechnical / Pavement / Structures	Settlement damage to bog roads due to prolonged dry spells.	More variable precipitation patterns with substantially more periods of prolonged dry weather.	This can occur when the groundwater in the peat layer on which a road is built is lowered due to prolonged periods of dry weather. This can lead to degradation and compression of the peat layer which in turn can cause settlement of the road.	Low	Medium	Low	Identify sections of the network which are vulnerable to this type of settlement based on records of historical occurrences. Put in place a regime of inspections to check for this specific issue during periods of prolonged dry weather. Develop schemes for road reconstruction in these areas which are designed to current standards.	This failure type can also occur on roads adjacent to bridges which can lead to differential settlement at the interface point(s) between the road and the structure.

Ref	Discipline	Common Failure Type	Predicted Climate Change	Description	Probability	Impact	Overall Risk	Adaptation Action	Notes
18	Geotechnical / Drainage	Damage to road surfacing / subgrade due to flooding.	More variable precipitation patterns with substantially more frequent heavy rainfall events.	This occurs when surface water flowing from adjacent areas of high ground causes roads to flood. The flooding can be either fast flowing which can wash away parts of the road surface; but even static flooding can cause damage to the subgrade which can lead to settlement.	Medium	Medium - High	High	Identify road sections which are vulnerable to this type of flooding based on records of historical occurrences. Put in place a regime of inspections to check for this specific issue at the at-risk locations during periods of heavy rainfall. Develop schemes for improved interceptor drainage in these areas which are designed to current standards.	

Ref	Discipline	Common Failure Type	Predicted Climate Change	Description	Probability	Impact	Overall Risk	Adaptation Action	Notes
19	Geotechnical	Damage to road subgrade and subbase due to freeze-thaw action.	Note that this failure type may be less common in future given that the number of frost and ice days is predicted to decrease by approximately 50%.	Occurs when the road make-up is not sufficiently thick to protect the underlying cohesive material from freeze-thaw action, or when the subbase granular material contains a high percentage of fines, hindering its free draining capabilities.	Low	Medium	Low	Climate change is likely to be a limited contributor to these types of failure. For this reason, no adaptation actions are proposed other than normal inspection and maintenance of these assets.	
20	Geotechnical	Damage to roads / embankments due to coastal erosion.	A separate project[9] is underway to predict the impacts of climate change on coastal erosion.	This failure type occurs when the material on the seaward side of a coastal road is eroded by wave action which then undermines the road leading to collapse.	Low	High	Medium	At present, no adaptation actions are proposed other than normal inspection and maintenance of these assets.	The adaptation actions for this failure type may change in future when detailed predictions are available for climate driven coastal erosion.

[9] A separate project is underway by the Office of Public Works and the Department of Housing, Local Government and Heritage to develop a national co-ordinated strategy to manage the projected impacts of coastal change on coastal communities, economies, heritage, culture, and the environment.

Ref	Discipline	Common Failure Type	Predicted Climate Change	Description	Probability	Impact	Overall Risk	Adaptation Action	Notes
21	Geotechnical	Damage to roads due to peat landslides.	Precipitation is expected to become more variable, with substantially more periods of prolonged dry weather and heavy precipitation events predicted.	Peat landslides occur due to changes in the groundwater regime which can be caused by heavy rainfall, construction activity, turf cutting or blocked drains. This weakens the peat material to a liquefied state which can then begin to slide downhill due to gravity. Once a peat landslide begins, the material can often move large distances and cause significant damage before coming to rest.	Low	High	Medium	Most peat landslides originate outside the road corridor and therefore the practical steps that could be taken by Local Authorities to prevent this failure type are limited. This is better dealt with by way of national legislation governing the management of peatlands.	

Sustainability

Sustainability

Although the main subject of this report is the climate adaptation of assets on Regional and Local roads, sustainability is also one of the core deliverables of the Climate Action Plan 2021. Therefore, it is important that the adaptation actions which are developed as a result of this report are delivered in a sustainable manner.

This section contains a number of guiding principles in Table 4 below that should be adopted where practicable when implementing the actions which have been developed under this strategy. These principles have been developed based on the adaptation actions identified for each of the Common Failure Types listed in Table 3 above and they are intended to ensure that these actions are delivered in a manner which is sustainable from an environmental, social, and economic perspective.

As stated in the Literature Review section above, international experience indicates that a key way to deliver climate resilience of road assets is to prevent failures before they occur by means of a structured regime of preventative maintenance.

However, the option which is often considered first as a solution to climate adaptation is hard engineering solutions, such as installing new drainage systems, replacing retaining walls, or additional coastal defences. This type of approach requires more construction activity, more energy consumption, and the generation of more greenhouse gases; all of which ultimately are contributors to climate change. It also diverts limited funding away from maintenance activities in favour of capital expenditure which increases the stock of assets that need to be maintained into the future. For these reasons, focusing on preventative maintenance is not only a proven mechanism to improve climate resilience but also ensures a more sustainable approach.

It is important to remember that when assets do require repair or replacement, latest relevant design standards which already include appropriate measures for expected climate change should be used for these works. This will ensure that assets are rebuilt in a cost effective and resilient way while minimising the risk of over-engineered or excessive solutions which is intrinsic in the uncertainty of climate predictions, particularly in the longer term.

There can be a tendency to carry out like-for-like replacement of assets which fail at end of life on the basis that the asset always performed well in the past. Solutions such as this which are not designed to modern standards are at risk of being either insufficient or over-designed, both of which are poor value for money and unsustainable.

Similarly, when funding is limited, there is an inclination to provide whatever solution is possible with the available funding. This often results in an insufficient repair which does not last and is a waste of money and materials. It is better to implement well-designed long-term repairs in a smaller number of locations than to spread funding too thinly over a large number of inadequate repairs.

The repair or reconstruction of assets which are not based on modern design standards should therefore be avoided.

Measure / Benefit	Environmental	Social	Economic
Improving the resilience of an asset to a particular failure type often involves identifying locations where that failure has occurred in the past. Identifying these locations of historical failures should be carried out as far as possible using a desk study rather than by site visits.	Reduces carbon emissions due to inspection vehicle travel.	Contributes to lower traffic congestion.	Reduces vehicle fuel and maintenance costs; and requires less staff time.
Vulnerability mapping involves identifying parts of the road network where the risk of a particular failure type is unusually high. This can be a useful tool in proactively identifying assets which are at risk of failure. Development of vulnerability mapping should be carried out as far as possible using a desk study rather than by site visits.	Reduces carbon emissions due to inspection vehicle travel.	Contributes to lower traffic congestion.	Reduces vehicle fuel and maintenance costs; and requires less staff time.
In developing vulnerability mapping, it may be necessary to carry out some site inspections to validate a sample of locations which are suspected to be vulnerable. As far as possible, these should be combined with other routine inspections rather than being carried out by dedicated inspections just for this purpose.	Reduces carbon emissions due to inspection vehicle travel.	Contributes to lower traffic congestion.	Reduces vehicle fuel and maintenance costs; and requires less staff time.
Determining which specific failure type is occurring at a location often requires access to as-built records. Where up-to-date existing as-built records are available, these should be used rather than resurveying.	Reduces carbon emissions due to less physical surveying work.	Contributes to lower traffic congestion.	Reduces or eliminates resurveying costs.
Where repair or reconstruction work is required, third parties engaged to undertake these works should be vetted for their approach to sustainability. Green Public Procurement should be incorporated into the appointment of any external contractors or consultants.	Encourages a sustainable approach in the Local Government supply chain which will lead to environmental, social, and economic benefits across a large section of the economy.		

<table>
<tr><th>Measure / Benefit</th><th>Environmental</th><th>Social</th><th>Economic</th></tr>
<tr><td>In certain cases, it may be necessary to monitor the climate adaptation works carried out to ensure its effectiveness. Any such monitoring which is required should be combined with other routine inspections rather than being carried out by dedicated inspections just for this purpose. Remote monitoring techniques should also be considered.</td><td>Reduces carbon emissions due to inspection vehicle travel.</td><td>Contributes to lower traffic congestion.</td><td>Reduces vehicle fuel and maintenance costs; and requires less staff time.</td></tr>
<tr><td>All relevant data collected as part of the climate adaptation process is to be stored in a structured dataset for future use (e.g. MapRoad) in order to reduce the need for duplicate data collection work in the future.</td><td>Reduces carbon emissions due to less physical surveying work.</td><td>More readily available data facilitates decision making.</td><td>Reduces or eliminates the cost of duplicate data collection works.</td></tr>
<tr><td>There is sometimes a tendency to replace assets on a like-for-like basis. This results in new assets which are not constructed to modern standards, and which therefore do not take account of expected future climate change.

Like-for-like replacements should be avoided in favour of a ‘Build Back Better’ approach where all new assets are designed using current standards which include appropriate measures for expected climate change.</td><td colspan="3">Like-for-like replacements can result in early failure of the asset as increasing demands due to climate change gradually overtake the capacity of the asset.

Premature asset failures result in the waste of the materials, energy and carbon which are required for the asset replacement works.

Avoiding like-for-like replacements will reduce the amount of carbon produced by road maintenance activities, will avoid materials being sent to landfill unnecessarily, and will prevent poor use of funding.</td></tr>
<tr><td>In some cases, the extent of asset repairs is based on the funding that is available rather than the optimum repair required for the long term.

This can result in early failure of the asset if the repair is insufficient.

The scope of repair works should be based on the design requirements and not the available funding.</td><td colspan="3">Repairs which have not been constructed to current standards can result in early failure of the asset as increasing demands due to climate change gradually overtake the capacity of the asset. Premature asset failures result in the waste of the materials, energy and carbon which are required for the asset replacement works.

Avoiding inadequate repairs will reduce the amount of carbon produced by road maintenance activities, will avoid materials being sent to landfill unnecessarily, and will prevent poor use of funding.</td></tr>
<tr><td>Climate adaptation should focus on preventative maintenance more than reactive repair works.</td><td colspan="3">Preventative maintenance is less expensive, requires less energy, produces less carbon and is less disruptive to road users than reactive repairs.</td></tr>
</table>

Table 4

Organisational Resilience

Organisational Resilience

The main aim of climate adaptation is to ensure that assets are more resilient to climate change and therefore, when implemented successfully, this will reduce the number of unplanned asset failures that occur.

However, it is not possible to prevent all climate related failures and where failures do occur, it is advisable to ensure that there is a second line of defence for dealing with those failures in a planned and controlled manner.

This aim is achieved by way of Organisational Resilience, which in this context means the ability of each Local Authority to anticipate and deal with climate related failures in order to maintain road functionality and mitigate the impacts of road closures.

Local Authorities have already put in place various measures for emergency planning such as:

- Major Emergency Plans,
- Severe Weather Plans,
- Flood Emergency Plans, and
- Winter Service Plans.

They also have access to a number of important resources which can be used to support the implementation of these plans, and these include:

- the Met Éireann weather warning system (https://www.met.ie/met-eireann-warning-system-explained),
- the GSI national landslide susceptibility mapping https://www.gsi.ie/en-ie/programmes-and-projects/geohazards/activities/Pages/National-Landslide-Mapping.aspx ,
- the GSI historic groundwater flood map https://www.gsi.ie/en-ie/programmes-and-projects/groundwater/activities/groundwater-flooding/Pages/Historic-groundwater-flood-map.aspx
- the OPW national flood information portal www.floodinfo.ie .

While these existing resources address the emergency planning requirements well, dealing with unplanned failures of assets can still be a major task and the ability to prioritise efforts to where they are most needed would be useful.

For this reason, a methodology has been developed in parallel with this strategy to identify Critical Infrastructure Routes. This process is intended to help identify which parts of the Regional and Local road network are more important in terms of socio-economic impact and emergency response functions.

The methodology defines how Critical Infrastructure Routes should be identified based on the following steps:

1. Identify certain strategic facilities such as fire stations, health facilities, power stations, and Local Authority maintenance depots etc. which are important from a socio-economic or emergency response point of view.
2. Identify sections of the Irish road network which are already resilient. For example, the National road network is considered to be resilient by virtue of the quality of construction, the design standards used, and the level of ongoing investment. In addition, the Regional

road network in urban areas also has a high level of resilience as it is sufficiently dense to provide a good level of redundancy in terms of alternative routes.

3. Routes which are required to connect these strategic facilities to sections of the network which are already resilient are then designated as Critical Infrastructure Routes i.e. routes which connect the strategic facilities to (i) the National road network in rural areas, or (ii) the Regional road or National road network in urban areas.
4. In both urban and rural areas, bridges and causeways which are the only road access to isolated or island communities are also to be designated as Critical Infrastructure Routes.

In order to validate this approach, the initial methodology developed was applied to three areas around the country which were chosen as a representative sample of the country as a whole i.e. one urban area (Fingal County Council), one regional town (Loughrea Municipal District) and one rural area (West Clare Municipal District).

The results from these three areas were then used as the basis of consultation with representatives from the Local Authority sector and the feedback received was used to update the methodology.

Technical Annex 1 to this document describes the methodology to be used for the identification of Critical Infrastructure Routes and how to apply this to other areas. One of the actions of this report below is that Local Authorities should apply this methodology to their respective areas in order to identify Critical Infrastructure Routes. It is intended that this information would then be stored as a single dataset in GIS format on the MapRoad system so that it can be used as a reference resource by all Local Authorities, the Department of Transport and their agents whenever required in the future.

The ability to identify Critical Infrastructure Routes will assist Local Authorities in their existing emergency planning activities but will also facilitate the prioritisation of funding of climate adaptation works to ensure that it is directed to the most critical areas.

Action Responses

Action Responses

This section sets out the action responses that should be implemented to address climate adaptation of assets on Regional and Local roads in a cost-effective manner. It is based on research into the approach taken in other jurisdictions and consultation with the Local Authority sector to identify the Common Failure Types that are currently occurring in Ireland due to climate change.

The overall approach is to amend the procedures which are already well established for the inspection and maintenance of assets to include measures to deal with the Common Failure Types which have been identified. In most cases, it is proposed to do this by amending some of the existing guidance documents by way of a Climate Adaptation Addendum; but in the case of geotechnical assets, the development of a new guidance document specific to this asset class is proposed.

The MapRoad system currently supports the implementation of the existing procedures for inspection and maintenance of assets. Therefore, this will need to be updated to reflect the changes which are proposed to address the Common Failure Types. It is also proposed to add additional modules to MapRoad which will deal with vulnerability mapping, Critical Infrastructure Routes, and the Works Prioritisation Methodology. This will allow the proposed climate resilience changes to be implemented more effectively and will also strengthen the management of road assets on the whole.

Action Response 1: Provide a Climate Adaptation Addendum to the existing Guidelines for Road Drainage document (2nd Edition, March 2022).

The Guidelines for Road Drainage (2nd Edition, March 2022) is published by the Department of Transport, and it provides guidance to Local Authority engineers and supervisors on current best practice in respect of road drainage.

The document provides guidance on the design and maintenance of drainage systems; how to record and rate the condition of road drainage elements; and how to select/implement appropriate rehabilitation works when required. It also describes the different types of drainage options, summarises the effectiveness of each against a number of criteria, and provides guidance as to which drainage type is most suitable in different scenarios.

This document already includes some guidance on how to future proof the road drainage network against climate change, but this is focused on design and does not address any specific failure types.

A Climate Adaptation Addendum should be drafted to accompany this document which will address the Common Failure Types identified in Table 3 above which are related to drainage. The general aim of this addendum should be as follows, but this may vary depending on the specific failure type:

- Undertake a desk-based study to identify potential Common Failure Types before they occur based on vulnerability mapping, where available.
- Undertake a desk-based study to identify areas where the failure types have occurred in the past based on historical records.
- Undertake a risk assessment to identify areas with the highest risk of a future failure.
- Inspect these potential failure locations progressively starting with the areas of highest risk.
- Identify potential maintenance, rehabilitation or improvement works to prevent occurrence or recurrence of the Common Failure Type in the future.
- Prioritise these works based on a cost-benefit approach.
- Implement the works with the greatest benefit based on available funding.
- Monitor the works which have been implemented over time to assess their effectiveness.

The Climate Adaptation Addendum should be drafted to take account of the guiding principles for sustainability as outlined in Table 4 above.

Action Response 2: Provide a Climate Adaptation Addendum to the existing Pavement Asset Management Guidance document (Version 1.0, December 2014)

The Pavement Asset Management Guidance document (Version 1.0, December 2014) is published by the Irish Pavement Asset Group which represents the Department of Transport, the Local Government Management Agency, and Local Authorities. The document provides a standardised pavement management approach for all Local Authorities in Ireland.

The document describes:

- How to establish a road asset register which describes all road assets in a hierarchical system.
- A recommended method of network referencing for use on Irish roads. This is based on a link and node approach with roads being further subdivided into segments in accordance with specified criteria. A system for referencing cross sectional positions in the road corridor is also described, as is a process for dealing with modifications to the network.
- The type of inventory data that road authorities should hold. It provides guidance on how data should be collected, validated, and updated.
- How defects should be identified, categorised, prioritised and repaired. It includes recommended frequencies for different inspection types; repair response times for different categories of defect; and sample photographs to assist in identifying different defect types.
- How condition surveys are carried out on Regional and Local roads to establish an overall condition rating of footways, pavements, and associated drainage. It details the frequency and extent of both machine and visual surveys required for network level and project level surveys.
- How pavement asset management strategies should be developed to identify sites for treatment; to analyse the different treatment options; to create short term works programmes; and to project future funding needs.
- Records that should be kept of road reinstatements which are required to assist with pavement asset management.
- The steps that should take place prior to a Local Authority taking a road in charge following works by contractors or developers.

This document does not currently make reference to climate adaptation or climate resilience.

A Climate Adaptation Addendum should be drafted to accompany this document which will address the Common Failure Types identified in Table 3 above which are related to pavements. The general aim of this addendum should be as follows, but this may vary depending on the specific failure type:

- Undertake a desk-based study to identify potential Common Failure Types before they occur based on vulnerability mapping, where available.
- Undertake a desk-based study to identify areas where the failure types have occurred in the past based on historical records.
- Undertake a risk assessment to identify areas with the highest risk of a future failure.
- Inspect these potential failure locations progressively starting with the areas of highest risk.
- Identify potential maintenance, rehabilitation or improvement works to prevent occurrence or recurrence of the Common Failure Type in future.
- Prioritise these works based on a cost-benefit approach.

- Implement the works with the greatest benefit based on available funding.
- Monitor the works which have been implemented over time to assess their effectiveness.

The Climate Adaptation Addendum should be drafted to take account of the guiding principles for sustainability as outlined in Table 4 above.

Action Response 3: Provide a Climate Adaptation Addendum to the existing Bridge Asset Management System document (September 2019)
The Bridge Asset Management System document (September 2019) is published by the Department of Transport, and it describes a consistent approach to the management of bridges and structures on the Regional and Local road network for use by all Local Authorities in Ireland.

The document describes:

- How to locate and survey all bridges and structures to create a bridge inventory.
- How to assign an initial rating to each structure based on a maintenance inspection.
- How to assign condition ratings to individual elements of each structure using more detailed engineering inspections based on which overall condition ratings can be assigned.
- Health & Safety considerations which are relevant to bridge surveys and inspections.
- Conservation principles which are relevant to bridge surveys and inspections.
- How to use the MapRoad system for the completion of surveys and inspections.

This document does not currently make reference to climate adaptation or climate resilience.

A Climate Adaptation Addendum should be drafted to accompany this document which will address the Common Failure Types identified in Table 3 above which are related to bridges and structures. The general aim of this addendum should be as follows, but this may vary depending on the specific failure type:

- Undertake a desk-based study to identify potential Common Failure Types before they occur based on vulnerability mapping, where available.
- Undertake a desk-based study to identify areas where the failure types have occurred in the past based on historical records.
- Undertake a risk assessment to identify areas with the highest risk of a future failure.
- Inspect these potential failure locations progressively starting with the areas of highest risk.
- Identify potential maintenance, rehabilitation or improvement works to prevent occurrence or recurrence of the Common Failure Type in future.
- Prioritise these works based on a cost-benefit approach.
- Implement the works with the greatest benefit based on available funding.
- Monitor the works which have been implemented over time to assess their effectiveness.

The Climate Adaptation Addendum should be drafted to take account of the guiding principles for sustainability as outlined in Table 4 above.

Action Response 4: Develop a Guidance Document for the management of Geotechnical Assets
A number of the Common Failure Types identified in Table 3 above relate to geotechnical assets such as embankments, cuttings or retaining walls. However, there is currently no guidance document for Local Authorities for the inspection and maintenance of these asset types.

A guidance document for the management of geotechnical assets should be drafted for use by Local Authorities which would provide guidance for the inspection, maintenance, condition rating, and risk assessment of geotechnical assets such as embankments, cuttings, and retaining walls. This document should address the Common Failure Types identified in Table 3 above which are related to geotechnical assets but should also include routine asset management requirements which are not climate related.

This guidance document should be drafted to take account of the guiding principles for sustainability as outlined in Table 4 above.

Action Response 5: Update the MapRoad system to reflect changes to guidance documents
The MapRoad Asset Management System is currently used by Local Authorities in parallel with a range of existing guidance documents to manage the inspection and maintenance of road assets on Regional and Local roads.

The system allows users to collect data in the field using a number of mobile applications, such as:

- The Pavement Surface Condition Index App which records the condition of the road pavement surface.
- The Works App which records project information.
- The Surface Inventory App which records road surface inventory information.
- The Speed Limits App which records the location of speed limit signs.
- The Bridges App which facilitates undertaking visual and engineering inspections of bridges.
- The Footways App which records hazards and the condition of footways.
- The MapRoad Public Lighting module which records inventory and condition information for public lighting.

The system also manages the process of submitting projects to the Department of Transport for funding under the restoration improvement programme and for restoration maintenance works. This permits the Department of Transport to undertake analysis of historical performance of the network and to predict funding requirements for the years ahead.

The MapRoad system should be updated to reflect the changes which are proposed above to the existing guidance documents for Drainage, Pavement and Structures. These changes should include the ability to collect relevant data for Common Failure Types such as the ability to record details of historical occurrences.

Action Response 6: Prepare vulnerability mapping for suitable Common Failure Types
Common Failure Types can be prevented by identifying where these failures have occurred in the past from historical records and then implementing maintenance, rehabilitation or improvement works to prevent their recurrence in future.

However, certain parts of the road network may be more susceptible than others to a particular Common Failure Type and the ability to identify these areas would allow a much more proactive approach than one which is based solely on previous failures.

For example, vulnerable locations for slope failures in embankments and cuttings could be identified initially based on slope angle, slope height, road age, and rainfall levels. As records of historical occurrences of slope failures are collected, the approach could be refined to reflect the real circumstances under which slope failures are occurring and this would lead to a good estimate of areas which are susceptible to these types of failure which has been validated by actual failure data.

Having access to this type of information would allow Local Authorities to focus inspection and maintenance works more effectively; would ensure that funding is allocated in areas where risk of failure is greatest; and would increase the chances of preventing failures before they occur.

However, mapping vulnerable areas reliably requires access to data which is (i) available or easy to collect; which is (ii) sufficiently accurate; and which has (iii) a significant influence on assessing the level of vulnerability. For this reason, vulnerability mapping may not be practical for all Common Failure Types but in many cases mapping vulnerable locations is both achievable and useful.

Vulnerability mapping should be generated for each Common Failure Type where access to suitable data is practical. This will categorise the Regional and Local road network on a national basis in terms of risk. This should take account of future demands on the road network and its assets; predicted climate change; the climate prediction time horizon; and the residual life of assets. Once completed, this information should be stored and updated within MapRoad.

Action Response 7: Identify Critical Infrastructure Routes

As set out earlier in this report, it is not possible to prevent all climate related failures to road assets and a robust approach to Organisational Resilience is essential for dealing with unexpected failures in a planned manner.

Local Authorities already have a range of plans in place for dealing with different types of unplanned events. These should be supplemented with a system which identifies Critical Infrastructure Routes i.e. those parts of the Regional and Local road network which are more important in terms of socio-economic impact and emergency response functions.

Each Local Authority should identify the Critical Infrastructure Routes within their respective areas using the methodology defined in Technical Annex 1 to this report. The resulting Critical Infrastructure Routes should be stored in an agreed format on MapRoad.

Action Response 8: Climate Adaptation Works Prioritisation Methodology

The Department of Transport currently funds climate adaptation projects which are proposed by Local Authorities on an annual basis under the Climate Change Adaptation and Resilience Works funding programme.

Under this programme, Local Authorities provide data on each scheme for which funding is sought following a defined structure and this enables the Department of Transport to quickly and accurately assess and prioritise the allocation of funding based on a cost-benefit approach.

A number of enhancements have been made to this Works Prioritisation Methodology in parallel with the development of this strategy document and these changes will be verified as part of the next round of funding.

This process is based on two spreadsheet templates – one for collecting the data from each Local Authority and another for undertaking the cost-benefit analysis calculations.

These spreadsheet templates have been used for a number of years by the Department of Transport for the prioritisation of grant allocations for climate adaptation projects. They have now been finalised to reflect user feedback and are available to be transferred to the MapRoad system when required.

This will ensure better control over the data collection process and in the long term will enable the prioritisation process to take better account of other data held within MapRoad such as historical climate failures, vulnerability mapping and Critical Infrastructure Routes.

Action Response 9: Monitoring & Review

Once the above actions have been implemented, the overall approach should be subject to a review on a yearly basis until systems are established to ensure effectiveness and identify areas for improvement.

Technical Annexes

It is intended that this strategy document will be supported by a number of Technical Annexes which will deal with topics of a more detailed or technical nature.

Some of these topics are already well developed and the Technical Annexes for these will be published concurrently with this document. However, it is expected that this list of supporting documents will grow over time as technical knowledge grows and improved climate adaptation techniques are developed.

The current list of Technical Annexes is as outlined below:

<u>Technical Annex 1: Critical Infrastructure Routes</u>
This document describes the methodology for the identification of Critical Infrastructure Routes.

It defines a process for identifying sections of the Regional and Local road network which service certain strategic facilities such as fire stations, health facilities, power stations, and Local Authority maintenance depots etc. This will aid Local Authorities in their existing emergency planning arrangements and will support the process to prioritise funding for climate adaptation schemes.

<u>Technical Annex 2: Works Prioritisation Methodology</u>
This document describes how Local Authorities should provide data following a defined structure for climate adaptation schemes for which funding is sought. This enables the Department of Transport to quickly and accurately assess and prioritise the allocation of funding based on a cost-benefit approach.

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