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Turasóireachta agus Spóirt
Department of Transport,
Tourism and Sport

Statutory Climate Change Adaptation Plan for the Transport Sector

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Contents

List of Tables and Figures

List of Tables

List of Figures

1 Introduction

Ireland's climate is undergoing unequivocal change; scientific observations show a rise in sea level on Irish coasts, increases in annual average temperatures, changes in precipitation patterns and increasing incidences of extreme weather event[1]. The observed scale and rate of change in Ireland's climate is consistent with climatic trends on a regional and global level[2]. Notwithstanding a degree of uncertainty about the level and extent of the likely impacts, these changes are projected to continue and to intensify over the coming decades. Notably, a recent Special Report by the Intergovernmental Panel on Climate Change[3] (IPCC) indicates significant impacts are set to occur even if global warming is limited to 1.5°C over preindustrial levels, which are below business-as-usual global average temperature increases by mid-century. If greenhouse gas emissions were to completely cease from today, global climate change would continue for many decades as a result of the delayed impacts of past and current carbon emissions.

Transport is a derived demand which is essential to the functioning of a modern economy and a key enabler of all other economic activities; however, changing weather patterns and violent weather extremes associated with climate change can cause infrastructural damage and deterioration, disruptions to transport operations and unsafe travel conditions. Such disruptions to private, public and commercial travel can have significant negative impacts to Ireland's economy, society, environment and public health. The transport sector must therefore put in place adaptation measures to address the unavoidable consequences and associated costs of climate change, as well as maximising any potential opportunities, by facilitating the development of climate resilience within key transport networks, infrastructure and services.

Adaptation measures should enable continued services and maintained infrastructure as well as safeguarding new assets from longer term impacts by ensuring that current design specifications will adequately address future infrastructure needs. Correspondingly, building long-term climate resilience should not hinder economic growth and social progress or Ireland's ongoing mitigation efforts to decarbonise the transport sector.

1.1 Strategic Policy Focus

Ireland's national policy in response to the challenge of climate change include the *National Policy Position on Climate Action and Low Carbon Development*[4] *as well as the Climate Action and Low Carbon Development Act 2015*[5]. The *National Policy Position* established the central objective of achieving a transition to a low carbon and climate-resilient economy by 2050. *The Climate Action and Low Carbon Development Act 2015* provided the statutory basis for this national transition objective, including the development of a *National Mitigation Plan*[6], a *National Adaptation Framework*[7] (NAF) and the associated preparation of statutory Sectoral Adaptation Plans under the aegis of the *Framework* by relevant sectoral Ministers and local authorities (LAs).

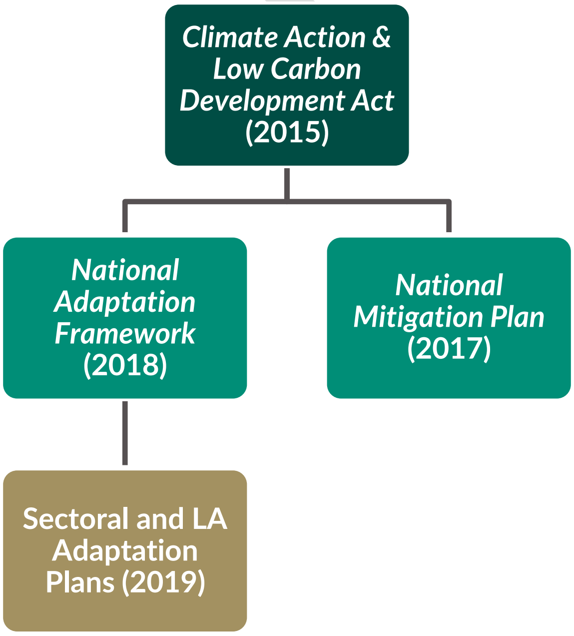


Figure 1.1: National-level climate policy hierarchy.

This sectoral adaptation plan for the transport sector will build upon the considerable knowledge base set out in *Developing Resilience to Climate Change in the Irish Transport Sector*[8]. This was the first step in adaptation planning for the transport sector and it was prepared under the non-statutory 2012 *National Climate Change Adaptation Framework*[9] (NCCAF). The 2017 plan indicates the likely climate impacts for Ireland and the risks posed to transport services and infrastructure, as well as highlighting ongoing adaptation measures undertaken by transport stakeholders.

1.1.1 International Policy Context

The international policy context for climate resilience is informed by the adoption of the Paris Agreement in December 2015 at COP21 by the United Nations Framework Convention on Climate Change (UNFCCC). Ireland ratified the Agreement on 4 November 2016 and is legally bound to fulfil the commitments made in Paris. Article 7.1 of the Agreement establishes a goal of "*enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change*"[10]. Notably, the Agreement recognises the role of both adaptation and mitigation measures in achieving this goal; acknowledging that greater levels of mitigation can reduce the need for additional adaptation efforts and that progress towards the temperature goal of well below 2°C and pursuing 1.5°C will determine the potential for adaptation and the costs of adaptation[11].

Ireland's climate resilience ambitions are also aligned with the United Nations' *Sustainable Development Goals*[12] (SDGs), which set out a series of goals and targets to ensure sustainable global development by 2030. Goal 13 on climate change addresses resilience directly. Target 13.1 is to "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries". Resilience is also part of Goal 9 on building resilient infrastructure and of Goal 11 on inclusive, safe, resilient and sustainable cities. Of equal importance, the Sendai Framework for Disaster Risk Reduction[13], adopted in 2015, recognises climate change and variability as key drivers of disaster risk and sets out goals and priorities for reducing disaster risk and enhancing disaster preparedness by building resilience.

Box 1.1: Definition of Climate Resilience

The *National Adaptation Framework* (2018) defines climate resilience as "…the capacity of a system, whether physical, social or ecological, to absorb and respond to climate change and by implementing effective adaptation planning and sustainable development (including governance and institutional design) to reduce the negative climate impacts while also taking advantage of any positive outcomes"[7]. This will allow the system to either return to its previous state or to adapt to a new state as quickly as possible.

An increasing understanding of climate interdependenices is also recognised within legislation at the European level. An overarching policy to build resilience to the impacts of climate change is being led by the European Union (EU) Commission through the EU *Strategy on Adaptation to Climate Change*[14], which was adopted in April 2013. The *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. In November 2018, the Commission published an evaluation of the EU Adaptation Strategy which emphasized that EU policy must seek to create synergies between climate change adaptation, climate change mitigation, disaster risk reduction efforts and sustainable development to avoid future damage and provide for long-term economic and social welfare in Europe and in partner countries[15].

Box 1.2: Definition of Adaptation and Mitigation

The *Climate Action and Low Carbon Development Act, 2015* defines climate change adaptation as "[...] any adjustment to

- (a) any system designed or operated by human beings, including an economic, agricultural or technological system, or
- (b) any naturally occurring system, including an ecosystem,
-

that is intended to counteract the effects (whether actual or anticipated) of climatic stimuli, prevent or moderate environmental damage resulting from climate change or confer environmental benefits" [4].

Climate change mitigation is defined by the *Act* as "[...] any human intervention aimed at reducing harmful influences on the earth's climate system, including action aimed at reducing emissions and creating or enhancing sinks" [4].

Mitigation is not the focus of this plan. It is however recognised that there are numerous inherent synergies and conflicts between mitigation and adaptation actions. For example, installation of temperature controls such as heating and cooling systems on public transport will protect commuters from variations in temperature and safeguard public health while in transit; but the use of diesel generators powering these systems may increase localised emissions of harmful air pollutants and CO_2 (carbon dioxide) emissions.

1.2 Methodology

Development of this sectoral plan has followed the six step approach outlined in the the *Sectoral Planning Guidelines for Climate Change Adaptation*[16]. The twelve sectors preparing sectoral adaptation plans under the NAF are required to develop their plans in line with the process described in the guidelines to ensure that a coherent and consistent approach to adaptation planning, drawing from existing sources of climate and adaptation information, is adopted at national and sectoral scales. The sectoral planning guidelines provide for an iterative six step planning cycle set forth in Figure 1.2.

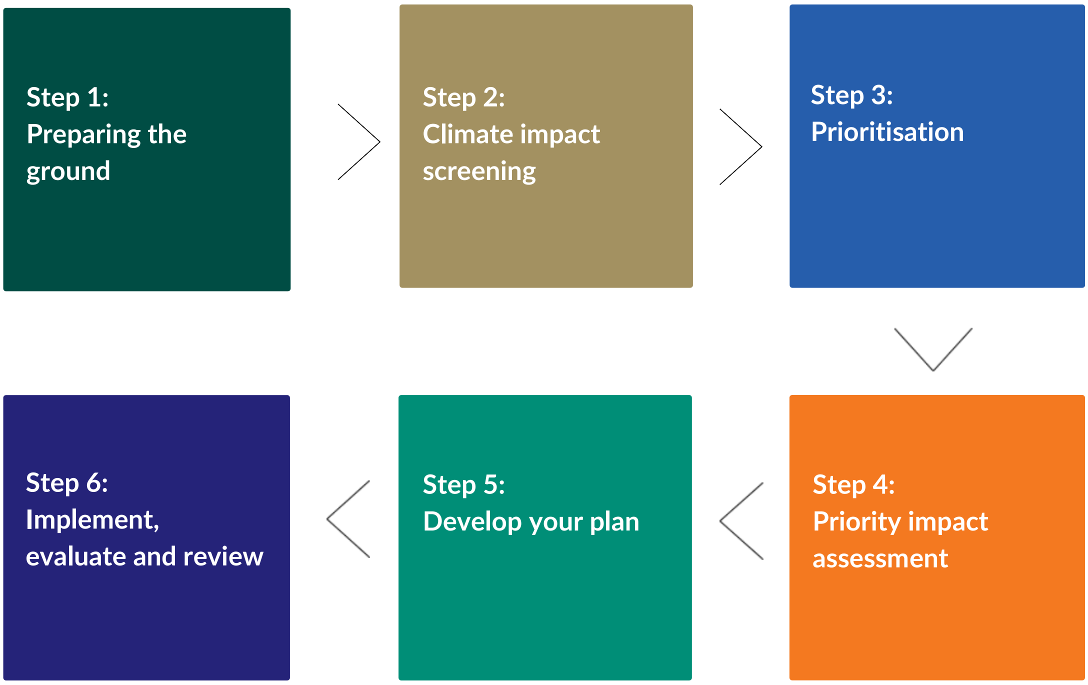


Figure 1.2: Schematic diagram of the sectoral adaptation guidelines' planning cycle.

The early steps (1 & 2) focus on preparing the ground for an effective adaptation planning process and identifying what changes and impacts have the potential to give rise to wider and unacceptable sectoral impacts. Following on from this, step 3 involves prioritising ongoing and potential future climate impacts in the context of sectoral and policy objectives and targets. Step 4 of the planning cycle builds on the scoping stage and examines those changes and impacts considered a sectoral priority; it involves a more thorough assessment of exposure, sensitivity and adaptive capacity (i.e. vulnerability). Steps 5 and 6 involve identifying a series of goals, objectives and actions, shifting the focus from potential impacts and vulnerabilities to identifying, prioritising and implementing adaptation actions. Further detail on the sectoral planning guidelines is available from the website for the Department of Communications, Climate Action and the Environment (DCCAE)[17].

1.3 Strategic Environmental Assessment and Appropriate Assessment

It has been determined following appropriate screening that Strategic Environmental Assessment (SEA) and Appropriate Assessment (AA) are not required for the statutory adaptation plan for the transport sector. A pre-screening document is published for public consultation alongside the sectoral plan on Department of Transport, Tourism and Sport's (DTTAS) website[18].

Figure 1.3 : Closure of Dublin Airport due to heavy snowfall during the confluence of Storm Emma and the "Beast from the East" weather system, February 2018. Source: Dublin Airport Authority (DAA).

2 Transport System Characteristics

Due to the slow response time of the global climate system to mitigation measures, changes to global climates are projected to continue and increase over the coming decades; with some changes, such as sea-level rise (SLR), projected to continue up to and beyond the end of this century. Climate impact, risks and vulnerability assessments are used to identify the nature and magnitude of these impacts and can vary widely depending on the geographic area and the sector or system[19]. It is therefore important to establish the transport sector profile and to identify key sectoral actors before undertaking a climate impact screening assessment.

2.1. Current Sectoral Profile

The Irish transport sector is currently supporting a rapid growth in travel demand for a broad range of social and economic purposes; growth has resulted in more commuters, freight goods and tourists using the transport network. After a number of years of decline, during the economic recession, Ireland is presently experiencing continued growth across multiple transport domains in the land, aviation and maritime sectors, notably a significant increase in the numbers of kilometres driven on Irish roads for private cars, goods vehicles and an increase in public transport use[20].

Passenger travel demand continues to rely heavily on use of the private car, primarily due to Ireland's relatively dispersed population; at end-April 2019, just over 2,155,600 private passenger cars were registered[21]. The *National Travel Survey*[22] examines transport use by adults for all types of journey in the land transport sector. The *Survey* shows 'work and education' are the major reasons for making journeys, with their share increasing from 27.8% in 2012 to 33.3% in 2016. 'Shopping trips' were the second biggest category accounting for 21.9% of the total, with 'leisure trips' at 11.6%.

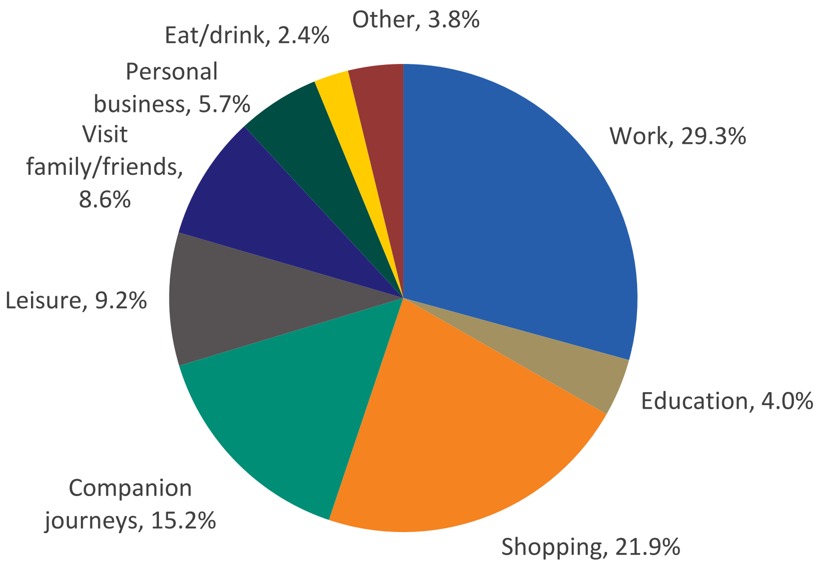


Figure 2.1: Distribution of journeys by purpose. Source: CSO[21].

Recent years have seen significant increases in the use of public transport and active travel modes (cycling and walking), particularly in urban and suburban areas. Public transport passenger journeys are increasing year on year; 266 million journeys were provided by Dublin Bus, Bus Éireann, Iarnród Éireann (Irish Rail), Luas and Go-Ahead Ireland on Public Service Obligation (PSO) services in 2018, a 6.28% increase compared with 2017 figures[23]. Active modes represent a growing share of transport users in Ireland, notably within the Greater Dublin Area (GDA). In 2016, the numbers walking to work increased to over 175,000, although this figure still accounts for less than 10% of the commuting population. Census data indicates that the number of people commuting to work and college by bicycle increased by 43% in Ireland between 2011 and 2016, with Dublin City Council reporting *c.* 95,000 daily cycle journeys in the city in 2017. Despite this growth in active and sustainable transport use, registration of private passenger cars is at an all-time peak, indicating increase in the demand placed upon the transport system.

The sector is also strongly characterised by rising commercial travel demand on both domestic and international transport networks. Ireland's road and rail networks play a vital role for economic activity by facilitating the movement of goods around the country. Road freight activity is continuing to exhibit strong growth (rising to 11.8 billion tonne-km in 2017), with rail freight utilised to a lesser extent, (carrying less than 1% of all freight tonnage in Ireland in 2017)[24]. Similarly, activity within the aviation and maritime sectors is increasing, with maritime freight tonnage and throughput exceeding the 2007 peak of 54.1 million in 2017, and air freight exceeding the 2006 peak levels of 145,500 tonnes[24].

2.2 Key Transport Infrastructure Networks

2.2.1 Land Transport – Roads

The Irish road network consists of 98,924 km of road; national roads, the primary links between cities and towns, account for 5,332 km or 5% of all roads. Of these, 969 km are motorway, an increase of 53 kilometres in 2017 due to the opening of the M17/M18 motorway from Gort to Tuam. Motorways accounted for 5% of national roads in 2017, while 301km or 16% of national roads are dual carriageway, and 4,062km or 77% are single carriageway. Collectively, these primary and secondary roads carry 45% of Ireland's total road traffic[22]. The national primary and secondary road network is operated and maintained by Transport Infrastructure Ireland (TII). The regional and local road network comprises of approximately 94,000kms and carries *c.* 55% of all road traffic. These roads are the sole means of access for local economic activity. The 31 local authorities manage regional and local roads as well as sections of some dual carriageway and national secondary roads.

In addition to private travel and commercial (freight) transport, road infrastructure additionally facilitates almost all other travel modes, including public, commercial, rural transport, school transport, tourist bus services, the small public service vehicle (SPSV) sector, (comprising taxis, hackneys and limousines) and a national network of greenways and cycle lanes.

Figure 2.2: Primary and secondary road network map. Source: Transport Infrastructure Ireland.

2.2.2 Land Transport – Buses

The national, regional and local road network supports the majority of Ireland's public transport through the provision of urban and rural bus services. Bus services throughout the country consist of a combination of PSO (Public Service Obligation) routes which are contracted by the NTA (National Transport Authority) and commercial routes which are licensed by the NTA. The largest providers of PSO bus services in Ireland are Dublin Bus; Bus Éireann and Go-Ahead Ireland, collectively accounting for just over 176.4 million passenger journeys on subvented urban, commuter, and rural routes in 2018. Route-side infrastructure such as bus shelters and real-time passenger information displays are provided by the NTA, while bus depots are the property of CIÉ (Córas Iompair Éireann Group, representing Dublin Bus and Bus Éireann) and Go-Ahead Ireland. Buses are not strictly considered transport infrastructure, and thus are beyond the scope of this Adaptation Plan; however, due to the important role buses play in the provision of key public transport services they have been included throughout this document where relevant.

In addition to PSO services, there are also a variety of other bus services reliant on road infrastructure, including commercial licensed services, tourist transport provision, and other subsidised bus services such as the Rural Transport Programme (Local Link) and the School Transport Scheme. Local Link services served 1.89 million passengers in 2017, representing a significant bus service subsector[25]; while 117,000 passengers, including 12,700 children with special educational needs, travelled on school transport buses during the 2016-2017 school year[26].

Commercial services do not receive State funding for vehicle procurement or associated infrastructure and are operated on a 'for-profit' basis by a range of operators across Ireland. The two principal contracted State-funded bus operators, Bus Éireann and Dublin Bus, provide some of their services on a commercial basis, such as Bus Éireann's Expressway services and Dublin Bus Airlink services. In 2017, almost 25.8 million passengers travelled on commercial bus services, accounting for 9% of all public transport journeys in the State and 45% of all vehicle kilometres travelled by public transport[23].

2.2.3 Land Transport – Heavy Rail

In 2018, Ireland is served nationally by a heavy rail network extending to approximately 2,400 km of operational track, *c*. 4,440 bridges, *c*. 1,100 point ends, *c*.970 level crossings, 144 stations, over 3,300 cuttings and embankments, 372 platforms and 13 tunnels. The network includes the national main lines, Dublin suburban and commuter passenger routes, together with freight-only routes[27]. There is a cross-border connection to the railway system in Northern Ireland (NI) between Dundalk and Newry, with services in NI operated by NI

Railways - Translink. Part of the Dublin suburban railway network, known as the Dublin Area Rapid Transit (DART) line, is electrified, with the remainder of the network operating through diesel traction. Iarnród Éireann (Irish Rail), a subsidiary of the CIÉ Group, owns, operates and maintains all heavy rail infrastructure in Ireland, while CIÉ retains ownership of stations and of the land underlying railway infrastructure. In 2018, the heavy rail network carried 48 million passengers[23]; while overall tonnage carried by rail was 546,000 tonnes (0.85% of total tonne-kilometres for the land freight sector in Ireland)[24].

Figure 2.3: National heavy rail network map. Source: Irish Rail.

2.2.4 Land Transport – Light Rail

Dublin is served by the LUAS electrified light rail system, which comprises a network of 67 stops over two interconnected tracks extending to 43 kilometres. The light rail system is operated by Transdev Dublin Light Rail Ltd. under contract to TII and the NTA. The network serves routes between termini at Bride's Glen to Broombridge (Cabra) on the Green Line; and between termini at Saggart/Tallaght to Connolly/The Point on the Red Line. Passenger carriage by light rail has grown year on year since 2010, reaching an all-time peak of 4.2 million passengers in 2018[23].

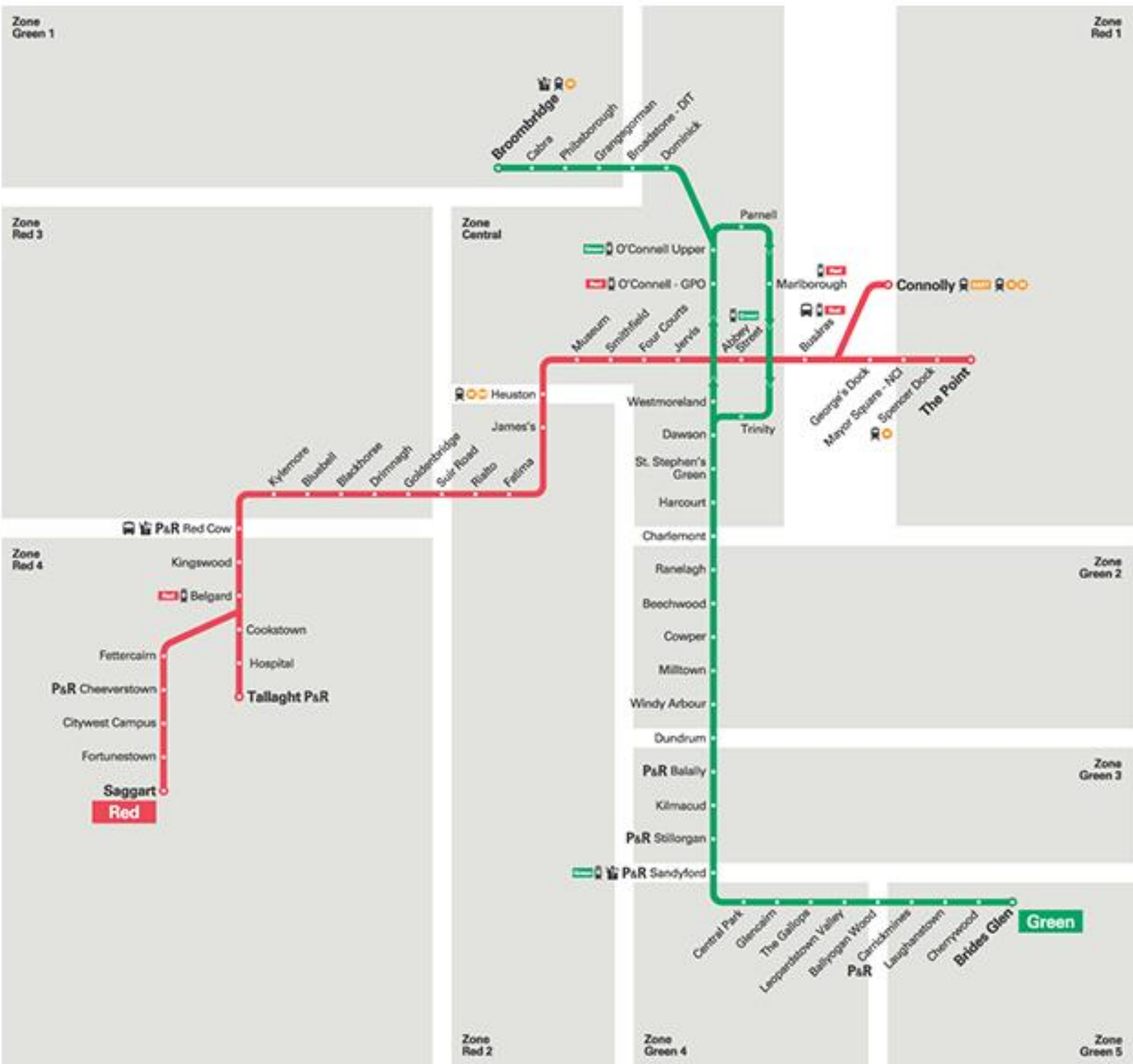


Figure 2.4: Luas light rail network map. Source: Transport for Ireland.

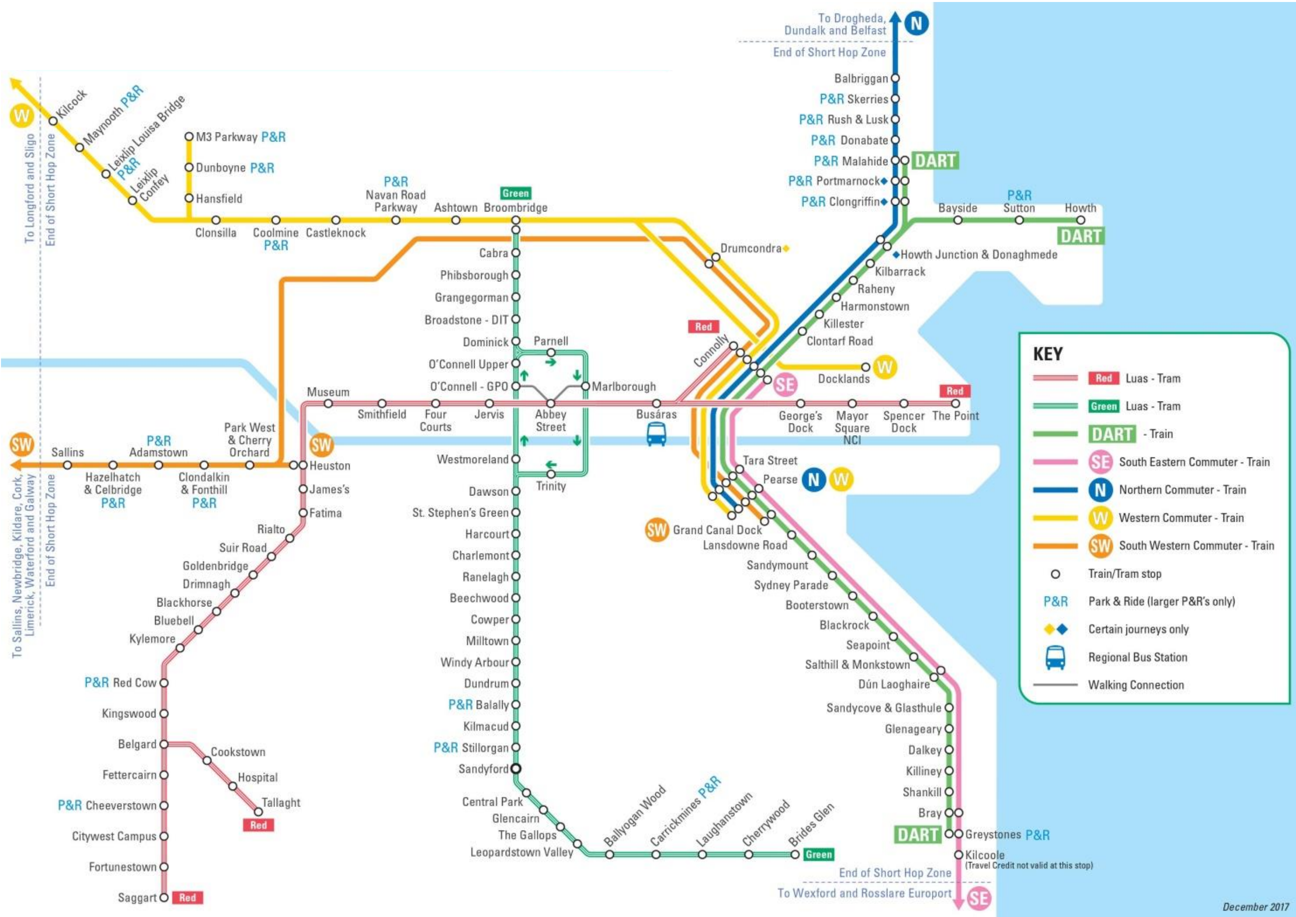


Figure 2.5: GDA transport (train and tram) network map. Source: Transport for Ireland.

2.2.5 Aviation – Airport Infrastructure

The aviation sector is critical to Ireland's connectivity to the rest of the world for travel, business and tourism. Ireland's aviation infrastructure is divided into two distinct categories of airports, as set out by the *National Aviation Policy*[28]; State Airports (Dublin, Cork and Shannon) which are the primary gateways through which air traffic accesses Ireland and Regional Airports (Ireland West Airport Knock, Kerry and Donegal) which play an important role in improving connectivity to their respective areas. Commercial flights to Waterford ceased in June 2016.

Ireland's aviation sector is exhibiting continued growth in commercial flights, passengers and air freight tonnes handled. Collectively, 36.6 million passengers and a total of 266,400 commercial flights were handled at State and Regional Airports in 2018. Dublin Airport represents the largest share of passengers serving 31.3 million people in 2018, followed by Cork Airport (2.4 million) and Shannon Airport (1.7 million)[24].

Air freight accounts for a tiny share (by weight) of all freight imports and exports but has also experienced growth in recent years; freight handled at Irish airports increased to an all-time high of 164,000 tonnes in 2017[24]. This figure fell slightly to 157,400 tonnes in 2018, of which Dublin Airport handled 143,700 tonnes (88.4% of total air freight in Ireland); Cork handled 100 tonnes (an increase of 100% over 2016 figures); and Shannon handled 13,600 tonnes[24].

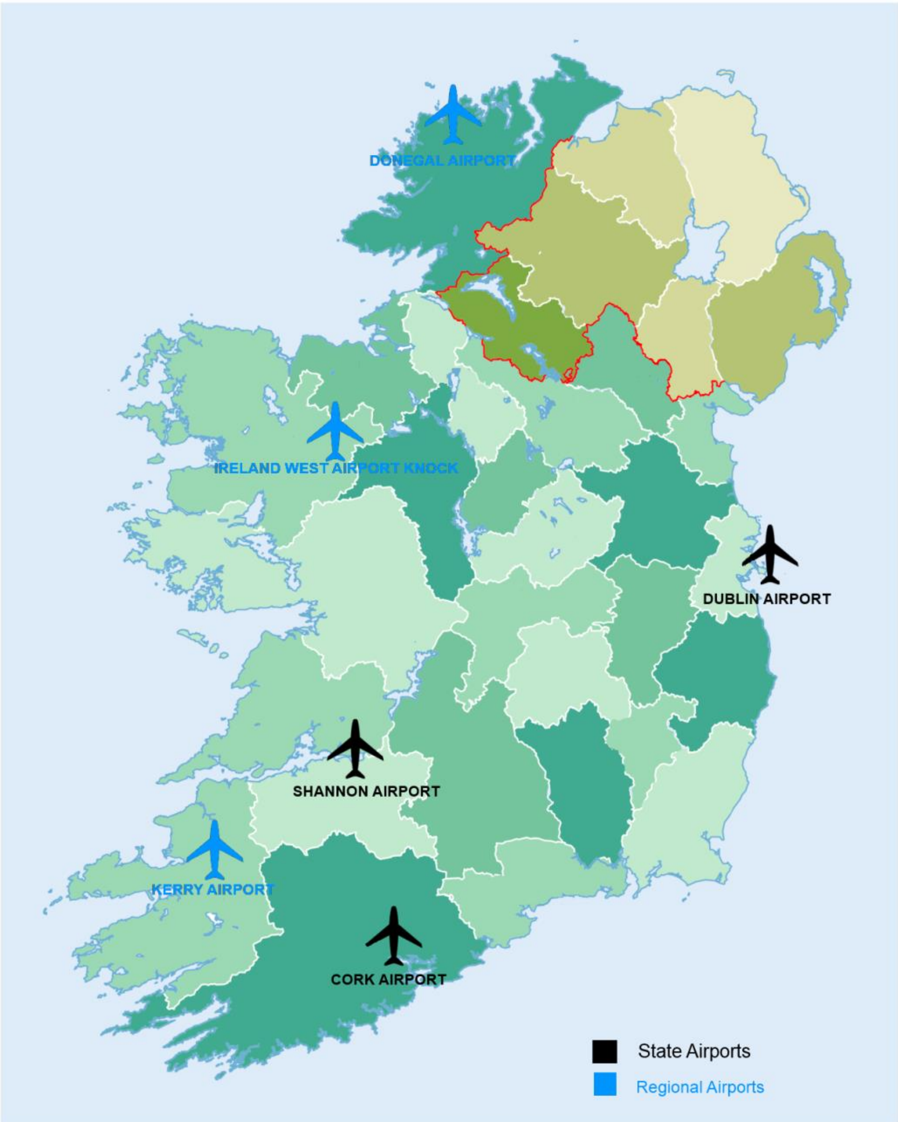


Figure 2.6: State and regional airports in Ireland 2019.

2.2.6 Maritime Transport – Port and Vessel Infrastructure

Irish ports provide the infrastructure which allows the movement of goods and people between Ireland and other countries by sea. Based on the classification in the *National Ports Policy*[29], Ireland has three 'Tier 1 Ports of National Significance' (Dublin Port, Port of Cork and

Shannon Foynes), two 'Tier 2 Ports of National Significance' (Waterford and Rosslare Europort) and a number of other commercial ports classified as 'Ports of Regional Significance', with the largest in freight terms (based on 2018 data) being Drogheda, Greenore, Bantry Bay, Galway and New Ross[24]. There are also 11 other ports nationwide where statistics for the carriage of goods and passengers are reported to the CSO.

Irish ports handle the vast majority of international freight cargoes. The amount of freight handled in Irish ports grew by 3.3% in 2018 to 55 million tonnes. Tier 1 and Tier 2 ports collectively represented the largest freight share (49.1 million tonnes), between Dublin Port (26 million tonnes), Shannon Foynes (19.4 million tonnes), the Port of Cork (9.5 million tonnes), Rosslare Europort (2.1 million tonnes), and the Port of Waterford (2 million tonnes) respectively[24]. Ireland is above the EU28 average for levels of maritime freight handled per capita (2017 figures)[20].

In addition to its role as an international gateway for imports and exports, the maritime sector also facilitates passenger travel through scheduled ferry services and cruise ship visits. Between 2016 and 2017, the number of maritime passengers (excluding cruise passengers on excursion) handled at all Irish ports rose by 2.1% to 2.8 million[20]. The number of cruise ship visits grew by 30% from 231 in 2017 to 301 in 2018, while the number of cruise ship passengers almost doubled; rising from 264,763 in 2017 to 390,069 in 2018[24]. Dublin and Cork had the highest shares of cruise ship traffic, accounting for 81% of ship visits and 91% of passengers collectively (196,899 and 157,857 cruise passengers respectively)[24].

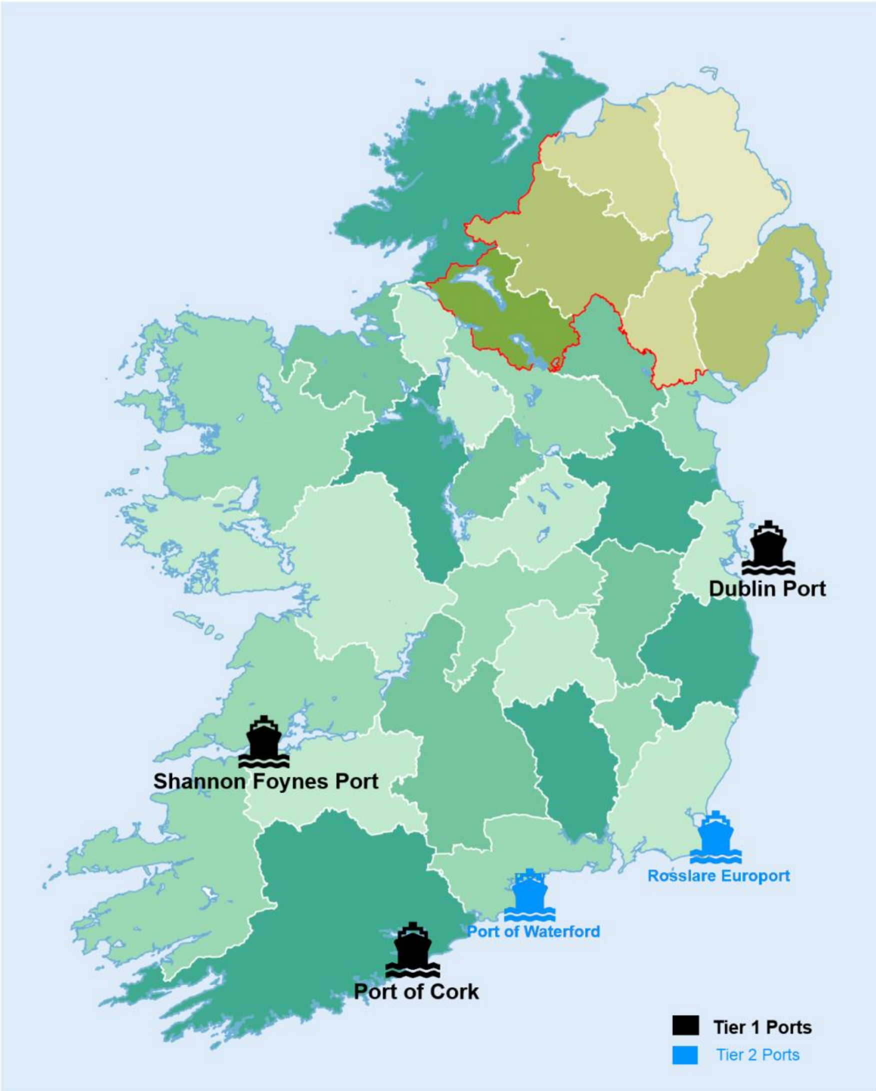


Figure 2.7: Tier 1 and Tier 2 ports in Ireland 2019.

Further detail on existing transport networks and service providers can be found in *Developing Resilience to Climate Change in the Irish Transport Sector*[30].

2.3 Future Sectoral Profile

By 2040 the population of Ireland is expected to grow by over 1 million to 5.7 million people, combined with current economic and employment rates greater demands for transport across various modes is very likely, with the increased movement of people and goods. While this is a sign of a vibrant economy, it strengthens the need to ensure that any adaptation measures put in place now account for anticipated changes on key transport networks. The transport sector will undoubtedly be characterised by increasing national efforts to maintain

Ireland's economic competitiveness and attractiveness through aviation, maritime and international road freight connectivity as well as ensuring enhanced local and regional connectivity through improved roads and public transport. All of these objectives must be undertaken in tandem with continuing efforts to achieve full decarbonisation of the transport sector by 2050 in line with the *National Policy Position*.

Figure 2.8: Cargo traffic delayed at Dublin Port, which temporarily suspended operation due to strong winds of up to 75 knots during Storm Diana, November 2018. Source: Gareth Chaney/Collins.

2.3.1 Project Ireland 2040

Project Ireland 2040[31] is the overarching national policy initiative which sets out, through the *National Planning Framework*[32] *(NPF)* and the *National Development Plan*[33] *(NDP)*, the Government's long-term strategic vision towards the development of an environmentally sustainable transport system in Ireland. The *NPF* is a high-level framework supported by a series of National Policy Objectives and National Strategic Outcomes which promote coordinated spatial planning, sustainable use of resources and protection of the environment. Based on *NPF* population projections a strategic infrastructure plan, *Planning Land Use and Transport Outlook* (*PLUTO 2040)* is currently being developed to assess the future needs for land transport in Ireland. *PLUTO 2040* will help identify the infrastructural and service provision requirements to meet the needs of the 2040 population. A number of National

Policy Objectives identified in the *NPF* directly call for the mainstreaming of climate change adaptation measures into the spatial planning and infrastructure development process, as set out in Table 2.1.

The *NDP* translates the policy objectives set out in the *NPF*, providing for significant investment in a programme of transport infrastructure projects. As such, the shape of future transport system (out to 2027) is known. An overview of the future transport infrastructure projects with investment provided for in the *NDP* to 2027 for the road, rail, bus, port and airport sectors is included as Appendix I to this plan.

Table 2.1: National policy objectives relating to climate change adaptation in the *NPF*. Source: Government of Ireland, 2018.

National Policy Objective 41b
In line with the collective aims of national policy regarding climate adaptation, to address the effects of sea level changes and coastal flooding and erosion and to support the implementation of adaptation responses in vulnerable areas.
National Policy Objective 54
Reduce our carbon footprint by integrating climate action into the planning system in support of national targets for climate policy mitigation and adaptation objectives, as well as targets for greenhouse gas emissions reductions.
National Policy Objective 57
Ensuring flood risk management informs place-making by avoiding inappropriate development in areas at risk of flooding in accordance with *The Planning System and Flood Risk Management Guidelines for Planning Authorities*.

2.3.2 Transboundary Interdependencies – Trade and Tourism

Following Brexit Ireland will no longer share a contiguous border with any European Union (EU) Member State. The subsequent impact on Ireland's positioning in the international TEN-T network (see Box 2) and the implications for trade activity are still uncertain; nevertheless, disruptions to supply chains and the movement of people/goods through ports and airports are possible. Cross-border transport networks will continue to play an important role in facilitating local travel, public transport services and considerable road freight activity between NI, the Border Region (Cavan, Donegal, Leitrim, Monaghan and Sligo) and the rest of the island. Ensuring network resilience in key economic corridors (such as the Dublin-Belfast road and rail corridors) will be important to preserve current high levels of economic and social activity.

Figure 2.9: Ireland's TEN-T core and comprehensive road networks.

Box 2.1: TEN-T (Trans-European Transport Network[56])

The Trans-European Transport Network (TEN-T) is a European Commission policy directed towards the implementation and development of a multi-modal trans-European network of roads, railway lines, inland waterways, maritime shipping routes, ports, airports and rail-road terminals to facilitate the free flow of goods in the single market (EC Europa, 2019). It consists of two planning layers:

- The Comprehensive Network, covering all European regions; and
- The Core Network, a subset of the Comprehensive Network accounting for the strategically most important nodes and links within trans-European networks.

Strategically significant transport nodes on Ireland's TEN-T Core Network include the three State Airports (Dublin; Cork; and Shannon); the three Tier 1 Ports (Dublin; Port of Cork; and Shannon Foynes); and the interconnecting road network serving these nodes: inclusive of the M50, M1/N1 linking Dublin with Belfast, the M7/N7 linking Dublin with Limerick, the N69 Limerick to Foynes, the M8/N8 linking Dublin and Cork, the Dunkettle Interchange, and the N28 Cork to Ringaskiddy.

2.3.3 Cross-Sectoral Interdependencies

The *NAF* lists twelve sectors for which adaptation plans are required and proposes a themed approach to adaptation planning to allow for cross-sectoral identification of synergies and conflicts. Under this themed planning approach, significant interdependencies have been identified between transport infrastructure and the national information and communication technologies (ICT) network and gas and electricity networks, collectively designated *critical infrastructure*.

Table 2.2: Sectors and lead departments in the *NAF*. Source: NAF: DCCAE, 2018.

Theme	Sector Level	Lead Department for Sectoral Adaptation Plans
Critical Infrastructure	Transport Infrastructure	Department of Transport, Tourism and Sport
	Electricity and Gas Networks	Department of Communications, Climate Action and the Environment
	Communications Networks	

Critical infrastructure supports and underpins the effective functioning and overall resilience of all other sectors of the economy. Extreme weather events rarely affect one sector in isolation. When transport networks (infrastructure and services) are rendered inaccessible or inoperable, this has severe knock-on impacts for access to co-located infrastructure such as overhead energy networks, transmission and distribution stations, delaying a return to normal operation.

Similarly, the transport sector is reliant on efficient telecommunications to facilitate the safe and timely transfer of domestic and international tourism and freight, to coordinate public transport provision and to communicate safety and traffic management information to transport users. In addition, energy supply is crucial to transport provision; no transport hub (ports; airports; public transport and private freight depots etc.) can operate without contingency in the absence of a power supply. This risk is exacerbated for certain key transport subsectors. Electrified rail, including the DART line and the LUAS light rail network, is wholly dependent on the supply of electrical power, and localised power outages can present severe road safety and traffic congestion risks should traffic light systems go offline.

The national electricity and gas networks are expected to play an increasingly significant role in the transport sector as decarbonisation becomes a growing national objective. The *National Policy Framework for Alternative Fuels Infrastructure for Transport in Ireland, 2017-2030*[34] suggests that the full electrification of the national car fleet represents a feasible option, where supporting grid infrastructure is developed. Under the Climate Action Plan[35] a target of 936,000 electric vehicles (EVs) within the national fleet by 2030 has been established. The majority of Ireland's public recharging network is currently operated by ESB e-cars and comprises of over 800 public, standard and fast charge points (over 1100 including NI). €10 million has been pledged under the Climate Action Fund to fund the further installation of over 100 high powered (150kW) chargers at key locations on the national road network. Any interruption in supply to the on-street public recharging network or to private home chargers will negatively affect people's ability to travel for work, education and leisure purposes and inhibit public confidence in electrified alternatives.

In the heavy-duty (freight truck and bus) sector, where electrification is a less mature technology, other alternative fuels such as compressed natural gas (CNG), liquefied natural gas (LNG), renewable biogas/biomethane and hydrogen, amongst others, may have a role to play. GNI (Gas Networks Ireland) has commenced the roll-out of 14 publically accessible fast-fill CNG refuelling stations, as well as renewable gas injection point under the *Causeway*

Project[36]. Grant approval has been given by the EU Commission for the *Green Connects Project*, which will provide for a further 21 public CNG stations installed on the TEN-T core network and 4 direct injection facilities for renewable gas by 2023[37]. Again, any disruption to the gas network could negatively impact on freight activity levels when refuelling opportunities are curtailed.

Figure 2.10: Ireland's current and proposed EV recharging network. Source: ESB e-cars.

Figure 2.11: Proposed CNG stations under the Causeway Project. Source: GNI.

Sectoral interdependencies are a product of complex and interconnected social and economic processes. Climate impacts and associated adaptation measures can therefore overlap across multiple agendas; for example, expected growth in indigenous production of renewable biogas/biomethane for use as a transport fuel indicates that adaptation planning within the agricultural and forestry sector in the coming years will have bearing on the decarbonisation objectives of the transport sector. Significant overlap can also be expected between transport infrastructure adaptation on a national level and infrastructure under the remit of local government, particularly in relation to adaptive measures for regional and local road infrastructure. An increase in public and active travel, in line with decarbonisation objectives, will have positive co-benefits for public health, while consideration of passenger health and welfare in extreme weather (such as heat waves or cold snaps) merits consideration. Flood risk management processes are similarly highly interlinked with transport infrastructure adaptation. Where transport adaptation measures have areas of intersection for parallel sectoral areas, these will be identified in the action plan.

2.3.4 Tourism and Sport

While this adaptation plan solely addresses the transport sector in line with the statutory requirement under the *NAF*, it can be expected that other sectors contributing to Ireland's economy under the remit of DTTAS (tourism and sport) will face similar climate challenges. The tourism sector in particular is exposed to numerous direct and indirect impacts from climate change. These impacts are not likely to be uniform and some areas will be more sensitive than others. Urban tourism may be less affected than coastal tourism e.g. beach tourism, marine-related attractions, or nature watching. Sea level rise, increasing ocean acidification and coastal erosion threaten Ireland's coastal tourism infrastructure and natural attractions[38].

There is little data available on changes in tourist behaviour as a consequence of climate change and it is therefore difficult to predict likely changes to the relative attractiveness of Ireland as a destination, the corresponding economic value of tourism or anticipated tourist transport demand. However, destination attractions such as Skellig Michael and the Burren in Co. Clare which represent key cultural and natural assets (biodiversity) are especially vulnerable, indicating an important shared agenda between the tourism sector and adaptation planning for the Built and Archaeological Heritage Sector and for the Biodiversity Sector.

Sport plays an important role in Irish society, to the economy and is considered an intrinsic part of Ireland's cultural heritage, as well as a major draw for international tourism in professional sports such as rugby, golf, soccer and boxing. Changes to Ireland's climate, particularly the projected rise in extreme weather events, may present new risks and challenges to how national sports are played. Probability of matches being abandoned or the risk of closure to courses and pitches in vulnerable areas rises in line with future climate change scenarios. These risks can be mitigated by future proofing outdoor sport infrastructure, for example by the development of indoor or covered sports facilities to accommodate players and spectators in adverse weather conditions[39].

Some important sector-specific considerations within the tourism and sport sectors are relevant for transport adaptation planning. Accessibility to important tourist sites and sports grounds, for both domestic and international tourist use, must be enabled by supporting transport infrastructure. Of equal importance, the implementation of adaptive measures to transport infrastructure should take into account preservation of co-located biodiversity and heritage sites. It is of course possible that, as well as presenting challenges, projected climate change may present positive opportunities for both the tourism and sport sectors. Climate change could facilitate diversification of tourism activities and development and consumption of sustainable tourism products, such as eco-tourism, activity tourism and an opportunity to utilise inland waterways and blueways. With a more stable summer climate and greater chance of dry weather conditions, the further expansion of outdoor leisure and recreation activities will be possible[40]. Projected stronger tides and waves, as well as stronger winds, would allow for the expansion of Ireland's international watersports offering. Similarly, higher summer temperatures may allow for an increase in the use of active travel infrastructure, including cycle lanes and national greenways, with a range of implications for the transport, sport and tourism sectors collectively.

Figure 2.12: Surfer in Coleraine, NI during Storm Gareth, 2019. Source: Charles McQuillan/Getty Images.

2.4 Establishing the Sectoral Adaptation Team

A sectoral adaptation team, divided into a core team and a planning team, for the transport sector was established in 2016 for the preparation of the non-statutory plan *Developing Resilience to Climate Change in the Irish Transport Sector*. The Climate Change Unit in DTTAS, with support from the Strategic Research and Analysis Division, Aviation Services Division, Airports Division, Roads Division, Maritime Safety Division, and Public Transport Investment and Sustainability Division, comprises the Core Team. A range of transport stakeholders were represented on the broader Planning Team. The Core and Planning Teams attended stakeholder consultation, facilitated by DTTAS, in May 2018 to monitor and review implementation of the precursory non-statutory adaptation plan.

For the development of the statutory adaptation plan, DTTAS has extended the Planning Team to account for the projected changes to the way we travel and the strategic transport investment priorities in the coming years set out in *Project Ireland 2040*. Notably, key transport system users, including representation for commercial freight operators, tourist transport services and active travel users, are reflected in membership of the extended team. Representation for other critical infrastructure (communications and energy) networks, as well as the local government sector, is also considered.

Table 2.3: Planning Team Stakeholders for the Statutory Adaptation Plan. Where additional stakeholders have been proposed for the implementation of this plan, this is illustrated using an asterisk.

Stakeholder	Sector
Bus Éireann	Bus Services
Connaught Airport Development Company	Aviation
Climate Action Regional Offices*	Local Government; Regional and Local Roads
Climate Ireland	Climate & Meteorological Data
Coach Tourism and Transport Council*	Private Bus and Coach Services
Dublin Airport Authority	Aviation
DCCAE	Communications & Energy Networks
Drogheda Port Company	Maritime
Dublin Bus	Bus Services
Dublin Port Company	Maritime
Dún Laoghaire-Rathdown CoCo	Maritime
Fáilte Ireland*	Tourist Transport Services
Freight Transport Association Ireland*	Commercial Freight
Go-Ahead Ireland*	Bus Services
Irish Aviation Authority	Aviation Services
Irish Road Haulage Association*	Commercial Freight
Met Éireann*	Climate Services & Meteorological Data
NTA*	Public and Active Travel
Office of Public Works*	Flood Management
Irish Rail	Heavy Rail and Maritime
Port of Cork Company	Maritime
Port of Galway Company	Maritime
Port of Waterford Company	Maritime
Shannon Airport Authority	Aviation
Shannon Foynes Port Company	Maritime
Sport Ireland*	Sport
TII	National Roads & Light Rail Infrastructure
Tourism Ireland*	Tourism

3 Climate Impact Screening for the Transport Sector

3.1 Observed and Projected Climate Impacts for Ireland to 2050

Establishing a climate baseline for Ireland is necessary to inform and prioritise future risks and adaptation options; studies of Ireland's climate clearly show that long-term prevailing weather conditions are changing. The last century was characterised by an upward trend in temperatures resulting in warmer, wetter winters and hotter, drier summers, accompanied by an increase in weather extremes. This pattern is projected to continue, with changes to include increases in average temperatures (surface air and sea surface), variation in typical precipitation patterns and ongoing sea level rise[41]. The changing climate leads to changes in the frequency, intensity, spatial extent, duration and timing of climate events, and can result in unprecedented extreme weather extremes.

Figure 3.1: Cyclist commuting in inclement conditions in Rathcoole, Co. Dublin during Storm Freya, March 2019. Source: BBC/PA.

Climate projections exist for all climate scenarios, at varying levels of confidence, for medium- (2031-2060) and long-term (2081-2100) timeframes. This adaptation plan focuses primarily on the medium-term timeframe; accounting for the periodic statutory adaptation planning as defined in the *NAF* (the lifetime of this plan is five years) and aligning *Project*

Ireland 2040 timelines. A summary of global and local climate change observations and projections towards 2050 is set out in Table 3.1.

Box 3.1: Representative Concentration Pathways (RCPs)

Representative Concentration Pathways (RCPs) are greenhouse gas (GHG) concentration trajectories adopted by the IPCC for its Fifth Assessment Report (AR5) in 2014. The pathways are used for climate modelling and research; they describe four possible climate futures, dependent on the level of GHG emissions in the years to come. The RCPs are labelled after a possible range of radiative forcing values in the year 2100 (2.6, 4.5, 6.0, and 8.5 W/m^2) accordingly the four pathways are named RCP2.6, RCP4.5, RCP6, and RCP8.5.

The RCP 2.6 scenario assumes that global annual GHG emissions peak between 2010 and 2020 and emissions declining substantially thereafter. The RCP 4.5 scenario is a stabilisation model which assumes that international climate policies will set out and implement measures designed to limit greenhouse gas emissions and radiative forcing, resulting in climate stabilisation by the year 2100[57]. Emissions in RCP 4.5 peak around 2040, then decline, while in RCP 6, emissions peak around 2080, then decline. The RCP 8.5 scenario corresponds to the pathway with the highest greenhouse gas emissions. RCP 8.5 assumes the continuance of population increase, slower income growth and modest rates of technological advancements, leading to high energy demand and GHG emissions in absence of climate change policies[58]. In RCP 8.5, emissions continue to rise throughout the 21st century.

Table 3.1: Summary of the observed and projected impacts of climate variables for Ireland. Source: Desmond *et al.* (2017)[42]; Nolan (2015)[43]; Nolan *et al.* (2017)[44]; Nolan (2019)[45]; O'Sullivan *et al.* (2015)[46].

Variable	Observed Impacts	Projected Mid-Century Impacts
Temperature	Mean annual surface air temperatures have increased by about 0.8°C over the period 1890–2012; an average of about 0.07°C per decade. The number of warm days (over 20°C) has increased while the number of cold days (below 0°C) and annual frost days has decreased.	**Mean annual temperatures will rise** by about 1°C - 1.6°C (RCP4.5 scenario) by mid-century compared to the 1961–1990 average; highest increase in the east. **Increase in extreme warm temperatures** [up to 2.6°C summer maximums & up to 3.1°C in winter] **Average number of frost days will further decrease** [by 50%].
Precipitation	Average annual national precipitation over the period 1981–2010 has increased by 5% relative to the period 1961–1990. The largest increases are observed over the west of the country. The likelihood of an extreme dry summer has doubled over the last century.	**Wetter winters** (14% increase in precipitation for RCP8.5 scenario by mid-century); **drier summers** (10 - 20% reduction for RCP8.5 by mid-century). **Increase in intense rainfall** (≥20mm/day) especially in winter and autumn by ~ 20%. **40% increase in 'dry periods'**, together with longer average duration (5 days with <1mm rain).
Wind Speed and Storms	There is no evidence of a sustained long-term trend in wind speed or direction but evidence exists 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 (EPA, 2009). The number and intensity of storms in the North Atlantic has increased by approximately 3 storms per decade since 1950.	**Slightly fewer storms, but more intense ones.** Projections indicate an overall decrease in wind speed but an increase in extreme wind speeds, particularly during winter. The number of very intense storms is projected to increase over the North Atlantic region and **the tracks of intense storms are projected to extend further south**. **Increased storm surge** [Atlantic coastal retreat rates likely to increase from current 0.5-1m/year].

Sea Levels and Sea Surface Temperatures	1993-2017 sea level rise of c. 35mm per decade (currently c. 3.4mm/year) has been observed. Tide gauge records pre-1990 show sea level rise of 1–2mm/year. Sea surface temperatures have increased by 0.85°C since 1950, with 2007 the warmest year in Irish coastal records.	Rise of c. 550–600mm to 2100 [based on IPCC RCPs 2.6–4.5 and other medium-scale climate warming scenarios. **Sea surface temperatures are projected to continue warming** for the coming decade. For the Irish Sea, projections indicate a warming of 1.9°C by the end of the century.
Humidity	In the period since 1961 the trend has been for a slight increase in summer and decrease in winter RH (relative humidity) values.	An **increase in RH** is likely, especially during winter months, while **decreases in summer are projected, mainly in the South and East.**
Environment	Trees and plants: evidence of change in timing of phenological phases such as bud burst, leaf unfolding, flowering, fruiting, leaf colouring and leaf fall in some trees and plants. Growing season has extended by one week.	Projections suggest that bud burst of birch will continue to advance until 2100; rate of advance will vary with the north-east region showing the greatest advance. **Growing season to extend by up to 35 days**.

3.2 Managing Climate Uncertainty and Projected Climate Scenarios

Climate change projections are subject to uncertainty; Ireland's geographic location and the influence of the North Atlantic Drift makes it particularly difficult to present projections with a high degree of confidence. This uncertainty allows for a broad range of potential climate outcomes for Ireland to the mid-21st century (*c.* 2050) and further to 2100. National-level climate data is analysed through an ensemble approach using a range of Regional Climate Models (RCMs) to simulate climate change, allowing for a medium-low emission scenario (aligning with RCP4.5) and a high emission scenario (aligning with RCP 8.5) to be developed with a measure of confidence[41]. Simulations were run for a reference period 1981–2000 and future period 2041–2060. The IPCC *Special Report on Global Warming of 1.5°C* (2018)[3] suggests that based on the current global emissions trajectories, without significant mitigating measures, a strong likelihood for a high-emission scenario and warming to over

1.5°C. To attempt to mitigate emissions and limit the likelihood of reaching the high-emission scenario Ireland produced both the *National Mitigation Plan*[33] and the *Climate Action Plan*[47] outlining a range of mitigation measures across multiple sectors. Ireland's climate will not solely be influenced by measures undertaken in this jurisdiction but it is possible that the cumulative impact of global mitigation efforts will alter the current trajectory.

For the preparation of this plan, the climate impacts associated with the medium-low emission scenario (RCP 4.5) has been tentatively identified as representative of the climate baseline in the coming years. Based on the IPCC findings, there is also merit in future sectoral adaptation measures allowing sufficient resilience to address impacts associated with the high-emission scenario (RCP 8.5). Establishing a consensus for a national emission scenario would be beneficial in ensuring a strategically aligned and cohesive approach to adaptation planning across sectors.

3.3 Identifying Climate Impacts and Sectoral Vulnerabilities

The most immediate climate-change related risks in Ireland are those associated with weather extremes, such as floods, precipitation and storms. In particular, systemic risks due to weather events leading to the breakdown of infrastructure networks and critical services such as transport, energy, communications, water supply, health and emergency services are expected. Vulnerabilities to climate change will vary depending on the specific service or infrastructure in question and may also vary depending on location, amongst other factors.

A qualitative climate impact screening and vulnerability assessment was undertaken in consultation with the transport stakeholders in the sectoral adaptation team, with support from Climate Ireland. This work has been summarised in an impact chain format in Appendix II. Projected changes in climate were applied to the impact chains to illustrate how impacts are expected to increase or decrease in line with a medium-low emission scenario to 2050 (RCP 4.5 equivalent).

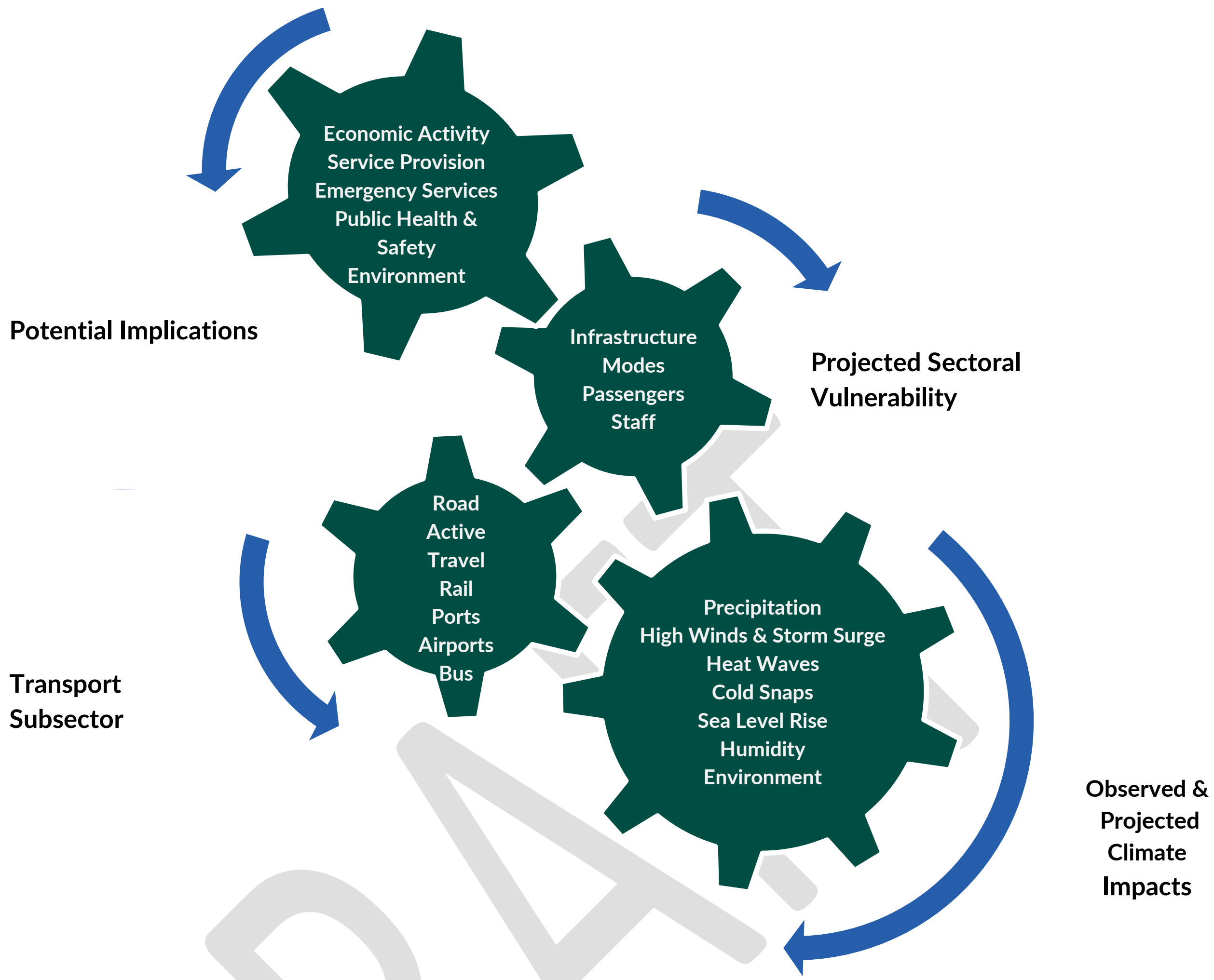


Figure 3.2: Process of determining sectoral vulnerability in climate impact screening.

3.4 Prioritising Sectoral Risks

The transport sector must ensure that any adaptation measures put in place are appropriate and proportionate to the levels of anticipated climate risk. The identification and prioritisation of sectoral risks was undertaken using the methodology proposed in the UK Climate Change Risk Assessment (2017). This methodology considers the future likelihood and magnitude of each projected climate impact (considered against identified vulnerability in transport infrastructure and services) to establish climate risk. Certain significant risks for the transport sector are not caused directly by the climate itself, but by the escalation of biophysical impacts of climate change, for example, coastal erosion and pluvial, fluvial and coastal flooding[48].

Climate risk prioritisation was applied to sectoral impact chains to calculate future adaptation priorities; risk levels were determined based on the likelihood of the climatic impact occurring and the degree of vulnerability within the sector to that event (Likelihood of Climate Impact x Level of Sectoral Vulnerability = Climate Risk). A basic traffic light system was employed to illustrate the level of risk for each climate impact; whereby the green colour indicates low levels of projected climate risk; orange indicates moderate levels and red indicates high levels of projected climate risk.

Table 3.2: Priority Impact Chains for the Transport Sector

Climate Impact	Likelihood of Climate Impact	Sectoral Vulnerability	Projected Climate Risk
Precipitation			
Flooding			
High Winds (Storms)			
Storm Surge			
Sea Level Rise			
Coastal Erosion			
High Temperatures			
Low Temperatures			
Humidity			
Environment			

Based on this analysis the key climate risks identified for the transport sector were:

1) High Climate Risk: Projected increase in precipitation extremes, flooding, high winds, increased storm intensity and projected rises in sea level;

2) Moderate Climate Risk: Projected increase in coastal erosion and temperature extremes; and
3) Low Climate Risk: Projected changes to humidity levels or environmental factors (e.g. change in bud burst dates, bird migration patterns) were deemed to be of low climate risk in the transport sector and so were not be considered further in the context of this Plan.

3.4.1 High Climate Risk

Precipitation Extremes and Flooding Events

As average global temperatures rise, the hydrological cycle is expected to become more intense, resulting in more frequent, sustained rainfall events with low lying areas being more vulnerable to pluvial and fluvial flooding. Pluvial flooding occurs when the ground cannot absorb rainwater effectively or urban drainage and surface watercourses are overwhelmed by excessive water flow, especially in densely built towns and cities. Fluvial flooding occurs when excessive rainfall increases stream-flow and loads, particularly in the autumn and winter months, causing riverbanks to erode and exceed river capacity. Damage from fluvial flooding is often cumulative as overflow affects smaller watercourses downstream. This impact is exacerbated when heavy precipitation follows a period of extended dry weather and high-velocity flash floods can occur without notice.

With much of Ireland's critical infrastructure located within dense urban developments or in close proximity to river floodplains, flood events pose a growing climate risk. During extreme weather events, key transport networks can be rendered inaccessible or unsafe for private and commercial travel and public transport services may be disrupted or suspended.

Gradual degeneration of transport infrastructure associated with extreme precipitation and subsequent flood events can severely impact multiple subsectors. Observed impacts include: the disintegration of road, pavement and cycle lane surfaces; increase in bridge scour events - where material from around bridge piers and abutments is removed by swiftly moving water causing structural instability and eventual bridge collapse; and heightened landslide risk as slopes become saturated by frequent precipitation events, blocking or damaging road, rail and active travel infrastructure.

Case Study 1: Extreme Precipitation, Pluvial Flooding and Fluvial Flash Floods

Overview – Ex-Hurricane Gert, August 2017

Hurricane Gert developed as a tropical depression in the Bahamas in mid-August 2017 and attained hurricane status on 15th August. It reached its maximum strength two days later, with sustained winds of up to 105mph. The Hurricane weakened as it moved into the North Atlantic, away from the United States, and was absorbed by another low pressure system travelling across the Atlantic. It hit the northwest of Ireland on 22nd August, bringing with it heavy, localised rain. Met Éireann issued a Status Yellow warning for nineteen counties, including all of Connacht, Cavan, Donegal, Monaghan and Longford. This heavy rain caused flash flooding in Co. Donegal and parts of Northern Ireland, severe damage to homes and infrastructure such as roads and bridges, and the temporary closure of City of Derry Airport.

Meteorological Conditions

A frontal system (the remnants of Hurricane Gert) crossed the Atlantic during the third week of August 2017, before affecting Ireland on 21st August. This gave heavy thundery rain mainly over the north of the country, and resulted in severe localised flooding disruption on the 22nd. On that day, 77.2mm of rainfall occurred at Malin Head, Co. Donegal, which accounted for over one-third of its monthly total and its wettest August day since 1955. 63mm of that rainfall fell in one 6-hour period.

Key Impact

The Inishowen Peninsula in Co. Donegal was the most severely affected area in the Republic of Ireland following this weather event. It is estimated that 1,500km of the road network in that area were damaged, including six bridges which were destroyed, and some roads remained impassable for weeks. One of the worst affected routes was the R328 road between Moville and Derry, including the typically heavy traffic corridor between Muff and Greencastle. More than 100 people were rescued from vehicles caught in flash floods throughout the affected counties of Donegal, Derry and Tyrone. Some 3,500 properties were left without electricity as a result of the floods and lightning strikes, with delays in recovery as access for repair crews was curtailed in places by local road closures.

Adaptive Measures

Government announced funding of *c.* €11 million for flood relief schemes in Donegal following the flooding. The Department of Public Expenditure and Reform agreed mechanisms for the progression of priority flood relief schemes for Lifford, Burnfoot, Castlefin, Carrowkeel, Downings and Glenties with Donegal County Council.

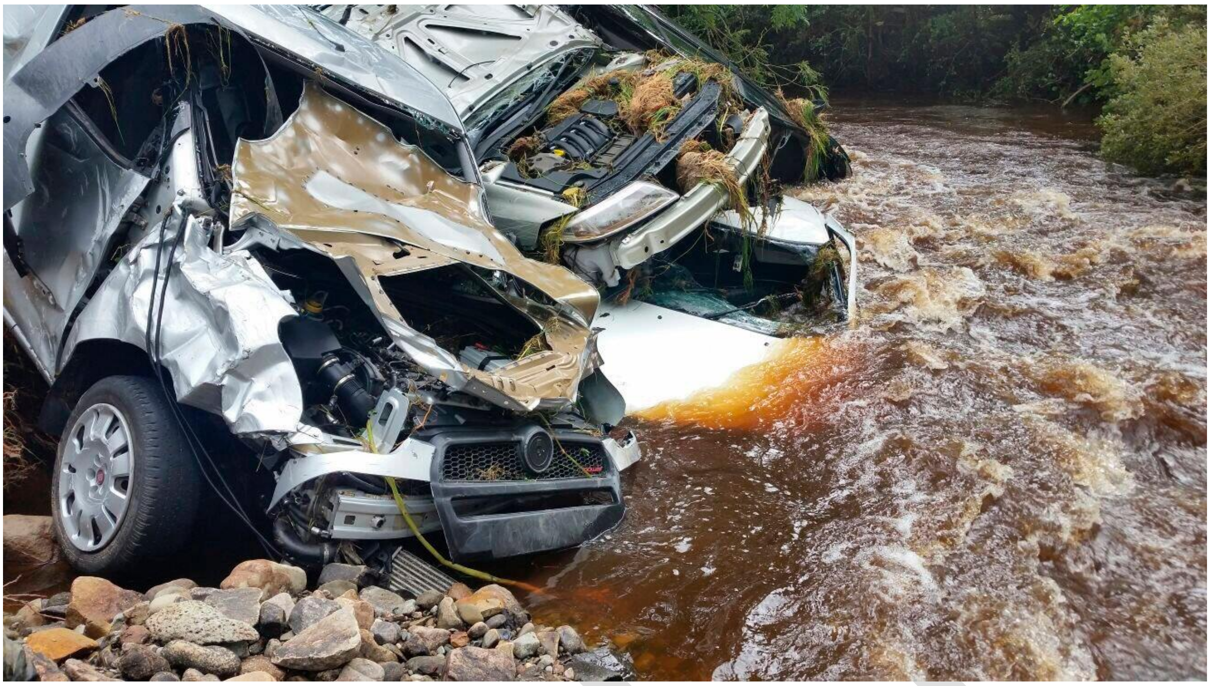


Figure 3.3: Vehicles damaged during flash floods in Carndonagh and Inishowen, Co. Donegal following ex-Hurricane Gert, August 2017. Source: Irish Times/Jimmy Stafford.

Figure 3.4: Damage to the R328 Derry to Moville Road in Co. Donegal caused by pluvial flooding during ex-Hurricane Gert, August 2017. Source: Brian Hutton/PA.

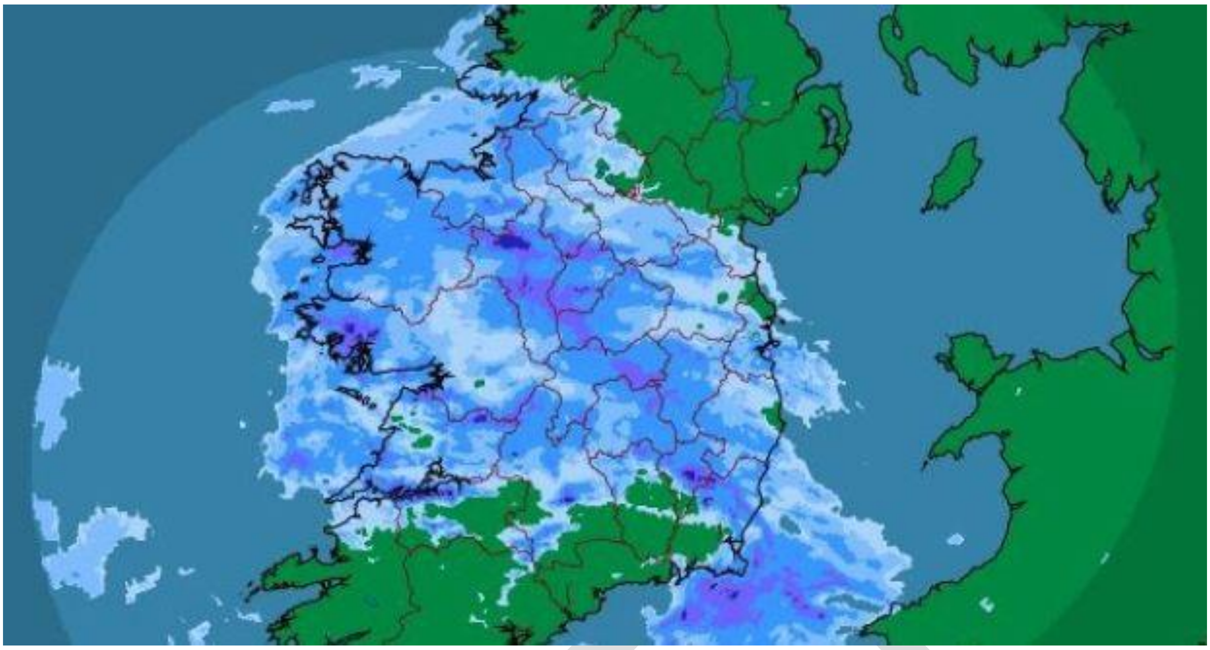


Figure 3.5: A rainfall radar image from Met Éireann from 20 August 2017, showing a band of precipitation tracking in a north-easterly direction across Ireland during ex-Hurricane Gert. Source: Met Éireann, 2017.

High Winds (storms), Storm Surge and Sea Level Rise

In 2016 over 2 million people lived within 5km of the sea (CSO, 2016). Due to the location of multiple critical infrastructure networks and hubs in close proximity to the coast, projected increase in the intensity of high winds, storms and storm surges, coupled with ongoing and projected sea level rise (SLR), poses significant risks for the transport sector. Transport infrastructure vulnerable to coastal inundation and erosion will be at increased risk, particularly infrastructure located in low-lying coastal areas, on eroding coastlines and on estuaries; for instance, the Dublin to Rosslare rail line, which is particularly susceptible to coastal erosion due to the soft bedrock in the region.

National port infrastructure is especially sensitive to storm surge and SLR, with potential for severe impacts including damage to port infrastructure, damage to vessels, disruption to navigations and implications for passenger safety. Storm activity can also cause the channels leading into ports becoming blocked with large amounts of sand silt and other materials driven by storm activity. Changes in sea level will have impacts on dredging requirements at ports and their natural scouring capability, particularly at estuarial ports.

Case Study 2: Storms (High Winds) and Storm Surge

Overview – Storm Ophelia

Storm Ophelia made landfall over Ireland as an extra-tropical storm on 16th October 2017. Gusts of up to 156km/h were observed during Storm Ophelia at Roche's Point station, Co. Cork. A Status Red Severe Weather Warning was issued by Met Éireann, which implies that people should take action to protect themselves and their properties. The storm caused major power outages, lifted roofs, felled trees and coastal flooding. Three lives were also tragically lost. Most schools and businesses took the decision to close for the day.

Meteorological Conditions

Ophelia originated as an upper-level trough in the Atlantic Ocean and initially had the characteristics of an extra-tropical low pressure system. It travelled north-eastwards and strengthened to become a tropical storm and subsequently a Category 3 Hurricane. It began to weaken by 15th October, and was classified as a post-tropical storm when it made landfall at Valentia Observatory, Co. Kerry, on the morning of 16th October. It tracked north-north-eastward across Ireland and steadily weakened throughout the day.

Shannon Airport experienced strong gale force winds with gusts of up to 122km/h, while Dublin Airport saw gale force winds with gusts of up to 104 km/h.

Key Impact

All public transport services were suspended on 16th October, including Bus Éireann, Dublin Bus, Luas, DART and Irish Rail, following the issuing of Met Éireann's Status Red weather warning. Ireland's airports remained open throughout the Storm but experienced flight disruption including cancelled and delayed flight departures and arrivals, particularly in Cork Airport. Over 300,000 properties were left without power. All ferry sailings to the UK were cancelled on the 16th. Many roads were impacted due to felled trees and debris from the storm. Very strong winds with violent gusts made driving conditions hazardous, especially for the more vulnerable road users e.g. cyclists, pedestrians, motorcyclists and high sided vehicles.

Adaptive Measures

The National Emergency Coordination Group issued statements on public safety advising citizens to avoid unnecessary travel and Met Éireann provided hourly updates on their website, social media platforms and traditional media sources. Contingency planning measures were activated by the ESB.

Figure 3.6: Tropical-storm-force wind speed probability (5 day forecast) provided by the U.S. National Hurricane Centre on 13 October 2017. Source: Met Éireann.

Figure 3.7: Falling debris caused by Storm Ophelia’s high winds hits a taxi in Kinsale, Co. Cork, October 2017. Source: RTE.

Figure 3.8: Storm Ophelia overflows flood walls at the Port of Galway, October 2017. Source: Port of Galway/James Corballis.

Figure 3.9: Felled trees block Centre Park Road in Cork City after Storm Ophelia, October 2017. Source: Darragh McSweeney/Provision.

Case Study 3: Storm Surge (Coastal Flooding) and Sea Level Rise (SLR)

Overview – Storm Callum, October 2018.

Storm Callum hit Ireland on 12th October 2018 and brought the windiest weather of that month and widespread heavy rain. Due to coincidentally high tides on the west coast of Ireland and a regional trend towards sea level rise of c. 3.5 cm per decade (Desmond, 2017), Storm Callum caused flooding in many areas and around 60,000 households and businesses experienced disruption to their electricity supply. Of particular concern was the high tide in Galway City. The impact of Storm Callum occurring at the same time as high spring tides was minimised due to the actions of Galway City Council who constructed a temporary aquadam along the banks of the Corrib River.

Meteorological Conditions

Storm Callum had the lowest early season pressure for an extratropical Atlantic storm since at least 1979. Mean wind speeds were storm force on 11th and 12th October at Sherkin Island, Co. Cork and Belmullet, Co. Mayo respectively. The highest gust reported during Storm Callum was 124km/h at Belmullet. The highest daily rainfall of October 2018, measuring 29.2 mm in Moore Park, Co. Cork, was also reported on the 12th.

Met Éireann issued a Status Orange wind warning for 13 counties during Storm Callum. Orange weather warnings indicate weather conditions which have the capacity to impact significantly on people in the affected areas, and that they should prepare themselves appropriately for anticipated conditions.

Key Impact

Storm Callum coincided with high spring tides on Ireland's west coast. The Salthill Promenade in Galway City had already been closed due to these high tides, and the strong winds of Storm Callum were predicted to exacerbate flooding in the area. The morning of 12th October saw high tides combine with a storm surge.

Adaptive Measures

To minimise damage from the rising sea water, Galway City Council installed an 80m portable dam at Spanish Arch and flood gates in Salthill ahead of the arrival of Storm Callum. More than 5,000 sandbags were available to the residents of Galway City. While flooding was mostly minimised due to these efforts, a number of areas in Galway were flooded during the storm.

Figure 3.10: Pedestrian in inclement conditions in Salthill, Co. Galway during Storm Callum, October 2018. Source: Brian Lawless/PA Wire.

Figure 3.11: School transport services impacted by storm surge in Garretstown, Co. Cork during Storm Callum, October 2018. Source: Irish Examiner/Michael Prior.

3.4.2 Moderate Climate Risk

Temperature Extremes

The transport sector has demonstrated a high level of resilience to current temperature conditions, with limited adverse impacts observed in response to increasing average annual temperatures. Nonetheless, temperature extremes (both heat and cold) can impact more strongly resulting in damage to critical assets and significant travel disruption. In addition, temperature extreme can interact with other climate impacts such as precipitation extremes; the ice freeze-thaw process can cause surfaces to become saturated with excess melt water, increasing flood risk.

With increasing air temperatures, an increase in the intensity and duration of heatwaves is expected. Under the high-emission scenario it has been suggested that summer conditions as warm as those experienced in 1995 - the warmest summer on record for Ireland - could occur as frequently as once in seven years by the end of the century[49]. In 2018 the highest average annual temperature in 23 years was recorded in some locations, including Oak Park in Carlow where it averaged 16.8˚C, the highest since 1995. High temperatures can cause severe degradation to infrastructure, in particular road surface deform and rail buckling incidents. In relation to public transport, over-heating of trains, trams and buses can greatly discommode passengers and increase the need for air-conditioning. Temperature control measures may also be required in transport hubs, particularly airports and public transport depots. Higher average temperatures may also to lead to a rise in active travel, with positive co-benefits for carbon mitigation; however, temperature extremes pose risks for public health and safety, as walkers and cyclists can be exposed to UVA/UVB, possible dehydration, and sunstroke.

Case Study 4: Temperature Extremes: Heatwave and Drought

Overview – Irish Summer Heatwave, June – August 2018

The summer of 2018 was one of the hottest and driest on record, with heat wave and drought conditions affecting many parts of the country. Many places had half their normal rainfall, and in some locations temperatures soared higher than 30°C. While this period of good weather was welcomed in general by the Irish public, it also had some detrimental effects on transport infrastructure such as melting road surfaces and the spread of gorse fires near rail infrastructure on Bray Head.

Meteorological Conditions

The highest maximum temperature of 32°C was recorded at Shannon Airport, Co. Clare on 28th June 2018, which was the highest temperature ever recorded at a synoptic station in Ireland. The total summer rainfall for Cork Airport was 109.5mm, the driest summer since records began in 1962.

All bar one of the rainfall totals measured by Met Éireann fell below their Long-Term Average (LTA) for June 2018, and all were below their LTA for July. The percentage of monthly rainfall for June 2018 was as low as 5% at Phoenix Park, Dublin which was its driest June since 1941. An absolute drought occurred at Belmullet the same month, and partial droughts were recorded during summer 2018 at Dublin Airport, Phoenix Park and Oak Park. The prolonged dry spell led to water restrictions and a fodder crisis. 15 synoptic stations recorded heatwave conditions and 21 synoptic stations recorded drought conditions during the summer.

Key Impact

Local councils had to provide grit for roads during the heatwave, as the high temperatures meant the surfaces were melting during daytime hours. In addition, drought conditions facilitated the rapid spread of a gorse fire on Bray Head, causing damage to electricity and telecommunications infrastructure and the cancellation of DART services for almost two days.

Adaptive Measures

Replacement bus services were provided to public transport passengers by Irish Rail while repair works were ongoing. Irish Rail provided free bottles of water to improve rail passenger comfort during the heatwave.

Figure 3.12: Gorse fires in a period of high temperatures, Wicklow, July 2018. DART services were cancelled due to fire damage sustained to electrical and telecommunications networks. Source: Twitter/Air Corps.

Figure 3.13: Local council crews gritting roads as heat melts tar on a number of secondary routes in Co. Mayo. Source: Twitter/Pat McGrath/Mayo County Council.

Figure 3.14: Complimentary bottles of water provided to Irish Rail customers during the heat wave, July 2018. Source: Irish Rail.

Projected occurrences of cold snaps and ice days are expected to decrease, reducing dangers to traffic and passenger safety from frost on road and pavement surfaces and from black ice, less road degradation. The relative rarity of these extreme cold days may however result in greater disruption to service and safety practices in the event of their occurrence. Icy conditions and compacted snow on roads can cause severe congestion, slow speeds and an increase in traffic accidents, while public transport services can face delays. Salt and grit surface treatments surfaces on major roads require salt stocks to be steadily maintained and shortages can occur in successive periods of low temperatures. In instances of extreme snowfall, transport networks can become impassable leading to deployment of emergency planning measures and systemic shutdown, with far-reaching social and economic consequences.

Case Study 5: Temperature Extremes: Cold Snaps and Blizzard Conditions

Overview – Storm Emma and the "Beast from the East", February – March 2018

Ireland experienced low temperatures, high winds and heavy snowfall in the first week of March 2018. Temperatures struggled to rise above freezing (with record low daily maxima in several locations) as bitterly cold easterly winds swept in over the country causing widespread disruptions to road, rail and air travel. Over 50cm of snow depths were reported at some locations, with drifts of several feet reported on higher ground and in isolated rural areas. Some rural villages were cut off for days.

Meteorological Conditions

An exceptionally cold polar continental easterly airstream coupled with the development of 'Storm Emma' and its associated frontal systems brought strong winds, widespread snow, ice and low temperatures to Ireland in early March 2018. On 1st and 2nd March, temperatures did not rise above zero at a number of locations. These are known as 'ice days', and apart from 2018 there were no ice days recorded in Ireland in March at any Met Éireann stations since 1942. The lowest air temperature of -7°C was recorded on 1st March at Cork Airport. These dates also saw strong gale force 9 winds at Malin Head, Co. Donegal.

Snowfall was varied across the country, and the highest depths were recorded in the South, East and Midlands. Glenmacnass, Co. Wicklow recorded a snow depth of 69cm on 3rd March. Snow depths became immeasurable at times in some places due to significant drifting in the strong easterly winds.

Key Impact

Met Éireann issued a Status Red warning for snowfall, which led to extensive flight cancellations into and out of Ireland's airports and stoppage of all public transport services during Storm Emma. Approximately 250 people were forced to sleep in Dublin Airport after road conditions prevented them leaving the airport. Motorists were advised not to drive unless absolutely necessary; road conditions were extremely hazardous for those who had to undertake a journey. Certain major roads were rendered impassable at times due to snowfall and treacherous road surfaces, including parts of the M1 motorway.

Adaptive Measures

The NECG (National Emergency Coordination Group) for Extreme Weather met in advance of forecasted snow to coordinate the national response and disseminate advice to the public. The public were advised to monitor transport operators web sites and social media for up-to-date information regarding their travel needs. The Defence Forces were placed on standby to assist with travel recovery operations, including rescue of citizens trapped in their cars by snowfall in Co. Dublin, and the National Ambulance Service prioritised emergency calls. No fatalities on transport networks were recorded. Irish Rail undertook inspections before rail services resumed and test runs of Luas and DART services took place to check the safety of electric lines.

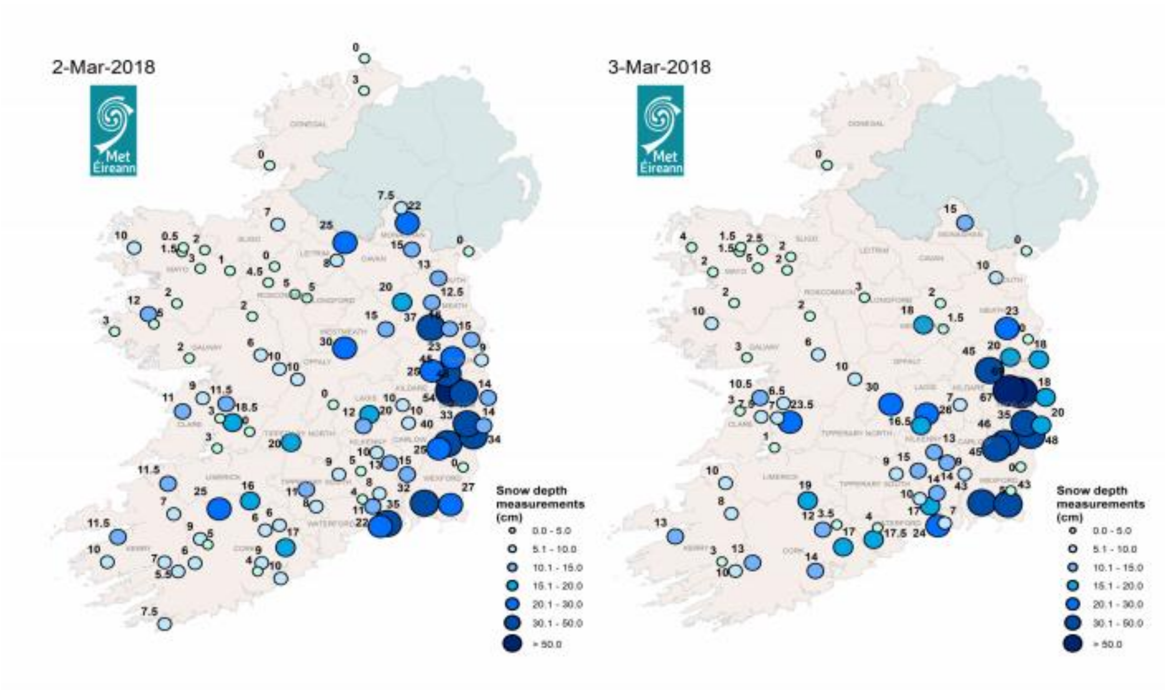


Figure 3.15: Snow depths recorded at Met Éireann climate and synoptic stations between 2nd and 3rd March 2018. Source: Met Éireann, 2019.

Figure 3.16: Flights grounded at Cork Airport in blizzard conditions during Storm Emma, March 2018. Source: Twitter/Cork Airport.

Figure 3.17: Limited trams ran in Dublin in the early hours of Storm Emma before total suspension of service, February 2018. Source: Newstalk.

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 are potentially susceptible to both gradual changes in rates of coastal erosion and the impacts of increasing coastal storms.

Case Study 6: Coastal Erosion

Overview – Erosion of the Eastern Rail Corridor

The main rail route between Dublin Connolly Station and Rosslare EuroPort is the Dublin to Rosslare railway. It is an important route as it connects with ferry services to the United Kingdom and mainland Europe. The Wexford coast is made up of soft sedimentary rock (carboniferous limestone and old red sandstone) covered with sandy soil, which is exposed to long-term ongoing coastal erosion due to wind, rain and sea level rise. As sections of the rail line are directly adjacent to the shoreline it is subject to erosion, and annualised erosion rates of up to 3mm per year have been recorded. However in most places these rates were less than 0.5mm per year which demonstrates the variability of erosion rates and how they are affected by localised conditions.

Meteorological Conditions

For the period 1961-1990, average monthly wind speeds at Rosslare were 11.5 knots; average daily temperatures between 7.6 and 12.6 degrees and average monthly total precipitation was 877.2 mm (Met Éireann).

Key Impacts

- The sea cliff near Ballygerry at Rosslare Harbour suffers erosion of up to two metres annually which could mean that the rail corridor could be unable to be used by 2030;
- There was a 135m recession of the coastline between 1905 and 1990 at an average of 1.4m per year. This rate has accelerated in recent years to 2m annually;
- From data and modelling prepared by the Office of Public Works (OPW), it is estimated that the coastline will continue to recede and could impact the existing rail corridor before 2030.

Adaptive Measures

Two studies were tendered in 2018 to assess coastal vulnerability along the east coast.

- Wexford County Council commissioned RPS Consulting Engineers to prepare a report highlighting the vulnerability of the Rosslare Strand area which includes 21 erosion zones. The firm identified that rock revetments would be the most effective barrier against coastal erosion, and these can be placed in a number of locations to mitigate the effects of erosion. Environmental and economic assessments will be carried out before funding is sought. It is envisaged that construction may begin in 2020/2021.
- In 2018 Irish Rail, together with Wicklow County Council, commissioned Arup Consulting Engineers to study coastal erosion along the Wicklow- Dún Laoghaire-Rathdown coastline, where the rail network runs along or near the coast for most the route between Dublin and Wicklow. The study will assess the long-term stability of significant sections of the track and other shore line locations, particularly with the effects of SLR exacerbated by climate change, and will include hydraulic modelling and assessments of coastal process; site investigations; topographical and bathometric surveys; as well as environmental and ecological assessments. The study is expected to conclude in 2020.

Figure 3.18: Backshore protection measures against coastal erosion in place on Rosslare Beach, *c*. 500m from Rosslare Strand rail station. Source: Wexford People.

Figure 3.19: Tidal surge flooding exacerbated by SLR at Salthill and Monkstown DART station in Dún Laoghaire-Rathdown, Co. Dublin, February 2018. Source: Irish Rail.

4 Priority Impact Assessment

4.1 Future-Proofing Transport: A Thresholds Analysis Approach

Future sectoral consequences of high-priority and moderate-priority climate risks for the transport sector are further explored through a thresholds analysis approach, including a description of spatial and temporal factors contributing to exposure, sensitivity and associated uncertainties. Thresholds analysis involves identifying the critical levels that will cause a system to suffer an intolerable shift in performance; they can be used to prioritise actions in adaptation planning[50]. This process can also be deployed to determine a level of acceptable sectoral risk. The purpose of this priority impact assessment is to determine the thresholds beyond which Ireland's future transport system, or key transport subsector within that system, can no longer support business-as-usual operation and subsequently fulfil its future economic, social and environmental objectives. These objectives include the high-level national strategic objectives as set out in *Project Ireland 2040* (Government of Ireland, 2018); namely, to support:

- Enhanced regional accessibility;
- Sustainable mobility;
- High-quality international connectivity; and
- Transition to a low-carbon and climate-resilient society.

Most threshold assessments focus on mid-century climate change projections due to the inherent uncertainty in climate projections beyond this point and reflecting the current availability of reliable climate information. High- and moderate-priority climate risks can also evolve (increasing or decreasing in severity) over time. In addition, investment in transport assets, which are generally designed for long service lives (for example, much of Ireland's extant transport infrastructure in road and rail has been in place for *c*. 100+ years)[51] should accordingly be considered over a long-term planning horizon.

Figure 4.1: A warning sign for high winds is seen on the M50 motorway in Dublin during Storm Eleanor, January 2019. Source: Reuters/Clodagh Kilcoyne.

The long-term uncertainty of the future climate system means that, in certain instances, establishing *indicative* adaptation pathways only is most appropriate. The RCM simulations for Ireland are presently being developed to cover the time period 1976-2100[52]. This work is being conducted by the Irish Centre of High-End Computing (ICHEC) and Met Éireann, through an EPA, Met Éireann & Marine Institute funded project. Preliminary results are in line with previous work and suggest it is likely that Ireland will experience enhanced temperature rises by end-of-century, wetter winters with a clear north-west to south-east gradient and a general decrease in wind speeds during summer times. It can be expected that future sectoral adaptation planning will be able to identify long-term risks, and their associated costs, with greater certainty.

4.1.1 Thresholds Analysis for the Transport Sector

The first steps in thresholds analysis are to characterise the system and investigate the possible impact of climate change on that system. Chapter 2 of this plan described and characterised Ireland's transport infrastructure networks; cross-sectoral interdependencies were also identified, such as the communications and energy networks, where loss of functionality in these systems may induce cascading failures in the transport network. Chapter 3 of this plan determined the climate 'trends' (slowly changing variables) and climate 'shocks' (extreme weather events) that are projected under climate change and sets out high-level qualitative risk analysis for the transport sector at a national level. Figures 4.2 and 4.3 outline the high-and moderate-priority climate risks identified in the sector to mid-century.

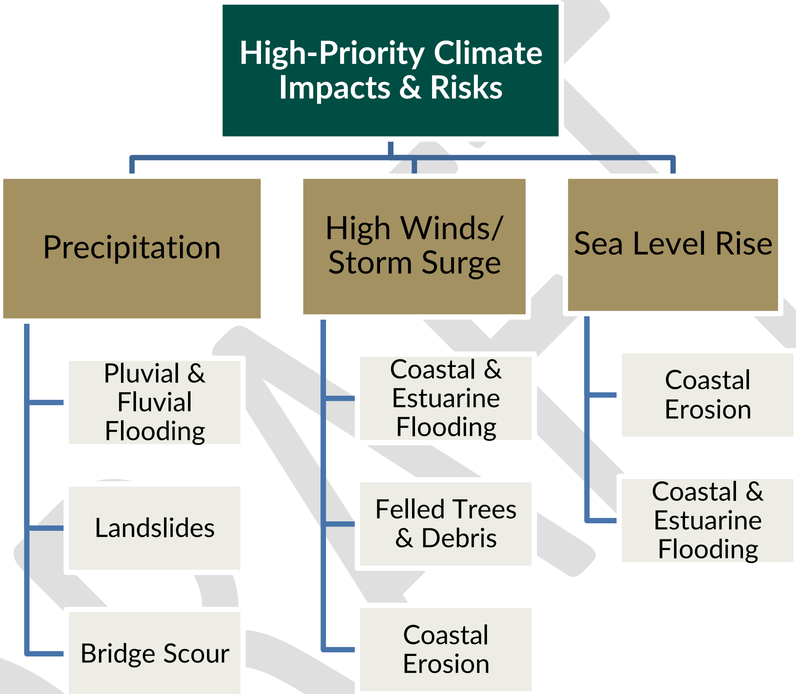


Figure 4.2: Summary of projected high-priority climate impacts and associated risks for the transport sector to mid-century.

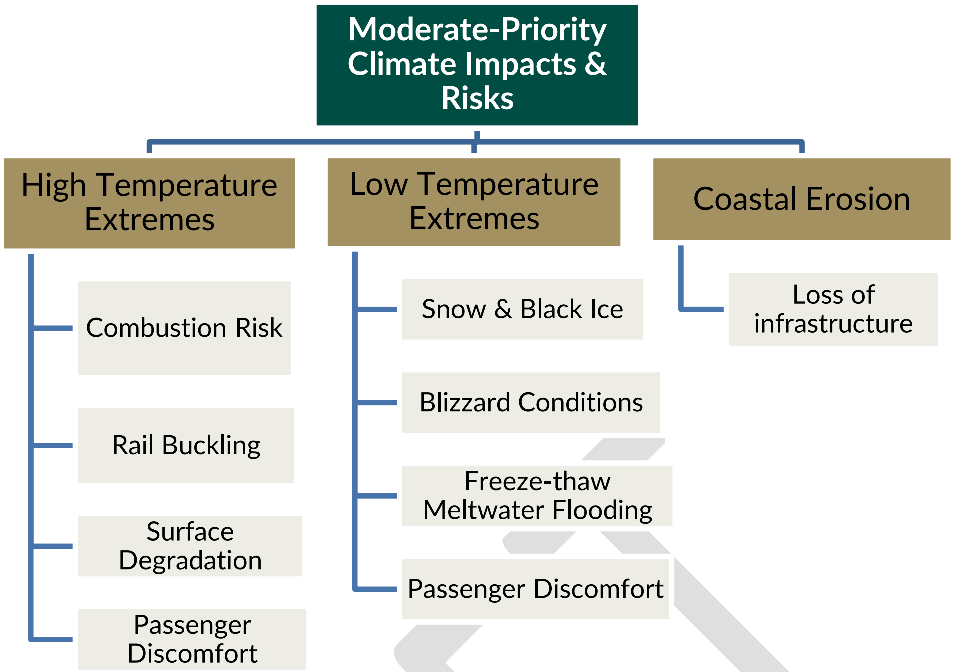


Figure 4.3: Summary of projected moderate-priority climate impacts and associated risks for the transport sector to mid-century.

4.2. Geospatial and Temporal Distribution of Transport Risks

The impact of climate change on transport networks varies depending on geographic location. Analysis is currently underway to help identity the geospatial distribution of climate change impacts in Ireland (see the forthcoming EPA research project *Critical Infrastructure Vulnerability to Climate Change* 2016-CCRP-MS.41 (CIViC)). To complement this research and to further the development of this Plan, a suite of maps illustrating projected downscaled regional distribution of changes to certain meteorological parameters was produced and overlaid with the transport networks highlighting areas of highest risk. This work was carried out in conjunction with ICHEC, TII and Met Éireann and based upon the projections outlined in EPA Report No. 159: *Ensemble of regional climate model projections for Ireland*[43]. A high spatial resolution (4 km) was employed providing an indication to transport stakeholders of infrastructure or sections of infrastructure networks that may be at greater risk in the coming years; presuming an indicative relationship between climate impact and climate risk. While in this Plan only the existing transport infrastructure has been mapped it will be possible to also include future planned infrastructure under *Project Ireland 2040* once route locations are finalised.

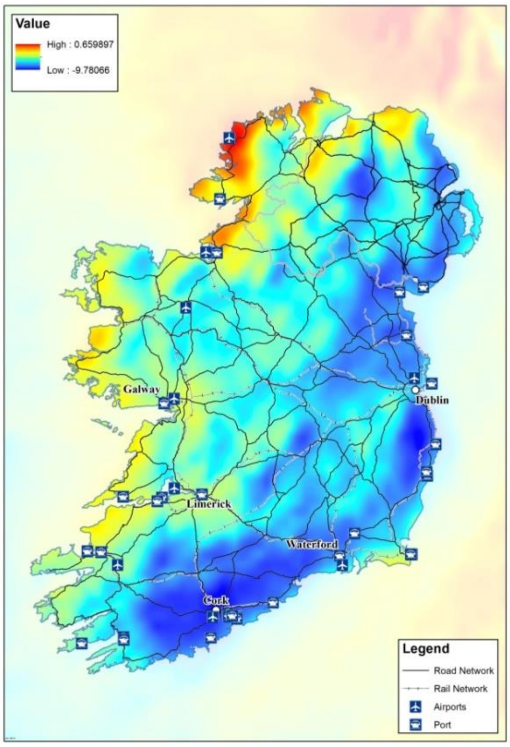
The maps presented are indicative only due to the level of uncertainty surrounding climate change projections. Higher confidences in the regional projections of temperature exist compared to wind and rainfall projections. Undoubtedly, future improvements in climate modelling will alter the present climate change projections as uncertainties are gradually reduced; a project helmed by ICHEC and Met Éireann, supported by the EPA, is simulating the periods 1975-2005 and 2020-2100, with publication anticipated end-2019. Cross-referencing with other resources, such as the *Irish National Flood Hazard Mapping* developed by the OPW, landslide susceptibility mapping developed by the Geological Survey of Ireland (GSI), and the outputs of the *CIViC* project, which could be employed to corroborate and future refine the presented geospatial indications. In addition, the maps could also benefit from future expansion to include co-located infrastructural assets in the ICT and energy (gas and electricity) networks.

4.2.1 High Priority Climate Impact: Precipitation

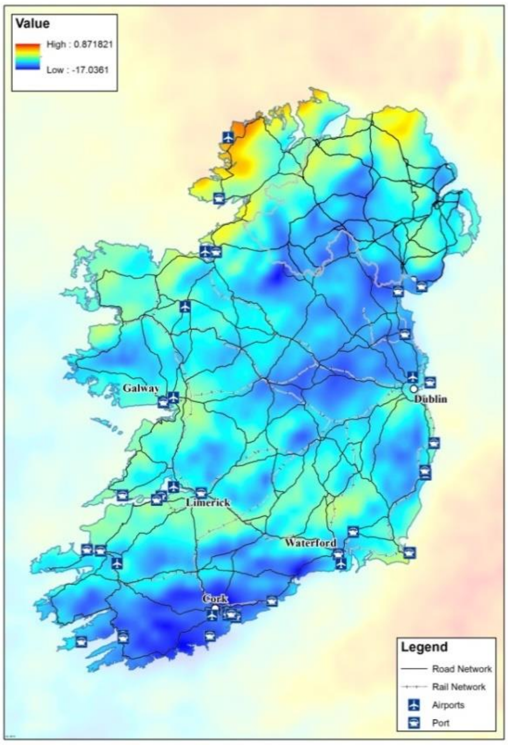
The localised nature and temporal variability of precipitation makes it less amenable to statistical analyses. Conservative results show significant projected decreases in mean precipitation during spring and summer and over the entire year by mid-century. The projected decreases are largest for summer, with “likely” values ranging from 0% to 13% and from 3% to 20% for the medium- to low-emission (RCP4.5) and high-emission scenarios (RCP 8.5), respectively. The drying signal for autumn is less robust. A projected increase in mean precipitation for winter was noted over most of Ireland for the high-emission scenario. Heavy rainfall events are projected to increase substantially during the winter and autumn months. The number of extended dry periods is also projected to increase substantially during autumn and summer and over the entire year by mid-century. The projected increases in dry periods are largest for summer, with “likely” values up to 40% for both emission scenarios[43]. Assuming a relationship between flooding (pluvial and fluvial) and increased heavy precipitation events in autumn and winter, it can be inferred that infrastructure located within the north and west of Ireland may be at greater risk, with a possible impact on road and rail embankment and verge stability in these catchments or regions, as well as changing patterns of situation for ports[42]. However, the projections of mean precipitation for autumn and winter exhibited great uncertainty and analysis with reference to OPW flood mapping is recommended.

(a) Medium–Low Emission: Seasonal Change in Standard Deviation of Precipitation (Mean Rainfall)

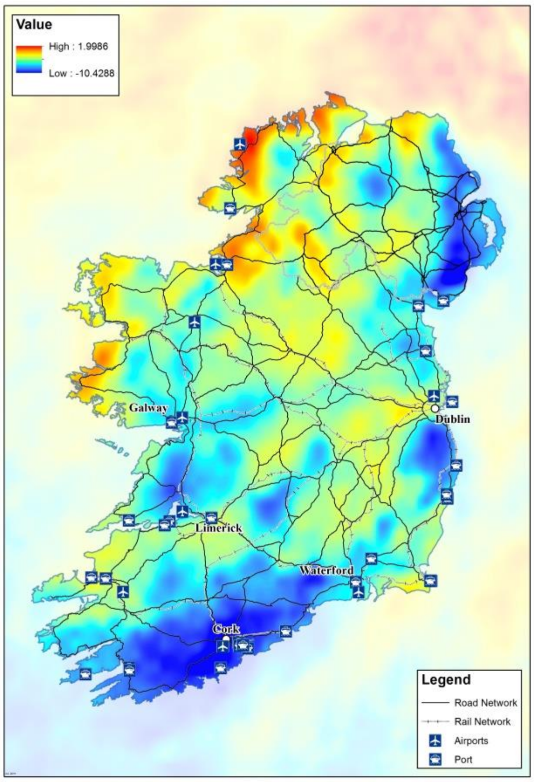
Spring



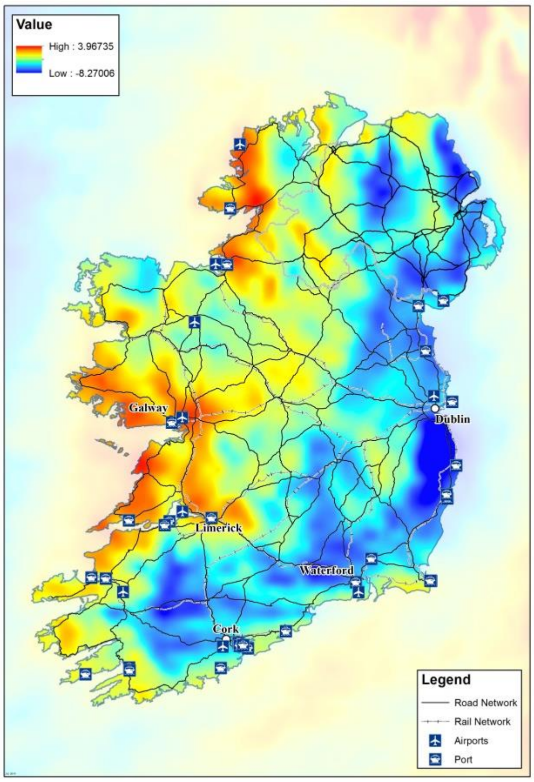
Summer



Autumn

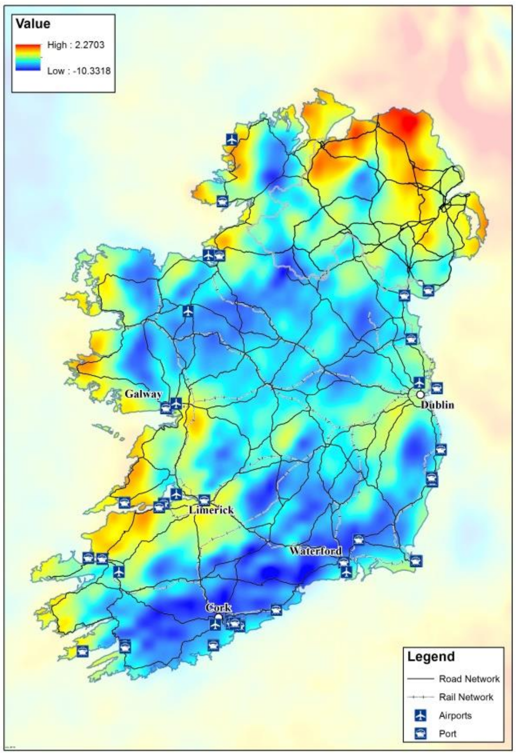


Winter

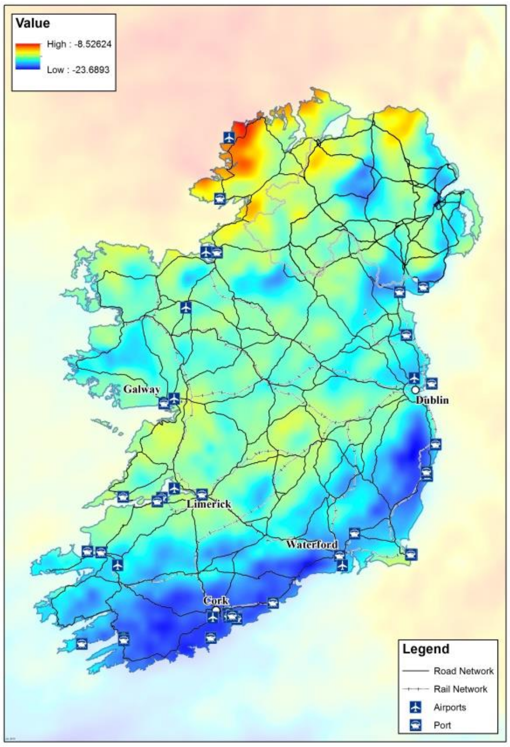


(b) High Emission: Seasonal Change in Standard Deviation of Precipitation (Mean Rainfall)

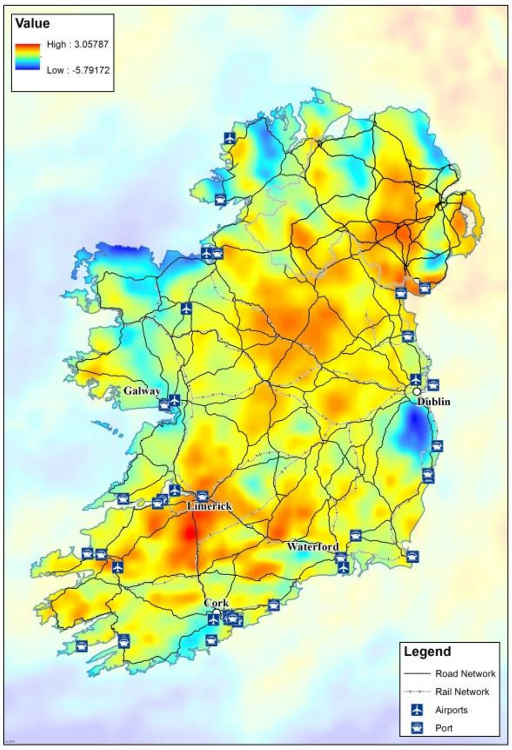
Spring



Summer



Autumn



Winter

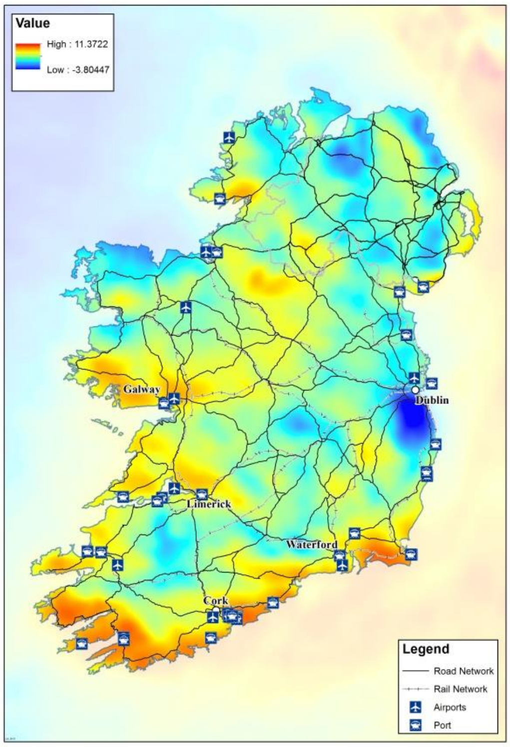
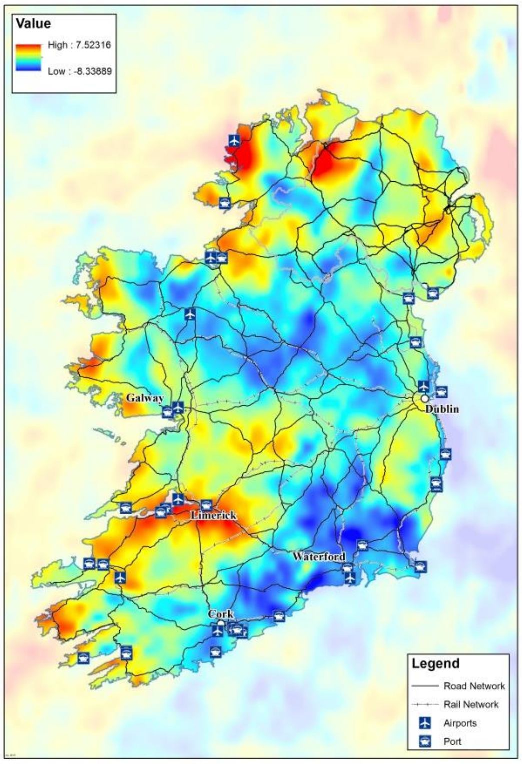


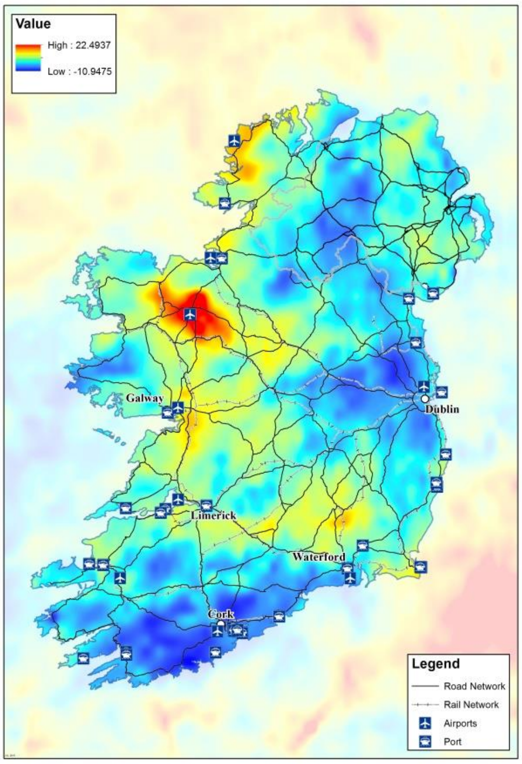
Figure 4.4: Projected changes (%) in seasonal precipitation. (a) medium- to low-emission scenario; (b) high-emission scenario. In each case, the future period 2041–2060 is compared with the past period 1981–2000.

(a) Medium–Low Emission: Seasonal Projected Changes in Standard Deviation of Daily Precipitation (Min. & Max. Projected Change)

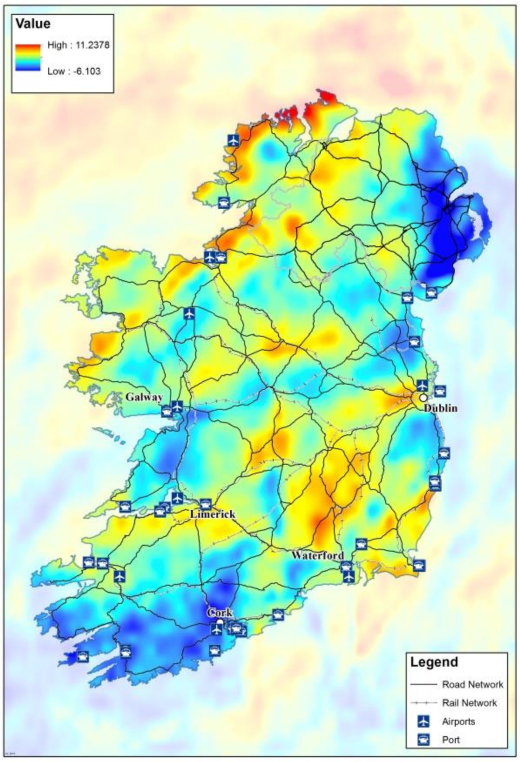
Spring



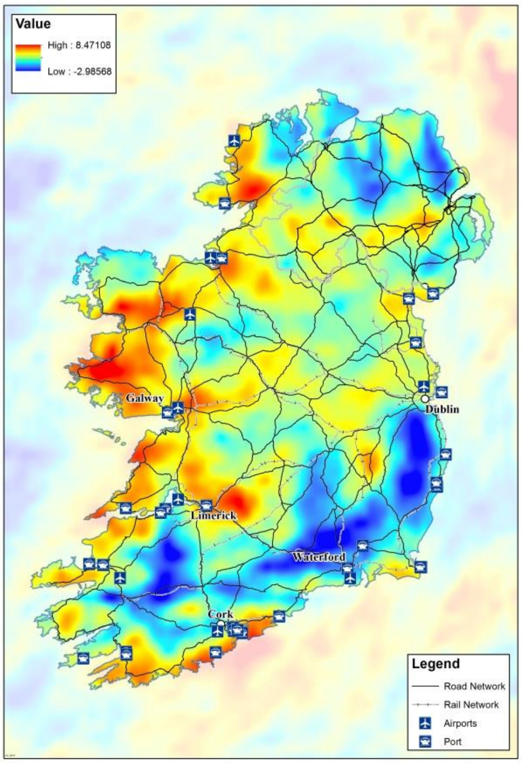
Summer



Autumn

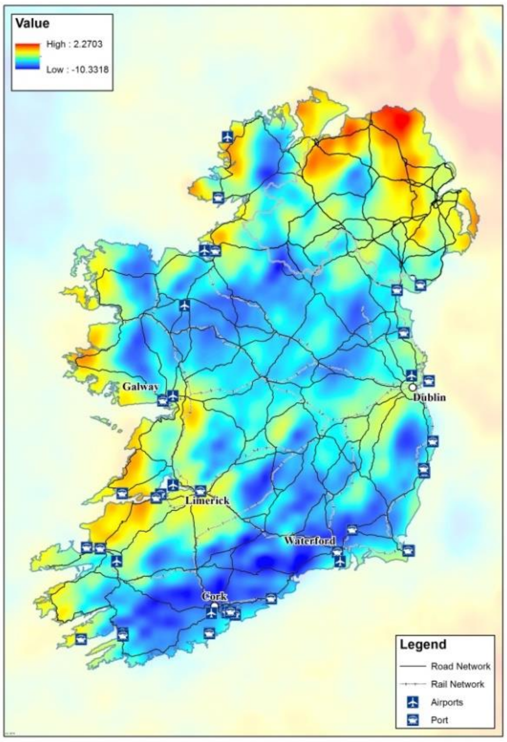


Winter

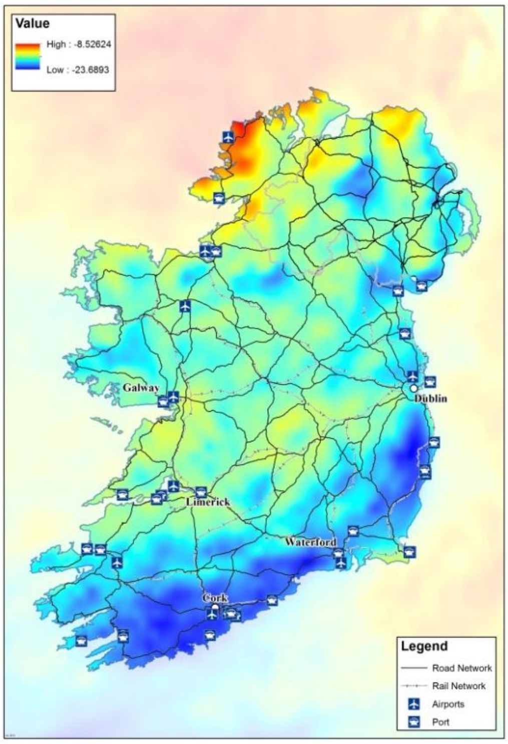


(b) High Emission: Seasonal Projected Changes in Standard Deviation of Daily Precipitation (Min. & Max. Projected Change)

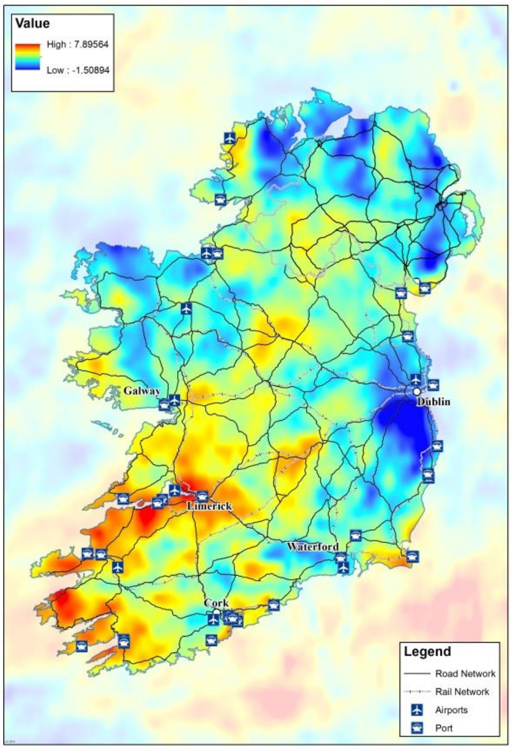
Spring



Summer



Autumn



Winter

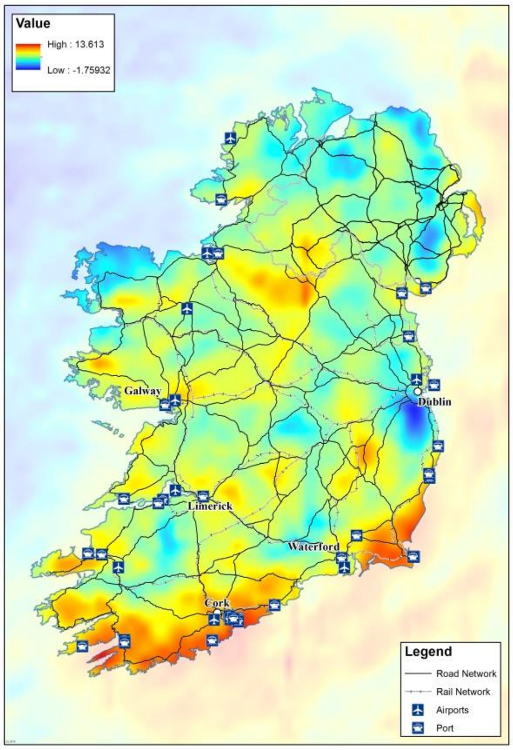


Figure 4.5: Seasonal projected changes (%) in the standard deviation of daily precipitation. (a) medium to low-emission ensemble; (b) high-emission ensemble. In each case, the future period 2041–2060 is compared with the past period 1981–2000.

4.2.2 High Priority Climate Impact: High Winds

The number of very intense storms in the Atlantic is expected to increase in the coming years. Projections indicate that the winter tracks of these very intense storms may extend further south, meaning that more of these storms will reach Ireland[43]. It is important, however, to note that storms of this magnitude are rare events and analysis of wind projections on a regional level should be considered with caution. The projected increase in mean sea level pressure (MSLP) will probably lead to a decrease in mean wind speed (and wind power) during summer, spring and autumn, when intense storms are rare. Furthermore, the projected increase in very intense storms is likely to be partially responsible for the projected increase in extreme wind speeds during winter[43]. Downscaling to a regional level for wind speed shows variation between the medium-low emission and high emission scenarios and accuracy in identifying particularly vulnerable regions is therefore limited; but increase in extreme wind speeds over the south and east of Ireland may be conservatively inferred[43] with corresponding impacts to infrastructure located in these regions.

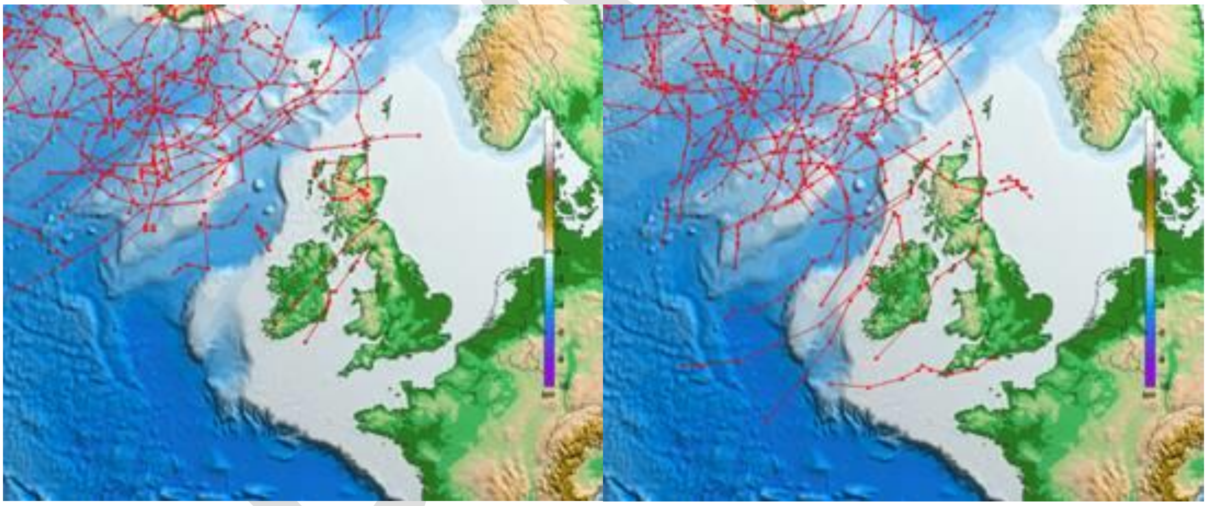
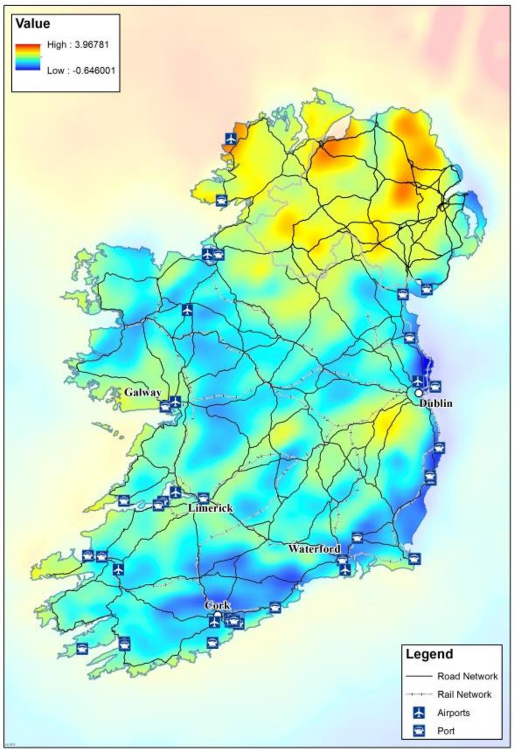


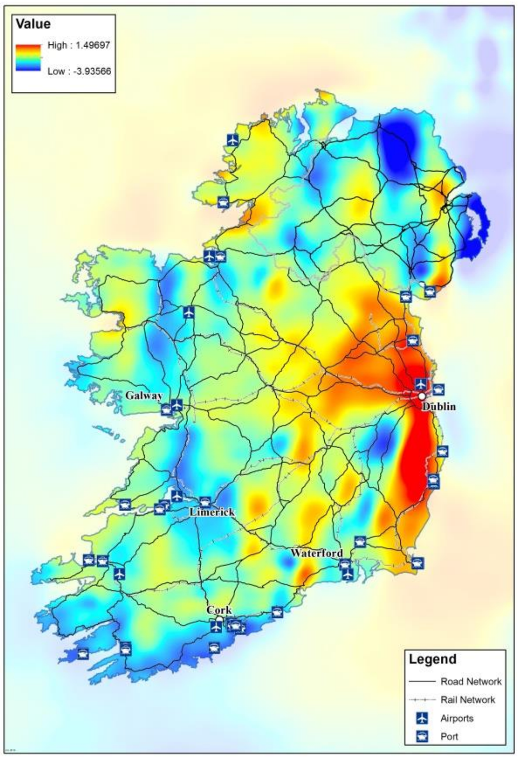
Figure 4.6: Tracks of storms with a core MLSP of less than 940 hPa (hectopascals) and with a lifetime of at least 12 hours: (a) Past RCM simulations for 1981–2000; (b) climate prediction simulations for 2041-2060, based on RCP 8.5 scenario[43].

Medium-Low Emission: Seasonal Change in Standard Deviation 60m Wind Speed

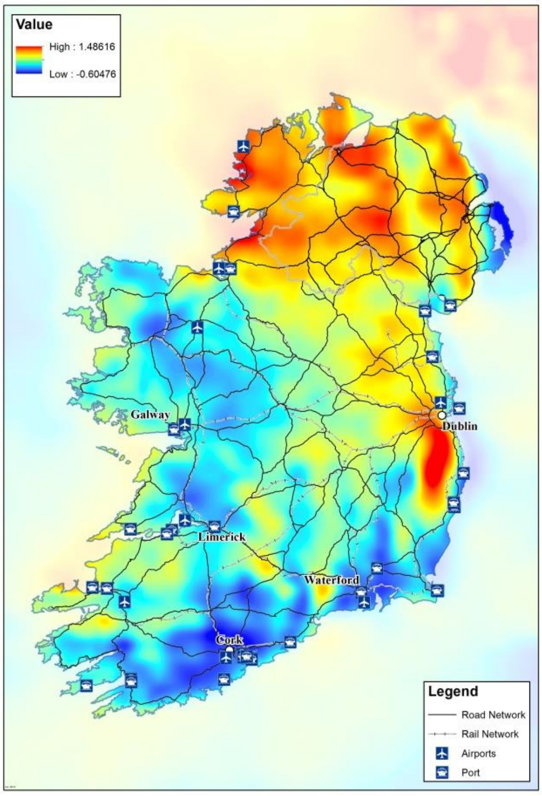
Spring



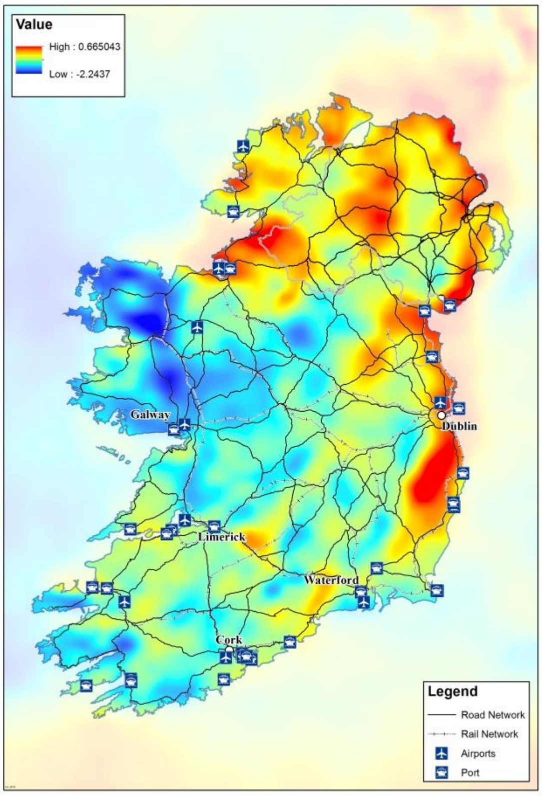
Summer



Autumn

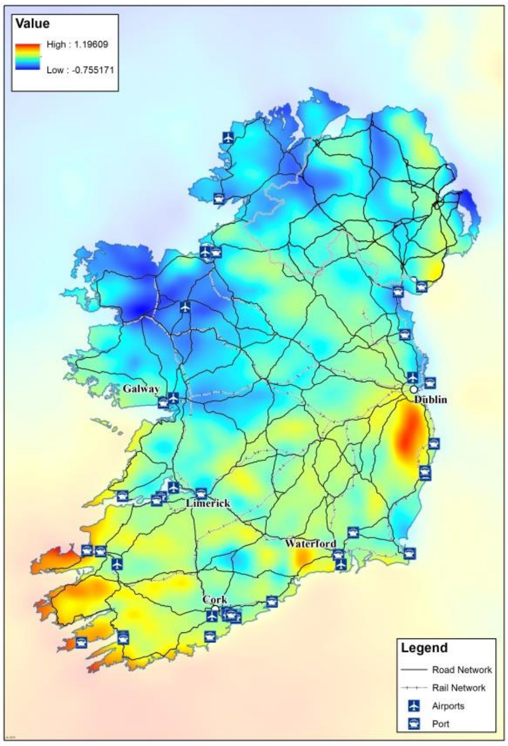


Winter

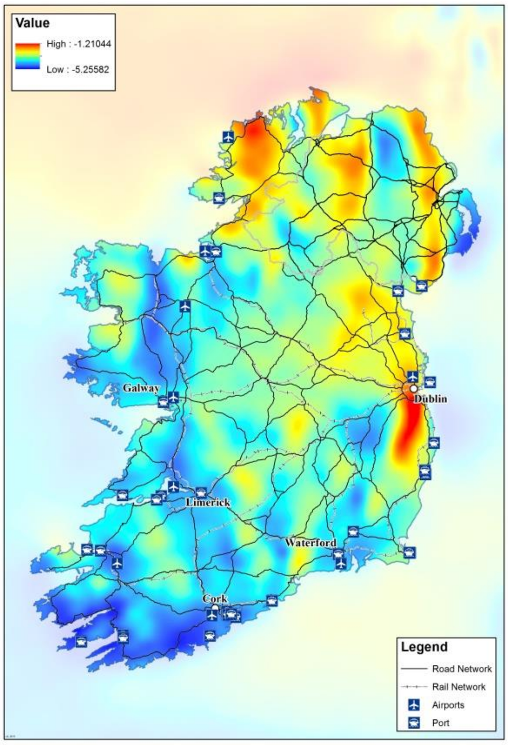


(b) High Emission: Seasonal Change in Standard Deviation of 60m Wind Speed

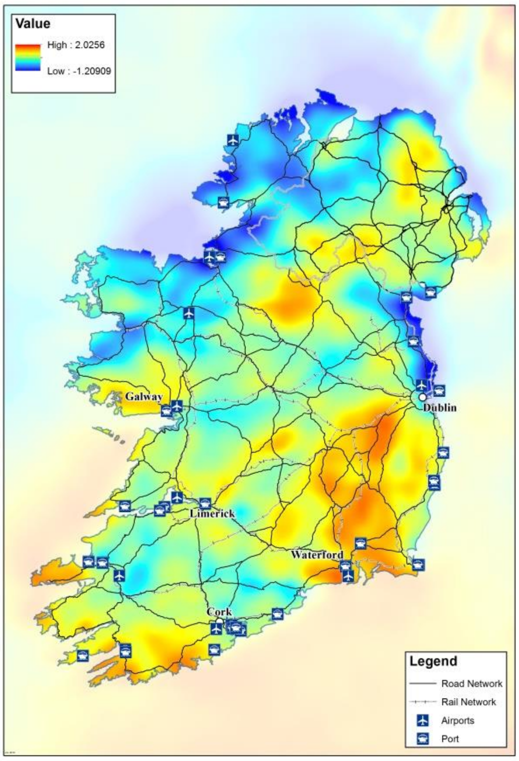
Spring



Summer



Autumn



Winter

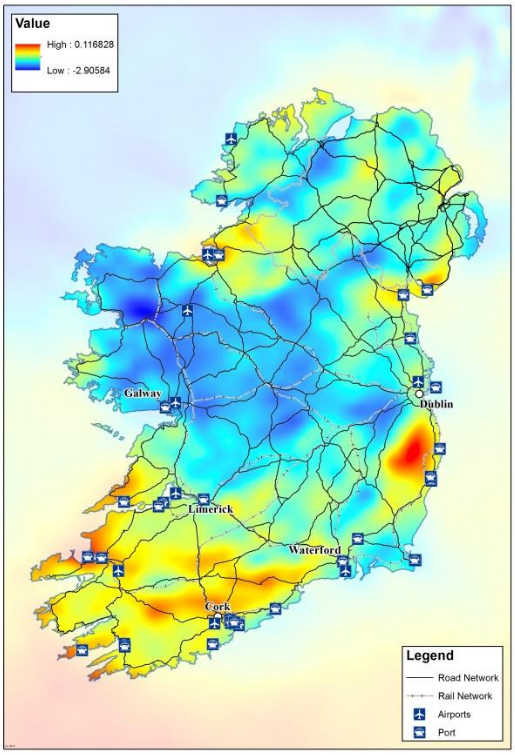


Figure 4.7: Seasonal projected changes (%) in the standard deviation of daily mean 60-m wind speed. (a) Medium- to low-emission ensemble; (b) high-emission ensemble. In each case, the future period 2041–2060 is compared with the past period 1981–2000.

4.2.3 High Priority Climate Impact: Sea Level Rise (SLR)

Downscaled (national-level) high-resolution models for projected SLR over the 21st century are not currently available; however, the rise in sea level relative to land along most European coasts is projected to be similar to the global average. It is expected that global mean SLR during the 21st century will very likely occur at a higher rate than during the period 1971–2010. Process-based models considered in the IPCC AR5 project a rise in sea level over the 21st century (2100 vs. 1986–2005 baseline) that is likely in the range of 0.28–0.61 m for an extremely low emissions scenario (RCP2.6) and 0.52–0.98 m for a high emissions scenario (RCP8.5), although substantially higher values of sea level rise cannot be ruled out[53]. Under the medium-low emissions scenario (RCP 4.5), Ireland will likely experience SLR between 0.3 m and 0.5 m.

The vulnerability of Ireland's coasts to SLR is related to physical characteristics of the coast and a range of variables known as coastal indicators, which include cliff type, coastline orientation, regional coastal slope, tidal range, significant wave height and long-term shoreline erosion and accretion rates[54]. A coastal vulnerability mapping initiative which is currently being undertaken by GSI is expected to produce maps denoting the relative susceptibility of the Irish coast to adverse impacts of SLR; the first phase of CVI mapping (2019-2020) will map areas from Co. Louth to Co. Wexford.

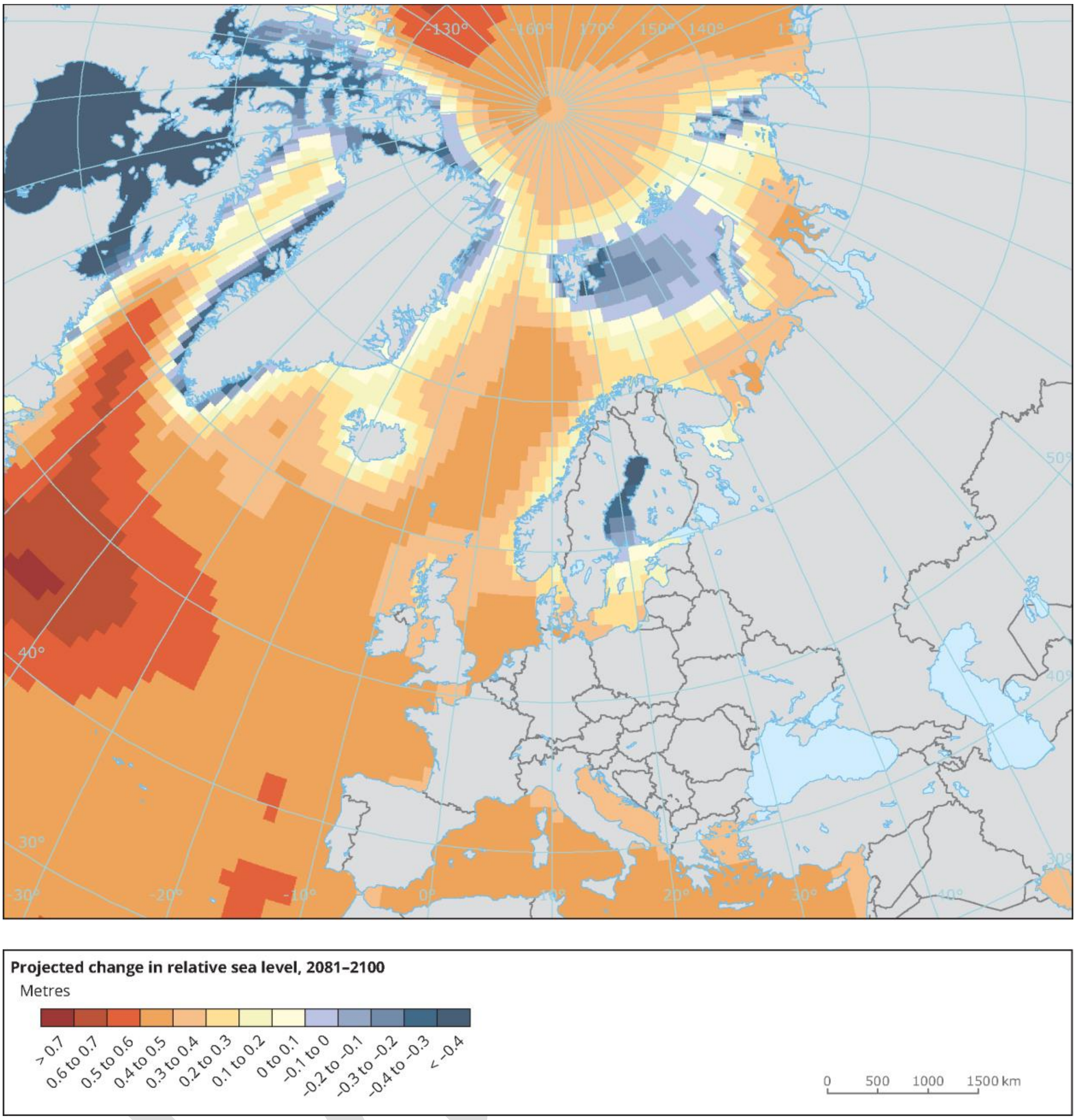


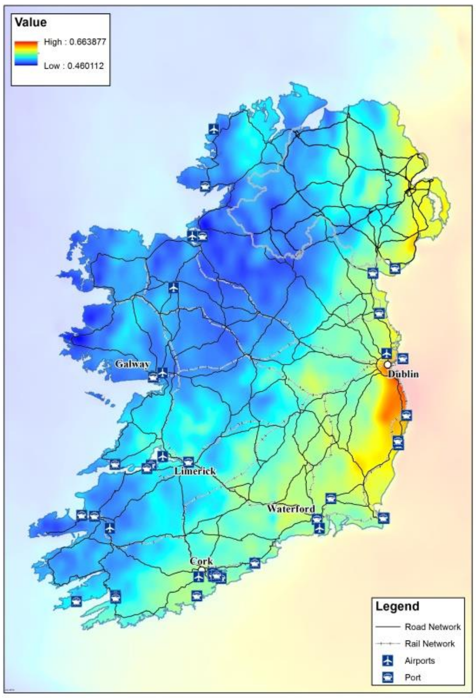
Figure 4.8: Projected change in relative sea level in 2081-2100 compared to 1986-2005 for the medium-low emission scenario RCP4.5 based on an ensemble of global climate models. Projections consider land movement due to glacial isostatic adjustment but not land subsidence due to human activities. Source: EEA, 2017.

4.2.4 Moderate Priority Climate Impact: High Temperatures

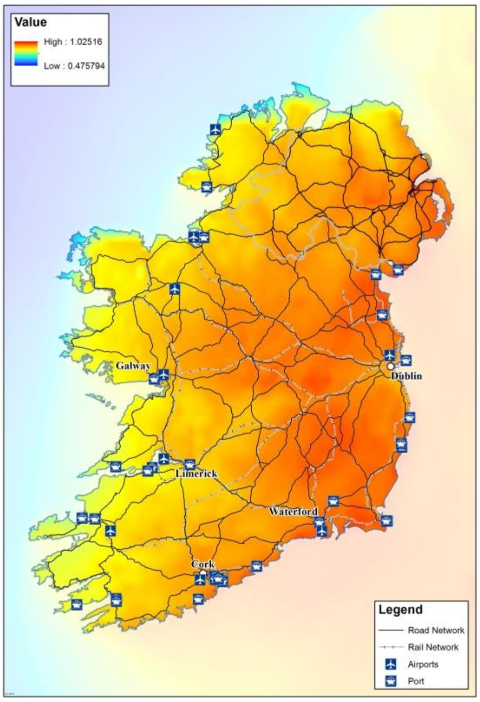
Projections indicate a rise of 1–1.6°C in mean annual temperatures, with the largest changes seen in the east of the country. The annual and seasonal projected increases are statistically significant for both emission scenarios, although warming is greater for the extremes (i.e. hot or cold days)[43] and both daytime and night time temperatures are expected to rise. Transport infrastructure located in regions where seasonal temperature rise is more pronounced may experience changes in energy demand for depots and fixed infrastructure (ports and airports) in both winter and summer, as demand for heating and cooling needs may change. It is possible that thermal expansion of roads and rail lines (leading to degradation and disintegration) may have a higher rate of occurrence within the regions identified below[42].

(a) Medium–Low Emission: "Very Likely" Seasonal Temperature Increase

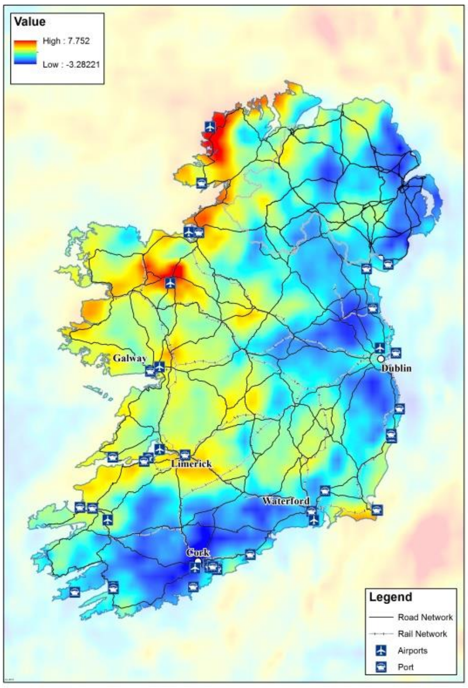
Spring



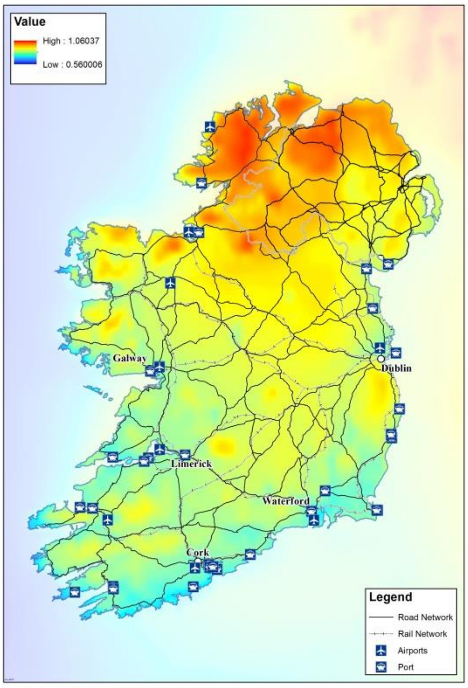
Summer



Autumn

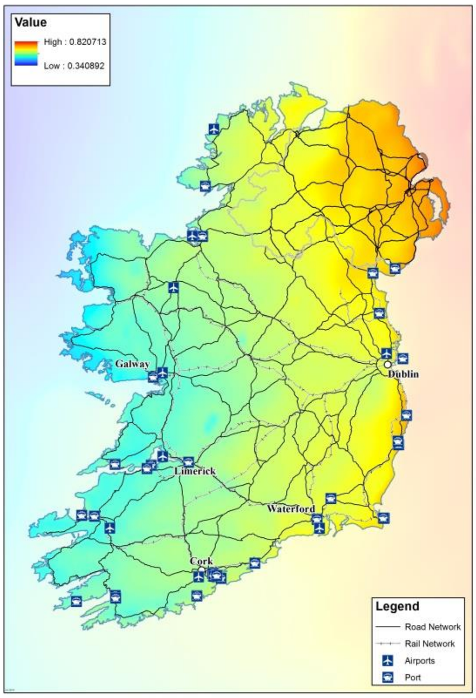


Winter

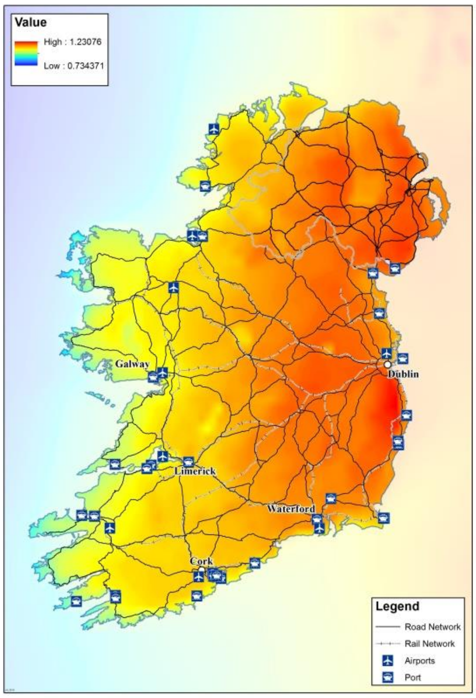


(b) High Emission: "Very Likely" Seasonal Temperature Increase

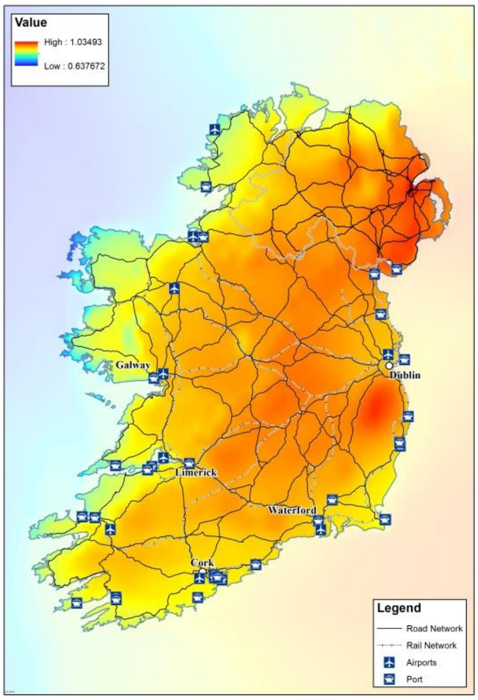
Spring



Summer



Autumn



Winter

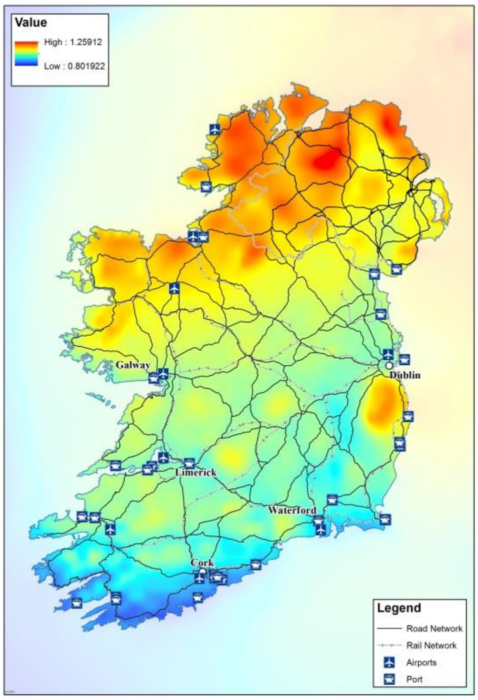


Figure 4.9: The "very likely" seasonal increase in temperature for the (a) medium- to low-emission and (b) high-emission scenarios. In each case, the future period 2041–2060 is compared with the past period 1981–2000.

(a) Medium–Low Emission: "Likely" Annual Temperature Increase

(b) High Emission: "Likely" Annual Temperature Increase

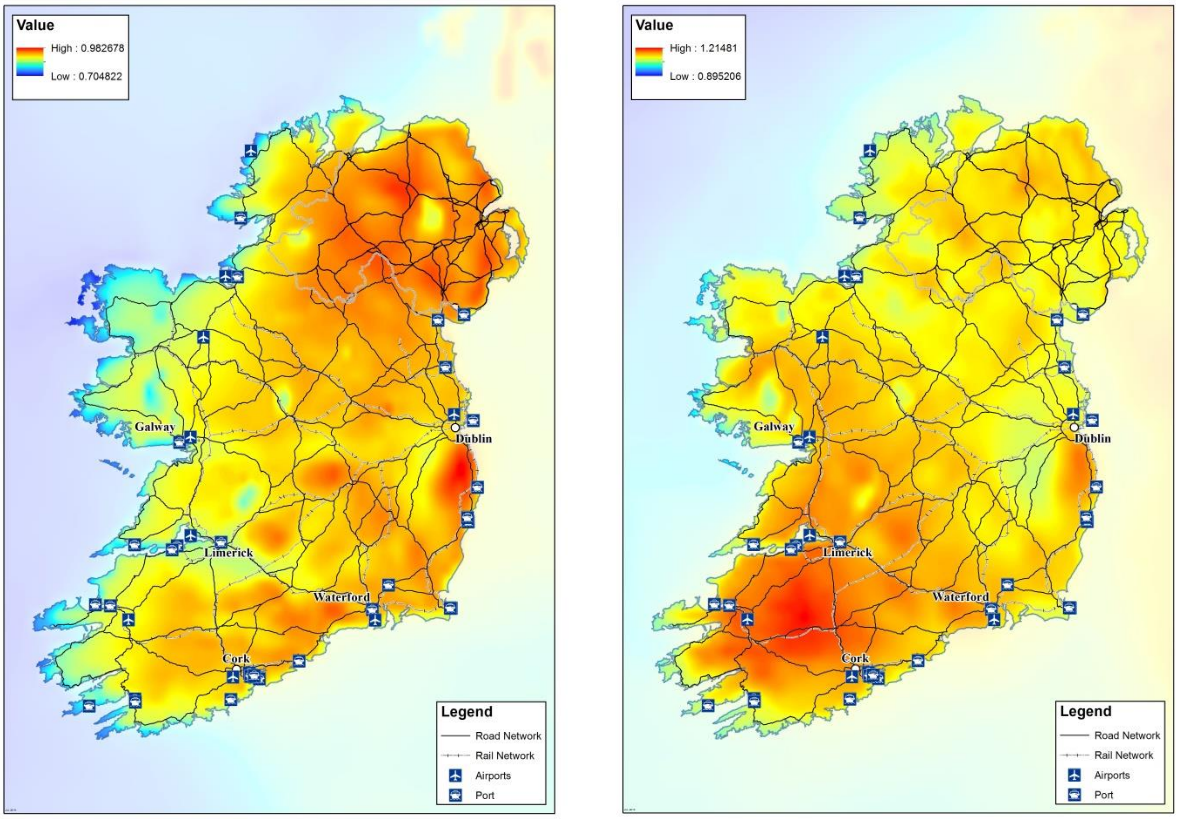
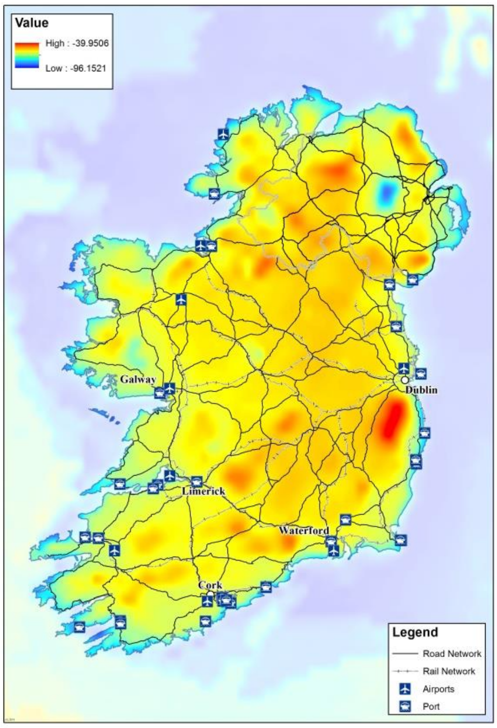


Figure 4.10: The "likely" annual increase in temperature for the (a) medium- to low-emission and (b) high-emission scenarios. In each case, the future period 2041–2060 is compared with the past period 1981– 2000.

4.2.5 Moderate Priority Climate Impact: Low Temperatures

The number of frost days (days when the minimum temperature is less than 0°C) is projected to decrease, on average, by 50% for the medium- to low-emission scenario and 62% for the high-emission scenario. Similarly, the number of ice days (days when the maximum temperature is less than 0°C) is projected to decrease by 73% for the medium- to low-emission scenario and 82% for the high-emission scenario[43]. The projected decrease in the number of ice days is greatest in the north of the country, with fewer snow days expected throughout. These changes may confer benefits to the transport sector; minor accidents and personal and motor insurance costs may be reduced[42].

(a) Medium–Low Emission: Annual Change (%) in Number of Frost Days (Min. <0°C)



(b) High Emission: Annual Change (%) in Number of Frost Days (Min. <0°C)

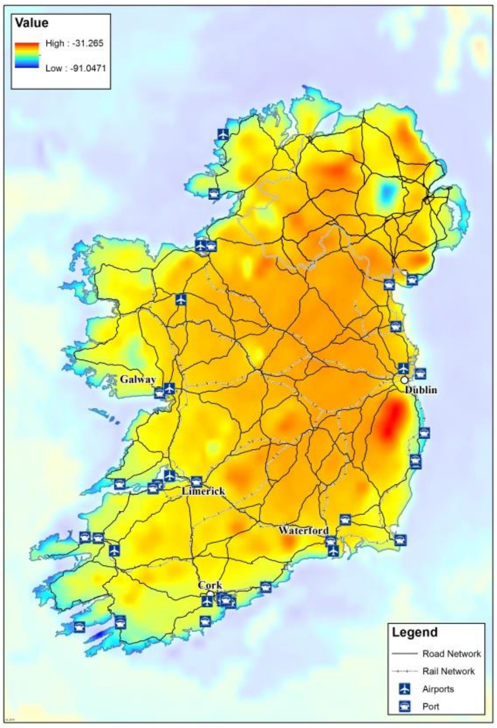


Figure 4.11: Projected percentage change in annual number of frost days for the (a) medium- to low-emission and (b) high-emission scenarios. In each case, the future period 2041–2060 is compared with the past period 1981–2000.

(a) Medium–Low Emission: Annual Change (%) in Number of Ice Days (Max. <0°C)

(b) High Emission: Annual Change (%) in Number of Ice Days (Max. <0°C)

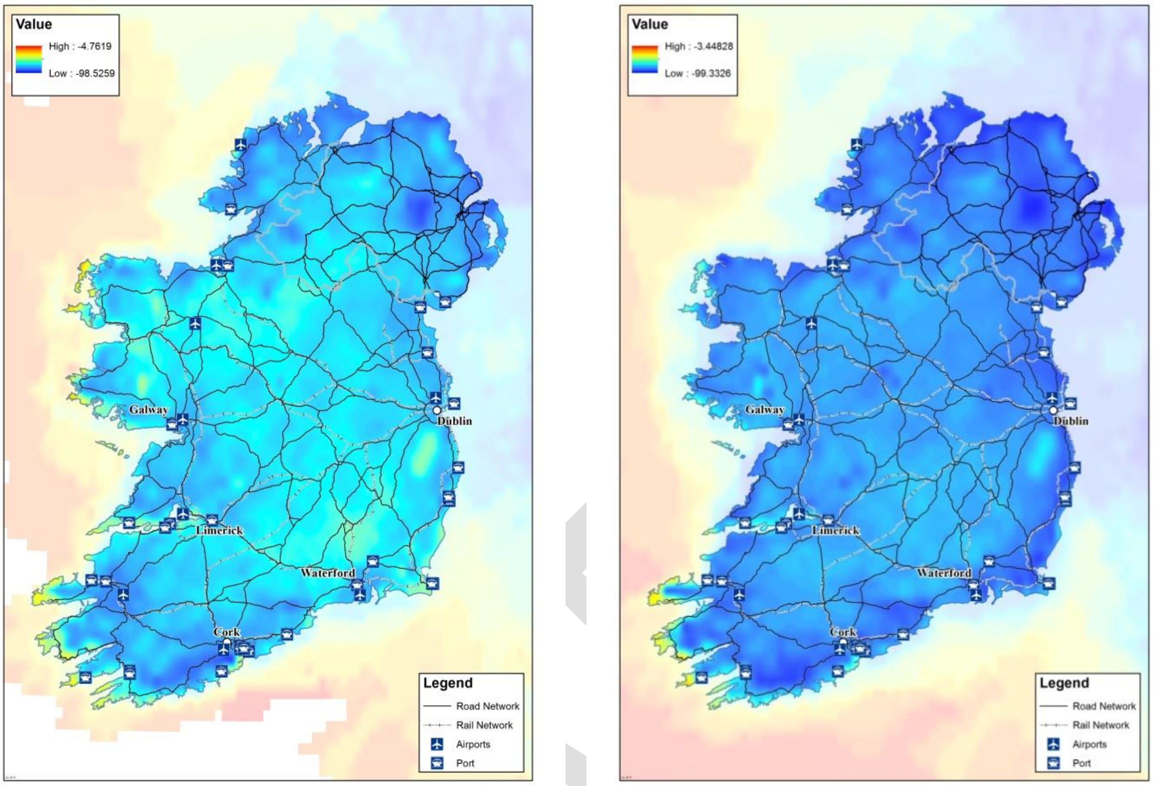


Figure 4.12: Projected percentage change in annual number of ice days for the (a) medium- to low-emission and (b) high-emission scenarios. In each case, the future period 2041–2060 is compared with the past period 1981–2000.

4.3 Assessing Transport System Resilience

In addition to identifying the transport assets situated in regions where the projected impacts of climate change may be more pronounced, it will also be helpful for transport stakeholders to determine the likelihood of these impacts to bring infrastructure and services towards their operational thresholds and assess resilience correspondingly. A lack of available quantitative data on the actual impacts of observed climate changes to the transport sector, including associated financial implications, was identified in the preparation of the precursory sectoral adaptation plan. The absence of a standardised framework to connect climate-specific or adaptation-specific actions with financial investments represents a significant knowledge gap which inhibits understanding of actual climate resilience within organisations and structures for all sectors across the State.

Together with transport stakeholders, a data collection exercise was designed in 2018 with the aim of outlining the impacts of observed climate change at a sectoral level. This exercise focused on costs incurred as a result of extreme weather events; the frequency and severity of such weather events, and their associated risks, is likely to intensify and increase in the mid-century period under both the medium-low emission and high-emission scenarios. As an example, Table 4.1 illustrates data gathered from five stakeholders in the land, aviation and maritime subsectors following Storm Ali (18-20 September 2018), a Status Orange storm with reported wind speeds up to 120km/hr. As impacts were not felt uniformly by all transport stakeholders, this table provides an indicative insight into adaptive capacity within the transport sector but is not representative of overall systemic resilience to weather extremes.

Table 4.1: Aggregated and anonymised data collected from 5 service operators/infrastructure providers following Storm Ali, September 2018.

Extreme Weather Event Type	Storm; high winds up to 120km/hr; average wind speeds nationwide of 65km/h to 80km/h. Met Éireann issued a Status Orange weather warning for 17 counties, with a Status Yellow warning in place for the rest of the country.
Event Date	18 & 19 September 2018
Observed Impacts	• Strong winds caused operational disruption across multiple services. • Some road blockages and closures caused diversions and traffic delays. • Storm surge observed at docks. • Facilitity/equipment damage and construction project delay x 2 days. • Displacement of wireless communications infrastructure at site.
Repair Works Undertaken	• Reinstall electrical boxes & repair fencing. • Repair to antennas; signage; emergency gates; & car park barriers. • Multiple call-outs to clear trees brought down by high winds. Removal of trees & debris from tracks & overhead line electrification.
Cost of Repair Works	C. €26,500 recorded in repair works by service operators & infrastructure providers
Closure or Suspension of Services	• 1 operator recorded 1x flight diversion & 1x flight cancellation (inbound & outbound). • 1 operator recorded pilot boat service off-station cancelled for *c.* 18 hours. • 1 operator recorded 9 services cancelled.
Revenue Forgone: Lost Manhours	Where services were diverted or cancelled, administrative/salaried expenditure was still incurred. Some stakeholders included unrecovered employee costs in overall costs and were unable to disaggregate the data.
Revenue Forgone: Lost Km	1x service operator noted 1,360 lost km.
Revenue Forgone: Service	1x service operator recorded 169 service delays totalling

Delays	5,326 delay minutes.
Passenger/Customer Impacts	• Flight disruptions • Loss of service in some areas • Delays incurred by vessels waiting to berth and commence operations • Rail service delays totalling 5,326 minutes while lines were cleared of debris
Total Financial Cost	All stakeholders reported that they were unable to quantify total financial costs.

Key findings from the data collection exercise showed that delineation of direct expenditure is complex. There is currently no definition of climate-specific investment available which would allow sectors to easily categorise relevant climate-specific expenditure; and maintenance, upgrade, and repair activities are typically captured as routine investment. Service providers were also unable to estimate indirect costs such as revenue forgone. In addition, metrics of loss of service provision were not uniform across the subsectors, making meaningful comparison of the effect of climatic impacts on different infrastructure and services difficult. Social and environmental costs arising from weather extremes are not easily monetised, limiting capacity to quantify current levels of resilience and proximity to transport system thresholds. The most significant limitation of the sectoral data collection process is that it is does not allow for cascading impacts to, and as a result of system failure in other sectors, be costed. Development of a methodology to capture cross-cutting economic, social and environmental consequences at a national level would assist in the quantification of cross-sectoral interdependencies for a more accurate assessment of current levels of systemic resilience. In addition, an improved understanding of cascading impacts between sectors would allow for the identification of specific sectoral assets which are critical to the functioning of particular subsectors within the transport sector. Criteria to identify, and subsequently prioritise investment in adaptive capacity are not currently available. Such criteria should consider the social, economic and environmental functions performed by each asset and its contribution to the functioning of the system overall. In the absence of this data, a full priority impact assessment, and identification of operational and systemic thresholds, is not yet possible.

Figure 4.13: Train damaged by falling branches during Storm Ali, September 2018. Source: Irish Rail.

5 Adaptation Action Plan

5.1 Transport Adaptation Goals and Objectives

Developing an adaptation strategy requires establishing goals, sequencing planning objectives and identifying and prioritising actions that can help in achieving these goals[7]. The goals and objectives presented in this Plan are commensurate with the expected five-year term outlined in the *NAF* for statutory adaptation planning. While identified goals and objectives may change over time (due to new scientific findings, improved vulnerability assessment, observed climate impacts, changes in the socio-economic, political and technological spheres, and based on implementation successes and failures), the overall objectives outline the sector's long-term strategic vision for building a level of systemic resilience to climate change.

Box 5.1: Adaptation Goal

The overarching goal of transport adaptation planning is to ensure that the sector can fulfil its continuing economic, social and environmental objectives by ensuring that transport infrastructure is safeguarded from the impacts of climate change.

The implementation objectives set out in this Plan are:

1. Improve understanding of the impacts of climate change on transport infrastructure, including cross-sectoral cascading impacts, and close knowledge gaps;
2. Assist transport stakeholders in identifying and prioritising climate risks to existing and planned infrastructural assets and enabling them to implement adaptation measures accordingly; and
3. Ensure that resilience to weather extremes and longer-term adaptation needs are considered in investment programmes for planned future transport infrastructure.

5.2 Developing Robust Adaptation Pathways

The actions presented in this plan are divided into three distinct workstreams aligned with the overarching implementation objectives. The actions should be understood as part of an iterative adaptation planning pathway to transition towards a climate-resilient economy and society by 2050. Chapter 4 of this plan highlighted that much of the work towards developing resilience in the transport sector is undertaken by transport stakeholders (infrastructure providers and service operators) as part of standard operational and business planning processes and there are few levers at a central level to encourage implementation of additional adaptation measures. However, DTTAS can take strong action through the implementation of 'soft' policy measures. It is notable that many of the adaptation options identified are cross-sectoral in nature. Where engagement with other agencies/departments and stakeholders is required, this is indicated accordingly.

Box 5.2: Types of Adaptation Action

Adaptation actions can be classified as soft, green and grey.

Soft adaptation measures involve alteration in behaviour, regulation or system of management. This could include targeted policy development and government support, such as strategic land use and effective integration with other sectors in the planning and development process; incorporating adaptation clauses into national transport infrastructure investment; or undertaking collaborative research between stakeholder and cross-sectoral bodies[16].

Green adaptation measures seek to utilise ecological properties to enhance the resilience of human and natural systems to climate change impacts. For example, increasing green space in urban areas could provide areas for retention of floodwaters, while efforts to reinstate dune systems could act as buffers against coastal storm damage[16].

Grey adaptation measures involve technical or engineering solutions to climate impacts, examples include raising roads where flooding is expected to occur or the construction of sea walls or tidal barrages in response to sea level rise[16].

5.2.1 Proposed Adaptation Actions under Implementation Objective No. 1

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
1	Extend Adaptation Planning Team to include representation from transport system users i.e. freight sector; tourism sector; active travel users etc. in line with NSOs in *Project Ireland 2040*	DTTAS	Sectoral Adaptation Team; DCCAE; OPW; Met Éireann	2019	ICT Networks (DCCAE) Energy Networks (DCCAE) Flood Management (OPW)	

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
2	Co-ordinate with the Climate Action Regional Offices (CAROs) to ensure that national and regional policies align and to ensure that infrastructure managed by LAs is considered within the Sectoral Adaptation Team	DTTAS; CAROs	LAs	2019	Local Government	3 Good Health and Well-Being; 7 Affordable and Clean Energy; 8 Decent Work and Economic Growth; 9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 13 Climate Action

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
3	Establish cross-sectoral Critical Infrastructure Working Group to complement the work of the Sectoral Adaptation Team	DTTAS; DCCAE	Sectoral Adaptation Teams	2019	Energy Networks (DCCAE) ICT Networks (DCCAE)	9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 13 Climate Action

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
4	Commission a study to develop appropriate monitoring indicators to evaluate the efficacy of adaptation measures	DTTAS	Sectoral Adaptation Team	2020		3 Good Health and Well-Being; 7 Affordable and Clean Energy; 8 Decent Work and Economic Growth; 9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 13 Climate Action

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
5	Review effectiveness of current quantitative data collection procedures for the impacts of extreme weather events and longer-term climate change with a view to developing a cross-sectoral reporting mechanism	DTTAS; DCCAE	Sectoral Adaptation Teams; CAROs	2020	Energy Networks (DCCAE) ICT Networks (DCCAE) Local Government	9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 13 Climate Action

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
6	Continue collaboration with the EPA, Climate Ireland and Met Éireann to ensure sectoral understanding of up to date climate information	Met Éireann; EPA; Climate Ireland	DTTAS	Ongoing	Climate Services (Met Éireann)	3 Good Health and Well-Being; 7 Affordable and Clean Energy; 8 Decent Work and Economic Growth; 9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 13 Climate Action; 14 Life Below Water; 15 Life on Land

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
7	Commission a study to identify common criteria to define critical assets within the transport; ICT and energy sectors	DTTAS; DCCAE	Sectoral Adaptation Teams; Met Éireann; EPA; 3rd level institutions	2020	ICT Networks (DCCAE) Energy Networks (DCCAE)	3 Good Health and Well-Being; 7 Affordable and Clean Energy; 8 Decent Work and Economic Growth; 9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 13 Climate Action

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
8	Undertake concise comparative study between output of the EPA *CIViC* project and the mapping exercise developed through this plan	DTTAS	DCCAE; EPA; UCC; OPW; Met Éireann	2020	ICT Networks (DCCAE) Energy Networks (DCCAE) Water Services & Infrastructure (DHPLG) Flood Management (OPW)	6 Clean Water and Sanitation; 9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 13 Climate Action

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
9	Perform a midterm review of the statutory critical infrastructure adaptation plans with potential input from relevant actors such as local authorities and CCMA	DTTAS; DCCAE	CAROs; CCMA; Sectoral Adaptation Team	2022	Energy Networks (DCCAE) ICT Networks (DCCAE)	9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 13 Climate Action

5.2.2 Proposed Adaptation Actions under Implementation Objective No. 2

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
10	Disseminate geospatial distribution impact maps to transport stakeholders	DTTAS	Sectoral Adaptation Team	2019	Climate Services (Met Éireann)	9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 13 Climate Action

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
11	Develop online repository host transport adaptation resources on the departmental website www.dttas.gov.ie to to encourage stakeholders to review network vulnerabilities and conduct risk assessments	DTTAS	Sectoral Adaptation Team Met Eireann; Climate Ireland	2020	Climate Services (Met Éireann)	8 Decent Work and Economic Growth; 9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 13 Climate Action; 14 Life Below Water; 15 Life on Land

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
12	Support transport stakeholders to avail of adaptation funding opportunities by providing information on potential EU funding sources	DTTAS	Sectoral Adaptation Team; DCCAE; DPER	2020	LIFE Programme (DCCAE) Connecting Europe Facility (CEF)	9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 12 Responsible Consumption and Production; 13 Climate Action

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
13	Following from Action 7, develop guidance for sectoral stakeholders to inform identification of critical transport assets, taking account of cross-sectoral interdependencies	DTTAS	DCCAE	2021	ICT Networks (DCCAE) Energy Networks (DCCAE) Climate Services (Met Éireann)	3 Good Health and Well-Being; 7 Affordable and Clean Energy; 8 Decent Work and Economic Growth; 9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 13 Climate Action; 14 Life Below Water; 15 Life on Land

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
14	Under the *NAF*, DCCAE to consider development of criteria to define critical national assets with a view to prioritisation	DCCAE	DTTAS; DAFM; DHPLG; DCHG; DPER; DFIN; DoH; OPW; CAROs	TBC	All Sectors	3 GOOD HEALTH AND WELL-BEING 6 CLEAN WATER AND SANITATION 7 AFFORDABLE AND CLEAN ENERGY 8 DECENT WORK AND ECONOMIC GROWTH 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE 11 SUSTAINABLE CITIES AND COMMUNITIES 13 CLIMATE ACTION 14 LIFE BELOW WATER 15 LIFE ON LAND

5.2.3 Proposed Adaptation Actions under Implementation Objective No. 3

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
15	Continue engagement with disaster risk management for transport through active participation with the Office for Emergency Planning and the National Directorate for Fire and Emergency Management	DTTAS	All Sectors	Ongoing	Emergency Planning (All Sectors)	3 GOOD HEALTH AND WELL-BEING 6 CLEAN WATER AND SANITATION 7 AFFORDABLE AND CLEAN ENERGY 8 DECENT WORK AND ECONOMIC GROWTH 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE 11 SUSTAINABLE CITIES AND COMMUNITIES 13 CLIMATE ACTION 14 LIFE BELOW WATER 15 LIFE ON LAND

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
16	Ensure that climate resilience and adaptation and needs are considered in appraisal guidance for future infrastructure projects	DTTAS		TBC		9 INDUSTRY, INNOVATION AND INFRASTRUCTURE 11 SUSTAINABLE CITIES AND COMMUNITIES 13 CLIMATE ACTION

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
17	Consider adaptation needs in contracts; performance delivery agreements; and service level agreements between DTTAS, transport infrastructure agencies, public transport service agencies and constituent operators as relevant	DTTAS	Transport infrastructure agencies and public transport service providers, including NTA; CIÉ; TII; Dublin Bus; Bus Éireann; Go-Ahead Ireland	TBC		9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 13 Climate Action

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
18	Ensure that adaptation needs are considered in the projects relating to future transport energy (recharging and refuelling) infrastructure networks under the *Climate Action Fund*	DTTAS	DCCAE; ESB e-cars; GNI	2019	Energy Networks (DCCAE)	7 Affordable and Clean Energy; 9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 12 Responsible Consumption and Production; 13 Climate Action

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
19	Ensure that adaptation needs are considered in EU-funded projects relating to future transport energy infrastructure networks where DTTAS has a role in project validation	DTTAS	GNI, others as appropriate	2019	Energy Networks (DCCAE)	7 Affordable and Clean Energy; 9 Industry, Innovation and Infrastructure; 11 Sustainable Cities and Communities; 12 Responsible Consumption and Production; 13 Climate Action

Action	Proposal	Lead	Stakeholders	Timeline	Cross-sectoral linkages	Related UN SDGs
20	Support implementation of remote working initiatives, including expansion of effective broadband connectivity, to facilitate remote working when travel is inhibited during extreme weather events	DCCAE	ICT Sector	c. 2021-2027	ICT Networks (DCCAE)	

6. Implementation and Governance

6.1 Implementation Timeframes

Reviewing, monitoring and evaluation are key elements of an iterative adaptation process to assess progress and performance, to share knowledge and inform future policy and practice. A monitoring and review process will allow for adjustments over time based on improvements in understanding, advances in climate science and experience of implementation. Under the *NAF*, a five year term is envisaged for the *Framework* and for associated statutory sectoral and local authority adaptation planning. Actions identified within this Plan have been developed accordingly to be completed before the end of 2024.

6.2 Monitoring and Reporting

Implementation of the actions outlined in Chapter 5 of this Plan will be monitored by the sectoral adaptation team, which will be scheduled to meet biannually, with the first meeting in early-2020. In addition, an annual progress report will be prepared by DTTAS and disseminated to the members of the Sectoral Adaptation Team. The progress report will be published on the departmental website alongside adaptation resources for stakeholders within the transport sector before end-2020, and each year following under the lifetime of the Plan as relevant.

Under the provisions of the *NAF*, the Minister for Transport, Tourism and Sport (MTTAS) will be obliged to present an annual sectoral adaptation statement to each House of the Oireachtas, with further presentation of statements as considered appropriate by the Minister for Communications, Climate Action and the Environment (MCCAE). DTTAS will provide quarterly updates to the National Adaptation Steering Committee as well as providing input into the *Climate Action Delivery Board* and the *National Energy and Climate Plans* (NECP).

6.2.1 Monitoring Indicators

Implementation of measures outlined in the non-statutory adaptation plan *Developing Resilience to Climate Change in the Irish Transport Sector* (2017) has been ongoing since early 2018. The measures outlined were considered in the context of their effectiveness, using a range of monitoring indicators to demonstrate progress towards implementation. These indicators were:

- baseline monitoring;
- recognition 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; and
- periodic reviews /evaluations.

A summary of implementation progress for these measures is presented in Appendix III. Measures which remain ongoing may be superseded by the targeted actions proposed in Chapter 5 of this plan and will be incorporated into the monitoring process as relevant. Preparation of cross-sectoral monitoring indicators may also be considered in tandem with the prioritisation of critical sectoral assets as our understanding of climate impacts and risks continues to develop. Monitoring indicators will take into account the review of international best practice presented in *EPA Report 263: Reflecting on Adaptation to Climate Change: International Best Practice Review and National MRE and Indicator Development Requirements*[55].

6.3 Evaluation and Review

A collective midterm review of the statutory plans for the critical infrastructure sector (transport; communications; and gas and electricity networks) will be performed under the aegis of the Critical Infrastructure Working Group to evaluate opportunities to optimise cross-sectoral adaptation planning processes, with reference to monitoring indicators. This process may draw upon consultation with key stakeholders in the transport, energy and ICT sectors, with input from other relevant actors such as local authorities and county and city management associations (CCMAs) as appropriate.

Table 6.1: Summary of Governance Processes for the Statutory Sectoral Adaptation Plan

Governance Action	Proposal	Lead	Stakeholders	Timeline
Ongoing Monitoring	Review of implementation of adaptation actions at biannual meetings	DTTAS	Sectoral Adaptation Team	Biannual for the lifetime of the plan as relevant; first meeting to be held early-2020
Ongoing Monitoring	Dissemination of a Progress Report on the Implementation of Transport Adaptation Measures	DTTAS	Sectoral Adaptation Team	Annual for the lifetime of the plan as relevant
Reporting Obligations	Publication of Progress Report on the Implementation of Transport Adaptation Measures on the Departmental website	DTTAS	Sectoral Adaptation Team	Annual for the lifetime of the plan as relevant; first publication before end-2020
Reporting Obligations	Provide quarterly updates on action implementation to National Adaptation Steering Committee	DTTAS	DCCAE	Quarterly for the lifetime of the plan as relevant
Reporting Obligations	Presentation of Annual Transition Statement to the Houses of the Oireachtas	MTTAS		Annual or as considered appropriate by the MCCAE
Reporting Obligations	National–level reporting on the delivery of the sectoral adaptation plan under the all of Government *Climate Action Plan*	DCCAE	DTTAS	Quarterly
Reporting Obligations	Sectoral input to international governance and monitoring reporting under the *NECP*s as relevant and appropriate	DTTAS	DCCAE	Annual
Review & Evaluation	Perform a Midterm Review of the Statutory Adaptation Plans for the Critical Infrastructure (Energy & ICT) sectors, with reference to performance indicators	DTTAS; DCCAE	Sectoral Adaptation Team; Sectoral Adaptation Teams for the Energy & ICT Sectors	Before end-2022

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