Editorial

Richard Dawson MEng, PhD

Professor of Earth Systems Engineering, Centre for Earth Systems
Engineering Research, School of Civil Engineering and Geosciences,
Newcastle University, Newcastle upon Tyne, UK

Infrastructure provides services that support jobs, drive economic growth, increase safety and improve quality of life (iBUILD, 2015). The extent of our infrastructure is considerable; within the UK, ports shift over 500 Mt of cargo (DfT, 2012); the railway network supports 1.3 billion journeys (ORR, 2014); ICT supports 13 billion minutes of mobile call time and connects nearly 23 million residential homes and businesses to the internet (Ofcom, 2014); over a quarter of a million miles of road (DfT, 2013) and half a million miles of electricity lines (Ofgem, 2014) support mobility and provide power.

Extreme events have repeatedly led to significant disruption of infrastructure services across the British Isles. For example, twelve extreme weather events involving high winds, rainfall and coastal surges between December 2013 and January 2014 were responsible for: seven fatalities; flooding of 1700 properties across England; loss of power for over 150 000 homes; closure of Gatwick Airport; disruption of rail and road travel, which included severing of the railway line to West Devon and Cornwall; overtopping and breaching of flood defences; and general damage to buildings and infrastructure assets (Met Office and Centre for Ecology and Hydrology, 2014). The rapid succession of events hampered efforts to restore these services, leading to loss of key services such as lighting, heating and transportation – in some cases for many weeks. Considered individually there are examples of comparable or more severe storms in recent years, but overall this was the stormiest period of weather for at least 20 years and the wettest winter in England and Wales since 1766 (Met Office and Centre for Ecology and Hydrology, 2014).

Evidently, natural variability in the UK's present climate already causes significant impacts upon infrastructure. However, over the coming century all areas of the UK are expected to warm, whilst average rainfall is not expected to change significantly. Drier summers are expected, particularly in southern England, but downpours may become heavier when they do occur (Murphy *et al.*, 2009). Sea levels will continue to rise and are likely to do so at a faster rate than we have observed in the last century (Murphy *et al.*, 2009). Storm tracks may shift north or south but predicted changes in wind speeds are uncertain, whilst increases in the number of lightning days are projected across the whole of the UK for all seasons. The number of annual fog days may reduce by up to 50% in some regions, but changes in fog, wind and lightning from climate models are particularly uncertain (Boorman *et al.*, 2010a, 2010b; Sexton and Murphy, 2010). However, changes in the UK's

climate have already been observed: central England temperature has risen by about 1°C since 1980, whilst the sea level around the UK rose by approximately 1–2 mm/year during the 20th century, the rate of rise varied from decade to decade and increased to over 3 mm/year in the last decade (Haigh *et al.*, 2010; Jenkins *et al.*, 2008; Met Office, 2015).

To improve understanding of the nature and scale of the physical impacts of climate change on UK infrastructure and thereby inform decisions about infrastructure management and future development, the Living With Environmental Change research programme (www.lwec.org.uk) commissioned a review. The work is summarised as one of a series of report cards (Dawson, 2015). An overview of the key relationships identified between climate impacts and infrastructure sectors is shown in Figure 1.

Collectively, these reviews highlight that without action, weather impacts to infrastructure are expected to increase as a result of these changes. Increased frequency of severe weather events such as flooding will lead to increased disruption of our infrastructure. However, more gradual trends, such as a rise in average temperature, reduce the capacity or efficiency of some infrastructure, such as overhead power lines. Together, changes in average and extreme conditions can alter the design life of the infrastructure and the effectiveness of the services it delivers. Members of the public will experience increased frequency of loss of services such as heat, communication, water and the associated discomfort or threat to health. Pressures on supply and demand may lead to increased prices. Infrastructure operators risk loss of revenue from assets that are damaged or operating with lower efficiency, whilst risks to business and industry include increased disruption of services that they rely upon, including transport and communication links. Investors and insurers bear increased risks and losses directly from infrastructure within their portfolio, and indirectly from losses that are reliant on infrastructure, whilst the government (and tax payers) often need to step in to assist with losses suffered in extreme circumstances.

This special issue on the impacts of climate change on UK infrastructure is split into two parts. Part one contains papers that provide a detailed analysis of electricity networks (Blake *et al.*, 2015), port and navigation (Brooke, 2015), road transport (Chapman, 2015), flood and coastal erosion (Sayers *et al.*, 2015) and solid waste (Watson and Powrie, 2015) infrastructure. Findings from analyses of other sectors will be reported in the forthcoming second part of this special issue of *Infrastructure Asset Management*.

		Rail transport	Road transport	Inland waterway transport	Ports & marine transport	Potable water	Waste water & sanitation	Flood & coastal erosion management	Information & communication technology	Solid waste	Nuclear, coal, oil & gas energy	Renewable energy generation	Power systems, transmission & distribution	Energy demand
Sea level rise	Damage or disruption from coastal flooding	x	x	x	x	x	x	x	x	x	x	x	x	x
	Tidelocking			x	x		x	x						
	Saline intrusion					x	x							
	Coastal erosion	x	x		x	x		x		x	x			
Rainfall	Damage or disruption from river flooding	x	x	x		x	x	x	x	x	x	x	x	x
	Damage or disruption from pluvial flooding	x	x	x	x	x	x	x	x	x	x	x	x	x
	Droughts and low precipitation	x	x		x	x		x	x	x	x	x	x	x
	Altered capacity or efficiency	x	x		x			x	x		x			
	Biological processes and/or disease					x	x			x				
	Stability of earthworks	x	x	x				x			x			
Temperature	Severe heat	x	x	x	x	x	x	x	x	x	x		x	x
	Severe cold, snow and ice	x	x	x	x	x	x		x		x			x
	Altered capacity or efficiency	x	x	x	x	x	x		x	x	x	x	x	
	Subsidence and/or dessication	x	x	x		x	x	x						
	Biological processes and/or disease					x	x	x		x				
	Demand for service	x	x	x		x								x
Other factors	Lightning strike	x						x					x	
	Humidity	x	x					x						
	Solar radiation											x		x
	Fog		x		x									
	Storminess and wind damage	x	x		x	x		x	x	x	x	x	x	x

Figure 1. Summary of potential climate impacts on infrastructure after Dawson (2015). An 'x' denotes an identified relationship. Where there are more relationships, the greater the potential for extreme weather events to impact upon multiple infrastructures

Ensuring the UK's infrastructure is resilient to events, such as those that occurred in winter 2013/2014, and to future changes in climate generally, is clearly of fundamental importance. A number of actions have already been taken by owners and operators across all infrastructure sectors to reduce the impacts of severe weather events and climate change and to embed climate change issues into investment programmes. Nevertheless, the long time frames, complexity of infrastructure systems and uncertainties involved still pose significant challenges. Whereas part one of this Editorial has summarised the climate drivers and main impacts to infrastructure, part two in the next issue will summarise general lessons on the management of climate impacts on infrastructure and the broader challenges of adapting to climate change.

REFERENCES

Blake S, Davison P, Greenwood D and Wade N (2015) Climate change risks in electricity networks. *Infrastructure Asset Management* **2**(2): 42–51, <http://dx.doi.org/10.1680/iasma.14.00035>.

Boorman P, Jenkins G and Murphy J (2010a) *Future changes in fog frequency from the UKCP09 ensemble of regional climate model projections*. Met Office Hadley Centre, Exeter, UK.

Boorman P, Jenkins G, Murphy J and Burgess K (2010b) *Future changes in lightning from the UKCP09 ensemble of regional climate model projections*. Met Office Hadley Centre, Exeter, UK.

Brooke J (2015) Climate change impacts on UK port and navigation infrastructure. *Infrastructure Asset Management* **2**(2): 52–57, <http://dx.doi.org/10.1680/iasma.14.00038>.

Chapman L (2015) Weather and climate risks to road transport. *Infrastructure Asset Management* **2**(2): 58–68, <http://dx.doi.org/10.1680/iasma.14.00032>.

Dawson RJ (2015) *A Climate Change Report Card for Infrastructure*. LWEC Report Card. Living With Environmental Change. ISBN 978-0-9928679-4-2.

DfT (Department for Transport) (2012) *UK Port Freight Statistics: 2011 Final Figures*. DfT, London, UK.

DfT (2013) *National Travel Survey: 2012*. DfT, London, UK.

-
- Haigh I, Nicholls R and Wells N (2010) Assessing changes in extreme sea levels: application to the English Channel, 1900–2006. *Continental Shelf Research* **30**(9): 1042–1055.
- iBUILD (2015) *Are You Being Served? Alternative Infrastructure Business Models to Improve Economic Growth and Well-being*. iBUILD Manifesto and Mid-term Report. Newcastle University, Newcastle, UK. ISBN 978-09928437-1-7. See <http://research.ncl.ac.uk/ibuild/2015manifesto/> (accessed 21/05/2015).
- Jenkins GJ, Perry MC and Prior MJ (2008) *The Climate of the United Kingdom and Recent Trends*. Met Office Hadley Centre, Exeter, UK.
- Met Office (2015) *Central England Temperature Dataset*. See <http://www.metoffice.gov.uk/hadobs/hadcet/> (accessed 21/05/2015).
- Met Office & Centre for Ecology and Hydrology (2014) *The Recent Storms and Floods in the UK*. The Met Office, Exeter, UK.
- Murphy JM, Sexton DMH, Jenkins GJ et al. (2009) *UK Climate Projections Science Report: Climate Change Projections*. Met Office Hadley Centre, Exeter, UK.
- Ofcom (2014) *Infrastructure Report 2014: Ofcom's Second Full Analysis of the UK's Communications Infrastructure*. Office of Communications, London, UK.
- Ofgem (2014) *Annual Reports and Accounts for Year Ended 31 March 2014*. Office for Gas and Electricity Markets, London, UK.
- ORR (Office for Rail Regulation) (2014) *Passenger Rail Usage 2014–15 Quarter 2 Statistical Release*. ORR, London, UK.
- Sayers P, Walsh C and Dawson R (2015) Climate impacts on flood and coastal erosion infrastructure. *Infrastructure Asset Management* **2**(2): 69–83, <http://dx.doi.org/10.1680/iasma.14.00040>.
- Sexton DMH and Murphy J (2010) *UKCP09: Probabilistic Projections of Wind Speed*. Met Office Hadley Centre, Exeter, UK.
- Watson GVR and Powrie W (2015) The impact of climate-related environmental change on the UK solid waste sector. *Infrastructure Asset Management* **2**(2): 84–94, <http://dx.doi.org/10.1680/iasma.14.00032>.