

Introduction

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The significance of a resilient infrastructure is usually something that does not come into the everyday thinking of users as they go about their busy lives. It can, however, come under the spotlight – especially by the media and perhaps the public – in anticipation of high-profile events such as this summer's Olympic and Paralympic Games. More usually, however, it can be drawn into sharp focus on those occasions when performance is below that usually expected, especially when significantly so. Those occasions, which may be seen as rare, can be for a number of different reasons, including both man-made and natural events.

This special issue of *Civil Engineering* explores the resilience for a number of different types of infrastructures, geographical locations and perspectives – all with a view to helping improve serviceability levels and expectations, with occurrences of lowered-performance experiences reduced still further. It can be argued that society has the right to expect this, albeit that expectations should be commensurate with the respective levels of investment. The level of performance to be expected, however, needs to be understood.

Indeed, management of infrastructure systems and assets for resilience may be seen as ranging from day-to-day continuity of performance – or service, for the main part – to a more dramatic scenario. A risk-management approach will bring the latter to the fore, considering less-frequent but more-hazardous events that may affect the integrity of the system, sometimes with catastrophic effects.

Infrastructure planning

Planning for the high consequence, low probability events tends to bring in the term emergency, with the attendant expression of 'planning for emergencies' becoming a crucial part of the overall considerations. Thus critical infrastructure planning and management is receiving significant attention by national governments, with many having drawn up national infrastructure plans where resilience is usually seen as a key requirement. The UK published such a document last year (Cabinet Office, 2011).

Planning for emergencies often follows a three-stepped process – response, recovery and building future resilience – ideas on which are included in the papers in this journal. Plans will, of course, require periodic reviews to maintain relevance as factors such as society, technology and environmental aspects develop. Part of the skills of risk management approaches can be seen when balancing risks with appropriate resources – such as the initial infrastructure investment, the on-going management (including maintenance) and possible updating and refurbishment.

The difference between man-made and natural hazards may be seen as clear-cut. Delving further, however, such as into root causes and mitigation strategies, could make the difference less

clear in some cases. For example, land where there has been human occupation over time is likely to have been altered in some way and may thus affect how a natural event may impact on the geographical environment. Also, where the performance of constructed facilities is not as planned, detailed investigations may show outcomes that may be different from that originally anticipated.

Consideration of issues such as sustainability, globalisation, emerging technologies and innovative solutions can be of help, especially when broadened by a wider and international context. Whereas the dedication and professionalism of civil engineers is often seen as being at the heart of ensuring that critical infrastructure remains resilient to natural and man-made hazards or events, many other disciplines are also involved actively and are crucial to the process. It can be seen from the papers in this special issue how professional interdisciplinary teams can help underpin infrastructure resilience strategies and their implementation.

Papers in this issue

In the first paper, Hudson *et al.* (2012) help to set the scene by outlining their views on engineering resilient infrastructure. The authors discuss the concepts and considerations associated with designing resilient physical infrastructure, including the case for resilience, providing a high-level overview of why it is important, the consequences of its absence and the significance of the concepts of risk and tolerance. This international introductory paper presents an overview for the following papers to build on.

Blockley *et al.* (2012) then give their views on infrastructure resilience for high-impact, low-chance risks and argue that civil engineers need a way of addressing low-chance but potentially high-impact risks if they are to deliver truly resilient infrastructure systems. A generalised vulnerability theory that can be applied to any infrastructure system is described.

Moving to a specific type of infrastructure, Doherty *et al.* (2012) present a detailed paper on enhancing the resilience of railway infrastructure. They explain that the interpretation of resilience in asset management is significantly different at the conceptual and design stages of new build compared with the application to existing infrastructure. Ways of dealing with this on the UK rail network are described, showing that they have led to a more resilient railway network and optimised asset preservation.

Montgomery *et al.* (2012) then describe how infrastructure resilience can be improved with a systems modelling approach, bearing in mind the interconnected nature of critical national infrastructure and its component parts. They describe how the approach is applied to highlight the key characteristics of complex adaptive systems that critical national infrastructure exhibits and show how the technique

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can be used to increase infrastructure resilience and sustainability.

Next, in an example from South Africa, Muller (2012) describes the development of the water resource infrastructure system that underpins the South African economy, with particular attention to the institutional processes that guide project selection and system operation. This illustrates recent work on understanding resilience in socio-ecological systems as well as the management of 'common pool' natural resources such as water. It suggests that the contribution of planning processes to social resilience may in its turn contribute to the achievement of the narrow goal of system reliability.

Moving to a paper dealing with water from a different perspective, Gersonius *et al.* (2012) present an adaptation process for flooding systems that can be applied whatever analytical method is used to account for climate change uncertainty. The process is aimed at providing flood risk infrastructure that is more resilient to climate change, where resilience is considered as the ability of the system as a whole to function as expected. The added value of utilising the proposed adaptation process is illustrated as part of a 'how-to' guide for providing greater resilience in flood risk infrastructure.

Continuing the theme of adaptation and climate change, Frankland *et al.* (2012) discuss appropriate technology for increasing the resilience of coastal defences on a small Pacific island, bearing in mind that ingrained responses over lifetimes will not be changed at short notice. Rather than introducing completely new and unfamiliar measures, they discuss pilot works to enhance and build on existing knowledge.

In the penultimate paper, Ingerslev (2012) discusses how immersed and floating tunnels are examples of using innovative design to increase infrastructure resilience. While the first floating tunnel has yet to be built, serious design efforts are well underway. This paper examines loadings and how these structures might meet their requirements for resilience, mentioning that because the risk of potential flooding exists, the requirements are somewhat different from those of land-based structures.

The final paper by Andrew (2012) on 'Building community resilience' looks at the post-event response and recovery stages. The author argues that communities can do a considerable amount themselves to build resilience to mitigate effects of future emergencies, and that the response and recovery stages can and should be concurrent. Recommendations are made about how community resilience can be enhanced in advance of any emergency event, with roles for the various stakeholders outlined.

We are grateful to all who have contributed to making this publication possible, including the authors, referees, assessors and their respective organisations. Also thanked is the Hazards Forum (www.hazardsforum.org.uk) for promoting the call for papers at its infrastructure resilience events. It is believed this special issue will be a valuable resource for civil engineers and other professionals who have an interest in infrastructure resilience.

References

- Andrew R (2012) Building community resilience. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **165(6)**: 59–64, <http://dx.doi.org/10.1680/cien.11.00051>.
- Blockley D, Agarwal J and Godfrey P (2012) Infrastructure resilience for high-impact low-chance risks. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **165(6)**: 13–19, <http://dx.doi.org/10.1680/cien.11.00046>.
- Cabinet Office (2011) *Keeping the Country Running: Natural Hazards and Infrastructure: A Guide to Improving the Resilience of Critical Infrastructure and Essential Services*. Cabinet Office, London, UK. See <http://www.cabinetoffice.gov.uk/infrastructure-resilience> (accessed 17/09/2012).
- Doherty A, Dora J and Newsome C (2012) Enhancing resilience in Britain's railway infrastructure. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **165(6)**: 20–26, <http://dx.doi.org/10.1680/cien.11.00064>.
- Frankland R, Hardwick L and Watkin S (2012) Climate change adaptation in a small Pacific island nation. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **165(6)**: 46–51, <http://dx.doi.org/10.1680/cien.11.00054>.
- Gersonius B, Ashley R, Pathirana A and Zevenbergen C (2012) Adaptation of flood risk infrastructure to climate resilience. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **165(6)**: 40–45, <http://dx.doi.org/10.1680/cien.11.00053>.
- Hudson S, Cormie D, Tufton E and Inglis S (2012) Engineering resilient infrastructure. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **165(6)**: 5–12, <http://dx.doi.org/10.1680/cien.11.00065>.
- Ingerslev LC (2012) Innovations in resilient infrastructure design: immersed and floating tunnels. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **165(6)**: 52–58, <http://dx.doi.org/10.1680/cien.11.00057>.
- Montgomery M, Broyd T, Cornell S *et al.* (2012) An innovative approach for improving infrastructure resilience. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **165(6)**: 27–32, <http://dx.doi.org/10.1680/cien.11.00062>.
- Muller M (2012) Water management institutions for more resilient societies. *Proceedings of the Institution of Civil Engineers – Civil Engineering* **165(6)**: 33–39, <http://dx.doi.org/10.1680/cien.11.00067>.

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