



*Hazards forum*



# The Hazards Forum Newsletter

Issue No. 91  
Summer 2016

Web version

# Hazards Forum Newsletter

## Issue No. 91 - Summer 2016

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***Edited by Dr. Neil Carhart***

***Views expressed are those of the authors, not necessarily of the Hazards Forum***

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Hazards Forum Executive Secretary: *Brian Neale*

*June 2016*

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# Hazards Forum AGM 2016

Brian Neale and Neil Carhart

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The Hazards Forum Annual General Meeting was held on Tuesday 22<sup>nd</sup> of March 2016 at the Institution of Civil Engineers, One Great George Street, Westminster, London, SW1P 3AA. The meeting began at 16:30 and was chaired by the Hazards Forum Chairman, Rear Admiral (retd.) Paul Thomas CB FREng.

The Chairman welcomed all those in attendance and reported the apologies for absence received from those who could not attend.

Noting that there were no specific matters arising, R/Adm Thomas turned the meeting to the Annual Report of the Trustees 2015. A copy of the report was made available to those in attendance along with a record of the previous Annual General Meeting. The Chairman sought and received acceptance for the Annual Report from the AGM, noting that it had been previously approved by the Hazards Forum Executive Committee. The report will be submitted to the Charities Commission with the year's Annual Return in the Summer.

The charitable objectives of the Forum have been recently revisited by the Executive Committee to ensure that they remain relevant and that the activities conducted by Hazards Forum are still driven by achieving those objectives. One of the ways in which the Forum continues to meet these objectives is the feedback and dissemination of information through principal stakeholders such as the engineering institutions and organisations that sponsor the Forum.

Turning to the financial accounts, the Chairman drew the attention of the AGM to the small deficit in the end of the year balance, noting that it was regrettably slightly larger than the previous year. Like many charities the sustainability of support

has been an issue, but thanks to the hard work of the Executive Committee the Forum is still supported by the engineering institutions and acknowledged by them to be of value. The Forum maintains the funds to wind up properly if needed, though that is not something currently being considered.

The Hazards Forum is actively looking at how to deliver more value to the sponsoring institutions. The Hazards Forum has an online presence in the form of a website and Twitter account. The Forum will have to consider how it engages with social media as it becomes increasingly important moving forward. The website was significantly improved in January 2014, though the headline messages of the website will need to be reviewed.

Access to Survey Monkey is provided by the Institution of Civil Engineers which enables the Forum to assess the response to its events and the Forum is thankful to Tim Fuller for his role in administering this.

The Hazards Forum holds four or five events each year and these continue to attract a reasonably sized audience. Survey Monkey and comments through other means indicate that these are well regarded in terms of the relevance of the topics covered and the quality of the speakers. While successful in that regard, more options should be considered to improve the delivery and attract larger audiences.

The Executive Committee held a facilitated workshop to approach this issue in a structured way. This looked at the Hazards Forum's charitable objectives, how it meets those objectives, and whether they could be achieved more effectively. This also includes securing the funds to ensure it can meet those objectives sustainably. The session resulted in a plan of actions to be

taken forward by the Hazards Forum Executive Committee looking at how it communicates and delivers events. Options such as webinars and holding events outside of London will be considered. Any members with additional experience in these areas are encouraged to contact the Executive Committee as their knowledge would be greatly appreciated.

Five events (two joint with other organisations) were held in the previous year, as reported in the Annual Report:

- 1) Returning to normal service – challenges of resuming normal operations following disaster (24<sup>th</sup> March 2015)
- 2) Reducing risk through sharing experience – why wouldn't you? (16<sup>th</sup> June 2015)
- 3) Managing risk in a connected world – time for the next generation (22<sup>nd</sup> September 2015)
- 4) Modern Offshore Quantitative Risk Assessment (4<sup>th</sup> November 2015)
- 5) Health care risk management and issues for the future (1<sup>st</sup> December 2015)

The Chairman acknowledged that the Forum was fortunate to have those with such a wide range of areas of expertise within the Executive Committee. He then thanked the professional engineering institutions who not only provide crucial financial support, but also venues and some Event chairs. The Forum is looking at how it can increase the value it offers to the institutions.

The Chairman also thanked the Trustees and other members of the Executive Committee, for their support and work in organising the regular events. On behalf of the Hazards Forum he went on to thank the independent accounts examiner, Alexander Bierrum; Accounting Technician, Janet Homer (in her absence); Forum Administrator, Tim Fuller; Editor of the Hazards Forum Newsletter, Neil Carhart, and Brian Neale, the Executive Secretary of the Forum for

all his efforts thought the year in keeping the Hazards Forum running.

The Chairman has been in position for six years as of the 2016 AGM. This is the current maximum term within the Forum's constitution. There has been some difficulty in finding an appropriate successor and any suggestions for potential candidates would be welcomed by the Executive Committee.

R/Adm Paul Thomas handed the session over to trustee and Executive Committee member Luise Vassie who asked the AGM to ratify a change in constitution to allow the current Chairman to remain a trustee for a further year and thus stay in role for this period in order to find a successor and appropriately transition them into the post. The AGM voted in favour of this amendment. The ExCom had prior agreed that should the change to the constitution be accepted, the position continue to be filled by R/Adm Thomas.

Four trustees will need to stand down at the next AGM, with only one eligible to stand again. Anybody interested in becoming a trustee is urged to discuss this opportunity with Executive Committee members or the Executive Secretary.

Having concluded all items in the planned agenda the Chair requested notification of any other business for discussion from those present. It was suggested that the Forum could consider producing a shorter summary of event reports to complement those in the newsletter and help disseminate the learning, particularly among school children and undergraduate students.

At the conclusion of the discussion and with no further business raised, the Chairman once again thanked those present and informed them that the next Annual General Meeting is planned to be held at the Institution of Civil Engineers on Tuesday 28<sup>th</sup> March 2017.

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# Developing resilient infrastructure – the role of collaboration and interdependency

Neil Carhart

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On **Tuesday 22<sup>nd</sup> March 2016** the Hazards Forum hosted an **evening event** at the Institution of Civil Engineers, One Great George Street, Westminster, London.

The resilience of UK infrastructure is critical to our social and economic wellbeing. Major failures of infrastructure, as experienced by many areas of the UK recently, has not only directly led to loss of life and property but has also placed additional long-term burdens on communities, industries and UK economic forecasts.

The key infrastructure systems of energy, transport, water, waste and ICT are individually extremely complex but they do not exist in isolation from one another. Understanding how they could fail individually or together is a major undertaking. The development of innovative world class infrastructure services which are resilient to these failures is an even greater challenge. This evening event will provide an insight into the work of three research projects which, with other groups, are coordinating their efforts to understand the issues. They are working with various stakeholders including central and local government and infrastructure operators to develop strategies.

The event began with a welcome from **Paul Thomas**, Chairman of the Hazards Forum, who thanked the event's co-sponsors, the Institution of Civil Engineers. He paid particular welcome to the large number of those in attendance who had not been to a Hazards Forum event before. He then handed over to **Andy Buchan**, the Head of Analysis and Assessment Security and Resilience at Sellafield Ltd. and chair for the evening's event.

Andy introduced the first speaker **Roger Street**, Director of Adaptation Science at the United Kingdom Climate Impacts Programme (UKCIP). In his talk, '*Collaboration and knowledge challenges of resilient exchange – addressing the infrastructure*', Roger explored the role of policy-practice-science dialogues in identifying and exploring the challenges and opportunities associated with addressing infrastructure interdependencies. To do this he drew on dialogues within the Environment Agency's Infrastructure Operators Adaptation Forum and the Adaptation and Resilience in the Context of Change network, to demonstrate the benefits of cross-institutional and multi-disciplinary collaboration and of linking with research.

The second presentation, '*Risk assessment of interdependent national infrastructure networks to inform resilience challenges*', was given by **Dr Raghav Pant**. Dr Pant is a Senior Post-Doctorate Researcher at the University of Oxford's Environmental Change Institute. In his presentation he looked at the basis for long-term planning for sustainable infrastructure, in particular: what are the risks of infrastructure network failures and how can such risks inform resilience planning? The presentation highlighted the modelling developments made in the Infrastructure Transitions Research Consortium by showcasing a spatial risk assessment framework. Key messages from a number of case studies with policy and industry stakeholders were also discussed.

The third speaker was **Professor Colin Taylor**, Professor of Earthquake Engineering at the University of Bristol. His talk, '*Learning how to be resilient*', examined barriers to learning by considering resilience as an emergent outcome of purposeful and collaborative human behaviours and actions. Many of

these behaviours and actions are enabled by infrastructure. Behaviours are learnt, so it makes sense for us to have a deep understanding of how we learn individually and collectively. The better we understand how we learn, the better our learning is likely to be and the more effective our purposeful behaviours are likely to be.

**Roger Street** began the first talk by introducing the Adaptation and Resilience in the Context of Change (ARCC) Network. This was convened by the Engineering and Physical Sciences Research Council (EPSRC) with the vision of expanding and accelerating the use of research to promote sustainability in the UK built environment and infrastructure sectors. The network has been in operation since 2003, refining its focus in 2008. It involves researchers and other stakeholders (e.g. business, industry, practitioners, policy makers) to facilitate collaboration and the co-production and exchange of knowledge in a way that is useful and valuable. It looks at how this knowledge can help inform policy and practice, and enhance the quality and relevance of research. The network is involved in a breadth of activities, from creating and mobilising usable evidence to enhancing communications and knowledge exchange, and developing a community to promote engagement and synergies. It also has a particular interest in supporting the development of the younger research community, and the future leaders of infrastructure resilience and sustainability.

The network has supported a number of *Policy-Practice-Science Dialogues*. These are very important as a mechanism to achieve the network's aims. The initial focus was on infrastructure interdependencies, an issue which was repeatedly highlighted as an area of key importance by practitioners, operators and policy makers. There is a significant interest in understanding and improving the understanding and management of these interdependencies. This interest also extends into governance through Infrastructure UK and now the National Infrastructure Commission. The ARCC

Network is trying to frame the research in a way that informs and is informed by policy and practice. They promote inter- and trans-disciplinary dialogues that are necessary to achieve this, and establish or reinforce the structures and incentive schemes that support such dialogues in the longer term. By their very nature, interdependencies are not something that any single group, be they within research, practice or regulation, can address alone.

**Adaptation and Resilience in the Context of Change (ARCC) Network**

**Policy-Practice-Science Dialogues**

Role in identifying, exploring and sharing on the challenges and opportunities associated with addressing infrastructure interdependencies:

- Address the need for a better dialogue across policy, practice and research on infrastructure interdependencies:
  - Framing research so that informs and is informed by policy and practice
  - Promote inter- and trans-disciplinary research and dialogues
  - Establish/Reinforce structures and incentive schemes that support interactive dialogue in the longer term
- To share learning, challenges and plans by providing opportunities to inform and discuss within and across the different communities and infrastructure sectors and to identify opportunities for potential collaborative efforts.

arcc EPSRC UKCIP

Roger then moved on to discuss the Infrastructure Operators Adaptation Forum (IOAF). This was created by the Environment Agency to bring together operators across the wide range of infrastructure sectors with the aim of making our assets and services more resilient to today's natural hazards, while also preparing them for the future climate. This includes work to support and challenge national and local policy on infrastructure and adaptation to inform and develop the National Adaptation Programme. Its interests include weather resilience planning, action and regulation as well as enabling a more integrated evidence-based approach. The Forum seeks to create 'champions' who promote good practice across the UK both within and outside the group, across various sectors. It too is interested in developing and supporting a community amongst academia, industry, regulators and government.

The IOAF held an initial dialogue at the IMechE to identify and further practice, policy and research initiatives, and to understand and address infrastructure

dependencies and interdependencies. The event was held just after the winter of 2013/14 and included a discussion and sharing of experiences and lessons from the extreme weather events that occurred. It looked at what happened within different elements of the infrastructure sector and how the different groups worked together. These dialogues highlighted the interconnected and interdependent infrastructure elements and helped understand failures in existing strategies. They also identified synergies and 'at risk' elements within the interconnected system, resulting in potential strategies to better minimise the overall impacts. The conversations also looked at the ways in which policy can be a potential benefit to joint infrastructure, producing long-term savings, as well as the ways in which it could increase risks and reduce resilience. There was an acknowledged need for more data and information concerning infrastructure interdependencies. Knowledge and evidence gaps were identified, in particular those relating to how we understand the value of infrastructure interdependencies in the context of building resilience. For example, can we better understand the potential value and risk of viewing High Speed 2 as an infrastructure corridor rather than just a railway?

In a second IOAF dialogue event the focus shifted to case studies and lessons of success and failure. The delivery of adaptation in the water sector, including the importance of partnerships and multi-agency working was discussed. This session identified the need for good business models that support adaptive and resilient behaviour within infrastructure. The role of natural infrastructure in delivering the services that infrastructure relies upon was also considered. There was a lot of interest in developing and communicating case studies and real-life examples of where dealing with cross-sector issues has influenced infrastructure projects. These provide a real opportunity to learn.

The most recent event was in collaboration with the Construction

Industry Research and Information Association (CIRIA). This again brought together industry, policy makers and researchers to look at three major investments that the EPSRC has made in infrastructure research: iBUILD, ICIF and ITRC.

The first, Infrastructure Business Models, Valuation and Innovation for Local Delivery (iBUILD), looks at business models and regional infrastructure. The second, the International Centre for Infrastructure Futures (ICIF) looks primarily at the national and international level. The third group supported by the EPSRC is the Infrastructure Transitions Research Consortium (ITRC), and it was the subject of the second talk of the evening. Collectively these represent around £12 million of infrastructure research investment.

The event with CIRIA looked at:

- Capturing the value of resilience and the business case for investment in this area;
- Making use of data to identify and manage critical interdependencies;
- The issue of scale interface between local, national and international scales;
- The value of considering a service-oriented approach to help with planning, identifying interdependencies and quantifying the risks of infrastructure failure.

This included an exploration of the meaning of resilience to the organisations represented at the event, actions to increase resilience, the challenges faced when acting to increase resilience, and the value organisations gain by becoming more resilient. The discussions identified how resilience is frequently viewed as a bolt-on rather than a primary objective, and explored why this might be the case. Roger emphasised how the detail of these discussions can be found online at [www.arcc-network.org.uk](http://www.arcc-network.org.uk).

Roger concluded his presentation by looking at the next steps for the ARCC Network. These are informed directly by the requests from operators and policy makers. It will continue working with the Infrastructure Operators Adaptation Forum and a number of other organisations to develop guidance and good practice for consideration of infrastructure interdependencies. This will aim to support infrastructure owners and operators in exploring and articulating the associated risks. This will reflect more recent developments and perspectives from within research and practice in practical, relevant and usable guidance for IOAF members.

**Adaptation and Resilience in the Context of Change (ARCC) Network**

**Next steps: Working with the IOA Forum**

**Development of guidance / good practice for consideration of infrastructure interdependencies**

- Support infrastructure owners and operators in exploring and articulating the associated risk, including in the context of their inclusion within the ARPs
- Practical, relevant and useable by IOA Forum members
- Reflect more recent developments and the perspectives of the IOA Forum members, to meet the perceived needs.
- Opportunity to identify and share good practices

Developing a work plan that includes engaging the IOA Forum members and research community

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There is a significant investment in infrastructure research, so there is value in synthesising and communicating the knowledge arising from across the research projects. This includes mining Research Council UK and European funded research and innovation to identify the relevant knowledge and evidence for infrastructure operators. This will be grounded in an understanding of priority needs for knowledge and evidence, allowing them to be mapped to research investments. Knowledge of these arises from continuing engagement with the IOAF, IET, ICE, IMechE and others. Areas of particular interest are interdependencies and extreme events or combinations; socio-economic implications, big-data for infrastructure resilience, multi-hazard risk assessment, and implications for achieving the Paris climate change agreement. This will be

used to inform potential future investments across the research councils.

**Adaptation and Resilience in the Context of Change (ARCC) Network**

**Next steps: Building and sharing the knowledge and evidence base**

IOAF: Opportunities to share experience and knowledge - dialogues

**The growing knowledge and evidence base**

- Infrastructure Transitions Research Consortium (ITRC) and Multi-scale infrastructure systems analytics (MISTRAL) <http://www.itrc.org.uk/>
- Adaptation in the energy sector <http://www.arcc-network.org.uk/futureinfrastructure/energy/>
- Engineering Grand Challenge 4: Identifying risk and building resilience into engineering systems <https://www.epsrc.ac.uk/funding/calls/howardengmtrcc/>
- Suite of new EPSRC-funded research fellows (risk and resilience) – to be announced
- NERC Environmental Risks to Infrastructure Innovation programme <http://www.nerc.ac.uk/innovation/activities/infrastructure/energyrisks/energyrisks/>
- Horizon 2020 Investments: Resilient Cities and Infrastructures <http://www.resilient-cities.eu/> and EU-CIRCLE <http://www.eu-circle.eu/>
- UK Collaboratorium for Research in Infrastructure and Cities <http://ukcric.co.uk/>

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The second speaker of the evening, **Dr Raghav Pant**, began by looking at the understanding of infrastructure system failure. Infrastructure failures do not tend to happen in isolation; they propagate and cascade throughout the physical and operational system of interdependent infrastructures. This creates disruptions amongst the socio-economic entities within the system which depend on the infrastructure, resulting in economic and other losses. These can create ripples through the infrastructure system. The importance of understanding these connections and the propagation of failure has been emphasised time and again in the realm of infrastructure planning. Documents such as the UK's National Infrastructure Plan, the Department for Transport's Transport Resilience Review and the ICE's State of the Nation infrastructure report have all noted a lack of systemic perspective and the need for a system-of-systems approach. While there is a broad appreciation for this, very little is actually done. It is not an easy task, and there is a general lack of evidence and analysis from the system-of-systems perspective to inform decision making.

The UK Infrastructure Transitions Research Consortium (ITRC) aims to address this by developing and demonstrating a new generation of simulation models and tools to inform the analysis, planning and design of national infrastructure. This has been developed by an inter-disciplinary group of engineers and social-scientists. To understand the

systemic risk perspective ITRC has broken the problem into four broad themes. The first concerns *extreme hazard analysis*. To understand the risks it is important to first understand the hazards. This theme seeks to understand the scenarios and probabilities of national infrastructure failure. The second theme looks at *infrastructure analysis*. This concerns the detailed understanding of national infrastructure as a complex system of systems, as well as the key vulnerabilities within the composite networks. The third theme investigates *infrastructure impact evaluation*, in particular the implications of interdependence, and how these can be understood from a modelling perspective. The final theme looks at *evaluating the economic losses* resulting from national infrastructure failures. These themes are connected together into a coherent system of systems framework.

Raghav then provided examples of some of the analysis and evidence generated under each of these themes. The *extreme hazard analysis* theme has looked to develop spatial hazard maps. This has included utilising the Environment Agency's national flood likelihood extent maps. ITRC partners JBA have developed comprehensive flood maps looking at all types of flooding. These provide evidence of the extent and predicted depth of flooding given a particular probabilistic event. These can then be used in multisite/multi-hazard analysis. This is based on the thinking that hazards cannot be fully understood if considered in isolation. Flooding can happen in combination with other hazards, and at multiple locations at the same time. Statistical models have been developed to look across multiple sites and identify appropriate indicators of hazards and create a much richer understanding.

In terms of *infrastructure analysis* ITRC has collated an extensive set of geo-spatial data for infrastructure. Most infrastructures are organised as networks, so this data set enables the construction of relevant network models. This includes data for electricity, gas, liquid fuels, rail, roads, airports, ports, water towers, water

pumping stations, sewage treatment works, solid waste facilities and telecom masts. In total over 1 million network assets have been mapped across Great Britain.

These infrastructures evolve as hierarchical networks. For example the electricity distribution system has a high-level network of large generation and transmission assets. Beneath this sits a lower-level of electricity sub-transmission assets, followed by local electricity distribution networks. There is a need to understand the behaviours within and between the different levels of the hierarchical infrastructure networks.

The assets of different infrastructure sector networks do not exist in isolation from one another. In addition to modelling individual infrastructure sector networks at various hierarchical scales, ITRC's analysis has also looked at topological interdependent networks across infrastructure sectors. For example, the modelling has looked at the interdependency links between the relevant assets in the national gas network and the various levels of the electricity hierarchy of networks. This modelling enables a richer understanding of the interdependency between the various infrastructure networks.

To understand the related sociological issues the group have also looked at customer demands and the flows of resources across the networks. These look at the grouping of infrastructure customers and how these affect the physical networks. The end-to-end delivery of electricity is modelled from the demand side to the supply side. This includes looking at usage statistics of direct electricity customers, where available, and the distribution of indirect customer demands on the energy network via other infrastructure systems such as sewage treatment, telecoms masts, water towers, railways, airports and ports.

Raghav then turned to look at how these models have been used in practice, and the wider impacts of the research.

ITRC have worked with many key stakeholders, including Infrastructure UK (IUK). With IUK the models have been used to perform an integrated critical assessment or hotspot analysis of the UK infrastructure networks. This has identified the geographical locations where there is a concentration of critical infrastructure, measured according to the number of customers directly or indirectly dependent on the infrastructures in that location. This modelling clearly shows the concentrations of energy, transport, waste, waste and ICT assets, as one would expect, correlating with major conurbations. Additional value comes from using the model to understand the network effects. This has highlighted assets, sometimes geographically removed from densely populated areas, which are nonetheless critical due to the way in which they are connected to the wider network. This knowledge can be used to inform strategies for enhancing the security and resilience of the network.

ITRC also collaborated with SAGE to look at vulnerability to extreme flooding. Various flooding scenarios were investigated. For each scenario the infrastructure assets that would be directly affected by the flooding were identified. Using the network models it was possible to also identify how other infrastructure systems might be affected via their dependency on those that were directly disrupted by flooding. This allows for an assessment of both the direct and indirect risks to infrastructure systems, and in each scenario the total number of infrastructure customers who might be affected, even those who do not directly rely on disrupted infrastructures located within the flooded areas. By first understanding the interdependencies between the systems, this approach builds on traditional analysis which tends to look just at the assets geographically located within the flood catchment area. This in turn helps develop understanding of the wider economic impacts of particular initiating events.

Another piece of work was conducted with the Department for Transport in relation to their resilience review. This work set out

to identify single points of failure in the railway network. A model was built of the whole railway network. The flows along each route were also modelled. Various disruption scenarios were then simulated to assess how the system was affected as a result of rerouting and other actions. Criticality was measured in terms of the volume of flows along routes, the losses of flows when routes are disrupted and the ratio of post-disruption losses to pre-disruption flows. This provides an insight into the capability of any given route to maintain its flow, therefore highlighting those that have a very limited capability and are particularly vulnerable feeling the effects of network disruptions.

The final piece of work Raghav described is looking at flood adaptation options with the Committee on Climate Change Adaptation. This looks at integrating the entire ITRC model risk analysis with a cost-benefit based approach. It looks at individual assets, such as single electrical substations in the energy network, their failures and the impacts of their failures. Potential adaptation strategies are then identified in consultation with National Grid and the wider electricity industry. These are then analysed in terms of the network. For example, a particular substation may be adapted by the addition of a concrete wall, thus minimise the risk of impact from flooding. Alternatively the whole substation could be relocated. For each the cost and benefits of each is assessed.

Raghav concluded his talk by summarising the system-of-systems network approach to risk analysis. It can be very data intensive, but as identified by many prominent governance stakeholders, it is necessary. We need a 'complete' perspective of the system and an understanding of systemic risks. The modelling undertaken by ITRC aims to achieve this. It has already been used to inform policy on infrastructure security and long-term planning for resilience and adaptation. The Multi-scale Infrastructure Analytics (MISTRAL) project will continue the work of ITRC looking deeper at local and regional scale as well as attempting to understand the UK's position within global infrastructure systems.

The final talk of the evening, delivered by **Professor Colin Taylor**, concerned work undertaken by the International Centre for Infrastructure Futures (ICIF). ICIF is one of the EPSRC-funded infrastructure projects described by Roger Street. It is a collaboration of six universities (Brighton, Bristol, Cranfield, Sussex, Southampton and UCL) led by Prof Brian Collins at UCL. Colin is the lead investigator at the University of Bristol. The project is looking at infrastructure business models, resilience and interdependency at a national and international scale.

Colin began by acknowledging that society is facing a number of very interesting 22<sup>nd</sup> Century challenges. What we do and how we address the challenges of today will impact the communities living 100 years from now. It will affect how they are able to cope with a changing future. Many of the changes they face will be a result of the things we are doing today and have done in the past. Issues such as climate change, food security, water security, natural hazards, energy systems, communication systems, transport systems, future cities, health, education and old-age are all societal challenges which engineers are fundamentally involved in. Perhaps the biggest challenge is poverty. We have a huge responsibility to reduce poverty around the globe. Today's young people, particularly those living in poverty, will be dealing directly with these 22<sup>nd</sup> Century challenges and their impacts. Our responsibility is to enable them to deal with these challenges effectively. Resilience is key to this.

A novel model of resilience is emerging from the work of the ICIF project at the University of Bristol. This focuses on how to be resilient. The underpinning concepts for this model come from work by the late Howard Odum. He investigated ecological system dynamics in terms of the flow of energy and matter as described in his books, such as 'Environment, Power, and Society for the Twenty-First Century'<sup>1</sup>. Odum uses the term 'Emergy' to capture the notion of the embodied energy which is transmitted through different parts of the ecological systems.

Resilience is a fundamental property of any successful system or living thing. The ability to cope with change is natural. Every animal and plant has an innate resilience. It is the way in which we survive as a species. If we are not resilient, we cannot cope with change; if we cannot cope with change the species will die out. The evolutionary records show many species that lacked sufficient resilience to deal with the changes they faced and became extinct.

In general, the individual members of a species have a limited capacity to acquire and transform energy for survival. Species have evolved different strategies for to address this. Methods include evolving to become physically large and dominating the resource network or developing large populations of independent individuals as a means to maximise the chance of the species surviving. Others, such as human beings, are very good at collaborating and working together. We can support each other in our individual and collective survival. We are also very good at creating tools and mechanisms to help us collaborate and survive. The thesis of this work is that it is human beings that are resilient not 'things'. These external things, such as infrastructure, help us as human beings to be resilient, but they are not necessarily in themselves intrinsically resilient.

Colin then turned to look at how we can be resilient, and use collaborative behaviours enabled by social and physical infrastructures to address the challenges we face. He began by discussing the impacts of the Tohoku earthquake and tsunami.

As a result of the movement of the subduction zone (the area where one tectonic plate moves under another) the whole of the east coast of Japan dropped by 1 metre. By the time the subsequent tsunami hit the Fukushima Daiichi nuclear power plant its wave walls were a metre lower than they were designed to be. Entire communities were destroyed by this natural hazard event. The resource flow systems - the means by which energy, matter food etc. are distributed - were

completely ruined. The infrastructure we created to enable us to acquire and distribute energy and matter for survival had been wiped out.

Resilience is really about being able to put back those community resource flows. When in a situation like the Tohoku earthquake it is necessary to very quickly identify the right things to do to move forward from the distrusted situation, and the right way in which to do those things. In this way resilience is about innovation and looking forward. It requires an understanding of the best steps to fulfil a desired purpose, and the best means through which to enact those steps.

Odum developed a symbolic language to describe energy flows. This provides a tool to look at the resource flows within our urban systems on which we depend. It provides a structured way of identifying and recording the *sources* of energy and other resources, the routes they take to *flow* through the city systems, and in particular, how they come together at critical points to *transform* into useful forms. It provides a unique way of looking at the *interdependency* of the resource flows on which we *depend*. From this we can look at understanding the infrastructure systems which convey these energy and resource flows from a more fundamental sense of their purpose. Ultimately, it is the valued and necessary resource flows and transformations that need to be recovered following a disruption. This may be achieved through different means than pre-disruption, and therefore is distinct from the recovery of the original social and physical infrastructures.

Colin compared the experiences of the 2011 Tohoku earthquake with those of the 2014 floods in Somerset as a means to analyse the actions that can be taken to become resilient. In particular he discussed the case of one Somerset resident that was able to keep their house protected from the direct consequences of the flooding compared to those who lived close by. This person happened to be a builder. He had good contextual awareness that allowed him to recognise

the rising flow of water. His profession afforded him the ability to be resourceful in the face of this. He drew on the labour and construction plant available to him and brought them to his house to construct a protective bund. He was able to work out the right things to do, and do those things right. The people living nearby were not as fortunate and in many cases saw their houses severely damaged by the flood waters. They did not have the resources they needed. They were completely dependent on external agents to provide their resilience to this type of hazard.

These types of hazard are unknowable in their actuality until they have happened. It might be possible to anticipate the sorts of things that might happen to a degree, but you don't know exactly what has happened until it has. As a consequence it is valuable to be able to learn very quickly in order to understand what has happened. Then it is possible to set a long-term purpose, or in other words 'what it is those affected actually want to achieve'. Reflecting on the Tohoku earthquake, it is clear that such learning exists at many different scales. The home-owner who has had their possessions destroyed will have the most detailed local knowledge at that place and time. The Prime Minister in Tokyo will be electronically receiving large amount of data, giving them the richest 'big picture' of the event. There will be others at intermediate levels with specific and valuable knowledge. A process is required that can bring this together to work what has happened and what should be done.

The long-term purpose might not resemble the pre-disaster state, particularly if the event has revealed vulnerabilities. Achieving this requires systemic thinking and resourcefulness. Collaboration is key to this. No one person can be resilient on their own. The homeowner in Somerset was dependent on the collaboration and coordination of his staff to bring the plant to his house and dig the bund. Learning and collaboration are crucial to resilience.

Dr Shima Beigi constructed a model of a resilient agent as part of her PhD at the University of Bristol<sup>3</sup>. This identifies the necessary qualities and actions a person needs to be enacting resilience. The model looks at the senses and resources required. These include sense of:

- history – how we have got to where we are,
- futures – where we might want to go,
- context,
- needs,
- wants,
- ethics,
- values, and
- resources

Absolutely crucial is a sense of purpose; a knowledge of what is to be achieved in the future and why. Underlying this is a sense of belief that we can get there, and a sense of confidence to actually undertake the journey. These are complemented by capabilities and resources.

While it is possible to look individuals as resilient agents, it is also possible to look at communities and organisations as a collective group of resilient agents. The objective is for the group to have the sense and capabilities to work together and deal with whatever changes emerge.

The individual or group must be good at learning and creativity. There must be a good knowledge base.

This resilient agent template is being used to look at long-term strategies. For example by 2065 the city of Bristol wants to be carbon neutral. That means that all of the supply networks in place in 2065 will have to be very different from the way they are now, and will have to go through many different transitions on the way to supporting that carbon neutral goal. All the networks will need to be resilient through those transition processes. Understanding the energy and resource flows that make the city what it is will be important, as well recognising that it is the people that are being resilient. The framework can be used to look at what can be done to enable people to develop their resiliency through the attributes of

sense and resources captured in the model. This will enable them to respond in a resilient way in order to achieve their outcomes.

Resilience is also about having positive mind-sets. There is a lot of interesting work looking at this within the field of psychology. Colin briefly highlighted the concept of Spiral Dynamics<sup>2</sup>. This identifies different patterns of thinking as a series of stages or waves. At one end of the scale is an isolated, instinctive survival sense while at the other end is a holistic and collaborative view of the whole. There are six other stages between these two. A highly-skilled individual can amend their patterns of thought to operate at the different levels as necessary. This may mean that during a crisis it is necessary to act a higher-level in order to generate a shared sense of purpose before moving to one of the middle layers aligned with a command-and-control model in order to reach the purpose.

To respond with resilience we need to be innovative. Achieving a stated purpose will often require the development of new capabilities through the connection of existing capabilities. Innovation is about bringing these strands of capability together and developing them to sufficient maturity. For High Speed 2 to achieve its purpose when it comes on line, many different systems and projects need to have been developed. They must be combined to a point of congruent maturity in order to achieve their common purpose. This is something we naturally do as part of many complex programmes. In that way resilience is no different from what we do normally; it is just that the circumstances are extreme. Developing resiliency and all of its associated senses and capabilities is therefore not just useful in rare circumstances; it is useful in day to day operations. It is valuable in normal circumstances.

An understanding of and integration with politics, governance, economics, the environment etc. are fundamental to our capability to be resilient.

When recovering from a disaster the system is moved through various levels of

tolerable performance improvement. Following a major disaster for example there needs to be a quick recovery of water, shelter and basic sanitation. This buys time to make the necessary actions to recover food supplies and thus incrementally improve the performance of the system. This requires exactly the same kind of innovation, resourcefulness and performance improvement processes as in normal time, just at a much greater scale. The response time is related to the power of the resilient agent(s). A powerful country like Japan can plot a recovery path to a natural disaster that is quicker than a country with fewer resources. Haiti for example does not have as powerful an economy or as many available resources as Japan, and as such is still recovering from the earthquake it experienced in 2010.

These ideas have been applied to the Clifton Suspension Bridge to try and understand its resilience. The processes necessary for the bridge to fulfil its purpose as a safe crossing of the Avon Gorge have been identified. These processes can be unpacked, deconstructed and refined into sub-processes and different aspects of performance. The resilient agent model can then be applied to this to evaluate the resilience of the Clifton Suspension Bridge Trust and the bridge itself. Clarity of purpose and resourcefulness can be analysed and assessed. Modelling has been used to assess evidence of performance against the necessary actions and sub-processes. The tool has been very useful for producing a dashboard for assessing resilience and identifying areas where there is uncertainty, or more could be done to develop the related sense or resourcefulness.

In the future it may be possible for individuals or organisations to implement the model through an application that allows them to monitor the performance against the attributes of a resilient agent in real time. It would tell you how resilient you were and identify gaps in your capabilities. This could lead to a new resiliency marketplace whereby

companies could offer the tools and methods to address identified shortfalls.

Colin concluded his talk by reiterating that learning and collaboration are key to resilience. They develop the resourceful human agency that ensures we can sustain the flow of necessary and valued resources, while physical and social infrastructures enable people to be resilient.

**Andy Buchan** thanked the speakers for their fascinating presentations before opening the session up to questions from the audience.

The first question asked the cost of resilience and whether financial institutions have a collaborator role to play? Colin responded first suggesting we should first ask the value of resilience before considering the cost. Understanding what you need to be able to do in order to be resilient in extreme circumstances is actually useful in ordinary operations. It can generate a lot of value. The problem comes in expressing that value. The tendency is to try and do this on a cost basis, but that is not necessarily the best way. This is one of things being investigated by the ICF project. It could be argued that one cannot afford to not be resilient. Resilience cannot be built all at once, but adding to the capabilities that make up resilience is also useful in a general sense, and in the longer term. Pervasive short-term views can be a challenge to developing these capabilities that may be valuable to us for decades and in ways that we probably can't even conceive of at the moment. We need a way of capturing the value proposition of this and perhaps breaking away from the business-as-usual mind-set of cost-benefit analysis. There isn't necessarily a solution, but this line of thinking may be valuable in challenging the current approaches. Roger added that a lot of the discussions going in the research community are looking at similar paradigm shifts, many of which were reflected in Colin's talk. For example there is a move towards the consideration of infrastructure in term of the services it provides, rather than solely in terms of

physical assets. Resilience then becomes a question of the sustainability of these services. The ability to provide bottled water during a flood is an example of the resilience of the service outcome even when the normal distribution assets are disrupted. These ways of thinking require new approaches to the valuation of resilience. The question of how to value resilience is being asked across Europe and beyond with one of the difficulties being the lack of a common framework for the valuation of resilience. Raghav reflected on the wider costs of extreme hazards that can be difficult to evaluate, such as the costs to national security or the security of communities. ITRC has been working with Infrastructure UK, a part of HM Treasury to use their infrastructure models to look at strategic investments into the national infrastructure. Andy quoted the late Trevor Kletz: "If you think safety is expensive, try an accident". Within communities and organisations there are important discussions to be had about how resilient we would like to be.

The second question asked whether there are any hard measures of resilience and interdependency, so that we can better understand the impacts of investments or whether the focus for resilience should be on recovery rather than preventative measures. Colin considered the potential difference between robustness and resilience. A robust system is one that can withstand shocks with a minimal disruption to performance. In designing infrastructure systems we may design them to be robust up to some level of hazard that we can tolerate. Once beyond that level, some level of damage and loss of performance is accepted, again down to a tolerable level. Resilience is about the energy and resources to repair the system, to restore the performance level or adapt the system. In the domain of earthquake engineering there has been a move towards *performance based engineering* whereby a structure is designed to fail in a controlled way. Damage is allowed to develop predictably like the crumple zone at the front of a car. The engineers make sure they understand

how the structure is likely to fail and make sure it doesn't fail under particular circumstances. The result of this is that things have failed, as intended, in real earthquakes but the infrastructure owners have responded that they actually do not want the structures to fail as it puts them out of business for extended periods. Now things are designed to be much more robust, because the cost of making the structures robust is small compared to the longer term business disruptions should they fail. In California and Japan the cost of the damage to buildings following an earthquake is very small in comparison to the subsequent commercial impacts. This changes the value proposition and makes the upfront investments much more attractive. This is particularly the case where people have a memory and awareness of previous disruptions.

Roger reflected on many of the ongoing discussions around how robust things need to be, and what level of failure and disruption society will accept. Understanding what is an acceptable investment in robustness and resilience first needs an understanding of what constitutes an acceptable loss or failure. There is a lot of uncertainty in this area. Everybody expects water when they turn on the tap and electricity at the flip of a switch, but we know there may come a time when achieving this becomes more problematic. We need to investigate the failure rate society is willing to accept and how much people are prepared to spend. There are countries where fresh water is not always available, and where electricity may not be continuously available. Is the UK willing to accept the same situation? Some years ago betterment was not something widely considered by insurance providers. If something failed it was replaced with an equivalent. Following Hurricane Katrina in 2005 US insurers stated to look at betterment as good investment. Therefore there are also questions to be asked following disruption to infrastructure regarding like-for-like replacement, or investing in the opportunity to make the system more robust and more resilient at a time when it is probably cheaper to do so. The

infrastructure we have will fail in the face of future changes if we do not invest. Roger concluded that in some circumstances, it already is.

Colin concurred that disasters can in fact present enormous opportunities for improvement. Most organisations want to improve under normal circumstances anyway; when faced with a disaster they are absolutely forced to take action. If there are plans in place for an improvement, then the disruption may present an opportunity to bring those plans forward. What you gain is an extra period of benefit from the planned improvement. However, you can only do this if you understand the robustness-resilience-innovation process coupled with a vision for the future.

All of your stakeholders have to be prepared to move forward with you, Roger added. All of your staff, your customers, those you depend upon and those who depend upon you must be aligned behind that purpose. If this is not the case there may be a risk of creating a system that is less robust and resilient.

Andy added that these situations can also enable people to break down the barriers between organisational silos and develop more resilient working structures. He thanked the audience for their participation and highlighted the importance of integration, interdependency, communication and collaboration that was apparent from all three presentations. He then handed over to the Hazards Forum Chairman who once again thanked the speakers on behalf of the audience and invited those in attendance to continue their discussions over refreshments.

<sup>1</sup>Odum, H. 'Environment, Power and Society for the Twenty-First Century: The Hierarchy of Energy', Columbia University Press, 2007

<sup>2</sup>Beck, D.E. and Cowan, C. 'Spiral Dynamics', Blackwell, 1996

<sup>3</sup>Beigi, S. 'Mindfulness Engineering: A Unifying Theory of Resilience for Volatile, Uncertain, Complex and Ambiguous (VUCA) World', PhD Thesis, Dept of Civil Engineering, University of Bristol, 2014

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## Health and Safety Scientists Given Centre Stage

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The Health and Safety Executive (HSE) has a breadth of experience and extensive expertise in science and engineering that is working to help predict the safety and health challenges of the future. At their headquarters in Bootle, Liverpool and its laboratory in Buxton, there are over 850 science experts, including psychologists, microbiologists and explosive specialists that are researching and testing innovative ways to make our workplaces safer and healthier. The **annual science review** showcases a number of examples of the year's research and how it will benefit workers, businesses and stakeholders.

Chief scientific adviser and director of research, Professor Andrew Curran, said: "HSE is a strongly scientific and evidence based organisation. Tragically 142 people lost their lives at work in 2014/15; our focus is to understand the root cause of these incidents. Our forensic approach helps us to secure justice, our experts testify in court every week. By learning from the past we hope to be able to support the present by transferring knowledge to others in the health and safety system and protect the future by better understanding the risks and challenges that social, economic and technical changes could bring."

More information can be found on the HSE's website: <http://www.hse.gov.uk/research>

The Science Review can be read in full at: <http://www.hse.gov.uk/research/content/science-review-2016.pdf>

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## From the Secretary...

Readers wishing to plan ahead may wish to note that forthcoming Evening events, after 14<sup>th</sup> June, are being planned for Tuesday 20<sup>th</sup> September at IMechE (as mentioned in the Diary below), Wednesday 7<sup>th</sup> December with IChemE and Tuesday 28<sup>th</sup> March 2017 at ICE after the AGM.

Brian Neale

## Calendar of Events

Please check the Events section of the Hazards Forum website for more information at [www.hazardsforum.org.uk](http://www.hazardsforum.org.uk) and to see any updates in the calendar. These may include additional events or perhaps amendments to the Events shown below. Please note that attendance at Hf events is by invitation via the Hf admin email address.

Date	Event	Venue	Contact/further information
June			
14 <sup>th</sup>	Hf Event: Procedural compliance; What works and why?	Institution of Civil Engineers, One Great George Street, Westminster, London, SW1P 3AA	<a href="mailto:admin@hazardsforum.org.uk">admin@hazardsforum.org.uk</a>
15 <sup>th</sup>	IET Event: Cyber Security in Modern Power Systems	One America Square Conference Centre, London	<a href="http://conferences.theiet.org/cyber-grid/about/index.cfm">http://conferences.theiet.org/cyber-grid/about/index.cfm</a>
15 <sup>th</sup>	ICE Event: From Risk to Resilience: Practice made perfect – ICE's 11 <sup>th</sup> Brunel International Lecture	Institution of Civil Engineers, One Great George Street, Westminster, London, SW1P 3AA	<a href="https://www.ice.org.uk/events/brunel-international-lecture-2016-london">https://www.ice.org.uk/events/brunel-international-lecture-2016-london</a>
15 <sup>th</sup> – 17 <sup>th</sup>	IChemE Event: Applied Hazards and Operability Study	London, UK	<a href="http://www.icheme.org/appliedhazard">http://www.icheme.org/appliedhazard</a>
16 <sup>th</sup>	SaRS Event: Big Projects, Big Problems?	Friends House, 173-177 Euston Rd, London NW1 2BJ	<a href="mailto:info@sars.org.uk">info@sars.org.uk</a>
16 <sup>th</sup>	SaRS Event: Risk in a Regulatory Context	RSSB, Helicon, London	<a href="http://www.sars.org.uk/branches/london-branch/">http://www.sars.org.uk/branches/london-branch/</a>
23 <sup>rd</sup>	IET Event: Environmental and Safety Assurance Symposium	Abbey Wood, Bristol	<a href="http://www.theiet.org/events/local/235062.cfm?nextId=235402">http://www.theiet.org/events/local/235062.cfm?nextId=235402</a>
23 <sup>rd</sup> – 24 <sup>th</sup>	IChemE Course: Introductions to Risk Assessment	Rugby, UK	<a href="http://www.icheme.org/ra">http://www.icheme.org/ra</a>
28 <sup>th</sup>	IMechE Event: reliability and asset management 2016 – Preventing the deterioration of assets and maintaining a high level of reliability	Hotel La Tour, Albert St, Birmingham, B5 5JE	<a href="http://www.imeche.org/alarp">www.imeche.org/alarp</a>
29 <sup>th</sup>	RAEng Event: Robots - faithful servants or existential threat?	RAEng, Prince Philip House, 3 Carlton House Terrace, London, SW1Y 5DG	<a href="mailto:events@raeng.org.uk">events@raeng.org.uk</a>
30 <sup>th</sup>	ICE Event: ICE Flooding and Water Management 2016	London, UK	<a href="http://www.ice-conferences.com/ice-flooding-and-water-management-2016/about/">http://www.ice-conferences.com/ice-flooding-and-water-management-2016/about/</a>
30 <sup>th</sup>	SaRS Event: Dangerous Decisions, Lessons from Andrew Hopkin's study of the Macondo Blowout	Birchwood Golf Club, Warrington	<a href="http://www.sars.org.uk/branches/the-north-west-branch/">http://www.sars.org.uk/branches/the-north-west-branch/</a>
September			
20 <sup>th</sup>	Hf Event: The Nuclear Legacy - progress with reducing the hazard (Provisional title)	IMechE, 1 Birdcage Walk, London SW1H 9JJ	<a href="mailto:admin@hazardsforum.org.uk">admin@hazardsforum.org.uk</a>
25 <sup>th</sup> – 29 <sup>th</sup>	SaRS Event: ESREL 2016, Glasgow UK	Conference Centre of the Technology and Innovation Centre (TIC), Glasgow	<a href="http://www.sars.org.uk/events/esrel-2016-glasgow-uk/">http://www.sars.org.uk/events/esrel-2016-glasgow-uk/</a>

The Hazards Forum's Mission is to contribute to government, industry, science, universities, NGOs and Individuals to find practical ways of approaching and resolving hazard and risk issues, in the interests of mutual understanding, public confidence and safety.

The forum was established in 1989 by four of the principal engineering institutions because of concern about the major disasters which had occurred about that time.

The Hazards Forum holds regular events on a wide range of subjects relating to hazards and safety, produces publications on such topics, and provides opportunities for interdisciplinary contacts and discussions.

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