ADAPTATION PLANNING

DEVELOPING RESILIENCE TO CLIMATE CHANGE IN THE IRISH TRANSPORT SECTOR
## CONTENTS

1. Introduction ................................................. 3
2. Strategic Environmental Assessment and Appropriate Assessment 8
3. Climatic Trends in Ireland .................................. 10
4. Transport Sector Profile .................................... 13
5. Vulnerability of the Transport Sector to Impacts of Climate Change 23
6. Weather Events and Climate Parameters ................. 25
7. Categories of Adaptation Options ......................... 49
8. Current Measures that Assist in Adaptation Planning .... 51
9. Possible Adaptation Measures for the Transport Sector .... 59
10. Monitoring and Reviewing ................................. 65
11. ANNEX 1 – Detailed Table of Impacts ................. 66
12. References ................................................ 75
13. Glossary ..................................................... 77
1. Introduction

Our climate is changing and the associated transformation could have critical implications for our planet and way of life. While there is still a degree of uncertainty about the level and extent of the likely impacts, an exacerbation of existing vulnerabilities is to be expected. The impacts of climate change are now being observed across all continents and oceans (IPCC, 2014).

Adaptation planning is crucial for the transport sector as a key player in the Irish economy. The level of service offered by any transport system has the ability to significantly impact on both the economic and social heart of a country. On that basis, it is vital that we seek to future-proof the efficient functioning of our transport system so that we can continue to accrue the many benefits of transport to the Irish economy and society in general.

Adaptation actions will be required to avoid or reduce the adverse impacts of climate change and to anticipate possible future changes.

Guidance and information on adaptation to climate change is provided by the United Nations Framework Convention on Climate Change and the Intergovernmental Panel on Climate Change (IPCC). The science in relation to the warming of the climate system is unequivocal (IPCC, 2013). It is within this context that we need to plan for the adverse, as well as the positive, impacts of climate change. There is now a clearer understanding of how the risks of climate change can be reduced and managed through complementary strategies which focus on adaptation and mitigation (IPCC, 2014).

1.1 Strategic Focus

An overarching policy to build resilience to the impacts of climate change is being led by the EU Commission through the EU Strategy on Adaptation to Climate Change, which was adopted in April 2013 (http://ec.europa.eu/clima/publications/docs/eu_strategy_en.pdf).

This Strategy supports action by promoting greater co-ordination and information-sharing between Member States with the aim of ensuring that adaptation considerations are addressed in all relevant EU policies. It sets out a framework and mechanisms for developing preparedness in respect of current and future climate impacts across the EU.
The Strategy is accompanied by a generic set of adaptation planning guidelines, which have been used by the Environmental Protection Agency to guide the roll-out of sectoral plans as well as the development of guidelines for local authorities in Ireland.

Aligned to the EU Strategy on Adaptation to Climate Change is Ireland’s National Climate Change Adaptation Framework, which was published by the Department of Environment, Community and Local Government in December 2012 (http://www.environ.ie/en/Publications/Environment/ClimateChange/FileDownload,32076,en.pdf).

The Framework brings a strategic policy focus to climate change adaptation at local and national level through the development and implementation of sectoral and local adaptation action plans. This includes the development of a national adaptation transport plan.

The evolution of climate policy in Ireland will continue to be an iterative process. In relation to adaptation, this is reflected in the commitment by Government to develop a series of adaptation plans over the period to 2050, which is underpinned by the Climate Action and Low Carbon Development Act 2015, Ireland’s landmark legislation dedicated to responding to the challenges of climate change. These plans will collectively provide a national strategy for the application of adaptation measures in different sectors to reduce the vulnerability of the State to the negative effects of climate change.

1.2 Transport Sector Approach

This first adaptation plan for the transport sector is a high level plan that is seeking to identify vulnerabilities at a national level across the transport system. This initial plan, which aims to set policy on adaptation strategies for transport, will help us to build capacity within our structures and organisations to better understand the implications of climate change for Ireland and how it may impact on transport infrastructure and services at a national, regional and local level.

The approach to adaptation planning for transport has been guided by the Environmental Protection Agency’s funded project Climate Ireland1, which is a

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1 http://www.climateireland.ie/climateinfo/about.html
climate change information platform for knowledge exchange and capacity building through the centralisation of existing climate information and data for Ireland.

Taking account of Climate Ireland, the approach used to create this plan followed five steps:

1. **Building the adaptation team: scope of work** – A stakeholder team was established to scope out and develop this Plan. The following is a list of organisations that were represented on the team and/or made contributions to the development of the Plan: Transport Infrastructure Ireland, Iarnród Éireann, Dublin Bus, Bus Éireann, Irish Aviation Authority, Commission for Aviation Regulation, Dublin Airport Authority, Shannon Airport Authority, IBEC/Irish Ports Association, Dublin Port Company, Port of Cork, Shannon Foynes Port, Port of Waterford, Drogheda Port Company, Dún Laoghaire Port Company, Port of Galway, South Dublin County Council, Department of Environment, Community and Local Government and the Department of Transport, Tourism and Sport.

2. **Climate impact and vulnerability screening** – In order to identify the full range of current and potential future climate impacts and vulnerabilities for the transport sector in Ireland, an extensive and national scale assessment of current and potential future climate impacts and vulnerabilities was undertaken. This assessment was based on literature review and stakeholder inputs and produced a list of the known range of current and potential future climate impacts. This assessment formed the basis for prioritising current and potential future impacts and vulnerabilities, priority areas and response capacity.

3. **More detailed analysis of priority climate impacts and vulnerabilities** – Climate impacts and vulnerabilities identified as a priority in step 2 (above) were then subjected to more detailed assessment and were reviewed in light of observed and projected changes to climatic drivers, the current weight of evidence and the confidence in the projected assessment, the magnitude and likelihood of impacts and the urgency of adaptation actions.

4. **Identifying, assessing and prioritising adaptation options** – An exercise was carried out to identify existing adaptation options based on the current impacts and vulnerabilities identified in step two. These current adaptation options were then used as a basis to identify potential future adaptation options.
5. **Monitoring and review** – The measures identified to establish a robust climate change adaptation plan will be considered in the context of effectiveness, efficiency and equitability. The monitoring system put in place for transport will be part of a larger system that monitors progress at local authority level, as well as national level. The Monitoring Mechanism Regulation is the mechanism for reporting to the European Commission (EC) and the United Nations Framework Convention on Climate Change. In the long term, there will be recurring National Adaptation Frameworks and sectoral plans as provided by the Climate Action and Low Carbon Development Act 2015.

In order to advance this adaptation work, the Department of Transport, Tourism and Sport (DTTAS) has been working with an adaptation expert from University College Cork (UCC) since December 2015. This support, which is being funded by the Department of Communications, Climate Action and the Environment, was an important contributor to the Department’s progress in advancing through the above process, particularly steps 2 and 3.

In addition to transport sector collaboration, DTTAS engaged with other sectors and local authorities currently involved in developing adaptive strategies, both directly and through representation on a steering group chaired by the Department of Communications, Climate Action and the Environment. The Local Government sector, in particular, will have a key role in adaptation planning given its role as a front line responder to the impacts of severe weather and climate change related events. Such collaboration between sectors seeks to secure a cohesive approach to this multi-layered adaptive strategy for Ireland.

### 1.3 Co-benefits

In a separate process, future low carbon measures for the transport sector are being developed within the context of Ireland’s first National Mitigation Plan. That Plan will reflect the fundamental national objective to achieve transition to a competitive, low-carbon, climate-resilient and environmentally sustainable economy by 2050. It will set out the context for the objective, will clarify the level of greenhouse gas mitigation ambition envisaged, and the proposed process to pursue and achieve the overall objective.

As part of that process, the Department is committed to identifying measures that will deliver tangible and sustainable mitigation results, allowing for the phased
development of a low-carbon transport sector for Ireland by 2050. It is important to acknowledge the synergies and co-benefits that exist between ‘mitigation’ and ‘adaptation’ and to recognise that these are likely to become more pronounced in successive plans as progress on mitigation and adaptation planning becomes more developed in Ireland.
2. Strategic Environmental Assessment and Appropriate Assessment

2.1 Strategic Environmental Assessment

Strategic Environmental Assessment (SEA) is the process by which environmental considerations are integrated into the preparation of plans and programmes.

The European Communities Environmental Assessment of Certain Plans and Programmes Regulations (S.I. 435 of 2004 as amended by S.I. 200 of 2011) stipulate that SEA is mandatory for certain plans/programmes which are prepared in a number of specified areas, including agriculture, energy and transport, and which set the framework for future development consent of projects listed in Annexes I and II to Environmental Impact Assessment Directive 85/337/EEC, or where it has been determined under the Habitats Directive that an assessment is required.

Following the screening process, where the context of the Plan has been assessed against the pre-screening check and the environmental significance criteria as set out in Schedule 1 of the SEA Regulations it is concluded that a full SEA is not required for the following reasons:

- The Plan does not provide a framework for development consent for projects listed in the Environmental Impact Assessment Directive.
- The propose of the Plan is to outline transport policy on climate change adaptation in relation to the development of strategies and measures but the Plan will not consider specific locations nor propose projects or measures. Detailed adaptation approaches and measures will be set out in later plans which will undergo SEA and Appropriate Assessment (AA).

The Plan is not considered likely to have significant effects on the environment; therefore, an SEA is not required.

2.2 Appropriate Assessment

Section 4.3.2 of the European Commission document on managing Natura 2000 sites, The Provisions of Article 6 of the ‘Habitats’ Directive 92/43/EEC, states that it does not seem appropriate to treat policy documents, which show the general political will or intention of a ministry or lower authority as ‘plans’ for the purpose of Article 6(3). The section further notes that this is particularly relevant if any initiatives deriving from such policy statements must pass through the intermediary of a land-use or sectoral plan.

It is concluded that a full AA of the Plan is not required because, as stated in section 5, it is not possible to carry out an assessment of the likely effects of the Plan on Natura 2000 sites as the purpose of the Plan is to outline DTTAS policy on adaptation to climate change within the transport sector, not to set out projects or propose specific measures. Detailed adaptation approaches and measures will be set out in later plans which will undergo SEA and AA.
3. Climatic Trends in Ireland

According to available research, climate change indicators are already present in Ireland. Observations show that Ireland’s climate is also changing. The scale and rate of change are consistent with regional and global observations and trends (Dwyer, 2013). These changes are projected to continue and increase over the coming decades (Gleeson et al., 2013).

They include increases in average temperatures (surface air and sea surface), changes in precipitation patterns and ongoing sea level rise. Extreme weather events are projected to disrupt most natural and managed systems and regions. In particular, systemic risks due to extreme weather events leading to the breakdown of infrastructure networks and critical services such as electricity, water supply, transport and health and emergency services are expected.

Table 1: Summary of the observed and projected impacts of climate variables for Ireland (National Climate Change Adaptation Framework, 2012)

<table>
<thead>
<tr>
<th></th>
<th>Observed Impacts</th>
<th>Projected Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature</strong></td>
<td>Temperatures have increased by about 0.8 °C over the period 1890–2012; an average of about 0.07 °C per decade</td>
<td>Average temperatures will rise by about 1.5°C (RCP4.5 scenario) by mid-century and up to 3°C by 2100 compared to the 1961–1990 average</td>
</tr>
<tr>
<td><strong>Precipitation</strong></td>
<td>Mean annual precipitation over the period 1981–2010 has increased by 5% relative to the 1961–1990 period</td>
<td>Wetter winters (14% increase in precipitation for RCP8.5 by mid-century); drier summers (20% reduction for RCP8.5 by mid-century)</td>
</tr>
<tr>
<td><strong>Extreme Events</strong></td>
<td>There is evidence of an increase in the frequency of days with heavy rain (10mm or more) over the period 1981–2010 relative to the period 1961–1990</td>
<td>Increase in the frequency of heavy rainfall, particularly in winter</td>
</tr>
<tr>
<td><strong>Sea Levels</strong></td>
<td>During the satellite era, a sea level rise of 3.5cm per decade</td>
<td>A rise of 50cm to 2100 is projected for Ireland, consistent with projections from regional and global models (Olbert et al., 2012). This sea level rise includes contributions due to changes in ocean density and also from ice melt</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td>Ecological impacts have been observed in species such as butterflies (e.g. a northward expansion of the population since the 1970s); impacts on key phonological phases associated with trees/plants, birds and insects have also been observed (1990–1999)</td>
<td>Advance of the ‘bud burst’ day for birch trees (e.g. up to 10 days earlier in the 2080s relative to the 1990s in the north-east of the country, but little change expected in the south-west)</td>
</tr>
</tbody>
</table>
Other key results for the Irish climate are as follows:

- Warming is enhanced for the extremes (that is, hot or cold days) with highest daytime temperatures projected to rise by up to 2 degrees in summer and lowest night-time temperatures to rise by up to 2–3 degrees in winter.
- In relation to observed warming, the strongest signals are in winter and summer.
- Milder winters will, on average, reduce the cold-related mortality rates among the elderly and frail but this may be offset by increases due to heat stress during summer.
- The frequency of heavy precipitation events during winter shows notable increases of up to 20%.
- Changes in precipitation are likely to have significant impacts on river catchment hydrology.
- The models predict an overall increase (0 to 8%) in the energy content of the wind for the future winter months and a decrease (4 to 14%) during the summer months.
- A small decrease in mean wave heights is expected around Ireland by the end of the century, while in winter and spring, storm wave heights are likely to increase.
- Expected increases in temperature will further affect the ecologies of Irish butterflies, in particular their flight periods, volatinism and abundances.
- Average sea level rise of about 43cm is projected in the North Atlantic. Local effects around Ireland will lead to an additional sea level rise of about 7cm in the Irish Sea. It is likely that all Irish coastal waters will experience a similar sea level rise.
- Projected warming trends in the sea surface temperature and depth-average temperature throughout the basin are approximately 1.9°C and 1.8°C respectively, with autumn accounting for the greatest warming and spring for the smallest. There will be a time shift in the annual temperature cycle: maxima and minima annual temperatures in future climate will occur about two weeks later each year.

Met Éireann and the national universities provide information on projected climate trends for Ireland. A summary of the state of knowledge was published by the Environmental Protection Agency in 2009. Key reports may be accessed as follows:
(a) Climate Change Research Programme (CCRP) 2007–2013. Report Series No. 1 (www.epa.ie/pubs/reports/research/climate/CCRP1(low).pdf); (c) www.climateireland.ie; and (d) Ireland’s Climate: The Road Ahead (www.met.ie/publications/).

Despite the above, the information that is currently available to us in respect of climate trends is still at a high level and tells us little about low level projection, which is critical for determining risks for the transport sector. Future modelling for the transport sector in relation to climate risk will be vital as we progress to more focused actions in subsequent adaptation plans.
4. Transport Sector Profile

4.1 Land Transport

4.1.1 Road Transport Infrastructure

Transport Infrastructure Ireland (TII) operates, maintains and improves the national primary and secondary road network in the Republic of Ireland. Ireland’s national road network totals 5,415km of road. It comprises 2,739km designated as National Primary Road and 2,676km designated as National Secondary Road. Contained within the national road network are the Motorway/Dual Carriageway sections, totalling 1,224km of road. Approximately 328km of these sections are maintained under existing Public Private Partnerships and 744km are maintained directly by TII through Motorway Maintenance and Renewals Contracts, with the remaining 152km maintained through local authorities.

The national primary and secondary road network carries approximately 45% of the country's total road traffic, and most of Ireland's freight is distributed by road. TII is responsible for three tunnels as part of the National Motorway Network: the Dublin Tunnel (M50), the Jack Lynch tunnel (N40) and the Limerick Tunnel (N18). The tunnels are maintained through maintenance contracts.

Some of TII’s other key responsibilities include:
- tolling operations;
- travel information services for road users;
- emergency phone services;
- electronic communications infrastructure;
- winter services; and
- emergency planning.

In addition to the above, the regional and local road network, which is approximately 93,000km long and includes a network of bridges, is managed by 31 local authorities across Ireland. These roads, which account for 94% of the country's roads network, carry around 55% of all road traffic.

Like the national network, the local and regional road network is critical for the operation of local and regional economies, the transportation of goods to the marketplace, connectivity to the national road and rail network in addition to seaports and airports. This network is also vital to the operation of local communities, providing links to schools and community centres as well as providing support to the development of the tourism and agriculture sectors.
The road network also supports, through high quality infrastructure, the operation of public transport services, both State and private funded, including those bus services operated by Bus Éireann and Dublin Bus.

4.1.2 Bus Services

Bus Éireann offers a wide range of services catering for different customer groups and market sectors, as follows:

- **Expressway** inter-urban coach services;
- **Eurolines** coach services to Britain and Europe;
- **city bus services** in Cork, Galway, Limerick and Waterford;
- **town services** in Athlone, Balbriggan, Drogheda, Dundalk, Navan and Sligo;
- **commuter bus services** radiating from Dublin, Cork, Limerick, Galway and Waterford;
- **local bus services** throughout Ireland;
- **school bus services** on behalf of the Department of Education & Science; and
- **ancillary services** – coach and bus hire.

Bus Éireann operates a total fleet of over 1,300 coaches and buses, of which 700 are allocated to school transport services. The remainder work on Expressway, rural and city services.

Dublin Bus operates the public service obligation bus network in the Greater Dublin Area. Carrying 122 million customers a year, Dublin Bus provides an extensive range of bus services – cross city, radial, orbital, Dublin Area Rapid Transit (DART) feeder, Airlink, express limited-stop commuter services, Nitelink and sightseeing tours.

In addition to publically owned bus transport services, private bus operators utilise the road infrastructure for many aspects of tourism and private hire. Additionally, private buses are becoming increasingly engaged in scheduled services as the public transport system becomes more liberalised and play an ever increasing role in the provision of inter-urban and local public transport. They also provide school transport services, both under contract to Bus Éireann and under contract to schools or families. The Coach Tourism and Transport Council of Ireland estimates that its members operate upwards of 1,000 coaches and buses in Ireland.

4.1.3 Rail Infrastructure and Services

The rail network in the Republic of Ireland can be categorised under two headings: Heavy Rail and Light Rail. Our heavy rail network is operated by Iarnród Éireann and our light rail system is operated by Transdev Dublin Light Rail Ltd. under contract to TII and the National Transport Authority (NTA).
**Heavy Rail**

Iarnród Éireann is the national railway company of the Republic of Ireland. It was formed under the Transport Act 1986 and Córas Iompair Éireann (a statutory body wholly owned by the Government of Ireland) holds 100% of the issued share capital of the company. Iarnród Éireann owns, operates and maintains the railway infrastructure and Córas Iompair Éireann owns both the land underlying the railway infrastructure and the stations.

The Iarnród Éireann network currently extends to approximately 2,400km of track, 5,100 bridges, 1,240 level crossings, 147 stations, 4,900 cuttings and embankments, 330 coastal/estuarial defences, 372 platforms and 14 tunnels. The network includes main line, Dublin suburban and commuter passenger routes, together with freight-only routes. There is a cross-border connection to the railway system in Northern Ireland between Dundalk and Newry. Part of the Dublin suburban railway network (DART) is electrified. The remainder of the network operates with diesel traction.

The vast bulk of the cuttings and embankments, bridges and tunnels which support the rail lines across the network date from the original railway construction and are considerably more than 100 years old. Most of these assets continue to provide good service today, well beyond their anticipated design life but inevitably the rate of required renewal and major refurbishment of these assets will increase to address the need for continued reliability and safety. Some renewal and major refurbishment will be as a consequence of the effects of climate change.

![InterCity Map](image-url)

**Figure 1: Iarnród Éireann intercity routes**
Iarnród Éireann also owns and operates Rosslare EuroPort, which is the second biggest port in the State. It handles 2.3 million tonnes of freight and 900,000 passengers annually. For the purposes of this Plan, Rosslare EuroPort is represented by the Irish Ports Association and has been included within the section about ports.

**Light Rail**

TII is mandated to deliver and operate new light railway and metro infrastructure and the planning and design of Bus Rapid Transit schemes as determined by the NTA.

The existing light rail network, known as the Luas, comprises two lines, the Red Line and the Green Line. The Luas Red Line runs from termini at Saggart and Tallaght to Connolly Station and The Point. The Luas Green Line runs from Bride’s Glen to Sandyford, Dundrum and St. Stephen’s Green. In total, Luas infrastructure comprises over 37km of twin track, serving 54 operational Luas stops. There are also two tram maintenance depots and 20 electrical sub-stations, in addition to seven Park & Ride sites. The Luas fleet consists of 66 Alstom Citadis trams.

The Luas Red and Green Lines are currently not connected. However, the Luas Cross City project is currently under construction, which will link together, for the first time, the two existing Luas lines in Dublin City centre. It will also connect Cabra (at Broombridge rail station) to St. Stephen’s Green, joining the existing Luas line at this location.

While the operation and maintenance of Luas is carried out under contract by Transdev and other contractors, the TII retains important safety and management functions as infrastructure owner and client for the current Luas operations contract.

**4.2 Air Transport**

**4.2.1 Airports**

Ireland’s largest airports are managed by two commercial semi-state companies: Dublin Airport Authority and Shannon Airport Authority.

Dublin Airport Authority has a statutory mandate to operate and develop the airports at Dublin and Cork. In 2015, Dublin Airport handled 25 million passengers, and is a significant driver of growth for the Irish economy, contributing 4% of GDP and directly supporting 15,700 jobs. The airport is the fourteenth best connected airport in Europe with over 180 destinations served by three airlines. Dublin Airport has 130 flights per week to North America, 1,000 flights weekly serving destinations in Europe and 830 weekly to Great Britain, as well as intercontinental routes to the Middle East, Asia and Africa.
Delivery of this network requires the upkeep and development of key airport infrastructure including runways, taxiways, airside pavements, lighting, car, bus and coach parking areas, roadways, terminals, other buildings and associated utilities. The level and scope of capital investment in infrastructure is regulated at Dublin Airport by the Commission for Aviation Regulation. Dublin Airport Authority also provides a range of aeronautical, commercial and support services to both airlines and passengers at the airports.

Cork Airport is the country’s second busiest and best connected airport after Dublin and makes a significant contribution to the regional economy in the areas of both business and tourism. More than 2.1 million passengers travelled through the airport in 2015, flying to over 50 destinations across the UK and throughout continental Europe.

In 2015, 1.71 million passengers passed through Shannon Airport. Shannon Airport is situated at the most western point of Europe and covers about 2,000 acres in County Clare on the north bank of the Shannon Estuary. More than 90,000 of the passengers travelling through Shannon are transit passengers who are availing of a stop-off while travelling between Europe, the Middle East and North America. During 2015, there were over 23,000 aircraft movements, these being a combination of scheduled and non-scheduled aircraft. Shannon Airport Authority is responsible for infrastructure development in respect of Shannon Airport.

There are also a number of regional airports supported by Exchequer funding operating in Ireland. The principal ones are located in Donegal, Knock, Sligo, Kerry and Waterford.

In 2015 these four airports handled over 1 million passengers – 35,528 from Waterford, 36,562 from Donegal, 307,079 from Kerry and 685,485 from Knock.

4.2.2 Aviation Services

The Irish Aviation Authority (IAA) is responsible for the management of Irish controlled airspace as well as the safety regulation and security oversight of Irish civil aviation. The IAA ensures that Irish civil aviation operates to safety standards set internationally by the International Civil Aviation Organisation, the European Civil Aviation Conference, the European Aviation Safety Agency, the European Joint Aviation Authorities, Eurocontrol and the EU.

Air traffic management includes the provision of operational services, engineering and communications in airspace controlled by Ireland and the provision of the related air traffic technological infrastructure. The IAA provides air traffic management services in the 451,000km² of airspace controlled by Ireland. This airspace acts as a gateway between Europe and North America, with the IAA’s Shannon Centre
handling over 90% of all air traffic on the North Atlantic. This equates to approximately 1,500 aircraft every 24 hours during the busy summer months. The IAA also provides air traffic management services to all aircraft arriving and departing from three State airports of Dublin, Shannon and Cork.

In 2015, the IAA managed one million flights, an increase of 5.6% compared to 2014. This equates to an average of 2,811 flights every day managed by the IAA at Irish State airports, through Irish airspace and on the North Atlantic.

Over 260,000 flights arrived at or departed from three State airports, Dublin, Shannon and Cork, in 2015, while Ireland’s en route centre in Shannon handled more than 317,000 overflights (flights that pass through Irish airspace but do not land). The IAA’s North Atlantic Communications service dealt with more than 442,000 flights in 2015.

4.3 Ports

Irish ports are an indispensable core national asset. As a trade dependent island economy that does not benefit from a land connection to continental Europe, our ports constitute infrastructure of strategic economic importance to the State. Access to ports infrastructure is a key determinant of site suitability for foreign direct investment.

According to the Central Statistics Office, in 2011, ports handled 45.1 million tonnes of cargo.

Ports differ greatly in size and the 2013 National Ports Policy introduced a clear categorisation of the ports sector into Ports of National Significance (Tier 1), Ports of National Significance (Tier 2) and Ports of Regional Significance. For the purposes of developing this Plan, the ports were represented through the Irish Ports Association with primary input from three Tier 1 ports, namely the Port of Cork, Shannon Foynes Port and Dublin Port Company, and from Tier 2, Waterford Port Company. Input was also received from three Ports of Regional Significance, namely Drogheda Port Company, Dún Laoghaire Harbour Company and the Port of Galway.

The Port of Cork is the key seaport in the south of Ireland and is one of only two Irish ports which service the requirements of all six shipping modes. In 2015, Port of Cork and Bantry Bay Port combined traffic amounted to 11.02 million tonnes with €29.8 million turnover (including €0.65 million Bantry turnover). The Port of Cork’s facilities and operations are situated at four distinct locations in Cork’s natural deep water harbour: City Quays, Tivoli, Ringaskiddy and Cobh. In addition, the Port provides and facilitates port activities and services including pilotage, channel dredging, land and property rental, port training, towage, mooring boats, storage and repairs.
Shannon Foynes Port Company is responsible for the management of Ireland’s largest portal area, with responsibility extending from an imaginary line drawn between Loop Head and Kerry Head to seaward and the Shannon Bridge in Limerick City to landward. There are six commercial terminals on the Shannon Estuary and three specialised private terminals, which are located at Moneypoint, Tarbert and Auginish. Shannon Airport Jetty is also a specialised facility and is used exclusively.
for the importation of aviation fuel for Shannon Airport. Foynes and Ted Russel Dock are multi-user facilities. Shannon Foynes Port Company is responsible for the management of a designated anchorage area to the west and east of Scattery Island.

Dublin Port Company is responsible for the management, control, operation and development of Dublin Port, Ireland’s largest commercial port. The port handles all cargo modes and has direct access to the country’s national road and rail networks. Over 80% of all imports and exports through Dublin Port are transported in containers and trailers. In 2015, Dublin Port Company’s turnover was €78.7 million, cargo throughput was 32.8 million gross tonnes and nearly 1.8 million passengers passed through the port on ferries and cruise ships. Dublin is Ireland’s busiest port with 7,166 vessel arrivals in 2015. Ferry connections to the UK are particularly important in Dublin with up to 16 sailings daily. Dublin Port is one of the country’s largest industrial estates at 260 hectares with 4,000 people employed in the port area. It is one of 83 ‘core’ ports in the EU’s TEN-T Network.

Port of Waterford is the commercial state company with responsibility for the operation and development of the Port of Waterford under the Harbours Acts. It is a Port of National Significance within the terms of the National Ports Policy and is a Comprehensive Port on the Ten-T Network. The main centre of operation is located at Belview Port 5km down river from Waterford city. Belview Port currently handles over one million tonnes of bulk products (mainly agriculture related) together with another 100,000 tonnes of break bulk (mainly timber and steel). The port also operates in the container/Lo-Lo sector handling 40,000 20-foot equivalent units annually.

Drogheda Port is a commercial semi-state company established under the Harbours Act 1996 and is the Republic’s largest east coast port next to Dublin, handling in excess of 1.2 million tonnes annually. The port is multi-modal handling all cargo modes and provides a relief to Dublin’s congestion in the short sea shipping bulk and break-bulk modes. The port is designated under European shipping policy as part of the Ten-T Motorways of the Sea Network as a port of strategic importance for the handling of municipal waste. It is the country’s main location for the handling of Class 1 cargos as categorised under the International Maritime Dangerous Goods Code.

Dún Laoghaire Harbour Company is the statutory commercial body charged with developing Dún Laoghaire Harbour as a marine/leisure/tourism destination, maintaining and enhancing the recreational and amenity value of the harbour and promoting investment and commercial development to support its long-term maintenance. The services offered by Dún Laoghaire Harbour Company include ferry services, marine services, cruise services, property management, car parking, boat storage, events and leisure services and property letting. There are many infrastructural elements within Dún Laoghaire Harbour, from the historic pier walls to
the modern Irish Lights building. Much of the harbour infrastructure is either
designated as Heritage Infrastructure (listed) or situated within an area of architectural
importance. The infrastructure under Dún Laoghaire Harbour Company control
includes east and west pier walls, public car parks, roads and foot paths, Carlisle Pier,
St. Michaels Pier, east and west marina breakwaters, Coast Guard cottages and station
building, Traders Wharf pier, Coal Harbour and the Marine Activity Training Centre.

Port of Galway is a commercial semi-state company and is the most central port on
the west coast of Ireland. Folan Quay is used exclusively for the discharge of oil
tankers and has discharge underground pipeline facilities for petroleum products.
Bitumen is discharged at North Dun Aengus pier via underground pipeline to storage
tanks. The remainder of the port is utilised to handle project cargos such as wind
turbines, heavy lifts, timber logs and timber bales, refuse-derived fuel and bulk cargos
such as limestone and scrap among others and has had throughput of up to 1.02
million tons annually. The cargo service to and from the Aran Islands operates from
the outer layby within the port. The port operates the pilotage service, and an
industrial park, public and contract car parking, marina, cruise services and property
letting. A Marine Activity Training Centre, engineering works, boat storage, and boat
repair service also operate within the port. A port extension is at the planning stage.

4.4 Cross-services Interdependencies

The Department recognises that transport is
central to the overall resilience of many
sectors. Changes in climatic trends and
weather events are unlikely to affect one
sector in isolation of another so it is
important that we understand the
interdependencies between the sectors and
address risks in a co-ordinated manner.

Critical infrastructure is often located in
clusters or involves development of inter-
modal junctions to generate the greatest
benefits to passengers. However, this can also
concentrate impacts and create challenges in terms of scaling of contingency plans
and responses to extreme events. Much greater consideration of the inherent capacity
within and between networks, to allow for switching between modes to take place,
could improve overall resilience to severe weather. The Department needs to ensure
that present and future policies recognise these interdependencies and consider those
risks that may be exacerbated by climate change.

The opportunities for adaptation of the various networks will need a well-researched mix of
technological development and improved long-term spatial planning, where the integrated
nature of the different transport networks is given greater recognition and importance in the
planning and decision making process with the consequential cost implications incorporated
from the beginning.
the integrated nature of the different transport networks is given greater recognition and importance in the planning and decision making process with the consequential cost implications incorporated from the beginning.
5. Vulnerability of the Transport Sector to Impacts of Climate Change

Climate change impacts will vary between transport modes and their associated infrastructure, and will also vary widely between regions. While it may be difficult to determine the extent to which climate change will impact on the transport system in the coming years, the sector is actively developing its understanding of climate and weather-related impacts and vulnerabilities through the collation of baseline data in relation to the impacts of severe weather events on transport infrastructure and services, particularly since 2009.

Through literature review and stakeholder consultation, a screening exercise was conducted to identify the wide range of impacts of observed and projected changes in key climate parameters as well as extreme weather events for the transport sector. This screening exercise was undertaken to develop an understanding of observed and potential climate and weather-related impacts in order identify priority climate changes and impacts for the transport sector.

In order to focus the analysis, five subsectors (road, bus, rail, aviation and port services) were selected for assessment, and impacts were identified on the basis of infrastructure, modes, staff and passengers. The impacts and vulnerability analysis was categorised by changes (observed and projected) in climate variables (for example increasing temperatures) and extreme weather event type (for example cold snap). Importantly, the observed and projected impacts of changes in climate variables and extreme weather events were determined with reference to the recorded impacts of recent extreme weather events and observed changes in Ireland’s climate.

The initial focus of this analysis was on impacts which have occurred due to observed changes in Ireland’s climate and also due to recent extreme weather events, in other words, weather-related events that had directly or indirectly affected the transport sector. On this basis, potential future impacts and vulnerabilities were identified and prioritised. Table 2 provides an overview of high and medium priority impacts and while low priority impacts are not included, it should not be assumed that these have been excluded from further consideration.

A more detailed table of impacts is contained in Annex 1 of this document.
<table>
<thead>
<tr>
<th>Area</th>
<th>High Priority Impacts</th>
<th>Medium Priority Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviation</td>
<td>Challenges for storm-water management</td>
<td>Damages to airport buildings and aircraft due to storm conditions</td>
</tr>
<tr>
<td></td>
<td>Increased requirement for de-icing facilities</td>
<td>Disruption of services due to extreme weather events</td>
</tr>
<tr>
<td></td>
<td>Coastal flood risk (Shannon Airport)</td>
<td></td>
</tr>
<tr>
<td>Road</td>
<td>Increase in fluvial flood risk</td>
<td>Degradation/Disintegration of road surfaces</td>
</tr>
<tr>
<td></td>
<td>Ice damage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased risk of road infrastructure risk from coastal flooding and erosion</td>
<td></td>
</tr>
<tr>
<td>Bus</td>
<td>Disruption of services due to flooding</td>
<td>Passenger and staff comfort</td>
</tr>
<tr>
<td></td>
<td>Extreme levels of snow can impact garages and stations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dangerous road conditions resulting in increased journey times</td>
<td></td>
</tr>
<tr>
<td>Rail</td>
<td>Failure of overhead electrification systems during freezing events</td>
<td>Degradation of track</td>
</tr>
<tr>
<td></td>
<td>Breaking performance on trains affected</td>
<td>Passenger and staff comfort</td>
</tr>
<tr>
<td></td>
<td>Damage to stations and infrastructure from storm events</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased risk of scour damage at bridges from fluvial flood events.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increasing risk for rail infrastructure from coastal erosion and flood risk</td>
<td></td>
</tr>
<tr>
<td>Ports</td>
<td>Sea level rise and increased occurrence of coastal storms will put port infrastructure at risk</td>
<td>Passenger and staff comfort</td>
</tr>
<tr>
<td></td>
<td>Damages to port infrastructure from freezing weather events</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Service disruption</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Changing patterns of siltation</td>
<td></td>
</tr>
</tbody>
</table>
6. Weather Events and Climate Parameters

Following the identification and prioritisation of the wide range of known climate and weather-related impacts for the transport sector in Ireland, this section will examine the climate change and impacts that are considered of particular significance to the transport sector.

These are:
- projected increase in the frequency of extreme precipitation events and the associated risk of high river flows;
- ongoing and projected changes in sea level and projected changes in the occurrence and intensity of storm surge; and
- projected increase in average temperature and projected increases in frequency and duration of heatwaves.

6.1 Extreme Precipitation – Risk of High River Flows, Fluvial Flooding and Erosion

As demonstrated through recent extreme precipitation events, flooding (fluvial and pluvial) due to periods of extreme rainfall has significant and detrimental impacts on the transport sector. These include damage to transport infrastructure and modes, disruption to transport services and significant financial costs. Projected changes in key climatic variables (precipitation) indicate that these risks will probably increase in the future. In addition, higher flood frequencies and intensities can lead to increased localised riverbank erosion, undermining structures such as bridges. To date there has been no national level monitoring of the impacts of projected climate change on risk of bridge scour, and the structural integrity of road and rail bridges, many of which were designed and built over a century ago, remains uncertain.

6.1.1 Risk of High River Flows – Fluvial Flooding

With many of Ireland’s major transport links running in close proximity to rivers, fluvial flooding poses a threat to transport infrastructure and results in service disruptions and significant financial costs. This has been demonstrated through recent extreme precipitation events.
Case Study 1 – Unprecedented Rainfall in October and November 2009

Overview
Unprecedented rainfall in late October and early November 2009 resulted in severe and prolonged flooding in many river catchments in Ireland. The event was truly exceptional with total recorded rainfall for November being the highest on record for most stations. Many rivers across the country reached record high levels, including the River Shannon which significantly exceeded the highest levels previously recorded over a period of 100 years.

Meteorological Conditions
The period 18th–31st October saw a series of Atlantic depressions and their associated fronts move across Ireland. The heaviest rainfalls were measured on 19/20th, 24th and 30th. There were also widespread heavy showers on the 21st and 22nd. In November 2009, a series of fast-moving Atlantic depressions brought a series of active frontal systems across Ireland, bringing very wet and windy conditions. In this month, more than twice the average rainfall amounts were measured at almost all stations and over three times the normal amounts at some stations. Rain and showers were recorded on almost every day while the frequency of heavy precipitation days was also well above normal.

Figure 3: (left) 1km gridded rainfall for November 2009, (right) November 2009 rainfall as % of normal (1961–1990)
Key impacts for the transport sector:

- The main impacts on transport were the closure of a number of roads to traffic for a significant period and the disruption of travel and public transport services. The most severely disrupted national roads were the N6, N17, N18, N63, N65, N67 and N7. Regional and local roads in the affected areas were either impassable, or only passable with difficulty.
- The flooding at this time, followed by a spell of severely cold weather, is estimated to have cost in excess of €225 million for repairs to national, regional and local roads.
- Bus and rail services were widely affected during November. Iarnród Éireann services were cancelled between Athlone and Galway for a period due to flooding at multiple locations on the line, while bus services between these centres were also suspended for a time. The DART was flooded at Sandy Cove causing closure of the line between Dún Laoghaire and Bray. There was flooding causing delays to the Dublin to Cork line at Hazel Hatch and again at Ballybrophy. The Dublin to Sligo line was flooded at multiple locations including Longford, Carrick-on-Shannon and Sligo with closure of the line for a period of time due to flooding from the River Shannon. The line from Athlone to Roscommon and Mayo was closed near Athlone for a period of time due also to flooding from the River Shannon. Flooding also closed the line between Waterford and Tipperary at Carrick-on-Suir and caused delays to services between Banteer and Millstreet on the Mallow to Tralee line.
Case Study 2 – Widespread Flooding Following Storm Desmond and Storm Frank, December 2015 to January 2016

Overview
In December 2015 the country was hit by two major storms, Storm Desmond and Storm Frank which resulted in widespread flooding. Storm Desmond mainly affected the western coastal counties, in particular, the Moy, Clare and Shannon catchments. Following Storm Frank, the main areas affected were along the south coast and in the catchments of the Blackwater, Suir, Slaney and Shannon rivers.

Meteorological Conditions
Jet streams play a key role in determining weather and the period December 2015 was exemplified by a pattern of continuous troughs and ridges across the North Atlantic and Ireland. This resulted in a predominant south-west to south-westerly airflow over Ireland and a spell of very mild and wet weather during which record temperatures and rainfall occurred. The widespread flooding in some parts of the country was exacerbated by already saturated ground following the normal rainfall in November.

Key impacts for the transport sector:
- Throughout the country, Iarnród Éireann experienced serious incidents. Speed restrictions were imposed on lines and in some places lines were closed due to flooding. In Cork, the Cobh/Midleton rail line and the Mallow line had to be closed due to flooding. There were also line closures due to flooding in Gorey and Wexford. There were instances of fallen trees and debris blocking railway tracks, high winds caused problems with automatic level crossings barriers.
- A significant number of national, regional and local roads were closed. National roads included the N25 Cork/ Waterford Rd (between Killeagh and Castlemartyr), N65 (between Portumna and Borrisokane) and the N4 (at Shannonside retail park). In relation to non-national roads, Cavan County Council reported in the region of 50 roads as impassable, many under 1m of water. In the case of East Cork, the County and City Managers Association reported that 20 roads were closed, many due to the disintegration of the roads. It was also noted that Bus Éireann had a diversion in Wicklow from the R752 regional road due to road subsidence.
- As a result of the damage caused to transport infrastructure, €106 million was allocated for repairs, €8 million for rail network , €90 million for regional and local roads and €8 million for national roads.
- Notably, and in contrast, there were few impacts on the Strategic Motorway Network which reflects the considerable efforts since the commencement of the Motorway Maintenance and Renewals Contracts to undertake preventative maintenance and to deal with sections of the network where flooding had previously been a problem. This has been possible due to dedicated funding by TII for such works.
Figure 7: Road disintegration in County Cavan, January 2016

Figure 8: Floods in Mallow County Cork, December 2015

Figure 9: Road damage in Waterford, 2016

Figure 10: Floods in Enniscorthy following Storm Frank in 2015
Storm Impact on Drogheda Port

Storm Frank effectively closed Drogheda Port to commercial traffic due to the sediment accretion within the defined and engineered approach channel from the south-east sea and swell. The result was to immediately reduce the channel depths by almost 1.5m, this reduction of depth stopped commercial shipping activity with a loss to tonnage immediately impacting on manufacturing and logistic raw material supply lines and effectively closing the port to all but light drafted commercial vessels.

On the passing of the storm an immediate remedy by dredging was not possible due to the lack of suitable dredging plant, leaving the port and its customers in a precarious position for business continuity.

It was five weeks after the storm and port closure before the port’s approach channel depths were fully restored by dredging and full shipping tonnage throughput operations returned to normal.
6.1.2 Bridge Scour and Landslide Risk

River bridges represent critical components of the transport infrastructure and carry services as well as people and traffic. As a result, the loss of a bridge can have multiple and wide-ranging impacts.

Bridge scour relates is the process by which material from around bridge piers and abutments is removed by swiftly moving water, typically in a flood situation. Bridge scour can result in structural failure as removal of material can undercut the foundations, resulting in instability and eventual collapse of the bridge if allowed to continue. The problem is exacerbated for many older masonry bridges (pre-20th century) because they typically have shallow foundations.

For example, across the UK, bridge scour causes on average one bridge failure per year. Iarnród Éireann currently manages 475 bridges that span water courses. The bridges vary widely in size, type and date with many bridge assets being up to 150 years old (Bateson, 2016). Moreover, it has been estimated that the foundation material for railway bridges over water is known for less than 10% of existing bridges (Bateson, 2016). Bridge scour is a major issue for Iarnród Éireann as the characteristic of many bridge assets is the presence of fast-moving water with, as a consequence, the potential to remove material.

A considerable proportion of the estimated 25,000 bridges carrying Irish roads are over watercourses. In addition to basic maintenance requirements, road bridges which span watercourses are liable to the same problems with scour damage as rail bridges. The risk of scour damage is increased when bridge piers or abutments are subject to fast moving or tidal water and there are many examples where road bridges have been undermined in this way.
Case Study 3 – Landslide Following Intense Rainfall, December 2015 to January 2016

Overview
On the 29th of December 2015, during Storm Frank, which was the strongest storm of the 2015–16 windstorm season, a localised landslide developed on the Irish Rail network halfway between Farranfore and Killarney. The steep inclination of both slopes leading down to the track exacerbated the issue and the debris covered the track resulting in track closure. On the 6th and 7th of February, following weeks of persistent rainfall, a further landslide occurred.

![Figure: Landslide 29th December 2015, County Kerry](image)

Meteorological Conditions
Met Éireann’s nearest weather station is located on Valentia Island approximately 55km from the failure site. During December 2015, 339mm of rainfall fell in Valentia which equates to 206% of the long-term average for December in the area and is the highest December rainfall since 1934 at the site. Approximately 10% of that total (31.5mm) fell on the 29th of December, the day of the first failure event.

January 2016 was the wettest January on record in Valentia Observatory since 1974 with 293.8mm of rainfall. This equates to 169% of the long-term average for January at the observatory. Between the 5th and 7th of February, 13.8mm, 16.6mm and 13.5mm of rainfall respectively fell per day. It was during this period that the second failure event occurred.
Case Study 3A – Bridge Scour Incident during Flood Event Following Extreme Rainfall, October 2011

Overview
On 24th October 2011 following a period of extreme rainfall and during a serious flooding event in the Ballsbridge area of Dublin, the railway bridge UBR63 which spans the River Dodder at Lansdowne Road DART station suffered a significant scour incident in which the pier and abutment at the Wexford end were undermined to such an extent that the structure was near to collapse. A cavity 2.5m deep, between 4m and 5m horizontal dimension, perpendicular to the line of the abutment was created. This cavity extended a total length of 30m from upstream of the abutment to a location approximately 10m downstream. The cavity developed over a short time due to the high velocity of the flow passing through the bridge, and because of constriction caused both by the bridge and by a significant amount of flood debris trapped at the bridge, which directed the flow down towards the channel bed from where it scoured material.

Iarnród Éireann monitored the flood event and imposed a speed restriction on the railway line until it was safe for divers to enter the water and inspect the structure. At that stage the seriousness of the scour incident was identified and the line closed.

Figure 13: Photo of debris trapped at UBR63 on 25/10/2011 as flood water recedes. The quay wall on the right hand side of the picture was completely overtopped at the peak of the event which caused major flooding of housing and cars in the Ballsbridge area
6.1.3 Projected Changes in Extreme Precipitation

As global temperatures increase, the hydrological cycle is expected to become more intense and will result in more extreme precipitation events and flooding.

For Ireland, projections indicate a marked increase in average levels of precipitation, and more extreme precipitation events, all of which have implications for flooding (fluvial and pluvial), stream-flow and load.

The relevant projections for Ireland for the 2041–2060 period are outlined below:

- There will be an increase in average levels of winter and autumn precipitation (Nolan, 2015).
- The frequency of heavy rainfall events is expected to increase (approximately 20%) during the autumn and winter months (Nolan, 2015).
- Increase in stream-flow and loads are expected during winter and autumn. The response of individual catchments to increased levels of precipitation will be determined by the characteristics of individual catchments (for example response time).

Experience has demonstrated the wide-ranging consequences of extreme precipitation and associated flooding (pluvial and fluvial) events on the transport sector. Increased levels of average precipitation and more occurrences of extreme precipitation will put the transport sector at higher risk from flooding (pluvial and fluvial).
Projected consequences of extreme precipitation for the transport sector:

- Change in the frequency and intensity of extreme precipitation events and associated flooding (fluvial and pluvial) has the potential to impact on transport modes, in particular buses and trains. Cars, trucks, buses and trains can all be damaged by driving through floods while extreme precipitation events can also result in dangerous driving conditions, particularly in areas where the capacity of existing drainage networks is overwhelmed.

- Changes in the frequency and intensity of extreme precipitation could also lead to a high level of disruption to services, which will impact on the safety and comfort of passengers with an associated cost to the economy.

- An increase in fluvial and pluvial flooding will most likely lead to a significant increase in the frequency and duration of road and railway flooding events. This is particularly the case for those areas located at the confluence of major rivers or those areas located around estuaries where projected rises in sea level in combination with increased river outflow may cause extensive flooding. The frequency of flooding for infrastructure located in floodplains and areas already considered at risk is projected to increase. It can therefore be considered that transport infrastructure already at risk of flooding will be at a higher risk.

- With the exception of Shannon Airport, Ireland’s airports are not located on river channels and as a result are not expected to be impacted directly by increased fluvial flood risk. However, increases in the occurrence and magnitude of extreme precipitation events and associated pluvial flooding will put existing storm-water drainage systems under stress with implications for airport operations.

- An increase in bridge scour events has been identified as a potentially significant impact under projected climate change. Projected increases in river/stream-flow will augment the potential for the fast-moving water to remove material from the bridge piers and abutments. Brick and masonry arches which are considered to be particularly vulnerable to scour (because of shallow foundations) are at an increased risk. Also, climate changes may mean that bridges which are currently classed as being adequately protected against scour risk may not be under future climate conditions.

- The increased occurrence and intensity of extreme precipitation events are expected to heighten landslide risk. This higher risk applies not only to railways and roads situated in cuttings or cut into hillsides but also to railways and roads situated on top of embankments. Extreme precipitation, leading to an accumulation of water and saturation of a slope, adversely affects the stability of the slope and increases the potential of a landslide. Many of Iarnród Éireann’s cuttings and embankments were constructed 100–150 years ago and have steeper slopes (and therefore greater likelihood of landslips) than would be permitted with modern design standards. Iarnród Éireann’s ongoing earthwork improvement programme, which operates on a prioritised basis, is
unlikely to achieve modern design standards in the foreseeable future. Those areas already considered at risk of landslide will probably be at increased risk.

6.2 Sea Level Rise and Storm Surge

Due to the location of key transport infrastructure on the coast, sea level rise and storm surges pose a significant risk for the transport sector. Coastal erosion and flooding as a result of extreme weather events already constitute a serious risk for transport infrastructure located on the coast and result in damage to infrastructure, service disruption and significant financial costs. Climate projections indicate that this risk is likely to increase in the future and in particular when considered in the context of the projected rise in sea level and increasing intensities of extreme weather events.

6.2.1 Coastal Erosion

Ireland has a coastline of approximately 6000km, half of which is categorised as soft coastline (non-rocky), and it is estimated that up to 500km is actively eroding and considered to be at risk. Currently, the coasts most susceptible to erosion are those composed of unconsolidated (soft) sediment and are most common on Ireland's eastern and southern coastline and in estuaries. A number of primary transport routes are located in these areas and past experiences have demonstrated the susceptibility of transport infrastructure located in these areas to both gradual changes in rates of coastal erosion and as a result of coastal storms.
Case Study 4 – Ongoing and Gradual Erosion of the Eastern Rail Corridor

Overview
The Dublin to Rosslare railway represents the main rail route between Dublin Connolly Station and Rosslare Europort where it connects with ferry services to the UK and mainland Europe. Services provided on the line include DART and Intercity services. A significant length of the line lies close to the shoreline which is subject to erosion, with incidents of annualised erosion rates of up to 3m per year recorded. However, at most places, erosion rates were less than 0.5m per year, reflecting the variability of erosion rates and the significance of localised conditions.

An example of a location that will become critical on this rail route is where a sea cliff supporting the railway at Ballygerry near Rosslare Harbour is being eroded by storm events. Coastal erosion has been an ongoing problem in Rosslare Bay for many decades. The area that threatens the railway is on the approach to Rosslare Europort. The coastline along this stretch is unprotected allowing continuous erosion of the soft cliffs. The soft cliffs are approximately 11m high and the ground level is relatively flat between the cliff top and the railway. Between 1905 and 1999, the coastline receded approximately 135m at an average of 1.4m per year. A comparison of the surveys carried out between 1999 and 2015 shows an acceleration in the rate of average erosion to a rate of approximately 2m per year. Critically, and from the survey data gathered to date and erosion modelling by the Office of Public Works, it is estimated that the coastline will continue to recede, and if left unprotected will undermine the existing rail corridor before the year 2030.
Case Study 5 – Erosion Resulting from Extreme Weather, Storm Frank (December 2015)

On the 29th and 30th of December 2015, Storm Frank, the third of three named winter storms (Desmond, Eva and Frank) set new records for high seas with a 6.2m wave height observed at the M2 marine weather buoy, which is situated off the east coast. Storm Frank resulted in significant erosion episodes with impacts for transportation infrastructure.

For example, north of Wicklow town and in close proximity to the Murragh nature reserve, a clay cliff supporting the railway line collapsed into the sea, leaving the railway line within 2m of the sea. The collapse took place immediately north of an area where Wicklow County Council had already placed ‘rock armour’ as part of a coastal erosion prevention scheme in 2009. Following the collapse, Iarnród Éireann added to and extended these defences by placing nearly 2,500 tonnes of boulders in a 185m-long barrier to protect the worst affected areas at a cost of €150,000.

Figure 16: Rate of erosion from Nov 2014 to Dec 2015, Murragh, Wicklow town
Coastal flooding poses a significant risk to transport infrastructure located in coastal areas. Recent experiences of extreme weather events have demonstrated the vulnerability of transport infrastructure to coastal storms and surges. These incidents have resulted in extensive damage to transport infrastructure, disruption to services and significant financial costs.

Case Study 6 – A Series of Unprecedented Storms, December 2013 to February 2014

Overview
During the period from 13th December 2013 to 6th January 2014 there were storms in or around Ireland roughly every three days. These storms coincided with high tides and created severe conditions in a number of coastal areas, causing disruption across a range of transport services. A study by the National University of Ireland, Maynooth, found that the winter of 2013/14 was the stormiest for at least 143 years, when storm frequency and intensity are considered together. Significant damage was caused to roads particularly along the western seaboard counties and the safety of road users was a major concern due to the stormy conditions and damage caused. In certain areas of the country, prolonged flooding led to significant disintegration of road surfaces.

Meteorological Conditions
The winter of 2013/2014 was severely affected by a series of exceptional winter storms. These were a result of the extension of the polar jet stream across the North Atlantic and directly over Ireland. Storm force winds occurred on 12 different days and precipitation amounts were between one and two times above normal and fell on saturated or waterlogged ground throughout the country.

Figure 17: Position of the Polar Jet Stream over the North Atlantic on December 14th, 26th 2013 and 3rd January 2014
Key impacts for the transport sector:

- Rail services were disrupted in various locations including Cork, Dublin and Waterford. While damage had been caused to station buildings, including the collapse of a canopy roof at Kent railway station in Cork due to high winds, most disruptions were caused by fallen debris and rock falls on various parts of the network. It is estimated that damage to the railway infrastructure cost some €7.2 million over the two weeks of severe weather.

- Ferries (particularly the swift services) were cancelled on numerous occasions across the period to the New Year. Likewise, some cruise ferries were also affected. A number of lighthouses were also damaged and the frequency and strength of the storms also had implications for the services of the Coast Guard.

- A large number of flights were cancelled, diverted, or delayed across all three State airports, mainly due to the strength, direction and gusting of the wind. Structural damage was also caused to aviation infrastructure.

- Storms, during the period in question, caused significant damage to Shannon Airport flood defence embankments (31st January/early morning of 1st February) along the Shannon Estuary resulting in severe flooding on airport property. Further storms, and Storm Darwin in particular (12th February 2014), also caused structural damage to buildings in the area and a regional aircraft (ATR42) was tipped on its side resulting in an undercarriage failure. The cause was a combination of a very high tide, a significant tidal surge, heavy rain and the prevailing wind direction on the dates in question.

- This short-lived storm in December 2013 is estimated to have cost the State in the region of €70 million. In terms of direct damage to the transport sector, the cost of repair to the road network was estimated at €16.6 million with a further €6.95 million needed to repair other transport infrastructure including rail, airports and Irish Coast Guard facilities.

- The severe weather during the later period of January to February 2014 caused further damage to roads and to other transport infrastructure with an associated repair cost of €13.5 million. It is clear that storm events can have significant implications for the Exchequer. Notwithstanding the stress and reduced safety caused to transport users, the fallout from the event can resonate over a much longer period particularly where severe damage has been caused to the transport infrastructure.
Figure 18: Platform canopy collapse December 2013 at Kent station due to storms

Figure 19: Damage to the roadway at Silver Strand, County Galway, February 2014

Figure 20: Storm causing flooding in Carrigaholt, County Clare, February 2014
6.2.3 Projected Changes in Sea Level and Storm Surge

Projected increases in the global sea level and in the intensity of coastal storms and surges will put transport infrastructure at more risk from coastal erosion and flooding. This is particularly the case when increased storm intensities are considered in the context of higher sea levels whereby inundation and erosion extent will increase dramatically. The relevant projection information for Ireland is:

- Global mean sea levels are projected to rise by up to 0.98m by the end of the century (IPCC, 2013). For Ireland, the greatest increases are expected in the south and west.
- The number of very intense storms (for example winter 2012/2013) is expected to increase (Nolan, 2015).
- Projections indicate that the winter tracks of these very intense storms may extend further south than the current situation, which means more of these storms will reach Ireland (Nolan, 2015).

Figure 21: Projected change in relative sea level in 2081–2100 compared to 1986–2005 for the medium-low emission scenario (RCP 4.5) (EEA 2014)
In Ireland, observed sea level trends are broadly consistent with the global average. However, levels of sea level rise will vary and are based on local conditions. For example, vertical land movements after the last ice age will augment this trend in the south of Ireland and reduce it in the north. As a result, areas of the south will be the first to feel the effects of sea level rise which will magnify the effects of storm surge. At particular risk are low-lying areas (for example east coast) and those already situated on eroding shorelines (south and east coast in particular). In conjunction with these are areas located on estuaries where higher sea level and changes in the incidence of high river flow events interact and can result in a volumetric combination of storm surge and peak river flows that can drastically increase flood hazard.

**6.2.4 Projected Consequences of Sea Level Rise and Storm Surge for the Transport Sector**

Projected increases in inundation extents and duration and levels of coastal erosion will have wide-ranging impacts for transport:

- Transport infrastructure currently considered at risk of coastal inundation and erosion will be at increased risk while areas currently not considered at risk may also be threatened. This is particularly the case for transport infrastructure located in low-lying coastal areas, on eroding coastlines and on estuaries.
- Port infrastructure will be at particular risk under projected changes in sea level and storm surge. The key impacts identified include: damages to port infrastructure, navigations and safety equipment; damages to vessels while in port and impacts on safety of passengers while embarking, in transit, and disembarking. Storm activity can also cause issues in relation to the channels leading into ports becoming blocked with large amounts of sand silt and other materials driven by storm activity. In addition, changes in sea level will have impacts on dredging requirements at ports, positive or negative depending on...
local circumstances, and implications for natural scouring capability at estuarial ports.

- In general, aviation infrastructure is situated away from the coast. However, Shannon Airport is located on the estuary and will be at increased risk from estuarine flooding.
- Increased floodwaters will make travelling conditions more dangerous and mean transport modes (bus, rail) will be at greater risk.
- Damages to infrastructure will result in higher levels of disruption to services (delays/cancellations/diversions) and a requirement for emergency planning to facilitate the transport of passengers from affected areas.

### 6.3 Extreme Temperatures

Extreme temperatures (heat and cold) can have a wide range of impacts for the transport sector and result in significant costs. From experience, it is clear that extreme cold temperatures have already resulted in significant impacts for all transport modes in Ireland. In contrast and to date, episodes of extreme heat, for example the summer of 1995, which was the warmest summer on record for Ireland, have not resulted in adverse impacts on transport infrastructure and modes, demonstrating the resilience of transport to current temperature conditions. However, projected climate changes for Ireland indicate that risks associated with extreme heat will increase for the transport sector. For example, projections suggest that rail buckling could occur more frequently in the future. While episodes of extreme cold will occur less often, nonetheless, due to the significant and adverse impacts of extreme cold weather events, transport must ensure adequate provision for periods of extreme cold temperatures.

#### Case Study 7 – Extreme Cold Experience, Winter 2009/2010

The cold spell that began on the 27th November 2010 was one of the most severe and prolonged cold spells recorded in recent Irish weather history and continued for 30 days. Extreme cold temperatures were accompanied by heavy snowfalls across many parts of the country, and extremely low temperatures were recorded – as low as minus 16 °C and well below normal winter ranges. Temperatures remained below freezing for prolonged periods, with a maximum daytime temperature of minus 9.7 °C recorded at one weather station. In terms of the impact on our transport system, most people continued to be able to travel, although with greater care than normal and at reduced speeds on the roads. National primary roads were generally kept open for traffic and public transport routes were largely able to operate throughout the period. Heavy snowfalls in the week before Christmas 2010, in association with closures throughout Europe, caused severe hardship for air travellers during the critical pre-Christmas travel period.
The Department of Environment’s National Directorate for Fire and Emergency Management Report showed that lessons learned from the earlier severe cold event in January 2010 had improved local authority (in association with Met Éireann, the National Roads Authority and other organisations) preparedness and capacity for keeping priority routes open to traffic during severe cold weather. It also made a series of recommendations to improve the State’s response to extreme cold/heavy snowfall conditions.

It is remarkable that two of the six coldest spells in the recent weather history of Ireland occurred in the same calendar year and that they were preceded by an exceptional flooding event in November 2009. This demonstrates the unpredictability of weather patterns which affect the country.

![Figure 23: Snow on tracks (Picture courtesy of Iarnród Éireann)](image1)

![Figure 24: Heavy snowfall can disrupt travel (Picture courtesy of Iarnród Éireann)](image2)

![Figure 25: Snow disrupts bus services (Picture courtesy of Bus Éireann)](image3)
6.3.1 Projected Changes in Extreme Temperatures

Although transport has demonstrated resilience to extreme heat episodes, the projected rise in temperature has the potential to increase risk of adverse heat related impacts for transport. In contrast, projected occurrences of extreme cold days are expected to decrease. Nonetheless, due to the extreme nature of previous cold events and the level of disruption and financial costs associated with these events, it is essential to ensure that preparedness actions remain in place. The relevant climate projection data for Ireland are:

- Average temperatures are expected to increase across all seasons and by up to 1.7°C by mid-century (Nolan, 2015).
- The warmest days are expected to be warmer by up to 0.7–2.6°C by mid-century (Nolan, 2015).
- With increasing air temperatures an increase in the intensity and duration of heatwaves is expected (Nolan, 2015). For the most severe climate change projections, Matthews et al. (2016) suggest that summer conditions as warm as 1995, the warmest summer on record for Ireland, will occur once in seven years by the end of the century.
- The number of frost days is expected to decrease by up to 62%, while the number of ice days is expected to decrease by up to 82% (Nolan, 2015).

Figure 26: Projected change in seasonal mean temperature for the medium to low emission scenario (left) and high emission scenario (right). In each case, the future period 2041–2060 is compared with the past period 1981–2000

Figure 27: Projected change in the top 5% of maximum daytime summer temperatures for the medium to low emission and high emission scenarios. In each case, the future period 2014–2060 is compared with the past period 1981–2000. Number included refer to the minimum and maximum increases displayed at their locations
6.3.2 Projected Consequences of Extreme Temperatures for the Transport Sector

- The effects of temperature extremes on the rail track range from buckling of rails in hot weather to freezing of points and broken rails in cold weather. As summer temperatures are projected to rise, so are rail temperatures and the thermally induced forces in the steel rail. Whilst buckling of rails is a rare occurrence in Ireland (less than one per year on average) the probability of it happening will be increased if extreme high temperature events occur. There will therefore be more requirement for trackside monitoring and more likelihood of blanket network-wide speed restrictions. A network-wide speed restriction is a precautionary measure to reduce the consequences should a buckle occur. There were network-wide speed restrictions in the south of England during the summer of 2016 which heavily impacted on train services. See this news story in The Independent:

- High temperatures may cause road surfaces to deform. This may be a particular problem on secondary roads as these have lower surface specifications than motorways. In relation to public transport, over-heating of trains, trams and buses can greatly discommode passengers.
- In ports, extreme heat can reduce the life of felt-type roofing products and cause degradation of road surfaces. Also, port workers may not be able to work in glass boxes on cranes. Drought may impact on natural scouring leading to increased siltation.
- Increased temperatures can cause aircraft climb problems and will also increase the need for air-conditioning in airport buildings.
- With fewer cold snaps expected as a result of climate change, the capacity to learn from such experiences may be diminished resulting in greater disruption to services and safety practices when such events do occur.
7. Categories of Adaptation Options

Adaptation can be defined as the ability of a system to adjust to climate change (including climate variability and extremes), to minimise potential damage, to take advantage of opportunities, and to cope with the consequences. There is a range of widely recognised options available in order to address climate change impacts. Arising from these options we can expect actions and measures to reduce vulnerabilities and increase resilience of transport systems. For the purpose of this draft Plan, adaptation options are being grouped mainly into two headings, policy/government and infrastructural. In this context, the following represents a widely accepted suite of general adaptation options available to the transport sector:

7.1 Policy/Government Options

This includes policy and government intervention options as well as changes in human behaviour. These options require a lot of commitment and ongoing support. In this context, the following represents a widely accepted suite of general adaptation options available to the transport sector:

- strategic land use and effective integration with other sectors (for example agriculture and tourism) in planning and development;
- collaborative research and co-operation between stakeholder bodies, including agencies, authorities and departments, in order to effectively address the likely impacts of climate change on infrastructure and services;
- green public procurement; and
- national transport infrastructure investment addressing the scale of potential risks associated with climate change

7.2 Infrastructural Options

Infrastructural options are technological or engineering solutions to address existing or future climate impacts. For example, the construction of sea walls, or tidal barrages in response to sea level rise. Actions of this nature are easy to quantify but can be very costly. The following represents an example of the types of infrastructural options available to the transport sector:

- new transport infrastructure to be positioned in areas less likely to be affected by climate change;
- transport infrastructure planners/designers to take climate change projections and impacts into account;
- transport infrastructure contracts to have climate change adaptation clauses;
- climate change to be incorporated into engineering management practices and integrated into national policies and regulations to ensure an aligned and consistent approach across all departmental and policy platforms; and
• auditing transport infrastructure to identify vulnerabilities and implement optimum adaptation measures.

7.3 Green Options

There are also measures of an ecological nature that can be deployed to lessen the impact of climate change; for example, efforts to reinstate dune systems to act as buffers against coastal storm damage. However, these actions can have very long lead-in times.
8. Current Measures that Assist in Adaptation Planning

In assessing the adaptive capacity of the transport sector, it became clear that existing planning systems already provide for some degree of resilience to the impacts of climate change, forming a sound basis from which to develop future adaptation plans.

8.1 Central Measures

8.1.1 Planning Law

The Planning and Development Act 2000 sets out the detail for regional planning guidelines, development plans and local area plans as well as the basic framework for the development management and consent system. Among other things, it provides the statutory basis for protecting our natural and architectural heritage and carrying out Environmental Impact Assessments (EIA).

EIA is the process by which the anticipated effects on the environment of a proposed development or project are measured. If the likely effects are unacceptable, design measures and/or other relevant mitigation measures can be taken to reduce or avoid those effects. In recent years, measures have been taken to integrate climate change, including adaptation, into the EIA. The EU Commission issued Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment, which aims to help Member States improve how climate change, both mitigation and adaptation, are integrated in EIAs.

8.1.2 Flood Management

The Office of Public Works (OPW) have produced guidelines to relevant authorities on flood risk management entitled The Planning System and Flood Risk Management – Guidelines for Planning Authorities (OPW-DEHLG, 2009). In addition, the Office for Public Works commenced the Catchment Flood Risk Assessment and Management (CFRAM) programme in 2011, which comprises three phases: Preliminary Flood Risk Assessment (2011); CFRAM Studies (2011–2015); and Implementation and Review (2016 onwards). The programme also provided for three main consultative stages, namely Preliminary Flood Risk Assessment in 2011, the Flood Hazard Mapping Process in 2014 and the Flood Risk Management Plans in 2015 for specific geographical locations. It is worth noting that, during this process, Shannon Airport was identified as an area for further assessment.

Flood Risk Management Plans for the specific catchment regions, arising from the Catchment Flood Risk Assessment, have now been developed. Indeed, flood defence recommendations have been made on the type of mitigation measures (for example raising in height of river embankments) required specifically to protect Shannon Airport from the possibility of experiencing flood events. This national project is being co-ordinated by the Office of Public Works and Jacobs Engineering. Shannon
Airport is covered under the Shannon catchment region. Further information is available at www.opw.ie/FloodPlans

8.1.3 Emergency Planning

In 2001, a range of government structures was put in place to support emergency planning in Ireland. A key objective was to improve co-ordination across the various existing national emergency plans. The Government Task Force on Emergency Planning directs and oversees the emergency planning activities of all government departments and public authorities in Ireland. The most common emergencies that arise are unexpected events which require a rapid response from the emergency services, particularly fire services and the Garda Síochána. In the context of adaptation, severe weather and flooding could be constituted as an ‘emergency’ depending on the scale of the event and the associated impacts.

Under the Emergency Planning Framework, DTTAS is the lead department for a range of transport-related emergencies (for example air and maritime major incidents) and supports other lead departments for emergencies which affect travel and transport (for example severe weather). The role of DTTAS in these situations is to oversee and co-ordinate a national level emergency response, where a national response is required.

The National Emergency Coordination Centre is activated in the event of a national emergency or a crisis requiring a national response. In terms of recent events, DTTAS had lead responsibility for the State’s co-ordinated response to the disruptions caused by volcanic ash in April/May 2010 and again in May 2011, and had a significant support role during the severe weather events including those of winter 2009/2010, the prolonged snow event of November/December 2010, and the series of high winds, high seas and flooding events of December 2013 to February 2014.

The future impacts on transport services and infrastructure from climate change will most likely arise from disruptions to services or damage to transport infrastructure caused by more frequent storm events, rising sea levels and increased incidents of flooding. The State transport operators and agencies have participated in the development of this Climate Change Adaptation Plan and will be carrying out any measures defined within this Plan. In parallel, they have built on the experience of the severe weather events since 2009 and have adapted and updated their mitigation and response plans to minimise the impact of both current and future weather-related events. Co-benefits with emergency planning will be a complementary outcome of this Plan.

The National Transport Authority (NTA) has a remit in the Greater Dublin Area to publish a Transport Strategy as well as an Integrated Implementation Plan. Nationally,
the NTA produces policy and technical guidance to aid local authorities which must consult the NTA when drawing up their Regional Planning Guidelines. The NTA has the role of sanctioning authority for the financing and construction of most public transport infrastructure projects. With regards to mainline railway projects, this work is undertaken by Iarnród Éireann due to the specialist nature of the works.

8.2 Transport Service Providers Measures

Transport sector service providers seek to build resilience into everyday operations as well as future plans. The following reflects a summary of current practice across the sector:

8.2.1 Roads Infrastructure/Services

- Local authorities play a critical role in responding to the impacts of flooding, coastal erosion and landslides on national, regional and local roads and are responsible for the salting and gritting of the road network during periods of sub-zero temperatures.
- The local authority sector also provides significant expertise in forward planning as well as being first responders to the impacts of disruptive weather events through a range of services (for example engineering, fire, civil defence and the operation of road crews). Each local authority is developing its own Climate Change Sectoral Adaptation Plan and the sector is actively involved in the Government's National Steering Group on Emergency Planning.
- TII is a longstanding member of the Conference of European Directors of Roads. Through this, a number of key strategies for adapting to climate change have been developed and are being implemented in a number of European countries, especially those facing more profound climatic impacts.
- As part of climate change initiatives, TII has drafted the Strategy for Adapting to Climate Change on Ireland’s Light Rail and National Road Network.
- In the context of new road projects, the identification of vulnerable areas already takes place during the planning process as part of the Constraints Study.
- TII has also developed a detailed flood mapping service of the entire national road network that identifies vulnerable sections requiring more detailed assessment.
- In addition, TII has developed a comprehensive flood protocol for addressing flooding on the road network. The aim is to allow an individual appraisal of sites that have been highlighted as potentially being at risk of flooding.
- Where flood events lead to road closures, the event is analysed to investigate the cause of the flooding and explore what mitigation measures are required to reduce the risks of a future event.
In the undertaking of any analysis of flood events and the implementation of mitigation measures, TII recognises the importance of co-ordinating such activities with relevant authorities, such as the local authorities and the Office of Public Works.

In addition, the TII design standards (DMRB) have been amended to include climate change adaptation; rainfall intensities are increased by 20% to allow for climate change in the design of drainage systems.

TII is constantly reviewing standards to adapt to climate influences and environmental objectives. TII’s drainage standards have recently been extensively modified to allow for the construction of more sustainable solutions to road run-off such as the use of constructed wetlands and grassed channels.

Pre-planned diversions, call-out services, road user information and speedy clear ups are among the range of measures implemented by road authorities and public service transport providers when dealing with an extreme weather-related event. In addition, Intelligent Transport Systems continue to be planned on national routes in order to keep road users informed.

**Bus Services**

In addition to having emergency response and environmental policies in place, Bus Éireann is guided by the key document, Providing Transport Services Resilient to Extreme Weather. Bus Éireann’s emergency plan caters for immediate response from all levels of management and staff and also for liaising with other stakeholders.

Priorities and approach on key routes have been agreed with local authorities. Route review and alternative route planning is in place.

Severe weather management plans are in place to provide co-ordinated response including arrangements for staff training and storage of supplies and equipment for use during major weather events.

Roadside real-time passenger information signs are used to provide information on service curtailments and diversions.

The internet and social media are used to provide communication and information.

Bus Éireann can engage private contractors at short notice in case of capacity issues.

Internal reviews are conducted to ensure that systems are maintained successfully.
8.2.2 Rail

Heavy Rail

- The cornerstone of arrangements for responding to extreme weather events and service recovery is the Iarnród Éireann Weather Management Protocol. This is a series of protocols developed to assist local managers to plan a response to a period of severe, possibly service-affecting weather. The document addresses the response to conditions of flooding, snowfall, ice, high winds and heat.

- In addition, there are further specific Technical Standards and Bulletins developed to address other engineering aspects which are a consequence of climatic conditions:
  - Flood and Scour Management Standard
  - Prevention of Track Buckling
  - Guidance on Alerts and Service Restrictions during Severe Weather Alerts
  - Work Limitations during Warm Weather
  - Six Day Weather Forecast Meteograms from Met Éireann
  - Tamping and Welding in Cold Weather Conditions.

- In order to address and manage the risk of bridge scour Iarnród Éireann undergoes active monitoring of bridges over watercourses. This monitoring consists of bridges being inspected by divers every one, three or six years depending on their risk condition rating. Iarnród Éireann has spent approximately €2.5 million in active monitoring for scour at these bridges since 2009 and has undertaken scour countermeasure works at 12 bridges in the last three years. Iarnród Éireann has identified a further 80 scour countermeasure projects and will implement these on a prioritised basis dictated by the results of active monitoring. In addition, there is a programme to investigate unknown foundations to determine their depth and material. Over the last three years, 32 investigations of this nature have been completed.

- Of the major impacts already identified for heavy rail, the existing trigger level for intervention in respect of track buckling and the existing trigger level for maintenance intervention/adjustment of the overhead line equipment will remain the same. As it is forecast that climate change will increase the frequency at which these trigger levels are exceeded (in the medium and long term), there is no requirement to adjust existing arrangements.
Luas

- TII has developed a severe weather management plan which provides a framework for managing responses to any weather event that has the potential to seriously disrupt Luas services.
- TII is signed up to the Sustainable Energy Authority of Ireland public sector partnership programme supporting the sector to achieve a target of 33% improvement in energy efficiency by 2020.
- In the short term and as a continuation of current practice, the TII will continue to plan and design new public transport infrastructure projects by implementing The Planning System and Flood Risk Management Guidelines for Planning Authorities (DoEHLG and OPW). In particular, the feasibility of projects and route options will continue to be evaluated and assessed with reference to the Office of Public Works National Flood Hazard Mapping (www.floodmaps.ie) and with Flood Risk Assessment and Management Studies that are available (for example the Fingal East Meath study).

8.2.3 Ports

- Dublin Port Company publishes an annual Sustainability Report to track and record progress on the port’s economic, environmental and social responsibilities. It has signed a joint energy efficiency agreement with the Sustainable Energy Authority of Ireland to work in partnership to achieve a target of 33% energy efficiency savings and improvements by 2020. Dublin Port Company is certified in Port Environmental Review System and ISO 14001 Environmental Management System and is a member of the Dublin Bay Biosphere Partnership.
- Rising sea level and fluvial flooding are priority issues for Port of Cork and the City of Cork as well. Infrastructure planning and design is based on risk assessment and strategic planning. Special attention is paid to maintaining the road access to the port under extreme weather conditions. Emergency planning procedures are in place, including monitoring of ship movements and crane operations in extreme conditions.
- In relation to dealing with impending weather events, Shannon Foynes Port Company recently developed a co-operative and combined approach with Limerick Combined Authority and the Office of Public Works. It also engaged
with the local communities, including initiating a text alert messaging system to advise of future events.

- Drogheda Port is currently involved in developing a project focused on small to medium sized Atlantic ports in Europe, the lead partner being the Association des Ports Locaux de la Manche. The project is designed to identify the impact on the existing infrastructure of ports and identify future infrastructural requirements to protect port operations.

### 8.2.4 Airports

- A key consideration in airport infrastructure development is the ability to accommodate growth in passenger numbers and also to facilitate technological change, both in the air and on the ground. Environmental aspects are considered, encompassing key climate change impacts, insofar as possible at the time. From a cost and sustainability perspective, airports seek to ensure new developments deliver increased resource efficiency.
- Airports and airlines operate in an environment highly regulated in relation to aviation safety and have detailed procedures in place to ensure safe and consistent airport operations both on a day-to-day basis and in cases of emergency.
- Any planning applications submitted by Dublin Airport Authority shall be subject to rigorous flood risk assessment by the local authority planning department prior to being approved or otherwise.
- Dublin Airport Authority uses standard drainage models for predicted peak flows, surcharges and average flows in the drainage network. These models include a climate change factor in all calculations.
- There will be continued use of detailed weather forecasting services provided by Met Éireann. Shannon Airport is the location for a weather forecasting station that specialises in aviation forecasting. Dublin Airport Authority and Shannon Airport Authority utilise a wide range of sources for day-to-day operations. These include weather data from Met Éireann and the UK Met Office. These data sources are used for near term weather to enable efficient airport operations. Historic climate data such as 30-year averages are used in some cases for studies relating to drainage or environmental impacts.
- The airport authorities prepare plans to deal with various emergency response scenarios, as required, including terminal building evacuation, snow and ice plan, aircraft emergency and crash procedures.
- The airport authorities regularly conduct reviews of operating and contingency procedures to ensure that they are consistent with aviation best practice.
- The airport authorities source data reports for information on climate change from the Environmental Protection Agency, Directorate General for Climate Action, Intergovernmental Panel on Climate Change, the European Aviation Safety Agency, the International Civil Aviation Organisation, the IAA, the Airports Council International and the International Air Transport Association.
• The airport authorities engage with representative organisations such as the Airports Council International and IBEC for up-to-date information on climate studies relevant to industry. Specific climate risk assessments from peer airports are also publicly available (for example Heathrow Climate Change Adaptation and Resilience Progress Report).
• Numerous other commercial meteorological service providers are available (for example Open Runway). These can supply forecast data on a contract basis at a price.
• Shannon Airport Authority’s Aerodrome Manual which contains the airport’s standard operating procedures outlines detailed procedures to be followed by employees to ensure the ongoing provision of a safe aerodrome during adverse weather events, for example snow and ice plans.
• For drainage projects, a climate change factor is included in the design specification and/or modelling exercises.
• Ireland West Airport Knock is developing a drainage plan based on information received from Met Éireann which is located in the airport.

**Airport Services**

• In relation to airport services, the IAA has a National Operational Contingency Plan which is periodically updated to account for changes in any relevant circumstances.
• The IAA utilises relevant information from Eurocontrol, the European Aviation Safety Agency, the International Civil Aviation Organisation and the International Air Transport Association with regards to climate change.
• The IAA will continue working with all stakeholders on optimising environmental efficiency in Irish airspace.
• The impact of climatic conditions is taken into account in any infrastructural developments undertaken by the IAA.
9. Possible Adaptation Measures for the Transport Sector

This sector’s adaptation to the impacts of climate change will require collective effort and co-operation between all stakeholders. In the long term, the need for targeted investment in the transport system will increase as the sector seeks to respond to the impacts of climate change, particularly those impacts that could be exacerbated by any existing vulnerabilities in our road and rail infrastructure. However, costs associated with such measures are high. A funding model will need to be considered in the context of addressing such vulnerabilities as part of a long-term adaptive strategy for transport in Ireland.

In the short to medium term, further research and the promotion of cost-effective measures should be supported. Low-cost mechanisms, based upon an improved understanding of risks and potential costs, can be deployed to begin the process of building resilience into our transport sector. The following represents a range of draft measures, which have been identified by the transport stakeholder group, which could potentially be deployed sector wide to combat likely vulnerabilities and to establish resilience.

9.1 Sector Wide Measures

<table>
<thead>
<tr>
<th>Integration of Policy</th>
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<tbody>
<tr>
<td>• Enhance co-operation and communication between departments, agencies, State bodies and other stakeholders, at a national and international level, in order to maximise the transport sector’s responsiveness to the impacts of climate change. Additional co-operation and communication channels will be identified including the establishment of a co-ordination body and/or steering group to lead policy on transport adaptation.</td>
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<tr>
<td>• Mainstream climate change adaptation into general transport policy, emergency planning guidelines and strategic objectives to 2050. This could include a review of existing transport policy in order to identify specific principles/measures with a view to making supplementary recommendations as new policy evolves.</td>
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<tr>
<td>• Ensure local authority adaptation planning is properly reflected in sectoral adaptation plans, securing alignment between policy making and front line services.</td>
</tr>
<tr>
<td>• Reflect adaptation options/measures in sector-specific management and development plans, master plans, emergency response plans, internal standard operating procedures and all maintenance works/plans. This could include an inventory of existing plans, helping to inform recommendations and the</td>
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development of a cohesive approach to planning across the system.

- Adopt a strategic, integrated and long-term approach to spatial and land-use transport planning through the identification of any gaps in planning/legislation with a view to making recommendations.
- Review and incorporate adaptation considerations into planning and design standards and engineering management practices.
- Reflect on green public procurement guidelines in the transport system and the need, if any, for changes to procurement and contract rules in order to address adaptation challenges including, potentially, the development of ‘green contractor/green supplier’ certification systems.

**Data and Risk Management**

- Establish the best approach to harmonising the collection of baseline data including costs related to adaptation measures (arising from identifiable climate impacts) and past extreme weather events.
- Consider the need for a transport modelling tool, which would help to project the likely impacts of climate change on the transport system in Ireland.
- Support collaborative and sector-specific research across stakeholder bodies by undertaking, inter alia, a literature review of existing research on transport adaptation. Look to establish a best practice approach to research development in this area in Ireland.
- Consider appropriate mechanisms by which to identify vulnerable areas and critical transport assets as part of a detailed risk assessment across the entire transport system.

**Investment and Development**

- Identify, through risk assessment, vulnerabilities in critical transport infrastructure and services.
- Redesign, retrofit, remediate, protect or relocate, as necessary, infrastructural elements to ensure appropriate protection against climate change and extreme weather events.
- Establish the cost profile of the adaptation measures needed to protect critical transport infrastructure.
- Assess levels of investment required for any equipment to prevent or reduce harmful effects of extreme weather events.
- Consider potential for, and costs of, improvements to user information, early warning systems and public awareness elements of adaptation.
- Assess potential of, and costs associated with, green adaptation options for transport sector including the identification of ecosystems and habitats that could act as ‘buffers’ to the impacts of climate change by helping to prevent damage to infrastructure.
- Develop funding model to address any long-term costs associated with the above.
9.2 Sector-Specific and Agency-Led Future Measures

The following represents a range of measures within the subsectors of transport that have been identified by transport agencies, which could be deployed to build further resilience:

### Roads

- In relation to **improving** existing services for roads, likely options could include event analysis with a measure to create a database for such events. While cost/benefit analyses on proposed improvements to the national road network are already carried out by TII, a database of events which could provide an overview of the distribution, type of event and consequences of each event would help to better inform the authority as greater resilience is built into the road network over the long term.

- Although climatic events are inevitable on Ireland’s road network, there are measures that can be taken to minimise, and in some cases prevent, significant disruption as follows:
  - identifying hot spots and preparing action plans – this process involves monitoring specific locations, investigating mitigation measures and carrying out improvements, if required;
  - ensuring that future schemes have taken full account of climate change in planning and construction;
  - continuation of TII’s policy of funding research on climate-related issues and ensuring such research has practical applications;
  - continued active participation and sharing of knowledge with European partners through the Conference of European Directors of Roads technical group on climate change; and
  - continuation of planning and installing Intelligent Transport Systems on national routes in order to keep road users informed. Liaison with local authorities is also required in relation to non-major inter-urbans in order to manage such events.

- In order to enhance communication and co-operation between the various transport stakeholders, a forum could be established in the form of a Severe Weather Group.

- TII is committed to improving energy efficiency and developing a better understanding of the carbon impacts associated with the construction and operation of the national road and light rail networks. Commissioned research studies have examined embodied and operational carbon on pilot road schemes in Ireland, with a view to implementing a carbon emissions assessment and comparisons of future schemes.
### Bus Services
- Review of bus design – better thermal insulation, possible inclusion of air-conditioning
- Improved flood risk assessment and management at depots
- Further development in smart communication
- Dublin Automatic Vehicle Location centre will operate 24 hours to cover national weather communications.

### Heavy Rail
- An increase in passenger heat stress was identified as a major impact on rail services but there is no universal solution to this as it will occur in different places and in different ways across the network. Further research into this impact could be an option for rail.
- An increase in river and localised flooding leading to scour and flooding of bridges, embankment scour, culvert washout, depot flooding and track and lineside equipment failure was also identified as a major impact. Currently Iarnród Éireann’s data records do not differentiate between different types of flooding and this is an area of improvement that has been identified, along with a revamp of the online GIS mapping tool of flood risk locations. It is believed that better recording of event data will enable Iarnród Éireann to make better adaptation plans in the medium and long term.
- Iarnród Éireann is a key stakeholder agency supporting the national CFRAM programme which is central to the medium and long-term strategy for the reduction and management of flood risk in Ireland. Its aims are to produce detailed flood mapping highlighting existing and potential future flood risk and also to identify measures and options for managing flood risk. Iarnród Éireann hopes to use this information to optimise strategic opportunities to enhance the resilience of the rail network so far as is reasonably practicable.
- Sea level rises and storm surge increases requiring improved railway flood/erosion defences was also identified as a major impact. Iarnród Éireann commenced a pilot study in early 2015 to develop a decision support tool for assessment of the likely impacts of sea level rises and storm surges due to climate change. This is based on modelling data derived from Office of Public Works studies combined with up-to-date maritime data.
- In relation to the railway line near Rosslare Harbour where the coast is being eroded by storm events, an evaluation of the options for remedial works ranging from localised major engineering solutions to line diversion will be required in the coming years.
- Remote monitoring will become an ever increasing part of the Iarnród Éireann approach to the management of its assets. It will continue to invest in systems and technologies that can enhance resilience of the rail network.
**Light Rail**

- In accordance with the Transport (Railway Infrastructure) Act, 2001, all new light rail and metro infrastructure has a statutory requirement for the preparation of Environmental Impact Statements, so these projects are subject to the Environmental Impact Assessment Directive. The newly amended EIA Directive (2014/52/EU), which entered into force on 15th May 2014, also introduced a greater focus on biodiversity, climate change and resource efficiency.

- The planning for Bus Rapid Transit will be progressed under the Road Regulations, 1994 (S.I. No.119 of 1994) and will also be subject to EIA as the threshold specified in the Road Regulations, 1994 for the widening of an existing road in an urban area (road widening to four or more lanes along existing roads of a length of approximately 6.5km) will trigger a mandatory EIA.

- TII will continue to audit and review the system to identify areas of the Luas system that are susceptible to flooding, inundation, landslips, subsidence, wind/storm damage etc.

- Following on from this audit, a risk assessment will be undertaken which will enable priority amelioration proposals to be identified and progressed.

- TII will undertake a transport study for Dublin in order to evaluate how climate change trends, including predicted wetter weather along with an increasing emphasis on public transport, will impact on Luas as well as other transport operations in the future.

- Asset management and renewal: TII is responsible for performing Lifecycle Asset Renewals programmes to identify and replace assets which are at the end of their useful life. This programme derives from the Luas Asset Management System which is being developed to optimise management of Luas infrastructure assets throughout their lifecycles and is based on PAS 55:2008 and ISO 55000:2014 Asset Management standards.

- The lessons learned from the previous 10 years of Luas operation are considered in developing proposals for the renewal of Luas assets. Severe weather events such as the heavy snow of 2010 and significant flooding events have led to investment in special tools to improve the operational response to severe weather events.

**Ports**

- Dublin Port is guided by its Masterplan (2012 to 2040). In 2015, it received planning permission for the Alexandra Basin Redevelopment Project, the first major project from the Masterplan. New quay walls will be higher and hinterlands will, in some places, be raised by 1.4m to future-proof against long-term increased sea levels. Dublin Port Company is also carrying out condition studies of breakwater infrastructures (North Bull Wall and the Great South Wall); as part of this the impact of long-term rising sea levels will be
• Development of long-term remediation works will only be considered once the national CFRAM programme is finalised. Existing internal standard operation procedures developed for working in extreme weather conditions are subject to ongoing review. Build programmes are cognisant of threats due to flooding and rising sea level.

• The future of shipping in Dún Laoghaire will be focused on the cruise industry, and the development plans for the proposed cruise ship berth will very much take into account all potential impacts of climate change, and will be designed to be resilient to them over the proposed lifespan of the development.

• In relation to planned future developments the impact of climate change is a factor which the design teams are considering very seriously. The impacts on final design vary depending on whether the most significant factor is the increased risk of flooding, significant storm events or rising sea level.

Airports

• Increased on-site drainage capacity is a likely adaptation measure which will be required to prevent on-site flooding risk.

• There may also be a requirement for larger attenuation and surface water management systems to prevent downstream flooding.

• Building heating and cooling systems may require greater capacity if average temperatures increase during summer months.

• Within the Shannon Airport Masterplan 2011–2021, one of the stated objectives relates to the proposed rail link from Shannon Airport to the existing Limerick–Ennis rail line. Any potential route for the rail link must be protected from the effects of climate change.

• The CFRAM programme is central to the medium to long-term strategy for the reduction and management of flood risk in Ireland. Its aims are to produce detailed flood mapping highlighting existing and potential future flood risk and also to identify measures and options for managing flood risk. Shannon Airport and Shannon town have been identified in this programme as areas for further assessment. Future improvement works to existing flood defence systems locally and additional flood protection measures will undoubtedly be required as a direct result of climate change globally.

• The air transport sector should continue to invest, as far as possible, in the provision of appropriate, all-weather systems which will ensure the optimum level of safe and efficient operation of air transport, regardless of weather conditions. These include instrument landing systems, enhanced surveillance systems, enhanced weather forecasting capability (for example runway temperature sensors) and improved ground infrastructure and equipment (for example appropriately capable snow clearance equipment).
10. Monitoring and Reviewing

As part of the process to establish a robust plan for adaptation in transport, it will be vital to establish a system for monitoring and evaluating measures identified in the Plan. Performance indicators will be used to establish whether adaptation measures are being achieved and considered to have value in terms of improving the future outcomes of an adaptation action. Future modelling for the transport sector in relation to climate risk will be vital as we progress to more focused actions in subsequent adaptation plans.

This Plan represents a very early stage in adaptation planning and in understanding how best to adapt to climate variability. Consequently, a monitoring system will help to support communication and learning and to indicate progress towards the goals of adaptation.

The measures identified will be considered in the context of effectiveness, efficiency and equitability. The monitoring system put in place for transport will be part of a larger system that monitors progress at local authority level as well as MMR reporting at national level to the EC and the United Nations Framework Convention on Climate Change.

Over the period of this Plan, the following indicators will help to demonstrate progress towards an ultimate goal of building resilience into the transport system against the impacts of climate change:

- baseline monitoring;
- recognition of adaptation needs within sectoral work programmes (mainstreaming);
- level of adaptation research;
- launch of adaptation measures/level of spending collected;
- co-operation with other sectors/sub-national levels is planned/happening; and
- periodic reviews/evaluations are planned.

In the long term, there will be recurring National Adaptation Frameworks and sectoral plans as provided for by the Climate Action and Low Carbon Development Act 2015.
## 11. ANNEX 1 – Detailed Table of Impacts

### Climate Impact – Precipitation

<table>
<thead>
<tr>
<th>Sector impacted</th>
<th>Observed impacts</th>
<th>Level of impact</th>
<th>Projected impacts</th>
<th>Change in level of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus Services</td>
<td>Disruption, overcrowding, delays etc.</td>
<td>Low</td>
<td>Disruption, overcrowding, delays etc.</td>
<td>Low to medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Increase in flash flood risk</td>
<td></td>
</tr>
<tr>
<td>Light Rail</td>
<td>Disruption, overcrowding, delays etc.</td>
<td>Low</td>
<td>Disruption, overcrowding, delays etc.</td>
<td>Low to medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Increase in flash flood risk</td>
<td></td>
</tr>
<tr>
<td>Heavy Rail</td>
<td>Reduction in slope stability and increase in land slides</td>
<td>Low</td>
<td>Disruption, overcrowding delays etc.</td>
<td>Low to medium</td>
</tr>
<tr>
<td></td>
<td>Drainage systems unable to cope</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Service disruption due to line closures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Passengers discommoded</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aviatioin</td>
<td>Pressure on building rainfall run-off systems</td>
<td>Low</td>
<td>Challenges to storm-water management</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Pressure on airport drainage systems (for example rain event 15th Aug’16 Shannon)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ports</td>
<td>Radar ability compromised during heavy precipitation</td>
<td>Low</td>
<td>Challenges to storm-water management</td>
<td></td>
</tr>
<tr>
<td>Sector impacted</td>
<td>Observed impacts</td>
<td>Level of impact</td>
<td>Projected impacts</td>
<td>Change in level of impact</td>
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<tr>
<td>Heavy Rail</td>
<td>Sea level rises require increased railway flood defences</td>
<td>Medium</td>
<td>Disruption overcrowding delays</td>
<td>Medium to high</td>
</tr>
<tr>
<td></td>
<td>Scour damage at bridges</td>
<td></td>
<td>Increase in scour damage at bridges</td>
<td></td>
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<tr>
<td></td>
<td>Damage to track</td>
<td></td>
<td>Increase in damage to track</td>
<td></td>
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<tr>
<td></td>
<td>Depots flooded</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Light Rail</td>
<td>Closure of depot for example Dundrum for 26 months</td>
<td>Low</td>
<td>Risk to low-lying junctions and substations</td>
<td>Low</td>
</tr>
<tr>
<td>Aviation</td>
<td>Runway drainage systems</td>
<td>Low to Medium</td>
<td>Danger of estuarine flooding from River Shannon</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Pressure on flood defence embankments (Shannon)</td>
<td>Medium</td>
<td>Emergency planning requirements for staff/passengers from flooded areas</td>
<td></td>
</tr>
<tr>
<td>Ports</td>
<td>Damage to pavements, road washout, road submersion, underpass flooding, overstrained drainage systems, risk of landslides, instability of embankments</td>
<td>Medium</td>
<td>Pollution risk where draining services exceed capacity</td>
<td>Low</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Risk to storage facilities</td>
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<td>Impact on dredging requirements – positive or negative depending the location</td>
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<td></td>
<td>Gradual impact on natural scouring capability of estuarial ports</td>
<td></td>
</tr>
<tr>
<td>Roads</td>
<td>Damage to pavements, road washout, road submersion, underpass flooding, overstrained drainage systems, risk of landslides, instability of embankments</td>
<td>Medium</td>
<td>Damage to paving from pluvial flooding</td>
<td>Medium</td>
</tr>
<tr>
<td>Bus Services</td>
<td>Disruption due to overcrowding, diversions, delays etc.</td>
<td>Possible damage to bus depots</td>
<td>Damage to vehicles caused by driving through floods</td>
<td>Medium</td>
</tr>
<tr>
<td>Sector impacted</td>
<td>Observed impacts</td>
<td>Level of impact</td>
<td>Projected impacts</td>
<td>Change in level of impact</td>
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<tr>
<td>Road Infrastructure</td>
<td>Western seaboard prolonged flooding leading to disintegration of road surfaces (€16.6m December/Jan 2013/14) Roadside tree/vegetation can block roads</td>
<td>Medium to High</td>
<td>Increased coastal flood risk of roads (western coast routes)</td>
<td>Medium to high</td>
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<tr>
<td></td>
<td>Damage to port infrastructure and damage to vessels in ports Challenging equipment’s ability to discharge at high water</td>
<td>Low to medium</td>
<td>Damage to port infrastructure, navigational aid and safety equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Damage to vessels in ports Impact on safety of passengers while in transit/embarking/disembarking</td>
<td>Medium</td>
</tr>
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<tr>
<td>Heavy Rail</td>
<td>Interruption in operation of automatic level crossing barriers due to high winds Damage to signalling and power equipment due to falling trees etc.</td>
<td>Low</td>
<td>Disruption, overcrowding, delays etc.</td>
<td>Low</td>
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<tr>
<td></td>
<td>Damage and/or blockage of track due to fallen debris and rock falls Trees and leaves on railway lines Structural damage to stations etc.</td>
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<tr>
<td>Mode</td>
<td>Impact Description</td>
<td>Severity</td>
<td>Other Impacts</td>
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<tr>
<td>Light Rail</td>
<td>Difficulty operating Luas, danger from overhead contact wires in high winds</td>
<td>Low</td>
<td>Speed restrictions due to high winds</td>
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<tr>
<td>Aviation</td>
<td>Damage to Shannon Airport due to river over-topping during Storm Darwin Jan/Feb 2014</td>
<td>Low</td>
<td>Landing and take-off issues</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Damage to Shannon Airport building from high winds Storm Darwin Jan/Feb 2014, €700k for one-off event</td>
<td></td>
<td>Damage to buildings and facilities</td>
<td></td>
</tr>
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<td></td>
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<td>Protection of aircraft on the ground</td>
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<td>Disruption of services to the public</td>
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<td></td>
<td>Damage to flood defence embankments</td>
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<tr>
<td>Bus Services</td>
<td>Can cause vehicles to be diverted, curtailed and cancelled</td>
<td>Low</td>
<td>Possible disruption of services caused by fallen trees, debris</td>
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<tr>
<td>Sector impacted</td>
<td>Observed impacts</td>
<td>Level of impact</td>
<td>Projected impacts</td>
<td>Change in level of impact</td>
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</tr>
<tr>
<td>Bus Services</td>
<td>Over-heating on buses</td>
<td>Low to Medium</td>
<td>Air quality problems, Increased over-heating on buses</td>
<td>Low to medium</td>
</tr>
<tr>
<td>Aviation</td>
<td></td>
<td></td>
<td>Aircraft climb problems, Increased need for air-conditioning</td>
<td>Low</td>
</tr>
<tr>
<td>Heavy Rail</td>
<td>Increase risk of rail buckling/misalignment of track, Increase in network-wide speed restrictions due to risk of rail buckling, Over-heating of equipment</td>
<td>Low</td>
<td>Disruption, overcrowding, delays etc.</td>
<td>Low</td>
</tr>
<tr>
<td>Road Infrastructure</td>
<td>Melting tarmac</td>
<td>Low to medium</td>
<td>Reduced life of asphalt roads</td>
<td>Low</td>
</tr>
<tr>
<td>Ports</td>
<td></td>
<td></td>
<td>Extreme heat can reduce life of felt type roofing products and cause degradation of road surfaces, Workers may not be able to work in glass boxes on cranes, Drought may impact on natural scouring leading to increased siltation</td>
<td>Low</td>
</tr>
<tr>
<td>Sector impacted</td>
<td>Observed impacts</td>
<td>Level of impact</td>
<td>Projected impacts</td>
<td>Change in level of impact</td>
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<tr>
<td>Bus Services</td>
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<td>Low</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Extreme levels of snow can impact on bus garages and stations</td>
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<td></td>
<td>Passengers at risk of accidents during snow/ice</td>
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<td></td>
<td></td>
<td></td>
<td>Staff unable to get to work, staff fatigue</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Can cause black ice and consequently reduce vehicle speeds and increase journey times</td>
<td></td>
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<tr>
<td>Ports</td>
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<td></td>
<td>Low to medium</td>
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<tr>
<td></td>
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<td></td>
<td>Potential increased damage to roads, walls, paving, water pipes and storage tanks</td>
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<td></td>
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<td></td>
<td>Operational fuel can freeze</td>
<td></td>
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<tr>
<td>Heavy Rail</td>
<td>Failure of overhead electrification systems</td>
<td>Low</td>
<td>Disruption, overcrowding, delays etc.</td>
<td>Low</td>
</tr>
</tbody>
</table>
| Light Rail | Failure of overhead electrification systems  
Braking performance of trains affected  
Falls on icy platforms, station entrances and exits, depot access, walkways and roads.  
Ice and snow damage to overhead catenary systems and rail joints | Low |  |
| Airports | Degradation of runways/tarmac from freezing temperatures  
Aircraft landing problems on damaged surfaces | Low |  |
<table>
<thead>
<tr>
<th>Sector impacted</th>
<th>Observed impacts</th>
<th>Level of impact</th>
<th>Projected impacts</th>
<th>Change in level of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airports</td>
<td>Pressure on flood defence embankments Shannon Airport (Feb 2014)</td>
<td>Low</td>
<td>Estimated figure is in excess of €100m for operation disruption costs to Shannon airport</td>
<td>Low</td>
</tr>
<tr>
<td>Heavy Rail</td>
<td>Flooding and erosion resulting in damage and loss of coastal rail infrastructure</td>
<td>High</td>
<td>Disruption, overcrowding, delays, etc. In the long-term it may be viable to realign the railway inland</td>
<td>High</td>
</tr>
<tr>
<td>Ports</td>
<td>Will impact on existing infrastructure, including existing equipment capabilities, i.e. ability to discharge at the top of high water etc.</td>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Bus Services</td>
<td>Possible disruption of services caused by coastal flooding</td>
<td></td>
<td></td>
<td>Low</td>
</tr>
</tbody>
</table>
12. References


EU Commission 2013 Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment

Gleeson, E., McGrath, R. & Treanor, M., eds. 2013 Ireland’s Climate: the road ahead. Dublin, Ireland: Met Éireann. Available at: http://hdl.handle.net/2262/71304


Matthews et al. (2016) the University of Sydney Absolute plate velocities from the Matthews et al (2016) plate reconstruction model.


OPW-DEHLG 2009 The Planning System and Flood Risk Management – Guidelines for Planning Authorities

TII Strategy for Adapting to Climate Change on Ireland’s Light Rail and National Road Network

Transport for London 2015 Providing Transport Services Resilient to Extreme Weather

www.climateireland.ie

www.opw.ie/FloodPlans

### 13. Glossary

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>Appropriate Assessment</td>
</tr>
<tr>
<td>CFRAM</td>
<td>Catchment Flood Risk Assessment and Management</td>
</tr>
<tr>
<td>DART</td>
<td>Dublin Area Rapid Transit</td>
</tr>
<tr>
<td>DTTAS</td>
<td>The Department of Transport, Tourism and Sport</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>EIA</td>
<td>Environmental Impact Assessment</td>
</tr>
<tr>
<td>EPA</td>
<td>Environment Protection Agency</td>
</tr>
<tr>
<td>IAA</td>
<td>Irish Aviation Authority</td>
</tr>
<tr>
<td>IBEC</td>
<td>The group that represents Irish business, both domestically and internationally</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>NTA</td>
<td>National Transport Authority</td>
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<tr>
<td>TII</td>
<td>Transport Infrastructure Ireland</td>
</tr>
<tr>
<td>SEA</td>
<td>Strategic Environmental Assessment</td>
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</tbody>
</table>