

# 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



In the editorial from part one of this themed issue on the impacts of climate change on UK infrastructure, Dawson (2015a) summarised key findings from a review commissioned by the Living With Environmental Change research programme (see [www.lwec.org.uk](http://www.lwec.org.uk)) on the physical impacts that climate change has on UK infrastructure. This review is summarised in a report card (Dawson, 2015b). Analysis across infrastructure sectors shows that the projected increased frequency of severe weather events such as flooding will lead to increased disruption of infrastructure services, while gradual changes such as rise in average temperature can reduce the capacity or efficiency of some infrastructure. Together, these can alter both the design life of infrastructure and the effectiveness of the services they deliver. This editorial highlights findings from this review about the strategies for managing climate impacts on infrastructure, and the characteristics of infrastructure that pose particular challenges in the context of resilience to climate change.

While severe weather events still pose challenges for continuous delivery of infrastructure services, a number of actions have already been taken by owners and operators to reduce the impacts of extreme events and to embed climate change issues into their long-term investment programmes. Over the long lifetime of infrastructure, climate drivers will interact with and exacerbate the impact of other pressures. Population growth and other demographic changes such as an ageing population change the demands placed on infrastructure. Meanwhile, ageing assets – some of which are over two hundred years old – can perform less efficiently and be more likely to fail during severe weather events. New technologies, such as ICT and electric vehicles, are creating new types of interaction between infrastructure systems that can alter their vulnerability to climate change impacts.

Modern infrastructure systems enable services to be conveyed over great distances; supply does not have to be local to demand. This provides many advantages, but vulnerabilities can emerge if regions become too imbalanced; for example, when regions responsible for a high proportion of supply are abruptly disrupted, or when communities rely on a single asset or route, as demonstrated by the failure of the railway embankment at Dawlish during the UK winter 2013/14 storms. Engineers must therefore consider both the spatial variability in climate, the physical properties of infrastructure assets and wider system effects. Moreover, engineering design must evolve beyond consideration of individual events. To ensure

long-term resilience, engineers must consider a much wider set of current and potential future hazards. This includes hazards acting collaboratively and events that are short and intense, as well as those that persist over days, weeks or longer periods.

Interdependencies between infrastructures are increasingly pervasive in modern infrastructure networks. A reliable energy supply and the use of ICT for automated control means that these systems increasingly underpin other infrastructure services. Many of these interdependencies are sensitive to changes in climate; for example, reduced availability of cooling water for an inland power station can affect its ability to generate electricity. These interdependencies can also lead to impacts upon one infrastructure being felt far beyond the original disaster footprint, which poses challenges for operators and responders. Moreover, these interdependencies provide a mechanism for well-intended interventions designed to manage climate impacts to cause undesirable consequences or trade-offs elsewhere. For example, protection of coastal communities can starve neighbouring beaches of sand and increase flood and erosion risks (Nicholls *et al.*, 2015). Likewise, infrastructure design and use is often directly related to energy consumption and greenhouse gas emissions; air conditioning reduces heat stress but requires energy; conversely, installation of low-carbon transport infrastructure supports energy reduction.

Research is improving our understanding of the potential extent and economic costs of these cascading impacts (e.g. Fu *et al.*, 2014; Hall *et al.*, 2015) but large uncertainties remain. In particular, the review highlights how future climate change impacts on the long-term physical performance of infrastructure systems are poorly understood. A long-term monitoring and research programme would improve understanding of how weather and other processes impact upon and degrade infrastructure systems. The Chancellor's announcement in both 2015 budgets (HMT 2015a, 2015b) of investment in the UK Collaboratorium for Research in Infrastructure and Cities (UKCRIC) provides an exciting and timely platform to tackle this huge challenge.

The UK's National Infrastructure Plan (HM Treasury, 2014) has identified £320 billion of infrastructure investment up to 2020/21. Given the longevity of these investments, to avoid longer term impacts to people and the economy, it is essential that they are designed to be resilient and sustainable in the context of the wide range of pressures and the characteristics of infrastructure

considered above. Developing suitable approaches for physical networks poses challenges and will require a combination of approaches to engineering infrastructure systems that include

1. adding redundancy into infrastructure networks in order to provide viable alternatives when parts of the network fail
2. building in flexibility to enable cost-effective modification of infrastructure assets in the future
3. retrofitting existing infrastructure to be more resilient to changing weather conditions
4. designing systems that account for changes in supply, demand and climate risks
5. identifying alternative and creative ways of delivering services
6. incentivising reduced demand for services by way of behaviour change and use of more efficient technologies
7. ensuring that infrastructure organisations and professionals have the skills and capacity to implement adaptation measures.

Papers in both special issues consider these issues in the context of individual sectors. Part one reviews climate change impacts on electricity networks (Blake *et al.*, 2015), port and navigation (Brooke, 2015), road transport (Chapman, 2015), flood and coastal erosion (Walsh *et al.*, 2015) and solid waste (Watson and Powrie, 2015) infrastructure. Papers in this second part of the special issue review the climate change impacts on wastewater (Campos and Darch, 2015), energy demand (Wood *et al.*, 2015), nuclear and fossil fuel energy generation (Byers and Amezaga, 2015) and renewable energy generation (Cradden *et al.*, 2015). Further papers are expected in forthcoming issues of the journal.

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