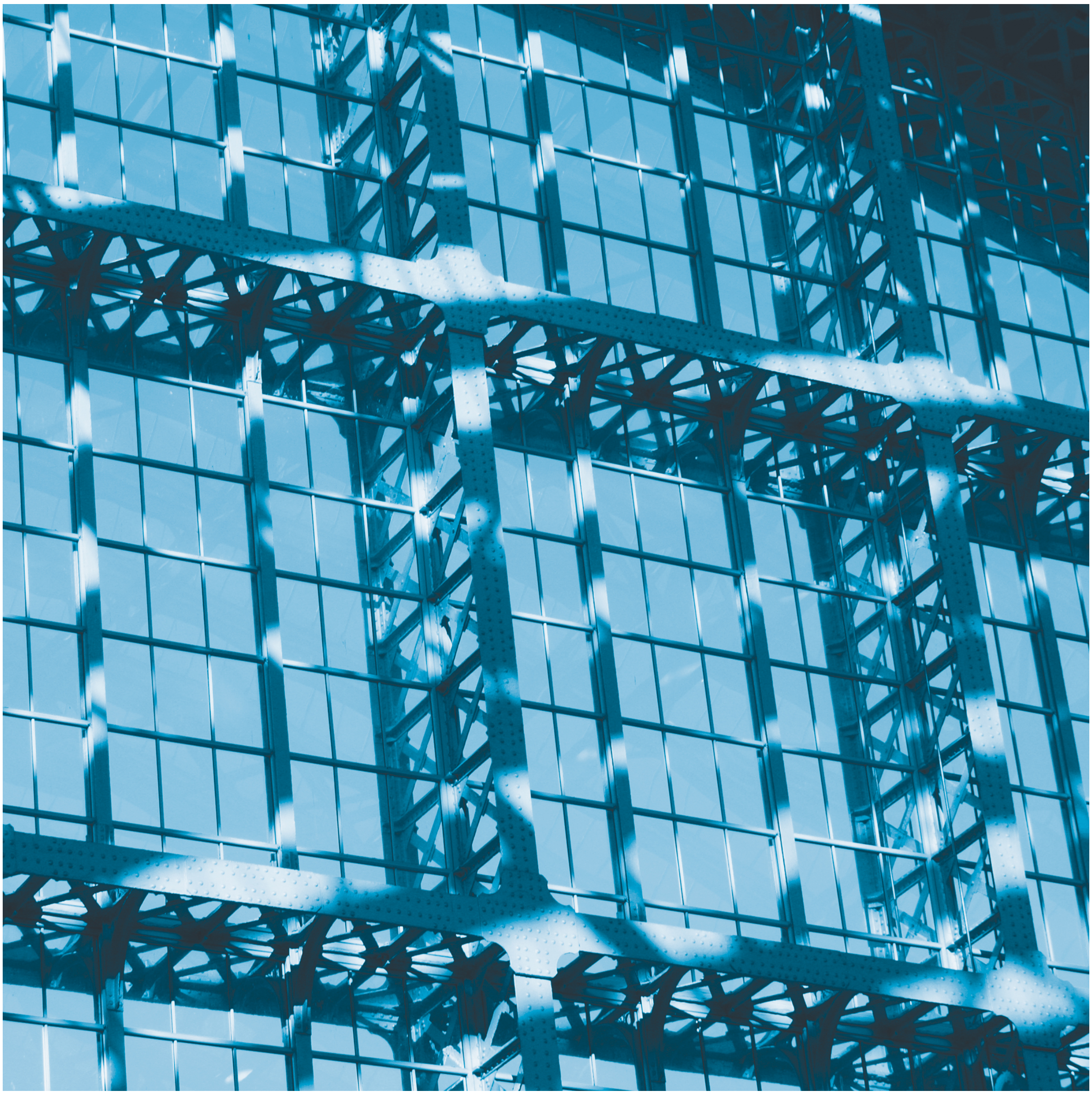

ITRC Early career researchers conference: Infrastructure delivery in an uncertain future

Clare College, Cambridge
27 November 2012

ITRC

The UK Infrastructure Transitions Research Consortium (ITRC), a 5-year EPSRC-funded research programme, is working in close collaboration with high level stakeholders from government and industry to inform the analysis, planning and design of national infrastructure through the development and demonstration of new decision support tools.

This inaugural ITRC Early Career Researcher conference will allow researchers involved in the ITRC and wider infrastructure research community to showcase and share innovative thinking on future challenges and opportunities.

Agenda

Infrastructure delivery in an uncertain future	
10:00	Welcome & introduction
	Prof Jim Hall, ITRC Principal Investigator, Oxford University
10.10	Career development, the EPSRC strategy and its infrastructure portfolio
	Dr Caroline Batchelor, EPSRC
Session 1	
Chair: Prof Jim Hall	
10.30	A factsheet about the UK's national infrastructure system Developing intuitive measures of the UK's infrastructure system performance
	Alex Lorenz, Oxford University (ITRC)
10.45	An open source spatial database schema and interface for the storage, representation and analysis of interdependent infrastructure networks
	David Alderson, Newcastle University (ITRC)
11.00	Assessing the vulnerability of interdependent infrastructures to extreme flood events
	Raghav Pant, Oxford University (ITRC)
11.15	Refreshment break
Session 2 (in parallel)	
	2a. Interdependencies and networks
	Chair: Prof Tim Broyd, UCL
11.40	The relationship between the economy and infrastructure in a natural disaster
	Scott Kelly, Cambridge University (ITRC)
11.55	Identifying the presence of hierarchical structure in infrastructure networks
	Craig Robson, Newcastle University
12.10	A framework to assess the effect of interdependency on infrastructure network vulnerability
	Matthew Holmes, Newcastle University (United Utilities & Yorkshire Water)

12.25	Integrating hazard and interdependent infrastructure models: risk assessment of key nodes
	Sarah Nodwell, Heriot-Watt University (BIOPICCC)
12.40	Discussion session
	2b. Infrastructure Futures
	Chair: Prof Chris Rogers, Birmingham University
11.40	Transitions of the UK Water-Energy Nexus
	Ed Byers, Newcastle University (ITRC)
11.55	Assessing the material dependency of low carbon technology infrastructure transitions
	Jonathan Busch, Leeds University (Undermining Infrastructure)
12.10	A solution based on human circulatory system analogy for the single infrastructure-based utility provision to households
	Fatih Camci, Cranfield University (All-in-one)
12.25	Resource-efficient and service-oriented infrastructure operation: towards MUSCos: Multi-Service Utility Companies
	Christof Knoeri, Leeds University (Land of the MUSCos)
12.40	Discussion session
13.10	Lunch
Session 3 (in parallel)	
	3a. Infrastructure Delivery
	Chair: Dr Douglas Crawford-Brown, Cambridge
14.00	The future's electric - can we take the heat?
	Ruth Wood, Manchester University (RESNET)
14.15	The assessment of current and future impacts of weather and climate on transport
	David Jaroszweski, Birmingham University (FUTURENET)
14.30	Resilience and sustainability assessment in the context of post-disaster infrastructure rebuild
	Kristen MacAskill, Cambridge University
14.45	Discussion session

	3b. Future Urban infrastructure
	Chair: Roger Street, UKCIP
14.00	The Evolution of the Physical Internet Infrastructure and its Impact on the Economic Development of Cities
	Ed Oughton, Cambridge (ITRC)
14.15	Challenging Lock-in through Urban Energy Systems: learning from the case studies
	Ksenia Chmutina, Loughborough (CLUES)
	Developing Urban Retrofit Roadmaps in the Context of a Low Carbon Agenda: Identifying Disruptive and Sustaining Technologies
	Judith Britnell, Oxford Brookes (Retrofit 2050)
14.45	Discussion session
15.10	Refreshment break
Session 4	
Chair: Prof Jim Hall	
15.25	ITRC EAG & international infrastructure research landscape
	Prof Tim Broyd, UCL and Chair of the ITRC Expert Advisory Group
15.45	Publication opportunities and delivery of impact from research
	Prof Chris Rogers, University of Birmingham and Chair of the Institution of Civil Engineers Innovation & Research Panel
16.05	Discussion: what next?
16.30	Close & networking

Participants

Early career researchers			
David	Alderson	david.alderson@ncl.ac.uk	Newcastle University
Simon	Blainey	s.p.blainey@soton.ac.uk	University of Southampton
Judith	Britnell	jbritnell@brookes.ac.uk	Oxford Brookes University
Jonathan	Busch	j.busch@leeds.ac.uk	University of Leeds
Edward	Byers	e.a.byers@ncl.ac.uk	Newcastle University
Fatih	Camci	f.camci@cranfield.ac.uk	Cranfield University
Ksenia	Chmutina	k.chmutina@lboro.ac.uk	Loughborough University
Raul	Fuentes	r.fuentes@ucl.ac.uk	UCL
Yasuaki	Hijioka	yasuaki.hijioka@ouce.ox.ac.uk	University of Oxford
Matthew	Holmes	matthew.holmes@uuplc.co.uk	Newcastle University
Xiaolong	Hu	xiaolong.hu@postgrad.manchester.ac.uk	University of Manchester
David	Jaroszweski	d.j.jaroszweski@bham.ac.uk	The University of Birmingham
Scott	Kelly	sjk64@cam.ac.uk	University of Cambridge
Christof	Knoeri	c.knoeri@leeds.ac.uk	University of Leeds
Alexander	Lorenz	alexander.lorenz@ouce.ox.ac.uk	University of Oxford
Kristen	MacAskill	kristen.macaskill@gmail.com	University of Cambridge
Marcela	Mele	marcela.mele@hull.ac.uk	University of Hull
Sarah	Nodwell	scn5@hw.ac.uk	Heriot-Watt University
Edward	Oughton	ejo31@cam.ac.uk	University of Cambridge
Raghav	Pant	raghav.pant@ouce.ox.ac.uk	University of Oxford
Craig	Robson	c.a.robson1@ncl.ac.uk	Newcastle University
Katy	Roelich	K.E.Roelich@leeds.ac.uk	Leeds University
Kelvin	Rose	kelvinrose@live.co.uk	University of Birmingham
Jonathan	Schachter	jonathan.schachter-2@postgrad.manchester.ac.uk	University of Manchester
Scott	Thacker	scott.thacker@ouce.ox.ac.uk	University of Oxford
Douglas	Thomson	d.c.thomson@dundee.ac.uk	University of Dundee
Tatiana	Vakhitova	tvv21@cam.ac.uk	University of Cambridge
Ruth	Wood	ruth.wood@manchester.ac.uk	University of Manchester
Kate	Young	katherine.young@ouce.ox.ac.uk	University of Oxford
Chengchao	Zuo	geocz@leeds.ac.uk	University of Leeds

Invited participants			
Caroline	Batchelor	Caroline.Batchelor@epsrc.ac.uk	EPSRC
Tim	Broyd	tim.broyd@ucl.ac.uk	UCL
Douglas	Crawford-Brown	djc77@cam.ac.uk	University of Cambridge
Jim	Hall	jim.hall@eci.ox.ac.uk	University of Oxford
Vicky	Hayman	vicky.hayman@ukcip.org.uk	University of Oxford
Sarah	Holmes	slh85@hermes.cam.ac.uk	University of Cambridge
Chris	Rogers	c.d.f.rogers@bham.ac.uk	Birmingham University
Phil	Sivell	phil@philsivellconsulting.com	Phil Sivell Consulting
Roger	Street	roger.street@ukcip.org.uk	University of Oxford

Abstracts

A factsheet about the UK's national infrastructure system
Developing intuitive measures of the UK's infrastructure system performance

Alexander Lorenz, Justin J. Henriques†*

** Environmental Change Institute, University of Oxford, UK*
† Department of Engineering, James Madison University, Harrisonburg, VA 22807, USA

Corresponding author: Alexander Lorenz (alexander.lorenz@ouce.ox.ac.uk)

National infrastructure (NI) provides infrastructure services to customers (e.g. households, industry, and businesses). The performance of NI services is a multivariate construct because defining and measuring performance can occur at different locations, points in time, and with respect to a number of priorities and metrics. However, high-level decisions and comparisons are often made by using performance indicators of NI systems. For example, infrastructure performance indicators are often used to describe differences in economic productivity and competitiveness between countries. This paper argues that in order to effectively use information about NI performance, indicators needs to use intuitive units instead of complex aggregated measures. This paper provides a "zero-order" version of such indicators of NI system performance, which can assist in answering the following questions:

1. How much infrastructure capital is there and how significant are the planned infrastructure investments?
2. How many infrastructure assets are there, and what is the current level of supply for infrastructure services provided by these assets?
3. What is the current environmental impact of the NI system (in terms of CO_2 emissions and air pollutants)?

An open source spatial database schema and interface for the storage, representation and analysis of interdependent infrastructure networks

David Alderson, Craig Robson, Tomas Holderness, Stuart Barr, and Alistair Ford

School Civil Engineering & Geosciences, Newcastle University, Newcastle upon Tyne, UK.

Corresponding author: David Alderson (David.Alderson@ncl.ac.uk)

The evolution of infrastructure networks often leads to a 'network-of-networks' being created, whereby components from one system become dependent upon a service or commodity from another infrastructure system (Rosato, 2008). Such physical interdependencies between infrastructure systems are important to understand because these relationships can result in infrastructure networks being more vulnerable and exposed to greater risk of failure. One important relationship between infrastructure networks is that of their spatial interdependency, as failure in one network as the result of a spatially localised event (such as flooding) may propagate or cascade to other infrastructure networks within the same neighbourhood. To model and understand how spatial dependencies and interdependencies introduce complexity and risk to a series of networks, a holistic approach to network modelling, representation and analysis is required. Traditional approaches have often considered physical infrastructure networks in isolation and have neglected to consider the spatial interdependencies that are present. Furthermore, spatial network representation and analysis has often been performed within a GIS environment, which can lack the analytical framework and capability to handle the complex analysis required to understand spatial interdependencies and what effects they can have on networks.

To address these issues we present in this work an open source spatial database schema and interface that couples the complex network analysis functionality available within the NetworkX Python package to the robust data storage capability of a PostGIS spatial database. The PostGIS database schema allows the explicit spatial representation of an infrastructure system as a network model, while the interdependencies between two or more such network models are represented by a series of related spatial interdependency tables.

Analytical analysis of spatial infrastructure networks and their interdependencies is conducted using the functionality of NetworkX. A Python-based wrapper has been developed that allows a user to request a network or series of interdependent networks and pass this/these to NetworkX for analysis, manipulation and interpretation. To demonstrate the high-level of functionality provided by this software framework we present a relatively simple spatial interdependency failure analysis using the National Grid-owned electricity substation network and the London Tube network within the Greater London Authority. These two infrastructure networks have been encoded within the schema along with a first-order approximation of their spatial interdependency. This has then been used within a simple failure model using NetworkX to simulate the sensitivity of the London Underground to failure within the electricity national grid using metrics of degree and betweenness.

References

Rosato, V. S. (2008). A Complex System's View of Critical Infrastructures,. In D. Helbing, Managing Complexity: Insights, Concepts, Applications (pp. 241-260). Springer.

Assessing the vulnerability of interdependent infrastructures to extreme flood events

Jim Hall, Scott Thacker, Raghav Pant

Environmental Change Institute, University of Oxford, UK

Corresponding author: Raghav Pant (raghav.pant@ouce.ox.ac.uk).

Infrastructure systems are interconnected because they share resources and information for improved functionality. One drawback of interdependence is that the failure of one infrastructure component may propagate through the system causing far-reaching disturbances to other infrastructures. This can be detrimental not only to the Nation's economy, but to the health and wellbeing of the populace. Recognising the interdependencies that exist between spatially distributed infrastructure assets, a methodology has been developed utilising a well-populated database of the UK's national infrastructure. This methodology seeks to identify the key vulnerabilities, implications of interdependence, and the potential consequences of major infrastructure failures. In this study we assess the vulnerability of a selection of key infrastructure assets to a number of spatially extensive flood hazards. In addition to estimating the direct vulnerability of assets due to intersection with the hazard, the inclusion of a demand dependency mechanism allows the vulnerability of more assets to be characterised. Counting the numbers of vulnerable assets provides estimates for the direct consequences of such extreme climate events. The indirect consequences are then estimated through the construction of a failure footprint for each vulnerable asset, where a footprint area and associated customer estimates are assigned to supply nodes within the network.

The relationship between the economy and infrastructure in a natural disaster

Scott Kelly

Cambridge Centre for Climate Change Mitigation Research, University of Cambridge, UK.

Corresponding author: Scott Kelly (sjk64@cam.ac.uk)

The economy and the infrastructure systems on which it relies are irrefutably and intrinsically linked in complex ways. Economic development relies on infrastructure as a means to supply the energy required as an input in production; provide the transport networks to distribute goods and services around the economy; and, to remove waste once all economic value has been extracted from the materials finally consumed. However, infrastructure systems also rely on the economy for expansion, maintenance, production. Thus the economy and infrastructure are dependent on each other symbiotically. Deeper understanding for how these two systems interact is critical, especially for understanding the impacts of an economy after a disaster. After a disaster infrastructure systems are often compromised affecting the total output in the rest of the economy. Likewise, a reduction in economic output may also disrupt infrastructure services creating a positive feedback loop and thus amplifying the effects of the disaster. Input-output methods have widely been used to analyse the effects of disasters on the economy. The most common method is to model changes to final demand and thus solving the Leontief inverse. A weakness of this approach is that it assumes the connections through the economic supply chain are a one-way street going from final demand back up the production supply chain. This is perfectly acceptable for sectors that face no supply constraints and are only limited by final demand. However, this approach makes no sense for sectors of the economy that are supply constrained (i.e. spectral output is curtailed by some exogenous factor such as a natural disaster). This research paper seeks to understand the relationship between infrastructure and the economy by analysing the forward and backward linkages of different infrastructure types in the economy. Thus we will be able to determine – for each infrastructure category – whether other sectors depend more on infrastructure or alternatively whether infrastructure depends more on other sectors of the economy for economic output. Finally, we will also be able to ascertain the economic relationships between different infrastructure categories. This information will then be used for the development of a national infrastructure economic model of the United Kingdom for modelling natural disasters.

Identifying the presence of hierarchical structure in infrastructure networks

Craig Robson, Stuart Barr, Phil James and Alistair Ford

School Civil Engineering & Geosciences, Newcastle University, Newcastle upon Tyne, UK.

Corresponding author: Craig Robson (c.a.robson1@newcastle.ac.uk)

Over the past decade there has been significant interest in gaining a better understanding of how infrastructure networks function as a complex system, influenced by well publicised critical infrastructure failures. To this end, a wealth of recent research has investigated the resilience of individual infrastructure networks and increasingly how this is attenuated by coupled dependency and interdependency between networks. In such studies, the topology of networks is often the means by which the analysis of resilience is performed, where the results are compared to theoretical graph-models such as random, small-world and scale-free networks; work that has led many studies to conclude that infrastructure networks exhibit a scale-free structure. However, such work ignores the possibility that infrastructure networks may be organised either spatially or logically over multiple levels or interrelated domains, possibly forming an important family of infrastructure networks that may exhibit subtly different resilience patterns. In particular, it has been suggested that some infrastructure networks have a well organised hierarchical spatial or logical structure, and hence a different resilience to various forms of failure. However, to date the explicit treatment of hierarchical networks with respect to infrastructures and whether they exhibit different behaviour to scale-free networks has not been fully investigated.

In this work we present initial results that aim to investigate if key infrastructure networks exhibit a hierarchal tendency and how this may change their resilience perturbations. Initially, we have employed a range of theoretical synthetic networks to ascertain if the topology of hierarchical networks is indeed seemingly different. The analysis has been performed using python and the python networkx library, facilitating an in-depth analysis which covers the theoretic graph spectrum. Eight graph models have been investigated, including the Albert-Barabasi (scale-freee) model, the Watts-Stogatz (small-world) model, the Erdos-Renyi and gnm (random) models, along with the standard hierarchal balanced tree model. In order to generate more realistic hierarchal networks, hierarchical community models have been used and two bespoke in-house algorithms ('hierarchical random' and 'hierarchal random+')

A suite for each graph structure was generated analysed using a range of metrics which included the assortativity coefficient (measures the correlation between topologically connected nodes in terms of their degree structure) and the max betweenness centrality value (a per-node normalised measure of the number of shortest paths between all node pairs which pass through the node). The results suggest there is a clear and significant difference between traditional graph structures and those of a hierarchical structure. This in turn suggests in the case of the theoretical graph-models investigated that hierarchal networks exhibit distinctive topological structure that if replicated in real infrastructure networks may reveal new insights into the their 'true' resilience to perturbations such as random failures or targeted attacks. This will be investigated in future work by extending the analysis to a range of real world infrastructure networks.

A framework to assess the effect of interdependency on infrastructure network vulnerability

Matthew Holmes, Dr Sean Wilkinson

School of Civil Engineering and Geosciences, Newcastle University, UK.

Corresponding author: Matthew Holmes (Matthew.Holmes@uuplc.co.uk)

It is widely accepted that interdependence between infrastructure systems represents a risk to the provision of essential services (Vespignani et al. 2010, Park et al. 2011 Cabinet Office 2011) but those managing this risk are limited by its uncertainty; tightly coupled, interacting systems create a complexity which makes incidents highly unpredictable (Reason 1990). Multiple studies have assessed the interdependence of specific systems in stand-alone cases (c.f. Buldyrev et al. 2010, Wang et al. 2012) which are beyond the capabilities of the average water utility provider, thus risk managers in water companies require a more pragmatic approach.

The problem is characterised by high complexity and limited resources. Complex in that infrastructure consists of multiple subsystems with their own specific vulnerabilities so the framework must be adequately precise. However, managers cannot afford detailed assessments of thousands of assets so must accept a level of abstraction and be prepared to justify why certain vulnerabilities were disregarded.

The framework is a progressive process which discards low risks to focus on substantive issues. Generic fault and event trees are combined into bow-tie drawings to trace the main pathways of risk through the interdependent systems; then detailed studies of these pathways are used to direct interventions to manage risk according to the company's risk appetite. Results from these studies can then be passed back up to the high level analyses to validate the results and test assumptions.

Work to date demonstrates the framework using preliminary input data and has shown the method to be effective at assessing, screening and, importantly, communicating risks to stakeholders. Ongoing case studies are applying these methods in the context of water studies to further test the frameworks viability.

Integrating hazard and interdependent infrastructure models: risk assessment of key nodes

Sarah C. E. Nodwell

School of the Built Environment, Heriot-Watt University, Edinburgh, UK

Corresponding author: Sarah Nodwell (scn5@hw.ac.uk)

It is expected that in future extreme weather events, such as flooding, are to become more likely, both in scale and frequency. Because of this, it is necessary to assess flood risk to critical infrastructure networks like water, electricity, and gas. Infrastructure models are commonly used to examine the propagation of failure in a complex system-of-systems including interdependencies between networks, such as the cascade of electricity failure on water and gas networks. Yet a problem exists: how to determine the nodes most likely damaged in a hazard scenario which cause the initial failure.

In order to estimate the likelihood of node failure, this research has coupled a weather-related hazard (flood) model with an extended network flow infrastructure interaction model and applied to a case study in England. The flood model determines the hazard to nodes in the infrastructure network by assessing the flood risk area and examining the spatial relationships between demand nodes, such as hospitals, and the networks that supply the services. As flood depths and extents in the case study area are rapidly generated, the likelihood of node failure under a range of future flooding scenarios is considered.

This approach allows a range of hazard scenarios and adaptation options to be simulated, allowing a range of adaptation measures to be considered.

If the nodes which would be most critical for infrastructure functioning during a hazard situation are known, it is possible to minimise impact on the entire network using adaptation measures. By using this approach, the nodes to focus adaptation may be limited to those key nodes that pose risk of failure to the entire network.

Transitions of the UK water-energy nexus

Edward Byers, Dr Jaime Amezaga*, Prof Jim Hall†*

** School of Civil Engineering & Geosciences & Tyndall Centre for Climate Change Research, Newcastle University, Newcastle upon Tyne, UK*
† Environmental Change Institute, University of Oxford, Oxford, UK

Corresponding author: Edward Byers (e.a.byers@newcastle.ac.uk)

Energy and water systems have become essential building blocks of human civilisations and their functionality much inter-linked, interdependent. All over the world, the availability of water has given us cheap energy, and cheap energy has provided us with otherwise inaccessible water. This bond has been termed the 'water-energy nexus' (WEN) and in many cases has been linked with a 3rd dimension, food.

The UK is faced with significant challenges that relate to the WEN. UKCP09 research has projected that water resources will become increasingly scarce (15% reduction in annual average precipitation), with hotter summers and more intense droughts. The water sector is burdened with ageing infrastructure, faces growing demands and uncertain supply options. Bound by ambitious targets for GHG emissions reductions, the energy sector faces considerable restructuring with a short term capacity deficit that must be bridged.

Faced with considerable exogenous pressures (population growth, climate change, rising fuel prices), both the water and energy sectors are faced with choosing policy options with uncertain future performance. Some energy capacity options such as thermo-electric generation are water-intensive, which may leave it vulnerable hydrological variability and competing with other sectors such as agriculture and public water supply. Similarly, some water capacity options are energy-intensive, making them more vulnerable to energy prices.

Drawing on principles of Robust Decision Making, we present a model framework that evaluates UK-wide infrastructure policy options over a wide range of uncertain futures. We present the water-intensity of alternative energy pathways and the energy-intensity of alternative water pathways. We also introduce a catchment-scale WEN model for the River Trent, designed to simulate the performance of alternative energy and water policy options against future variability in water and energy demands. Finally we discuss methods for evaluating robust performance of policy decisions that lock-in for decades to come.

Assessing the material dependency of low carbon technology infrastructure transitions

Jonathan Busch [1], Julia K. Steinberger [1,2], David Dawson [3], Phil Purnell [3], Katy Roelich [1,3], Ruairi Revell [3]

1 Sustainability Research Institute, School of Earth & Environment, University of Leeds, UK
2 Institute of Social Ecology, Vienna, Alpen-Adria University, Austria
3 Institute for Resilient Infrastructure, School of Civil Engineering, University of Leeds, UK

Corresponding author: Jonathan Busch (J.Busch@leeds.ac.uk)

Emissions reductions of the scale required to meet the challenging targets set by international and national bodies will require rapid, systemic change including extensive refurbishment and replacement of infrastructure systems and unprecedented roll out of low carbon technologies. These technologies often rely on critical materials that may be at risk of supply disruption and difficult to substitute.

Previous research has highlighted potentially critical materials based on a set of criticality factors, as well as identifying those materials that could be considered essential for specific low carbon technologies. There is, however, no systematic methodology for assessing the vulnerability of a particular low carbon infrastructure transition to supply disruption of critical materials.

Our research aims to develop such a methodology with three particular features. First, it is based on a modelling framework that uses a hierarchical representation of technologies, components and materials to generate a dynamic forecast of the materials requirements of an infrastructure transition. Second, the assessment of material criticality, which includes factors such as geological scarcity and geopolitical interest, is integrated with the model to generate a dynamic description of system vulnerability to supply disruption. Third, we focus on identifying the potential for reducing system vulnerability by analysing the relationships between the properties that guide the design choices of an infrastructure project and the resulting vulnerability of the project. The methodology is demonstrated using a proof-of-concept case study.

A solution based on human circulatory system analogy for the single infrastructure-based utility provision to households

Ferhat Karaca and Fatih Camci

IVHM Centre, Cranfield University, Bedford, UK

Corresponding author: Fatih Camci (f.camci@cranfield.ac.uk)

All in One[1], an EPSRC funded 2011 sandpit project, proposes an alternative future utility infrastructure systems that base on provision of utility services through only one infrastructure or distribution of one utility product. The project aims to investigate the question of "Can a single utility product or service ("the one") supply all the services that the end users need?". The "all in one" idea is fundamentally challenging and removes the need of delivering multiple utility products by provision of all needed services through a single utility product (the one)[2]. The idea aims to reduce the complexity and redundancy in the current utility infrastructures.

This study presents one of the All in One vision vignettes called as "City Blood: the human circulatory system analogy for a future city utility infrastructure". This vignette proposes to use "city vessels" as the only infrastructure for utility distribution and collection in future cities similar to human circulation system in human bodies. In human body, energy/water distribution and waste collection to/from cells are achieved through the blood as utility product and vessels as the infrastructure.

City Blood vignette suggests using an existing infrastructure, city water pipeline systems, with some modifications. In this future city circulation system, the carrier liquid (an analogy to blood) is mainly water and will be pumped by similar means of today's existing water distribution practices. The main difference is that in every receptor sites/points (e.g. houses), clean water will be separated from the city blood (a mixture of water and energy carriers) by means of a future filtration/separation technology as similar to capillaries do it in body cells.

This vignette also suggests a new approach to the household energy distribution. It is based on the distribution of hydrogen or any other alternative future energy carrier in the form of energy cells (solid hydrogen carriers) or energy liquid (liquid energy carriers) which are mixed in city water and distributed through water pipeline systems (city vessels). These energy carriers will be separated from water and collected at the receptor sites (e.g. houses, buildings) and they will be utilised to produce household energy in future house type fuel cells for both home and business use.

In human circulation system, body vessels are being used to remove waste materials from the body cells and tissues. This vignette is also discusses the possibility of the collection and removal of the household waste materials using the city vessels.

The main aims of this paper are (i) to present City Blood vignette with its assumptions, (ii) to address the needed technologies and technological challenges, (iii) to identify and discuss the main bottlenecks and their potential solutions.

References

1. All-in-One: Feasibility Analysis of Supplying All Services Through One Utility Product (EP/J005592/1), http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/J005592/1

2. Camci, F., Ulanicki, B., Boxall, J., Chitchyan, R., Varga, L., and Karaca, F., 2012. Rethinking Future of Utilities: Supplying All Services through One Sustainable Utility Infrastructure, Environ. Sci. Technol., 46 (10), pp 5271–5272, DOI: 10.1021/es301646m.

Resource-efficient and service-oriented infrastructure operation: towards MUSCos: Multi-Service Utility Companies

Christof Knoeri[1], Katy Roelich[1], Julia K. Steinberger[1], Liz Varga[2]

1 Sustainability Research Institute, School of Earth & Environment, University of Leeds, Leeds, UK.
2 Complex Systems Research Centre (CSRC), School of Management, Cranfield University, Bedford, UK

Corresponding author: Christof Knoeri (c.knoeri@leeds.ac.uk)

The present form of infrastructure operation can be described as separate utility supply systems provisioning unconstrained demand, with higher throughput corresponding to larger economic revenue. In contrast, an environmental perspective would prioritize coordinated infrastructure operation focused on essential service delivery at the lowest possible level of resource use. Our research investigates the possibility of a transition in infrastructure operation away from supply of unmanaged demand and towards resource-efficient service delivery. Infrastructure design and operation is a crucial, but often overlooked, factor in determining the metabolism (the level and composition of resource use) of industrial societies, from flows such as energy and water, to activities ranging from transportation to communication. Innovatively, this research considers multiple infrastructure streams from the viewpoint of the end-user. Indeed, the end-user constitutes both the actor with the most decision-making regarding demand levels, and the location of the integration of multiple utility streams (through appliances using both water and energy, for example). Starting from the end-user, and the wide range of efficient technologies available to satisfy their demand for essential services, this research then investigates alternative resource-efficient service delivery, through a variety of alternative supply configurations we have termed "Multi-Utility Service Companies", or MUSCos. On the basis of a review of such alternative end-user technologies and supply configurations, we will develop a socio-technical model in order to test scenarios of measures leading to the transition of resource-efficient infrastructure operation. The resulting recommendations will be collated in a "MUSCo Charter" intended for policy-makers and relevant industries. In this paper we will present the context and plan of the project, as well as first insights from existing examples of MUSCO-like configurations. We identify how these alternative configurations might lead to a transition from throughput-based to service-based utility provision as a cornerstone of a society that emphasizes well-being rather than increasing material and energy use.

The future's electric - can we take the heat?

Steven Glynn, Ruth Wood, Sarah Mander, Kevin Anderson

Sustainable Consumption Institute and Tyndall Centre for Climate Change Research, School of Mechanical, Aerospace and Civil Engineering, University of Manchester, Manchester, UK.

Corresponding author: Ruth Wood (Ruth.Wood@manchester.ac.uk)

The UK's electricity network will face significant challenges from both the impacts of climate change and the UK's decarbonisation strategy. In addition to coping with future climate impacts such as increased temperatures, extreme weather events and the increased penetration of intermittent renewables, many low carbon strategies for the UK's energy system describe the large scale electrification of energy services. To examine the future resilience of the transmission network, an understanding of the electricity demand the network could be required to support is required. Different demand and supply scenarios suggest different configurations of transmission network and thus network vulnerabilities. This paper presents work on future demand scenarios that form part of a wider project (RESNET) that will assess the resilience of the electricity network to climate change impacts and mitigation pathways. Scenarios of future demand profiles must be mindful not only of current trends such as the increased ownership of electrical appliances in households but of the implications of the electrification of heat demand and surface transport and any future loads such as domestic cooling and desalination. The resulting demand profile may also be shaped by the evolution of smart grid technology and increasingly active demand management measures.

To enable research assessing the resilience of the electricity network a bottom up scenario tool is presented to help understand how changes in the use of electricity by households, commercial buildings, industry and surface transport could impact diurnal electricity demand profiles. The tool combines a database of load profiles from current electricity uses with a scenario tool to estimate how various changes in efficiency and technology could alter the load profile. On this basis new load profiles will be developed taking into account improvements in the efficiency of technologies (for example LED lighting) and newer technologies such as heat pumps. The resulting tool can enable the RESNET team to interpret future energy scenarios quantitatively to understand the potential shape and level of UK diurnal load profiles out to the 2020s, 50s and beyond.

The assessment of current and future impacts of weather and climate on transport

David Jaroszweski

The University of Birmingham, Edgbaston, Birmingham, UK.

Corresponding author: David Jaroszweski (d.j.jaroszweski@bham.ac.uk)

This paper synthesises the findings and ongoing work of the FUTURENET project, a major multidisciplinary climate change impact assessment on a multimodal transport along a corridor between London and Glasgow. Multidisciplinary techniques are applied to determine how weather currently affects infrastructure and operations, how climate change may alter the frequency and magnitude of these impacts, and how concurrent technological and socio-economic development may shape the transport network of the future, either ameliorating or exacerbation the effects of climate change.

This paper has a particular focus on the ways in which weather-related disruption propagates through the transport system in time and space following disruptive events and weather-related infrastructure failure. Detailed analysis is made to notable disruptive events on the corridor, such as the closure of the West Coast Mainline and disruption to the Motorway network due to heavy rainfall on the 28th and 29th of July 2012. By using large ensembles of detailed train timing data coupled with observed meteorological data it is possible to determine how geography and timetabling affect the propagation of disruption and recoverability of the rail network to meteorological events. Similar delay relationships for the effect of weather on road transport are determined. These relationships are combined with physical relationships between weather and infrastructure failure into a delay simulation model which uses synthetic weather data based on UKCP09 climate scenarios to assess the potential impact of climate change on this economically important transport route.

Resilience and sustainability assessment in the context of post-disaster infrastructure rebuild

Kristen MacAskill

University of Cambridge, Cambridge, UK

Corresponding author: Kristen MacAskill (kristen.macaskil@gmail.com)

The overall aim of my research is to employ risk management as a framework for incorporating and addressing the many and varied aspects of sustainability into the development and design of civil infrastructure projects. As it stands, there is no consistent and robust framework that embeds sustainability and resilience into infrastructure development decisions. Sustainability thinking tends to focus on environmental, social and economic impacts of a project whereas resilience thinking considers the life cycle of infrastructure, its vulnerability to hazards and its adaptive capacity. These concepts align but are not always explicitly addressed together. My research aims to better integrate resilience thinking into infrastructure sustainability assessment.

Sustainability assessment tools are increasingly prevalent in the civil infrastructure sector. These tools, in the form of Rating and Certification schemes, Decision Support Tools, Calculators or Guidelines are contributing towards broadening the scope of factors that influence infrastructure development decisions. Although these tools help to define sustainability in the context of civil infrastructure, resilience thinking is not necessarily integrated into the process. The tools are not often structured in a way that provides a business case for making decisions.

My work has involved investigating existing approaches to decision making for sustainable infrastructure. It has also involved gaining first-hand experience of the challenges and complexities in the post-earthquake rebuild of Christchurch, New Zealand. In this rebuild, infrastructure resilience is a key consideration in the civil infrastructure design philosophy. This includes considering alternative materials, redefining infrastructure systems and seeking to minimize hazards. Yet developing a suitable sustainability assessment remains a challenge. This paper will present the early stages of my research, reflecting on the current sustainability assessment approaches, discussing the gaps in guidance for a post-disaster rebuild and outlining basic factors that influence key infrastructure decisions in the rebuild context.

The ultimate outcome of this research will be the development of new framework and industry guideline that links risk management, resilience and sustainability theory to guide infrastructure development from project definition stages through to design.

The Evolution of the Physical Internet Infrastructure and its Impact on the Economic Development of Cities

Edward Oughton

Cambridge Centre for Climate Change Mitigation Research (4CMR), University of Cambridge, 19 Silver Street, Cambridge, UK

Corresponding author: Edward Oughton (ejo31@cam.ac.uk)

The impact of infrastructure on the economic development of cities is relatively poorly researched, especially with reference to the physical Internet infrastructure. A conceptual framework is developed to establish the extent to which a city's digital infrastructure endowment and degree of connectivity influence its economic development. Although on a day to day basis it may seem that infrastructure hardly changes, when one examines an infrastructure network over a number of decades we see that its evolution can have a significant effect on the shaping of the urban environment. In turn, the urban environment shapes the way in which individuals and firms routinely interact within cities.

A thorough understanding of how the long and rigid lifespan of infrastructure and the urban environment can affect economic, social, and environmental outcomes is important. Without it there is the risk of cities being locked into less productive, less equitable and unsustainable growth trajectories. However, spatial economic theory at the city scale provided by modern geographical economics, such as Urban Economics and the New Economic Geography, largely ignores network effects and takes a fairly ahistorical analytical approach; in spite of this, network connectivity and the impact of historical factors on urban development are profound.

Consequently, the proposed conceptual framework incorporates these relatively excluded analytical approaches. Firstly, a network perspective is proposed as a heuristic framework for understanding how connectivity impacts on urban economic development. Secondly, and building on the former, the application of evolutionary economics to infrastructure is proposed as an enabling tool with which to incorporate enhanced notions of history and time into economic analysis. Once this conceptualisation is complete, the paper explores the problems surrounding the assembly of evidence on this topic by critiquing existing methodologies. In conclusion, the methodological issues which need to be overcome in establishing the extent to which a city's digital infrastructure endowment and degree of connectivity influence its economic development are identified.

Challenging Lock-in through Urban Energy Systems: learning from the case studies

Ksenia Chmutina

School of Civil and Building Engineering, Loughborough University, UK

Corresponding author: Ksenia Chmutina (K.Chmutina@lboro.ac.uk)

In order to meet its ambitious 2050 target of 80% reduction, the UK is facing a significant challenge of restructuring its energy system, currently characterised by lock-in to centralisation. There is however potential to challenge this lock-in through the development of more decentralised energy systems - based not only on technological, but also on more innovative governance, social and economic approaches.

The Challenging Lock-in through Urban Energy Systems (CLUES) project has provided a greater understanding of the contribution of decentralised energy systems to these national decarbonisation goals. Using a multi-disciplinary framework, this project critically analyses several urban decentralised energy systems around the world through the assessment and comparison of exemplar international case studies and tests their potential applicability in the wider UK context.

This work emphasises the variety and inter-relationships of barriers and drivers involved in the implementation of such projects internationally, as well as probes deeper into the definition of success. The findings are also compared and contrasted with the barriers and drivers identified as having an impact on decentralised energy projects in the UK.

Although it is widely believed that regulations heavily influence the implementation of decentralised energy projects, these projects are frequently driven and motivated by other factors, such as reputation, profitability, and the opportunity to show others that “we can do it”. The main non-technical barriers are not necessarily financial, as is often supposed. Governance barriers - such as out-of-date regulations or unreliable partners - also play an important role in the success or failure of a project. Social barriers in the form of public apathy and misinformation regarding energy consumption can also be significant, often affecting the on-going operation and efficiency of the project.

Developing Urban Retrofit Roadmaps in the Context of a Low Carbon Agenda: Identifying Disruptive and Sustaining Technologies

Judith Britnell[1], Prof. Tim Dixon[2], Prof. Georgia Butina Watson[3]

1 Dept of Real Estate and Construction, Faculty of Technology, Design and Environment, Oxford Brookes University, Oxford, UK
2 School of Construction Management and Engineering, University of Reading, Reading, UK.
3 Faculty of Technology, Design and Environment, Oxford Brookes University, Oxford, UK.

Corresponding author: Judith Britnell (jbritnell@brookes.ac.uk)

In the context of retrofitting cities and re-engineering infrastructure, roadmaps can be a valuable tool in helping to navigate uncertainty, advance innovation and explore the transition towards a low carbon future. They should not be considered as one off exercises but tools that need to be regularly updated and kept alive.

This paper summarises recent work on low carbon roadmaps and goes onto explain the three UK national retrofit roadmaps that were developed as part of the EPSRC Retrofit 2050 research project, for energy, water, waste and resources. The retrofit roadmaps were used to illuminate the development of pathways (What, When ,How, Who) from the present to a set of plausible retrofit city-regional futures that are being developed as part of the scenario process of the Retrofit 2050 research programme. These retrofit visions illustrate possible futures, technologies and prospective societal choices. With the help of these roadmaps the question is how can we identify and distinguish between the disruptive and sustaining technologies of the future?

Footnote:

Retrofit 2050 (Re-Engineering the City 2020-2050: Urban Foresight and Transition Management) is a major interdisciplinary research project funded under the EPSRC Sustainable Urban Environments (SUE) programme. The Retrofit 2050 project brings together an interdisciplinary team from the Welsh School of Architecture at Cardiff University, the Oxford Institute for Sustainable Development at Oxford Brookes University, the Centre for Sustainable Urban & Regional Futures at Salford University, the Durham Energy Institute, Durham University, the Centre for Sustainable Development at Cambridge University Engineering Department and Reading University in order to undertake research into delivering a 'step change' in urban sustainability. Working with key stakeholders, the project aims to illuminate challenging but realistic social & technological options for systemic retrofitting of Greater Manchester and Cardiff/SE Wales.

For more information see: http://www.retrofit2050.org.uk/

ITRC

http://www.itrc.org.uk/