MEASURING THE RESILIENCE OF CITIES

The Role of Big Data

Proceedings of the Conference Measuring the Resilience of Cities: The Role of Big Data, 25 October 2013

Edited by Jennifer Cole

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Foreword

Bryan Edwards

Of all the challenges facing the UK today, few are as demanding as those of national security. Some threats to the UK and its citizens are modern variants of those they have faced for many years. Others are entirely new and are characteristically different to anything that has preceded them; while some, no doubt, have yet to be recognised let alone understood and countered.

One feature of this large, complex and constantly evolving array of challenges is that few, if any, lend themselves to single-discipline solutions.

With that in mind, the Science and Technology Facilities Council (STFC) operates a Defence, Security and Resilience Futures Programme. Challenge-led, and agnostic with respect to academic discipline, the STFC's aim is to identify and facilitate opportunities to engage relevant capabilities of the UK National Laboratories and university research groups with some of the most demanding and highest priority challenges in national security.

As part of this programme, the STFC is delighted to fund, and proud to collaborate closely with, RUSI to deliver a series of conferences on topical issues within the domain.

Each meeting is designed to explore the interface between academic research and government policy and operations in order to stimulate debate on how to achieve step rather than incremental change in the protection of the UK. The meetings are strategic in character, with contributions from an atypically broad community drawn from universities, industry, government and its agencies and partners. At the forefront of the organisers' minds was a deceptively simple question: What can academic research offer now and in the future that would allow the government to further enhance its capabilities in key areas by enabling it to either do significantly different things and/or do the things it does now, but in significantly different and better ways?

On some occasions the problem and the constraints within which viable solutions need to be found are well understood and discussion can focus immediately on novel concepts and approaches. However, for many of the more complex problems this is not the case.

This is well illustrated by the topic covered by this report: urban resilience. To some, this is no more than construction and operation of robust physical infrastructure (e.g., transport or telecommunications networks) that is

protected or insensitive to external interference such that the services it provides are insensitive to shocks and perturbations.

And yet even a cursory consideration suggests that this focus on infrastructure, while important, cannot be the entire story. Some cities are the social/economic equivalents of supernovae – enjoying short but spectacular success, outperforming all around them but lasting perhaps only for decades; Detroit is a case in point. Other cities have more complex histories. London, for example, has existed for over 2,000 years and despite plague, firestorm, extreme weather events, wars and social upheaval, it has not only survived but thrived. Perhaps resilience, therefore, is best viewed not as not as insensitivity to the forces of change but as inbuilt capacity to continually evolve in the face of it. This, then, invites questions such as what characteristics of an urban centre and its population contribute to resilience (since some influences are gradual and others sudden)? How many and which of these factors can be influenced by government intervention or engineered into the urban environment by deliberate design? Should we be considering individual cities in isolation, thinking regionally, or perhaps nationally? How might one objectively measure the intrinsic resilience at whatever level we think is most appropriate? What data would a meaningful methodology require and how could it be collected? And so on.

Clearly, a one-day event is incapable of providing answers to all such questions, but it can and has expanded our understanding of what we actually mean when we talk about resilience. This document is intended to serve as an enduring record of the meeting. More than that, we hope it will encourage academics from all disciplines to consider how their particular expertise might contribute to a better understanding of the issues raised.

Thanks must go to staff at the STFC and RUSI for all their extremely hard work which made this event possible. However, the final word of thanks is reserved for all those who participated so enthusiastically on the day, whether as speakers or delegates.

Anyone wishing to know more about the STFC's Defence, Security and Resilience Futures programme in general, or these conferences in particular, is invited to contact me using the e-mail address below.

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Introduction: Measuring Resilience – Challenges and Opportunities of Big Data

Jennifer Cole

The aim of the STFC-funded conference 'Measuring the Resilience of Cities: The Role of Big Data', held at RUSI on 25 October 2013, was to step back, a decade after the introduction of the Civil Contingencies Act 2004, and ask not only how resilience has improved in that time, but how do we measure improvement?

What are the baseline standards by which resilience should be measured? Are we clear on what these baselines are, and on how improvements on them can be identified and quantified? In short: What resilience indicators do we use, and are we sufficiently able to measure how much better we are now, as well as whether or not we are simply better?

In order to answer such a question, it is first necessary to ask a series of others.

What do we want to be resilient against?
It is not sufficient to suggest just that we should be resilient to 'flooding' or to 'terrorist attacks': resilience often has a trade-off that requires some amount of risk to be tolerated in one or more areas. Making the London Underground network completely resilient to terrorist attacks of the kind carried out on 7 July 2005, for example, would require the introduction of security scanners for passengers and luggage of the kind introduced to airports following the 9/11 attacks on the World Trade Centre, but this is completely impractical considering the volume of people using the network and the speed with which they need to move through it. In the case of flooding, flood risk is often presented in terms of a 1:100 or 1:1000 year flood risk; acknowledging that there is a point at which defending against a flood risk though, while it may be severe is likely to be extremely rare (occurring less than once every thousand years), is entirely impractical. A good example here is the tsunami defences around the Fukushima Dai-ichi nuclear power station in Japan: built to withstand a tsunami wave 10m high, the defences were unable to deflect the 14m-high wave encountered on 11 March 2011. The power station's defences also – understandably – struggled to cope with such an extreme flooding event on top of an equally extreme earthquake event that damaged its reactors, back-up generators and water pumps. Measurements of resilience need to consider what is practical, as well as what is possible, to enable honesty about the points at which realistically practical measures are likely to fail.

How much does resilience cost?

The answer to the above question leads directly into the second, on the cost of resilience. This should not only be approached in financial terms, though the financial cost is clearly an issue – particularly in times of austerity, when investing in a possible event has to be offset against the cost of dealing with more immediate and challenges that are already present. Cost may also need to be measured in terms of organisational reputation, of political and media reputation, and of the relative cost of one approach against another. In Chapter I, for example, John Tesh discusses how the need to maintain the ambiance of Paris as an attractive tourist destination has to be balanced against the impact of physical flood defences that would defend the city against levels of flooding that have been seen in the past and may well be seen again in the future. Making Paris physically resilient to flooding has to be offset against its cultural resilience of remaining quintessentially Parisian, and the economic resilience that is dependent on that ambiance. The cost of resilience may not be the immediately obvious one: does resilience come from stopping the flood water, or from accepting the damage a flood may cause and repairing that damage as quickly as possible even if doing so perpetuates the same vulnerabilities that existed before?

How often may we be willing to fail?

This third question, which is a consequence of the second, may need to be considered more often, and with more complexity, in the face of increasing challenges from natural disasters. Tolerance of terrorist attacks and attacks by other malicious actors can more easily be set at zero: the aim should be to prevent all malicious actions, with each one that slips through the net being seen as a failure and an opportunity to try to review and strengthen the system. Floods, severe storms, infectious disease and other hazards are harder – perhaps impossible – to attempt to eradicate, and the challenge comes with deciding where the tipping point between tolerance and intolerance of the risk lies, as well as who should primarily hold the responsibility for that risk.

What do we need/want to be resilient?

Lastly, considering the questions above will help to shed light on the last question: what is it essential to protect, and what might it be possible to sacrifice? Continuity of a sub-optimally resilient state might be more valuable than resilient adaptation for a city dependent on its historical monuments for its economic stability. Some degree of risk tolerance may be required to ensure that security arrangements for travelling on rail networks do not become so cumbersome and time-consuming that passengers no longer want to travel by train. Is the more important measure of resilience – in the context of the UK Security Strategy's aim to enable citizens of the UK to 'go about their business freely and with confidence' – the measure of freedom, or of confidence? This also raises questions over whether high levels of 'hard

security', such as armed police in central London and concrete bollards in front of government buildings along Whitehall, convey a sense of confidence that everything necessary is being done to protect those at risk, or a lack of confidence: if terrorists are being adequately investigated and their plans disrupted, why are we so afraid they will get so far? Such questions play off against one another in discussions of resilience and the investments that should be made it in.

Measuring the impact of events

Even if those questions can be answered, there are still many others that need to underpin the quantitative approach to resilience. The cost of failure is often – and often most dramatically – counted in human lives. Yet this often relates only to the number of deaths that happen in single, isolated events such as terrorist bombings or severe flooding: close to 40,000 people die in the EU each year from both road accidents and hospital acquired infections (HAIs), yet neither are seen as traditional resilience challenges. In contrast, fifty-two deaths in the 7 July 2005 London bombings led to far more significant changes in UK policy and resilience architectures.

Another resilience challenge is how the impact of an event should be calculated: for example, should a mass-casualty attack be quantified by the number of deaths, the number of people injured or directly affected, or the ability of the (local or national) healthcare sector to cope with the sudden upsurge in those requiring treatment? In turn, this opens additional questions relating to how resilience capabilities are measured and audited – by the number of professional paramedics available, with or without the number of volunteer paramedics and first aiders from organisations such as Territorial Army field hospitals and St John Ambulance available to support them during a surge, or by the number of hospital beds available at a number of receiving hospitals? The way assets are counted, as well as the count itself, can have a bearing on resilience: volunteers may volunteer with more than one organisation, or volunteer in their spare time for a role similar to that of their day job. A count of 100 ambulance service paramedics, twenty-five Territorial Army Paramedics, twenty-five St John volunteers and twenty-five Red Cross volunteers may represent far fewer than 175 actual individuals, and they are certainly unlikely to all be available at the same time.

It is also important to measure the different impacts a single event might have across distance and time. In Chapter VII, Malcolm Sperrin raises some of these issues with specific reference to CBRN attacks on crowded urban environments. The spatial impacts of a radiological incident, for example, will differ from the relatively small area affected by radiation around the site where the radiation is released, to an area of wider circumference at risk of being contaminated by radioactive dust carried away from the blast area by wind or dispersing contaminated individuals, to an even wider area impacted

by displaced people evacuating the contaminated (or possibly contaminated) area. Each of these may impact on different areas of resilience and require different assets and considerations.

Staying with the example of a CBRN incident, the impact will be different according to which determinant is used. There will be a risk to human health (which will differ depending on whether health is considered in the context of short-term radiation burns and radiation sickness or long-term risk of cancers; and to what extent mental as well as physical health is considered), a risk to the environment, and also a risk to the economy. These risks may often result in resilience contradictions: forcing a community to evacuate the immediate area following a radiological incident may decrease the risk of developing cancer over the subsequent forty years but increase the risk of stress-related mental health issues that themselves impact on physical health, counteracting any benefits to average life expectancy gained from the evacuation. Similarly, the risk of environmental contamination may need to be weighed against the damage done to the economy of closing off large areas of a country. In retrospect, the damage to the agricultural and tourist sectors caused by slaughtering herds and severely restricting movement during the 2001 Foot and Mouth outbreak in the UK, which led to a number of suicides amongst farmers whose livelihoods were seriously affected and the bankruptcy of several rural businesses, resulted in a different approach being adopted during the 2007 outbreak of the same disease.[1] A measure that increases resilience in one respect may have a disproportionately negative impact elsewhere.

Complex indicators for resilience

Measuring resilience depends on complex indicators, some of which are not yet well understood. Flood risk is one of the better understood risk factors in the UK, for example, with detailed flood prediction maps on which property owners can check whether their property is located in an area of 1:100 or 1:1000 year flood risk. Extensive weather prediction processes enable flood warnings to be issued at the earliest opportunity. However, a flood risk management workshop held at RUSI in February 2014 raised the issue of there being no scale by which the quality of flooding as well as the quantity can be assessed, equivalent to the Richter Scale[2] by which the severity of earthquakes is measured, the International Nuclear and Radiological Events Scale[3] that measures the seriousness of nuclear accidents, or the Beaufort

1. Iain Anderson, 'Foot and Mouth Disease 2001: Lessons to be Learned Enquiry Report', Defra, 2002.
2. Earthquake Magnitude Scales and Classes <http://www.geo.mtu.edu/UPSeis/magnitude.html> accessed 7 April 2014.
3. IAEA, Department of Nuclear Safety and Security, INES: The International Nuclear and Radiological Events Scale, <http://www-ns.iaea.org/tech-areas/emergency/ines.asp>, accessed 7 April.

wind force scale.[4] Without such a qualitative measure, it is difficult to measure trends and to see if the severity of flood events is increasing as well as (or instead of) the incidence, which would present very different resilience challenges.

The aim of the October 2013 conference was, therefore, to raise and discuss challenges such as these, and to identify areas where the academic community may be able to help: either by carrying out the measurements, determining how the data to be measured might be best collected, processed and analysed, or by helping to frame the questions that will ensure the most appropriate data are collected from the right sources and interpreted in the most useful way. Participants were encouraged to consider a range of methodologies currently in use for measuring resilience, including those underpinning the Global Risk Register produced by the World Economic Forum, the Making Cities Resilient campaign of the United Nations Office for Disaster Risk Reduction (UNISDR) and examples from organisational resilience and climate change studies. The conference aimed to consider how appropriate these are to measuring resilience overall, and to assessing the resilience of the UK both in isolation and in international context. All of the above methodologies will be covered in later chapters of this report.

In addition to providing a number of examples of how resilience is currently measured, and considering the challenges and opportunities of each method, participants were also encouraged to focus on the main resilience challenges facing the world in the twenty-first century, from climate change to global urbanisation, to the increasing proliferation of dual-use material and the knowledge of how to weaponise it. This was intended to ensure that resilience is sufficiently future scoped, and that the resilience challenges of tomorrow are being sufficient considered. There is little value in building resilience to today's challenges if these are likely to evolve significantly in future. This focus was informed by, and fed into, RUSI's contribution to work carried out by DSTL for the Development, Concepts and Doctrine Centre (DCDC) on the Future Operating Environment: Global Urbanisation.

Lastly, having considered current and potential future resilience challenges, attention was given to how data collected against resilience indicators can be best modelled to help understand the challenges and to plan responses to them.

Options for the future

Options for addressing the challenges were discussed and debated during the afternoon discussion forums, the aim of which was to identify specific areas where more academic research is likely to make valuable contributions to

4. Beaufort wind force scale <http://www.metoffice.gov.uk/weather/marine/guide/beaufortscale.html> accessed 7 April 2014.

the understanding and planning of future resilience. Five different discussion forums returned remarkably similar results. There is a need to understand why and how resilience fails as well as to identify resilience successes; historical analysis of past strategic shocks and the rise and fall of communities will help to provide this. There is insufficient understanding of the human factors that drive or impede resilience: is the desire of a community to survive and thrive in the face of adversity more or less important than the strength of its physical defences? There is still additional work needed on how complex drivers and inhibitors of resilience interweave, which in turn will help to determine where mitigation measures in advance of an event, and support and recovery assets following one, are best deployed. We need to understand how societies and communities are changing, and how their resilience will evolve in the face of these changes.

The conference by no means set out to provide comprehensive answers to these questions. On the contrary, the aim was to raise and ask additional questions that would identify gaps in current understanding and research programmes, so that future research might seek to bridge those gaps. Resilience has come a long way in the last decade, but there is a lot further to go. It is important that the evolution of the challenges, as well as the challenges themselves, are well researched and well understood.

Jennifer Cole is a Senior Research Fellow at the Royal United Services Institute, working within the National Security and Resilience Department. Educated at Cambridge University and Royal Holloway, University of London, her work at RUSI has focused on emergency preparedness to major incidents, in particular CBRN, serious infectious disease and widescale flooding.

Perspectives on Resilience

I. Identifying the Risks to Resilience

John Tesh

Cities exemplify a particular problem for resilience planners in the modern era: how to seize the opportunities offered by advances in science and technology, whilst managing the vulnerabilities to which people are thereby exposed. In the past, risks have been either insufficiently understood or ignored. In the future, however, when more than half of the world's population will live in cities, urban development strategies will need to improve resilience to risks from the outset and also drive the need for information and data.

Urban resilience strategies should be able to deliver four components:

- **Identify the current risks**, and understand how these are affected by modern networked societies and the interdependence of services essential for survival
- **Identify risk drivers** for the future, including well-known risks arising from climate change but also the potential interaction of these risks with other, less well-known, sources of vulnerability – most of which are likely to be man-made
- Maintain readiness for the present while building resilience for the future. The UNISDR toolkit described in Chapter IV provides one model; other models are provided by the OECD work on future global shock,[1] and the World Economic Forum Global Risks Report 2013[2]
- **Communicate risk**, to enable resilience to be built from the 'bottom-up' avoiding excessive reliance on the resources of central government.

Past, Present and Future Risks to Major Cities

In Chapter II, Hamish Cameron gives some suggestions as to how and why London has survived fire, war and pestilence in the past and how this is relevant to the resilience of great cities like London in the future. The London example illustrates a fundamental point about resilience. It is clear that some cities survive despite the risks they face, whether these risks emerge from conflict or natural hazards, while other cities do not, even though they may seem more secure from such hazards.

Venice and Tehran are examples of the former. They face very real threats to their survival, and yet continue to exist. Examples of the latter are cities

1. Organisation for Economic Co-operation and Development, 'Future Global Shocks: Improving Risk Governance, Preliminary Version, OECD Reviews of Risk Management Policies' (Paris: OECD, June 2011), <http://www.oecd.org/governance/48256382.pdf>, accessed 21 January 2014.
2. World Economic Forum, *Global Risks 2013*, eighth edition (2013), <http://www.weforum.org/reports/global-risks-2013-eighth-edition>, accessed 21 January 2014.

like the 'secret cities' of the Soviet era in Russia – the closed environments in which military personnel and nuclear scientists lived and worked during the Cold War – and possibly Detroit in the United States. Such cities are now under threat because of changes in the geostrategic and economic environment. Both examples illustrate that cities survive because of the extent to which they are valued by their citizens or by the nation as a whole.

These examples indicate that cities' 'objects of value' have to be put at the forefront in developing strategies to improve resilience. To take an example: the measures necessary to make Paris truly resilient to floods – to prevent the levels of damage from an event such as the 1910 Great Flood, for instance – would in all probability ruin the enjoyment of the city for its inhabitants and visitors alike. Preserving Paris's value as one of the world's iconic cities trumps resilience considerations or at least forces consideration of resilience strategies that may be sub-optimal. Venice faces the same challenges, as Paola Albrito covers in Chapter IV.

Then there are cities that raise questions about survival, of which Tehran might be an example. Is there a tipping point between living in inherently vulnerable places and the risks of doing so? This is true of megacities in particular.

In most British cities, of course, the risks that people consciously or unconsciously accept in settling where they do are less existential. Rather, risks inhere in the cultural, economic or social costs of living in these particular environments. For the citizens of British cities, the real issue is not whether the city is going to survive but how the quality of life for its inhabitants can be preserved at a cost that they can afford.

The Present Risks

The UK's National Risk Register presents a risk profile for the UK that is diverse, complex and unpredictable.[3] No single risk dominates; links can suddenly and randomly appear between events. As is also clear from the London Risk Register, this type of risk profile is as true for cities within the UK as it is for the country as a whole.[4] It reflects a highly networked society with relatively advanced and inter-linked infrastructure systems, which have the potential to propagate the effects of natural hazards even though these are, relatively speaking, usually moderate. The UK currently has a relatively high exposure to the threat of Jihadist terrorism but an otherwise relatively low exposure to the effects of conflict.

3. Cabinet Office, *National Risk Register for Civil Emergencies*, 2012 edition (London: The Stationery Office, February 2012), <www.gov.uk/government/publications/national-risk-register-for-civil-emergencies-2012-update>, accessed 21 January 2014.
4. Greater London Authority, *London Local Resilience Forum: London Community Risk Register, Version 1.0*, (London: GLA, September 2011), <http://www.london.gov.uk/sites/default/files/archives/London-risk-register-v1.pdf>, accessed 21 January 2014.

These features of emergencies in the UK – that they happen relatively frequently but unpredictably, and on a generally lower scale than in other more exposed countries – is what drives the government's current resilience strategy, which will be covered in more depth below.

Is this, however, the same risk profile as we are likely to face a number of decades from now? The National Security Risk Assessment, which is based on the National Risk Assessment but attempts to look further ahead and further afield at the global risk picture, suggest otherwise.

Risk Trends for the Future

In future, the task of assessing risk will be made more difficult because of what the Organisation for Economic Co-operation and Development (OECD) calls 'the interaction of known risks with previously unknown or unprepared-for vulnerabilities'.[5]

Probably the best known – or most easily understood – risk trends arise from the certainty of climate change and the probability of population growth. Although the extent and the distribution of effects in either case may not be fully known, the trends can be monitored and a calculation made of the degree of confidence in the likely resulting phenomena. This is the approach taken, for example, by the UK government's Climate Change Risk Assessment (CCRA).[6]

Some risks are large events (floods, earthquakes, windstorms, pandemics) that appear to be well enough understood: the challenge instead may come from poor judgement concerning the extent of the event's consequences. This happened in Japan in March 2011, when the combined effects of a serious earthquake and tsunami were not fully considered in existing planning assumptions. The challenge is to ensure that resilience planning keeps pace with improvements in scientific understanding of the risks and their history.

Many of the 'previously unknown or unprepared-for vulnerabilities' that cities face today are man-made. These are driven by economic or political changes, several of which have been identified by the OECD, including:

- Heightened mobility of people, data and goods
- Inter-dependency of production and delivery systems and their infrastructure
- Centralisation and concentration of systems
- Urbanisation and concentration of populations and assets

5. OECD, *ibid*.
6. HM Government, *UK Climate Change Risk Assessment: Government Report* (London: The Stationery Office, January 2012), <https://www.gov.uk/government/publications/uk-climate-change-risk-assessment-government-report>, accessed 21 January 2014.

- Herd behaviour and 'group think' in corporations and professions, and among regulators.

These can be allied with broader social or economic trends (for example, growing income disparity or growing financial uncertainty, resulting in loss of confidence and market paralysis), contributing to a risk landscape rich in uncertainty and fraught with traps for the long-term resilience planner.

The challenge is to understand how these trends and risk drivers, and the networks and interdependencies associated with improved living standards and economic productivity, interact with other risks. This can be difficult to weigh because of the myriad ways in which the risks can propagate – though the science of network analysis has made rapid progress and there is growing evidence on which to base future response planning.

One certainty is that events will become increasingly unpredictable. This does not necessarily change the risk profile but does mean that some modelling of the interactions may be worthwhile, particularly as a way to assess the resilience needs of new systems as they are built. The purpose of such modelling would be two-fold. First, it will ensure that the planning assumptions on which response toolkits are based remain current and that no new kinds of impact need to be planned for. Second, it will help in the long-term task of building the resilience characteristics of different sectors.

Table 1: Current Planning Assumptions for UK Resilience Capability Building

Functional Planning Assumptions	**Essential Service Planning Assumptions**
Human fatalities with infectious disease	Water supply
People with illness	Transport
Human fatalities caused by conventional incidents	Oil and fuel
Human casualties caused by conventional incidents	Gas
Biological hazard	Electricity
Chemical hazard	Telecoms
Debris/Rubble	Health
Major flooding	Financial services
Displaced persons	
Influx of British Nationals	
Animal diseases	

Building Resilience

The main components of the UK government's approach to resilience are generic emergency response capabilities, crisis management capabilities, specific contingency plans at national level for the top risks, and improved 'socio-economic' resilience. Taking these in turn, generic emergency response capabilities need to be just that: generic capabilities that are not specific to any particular risk but provide resilience against the most common types of impact. Next, crisis management capabilities are built on two levels: police 'gold' arrangements at the local level, creating multi-agency strategic co-ordination centres and, at the national level, a system of crisis management centres in those government departments that will have lead responsibility for particular crises. This arrangement culminates in the central Cabinet Office Briefing Room (COBR) arrangements, originally established for terrorist emergencies but, since 2001, opened up to all kinds of crises. Thirdly, the government has set out specific contingency plans at the national level for the top risks – in particular the risks of an infectious disease pandemic and wide-spread flooding – and surge capacity for handling incidents that grow beyond local capacity. Finally, there is improved 'socio-economic' resilience, which focuses on three areas: the resilience of critical national infrastructure; improved business continuity planning and practices by other organisations and businesses, especially small and medium-sized enterprises; and community resilience.

These capabilities are focused on what the World Economic Forum (WEF) calls 'resilience performance': aspects of preparedness that enable the country, and its major components, to respond and recover effectively in the event of a crisis.[7] The WEF approach underlines the key point that resilience is everyone's business; has a short-term and long-term perspective (which the WEF calls 'resilience performance' and 'resilience characteristics', respectively); and has a close link to issues of national economic competitiveness, in that countries with high risk-management effectiveness appear also to score highly in the WEF's Global Competitiveness Index.

The WEF model has a number of major components or 'sub-systems':

- **Economic sub-system** including such aspects as the macroeconomic environment, goods and services market, financial market, labour market, sustainability and productivity.
- **Environmental sub-system** including aspects such as natural resources, urbanization and the ecological system.
- **Governance sub-system** covering institutions, government,

7. World Economic Forum, 'Special Report: Building National Resilience to Global Risks' in *Global Risks 2013*, eighth edition (2013), <http://reports.weforum.org/global-risks-2013/section-three/special-report-building-national-resilience-to-global-risks/>, accessed 8 March 2014.

leadership, policies and the rule of law.
- **Infrastructure sub-system**, also known as critical infrastructure, namely communications, energy, transport, water and health.
- **Social sub-system** covering human capital, health, the community and the individual.

In recent years, work in the UK on capabilities has focused initially on improving 'resilience performance' (short-term resilience), following the unimpressive response of the national civil contingencies system in the flooding, foot and mouth disease, fire-fighters' strikes and fuel disputes (the 'four Fs') in 2000 and 2001. In some important respects, this work has been driven by the evolution of the national risk profile from one dominated by a single external threat – that of the outbreak of a third major global conflict originating in Europe – to the more varied and unpredictable risk profile described earlier.

The Importance of Redundancy

Another driver has been the progressive weakening of the other main component of national resilience in the WEF model: the long-term 'resilience characteristics' of national sub-systems, whose robustness has weakened over the past thirty years. Certainly the provision of 'redundancy' (where this means excess capacity and back-up systems that enable the maintenance of core functionality in the event of disruption) has been extensively reduced following the privatization of key nationalised infrastructure services in the 1980s. Arguably, the last half-century has also seen a reduction in the robustness and resourcefulness of many systems, resulting in a reduction in societal and economic resilience in the UK. That was certainly the implied conclusion of the 2008 National Security Strategy, which identified the improvement of socio-economic resilience as a key new strategic objective.

The WEF model implies that the resilience characteristics of the economic, environmental, governance, infrastructure and social sub-systems of nations can be built independently of each other but it seems likely that the key factor for the future is going to be the ability of the key infrastructure sectors to maintain resilience in the face of climate change and other developing risks. As the recent Institution of Civil Engineers report on adaptation of flood risk infrastructure points out, it is important to take account of climate change uncertainty and to avoid closing off options that may be useful in the future.[8] A systematic and interlinked approach to building the resilience of the main infrastructure sectors, following the initiative of the government in drawing

8. Institution of Civil Engineers, The State of the Nation: Defending Critical Infrastructure (London: ICE, June 2009), <http://www.ice.org.uk/getattachment/5e93aedd-3b4c-44db-acfa-d176e0ccbb0e/State-of-the-Nation--Defending-Critical-Infrastruc.aspx>, accessed 22 January 2014.

up all-risk sector resilience plans following the 2007 floods, will be a necessary condition for building the resilience characteristics of the UK in future.

John Tesh is a Visiting Senior Fellow at King's College London Department of War Studies, an Associate Fellow of RUSI, and freelance consultant to OECD and others on emergency/disaster risk and resilience. From 2006 to 2012 he lead UK government work on national resilience building in the Cabinet Office Civil Contingencies Secretariat during which time he developed the UK's National Risk Assessment to the point where, in 2009, this was acknowledged as best in class internationally by the OECD. He pioneered work on risk communication in the first National Risk Register, a version of the National Risk Assessment designed for small businesses and communities (also rated innovative best in class by the OECD); initiated, designed and delivered the first Safety and Security Strategic Risk Assessments for the 2012 Olympic and Paralympic Games; and was involved in developing the Climate Change Risk Assessment for the UK first published in 2012. He was awarded the CBE for his work on civil resilience and the development of the National Risk Assessment in the 2013 New Year's Honours list.

II. London: The Resilient City

Hamish Cameron

London, the UK's capital city, has a population of some 8.3 million.[1] A centre for business, administration and culture since Roman times, it is now a global hub for business, culture, education and international affairs. London accounts for 21.9 per cent of UK output and continues to attract investment, outperforming the rest of the UK since 2007, in spite of the global downturn.[2] The capital must be resilient to emergencies if it is to maintain its strong reputation as a place to live, visit and do business, continue to attract investment and uphold its position as a global city. This chapter considers what resilience means to London, how it is measured, and consider its relevance to the resilience of cities in general.

Resilience Capabilities: The London Resilience Forum

Resilience activity in London is delivered through the framework provided by the 2004 Civil Contingencies Act,[3] which provides a structure for emergency management activity in the United Kingdom. The Act established structures based on police areas to manage civil protection; and gives duties to responders ranging from the emergency services to transport and utility providers. It defines an emergency as:

- An event or situation which threatens serious damage to human welfare
- An event or situation which threatens serious damage to the environment
- War, or terrorism, which threatens serious damage to security.

The London Resilience Partnership is a coalition of agencies with duties under the Act. Each agency has a role in preparing for, responding to and recovering from emergencies in London. The London Resilience Forum (LRF) gives strategic direction and oversight to the partnership; and consists of

1. Office for National Statistics, 'London's population was increasing the fastest among the regions in 2012', press release, 17 October 2013, <http://www.ons.gov.uk/ons/rel/regional-trends/region-and-country-profiles/region-and-country-profiles---key-statistics-and-profiles--october-2013/key-statistics-and-profiles---london--october-2013.html>, accessed 11 February 2014.
2. Office for National Statistics, 'London's economy has outperformed other regions since 2007', press release, 13 March 2013, <http://www.ons.gov.uk/ons/rel/regional-trends/regional-economic-indicators/march-2013/sum-london.html>, accessed 11 February 2014.
3. Cabinet Office, 'Preparation and planning for emergencies: responsibilities of responder agencies and others', 20 February 2013, <https://www.gov.uk/preparation-and-planning-for-emergencies-responsibilities-of-responder-agencies-and-others>, accessed 11 February 2014.

senior representatives of responders in London, with a chair appointed by the Mayor of London. The LRF has a vision of London as a 'resilient city', a concept based on the UK Civil Protection Lexicon, in which resilience is defined as 'the ability of London to detect, prevent and if necessary to withstand, handle and recover from disruptive challenges'.[4]

The work of the Partnership is supported and facilitated by the Greater London Authority's London Resilience Team.[5] In light of its experience in the 2012 London Olympic and Paralympic Games, a strategy was developed in 2013 'to ensure London is prepared to respond to and recover from emergencies, reinforcing London's position as a resilient city'. The activities to achieve this are set out below in Figure 1.

The London Risk Assessment Group (including representatives from a wide range of agencies) prepares the Community Risk Register for the LRF, in order to assess the risk of emergencies (or disruptive challenges) in London.[6] The register assesses the risk of emergencies in London over a five-year period and is informed by local knowledge and the National Risk Register.[7] The Group develops planning assumptions to demonstrate the maximum extent and duration of the impacts of a risk, allowing the LRF to determine what capabilities are needed to respond to particular risks. Like the Community Risk Register, planning assumptions are informed by local assessment and national planning assumptions.[8]

The LRF is accountable for multi-agency co-ordination of emergency preparedness arrangements in London, including the development of capabilities to ensure effective response to the risks that it has identified.[9]

4. Cabinet Office, 'Lexicon of UK civil protection terminology', version 2.1.1, 19 February 2013, <https://www.gov.uk/government/publications/emergency-responder-interoperability-lexicon>, accessed 11 February 2014.
5. Greater London Authority, 'Introducing…the London Resilience Team', 1 October 2012, <http://www.london.gov.uk/mayor-assembly/mayor/london-resilience/london-prepared-blog/2012/10/introducingthe-london-resilience-team>, accessed 11 February 2014.
6. London Resilience Partnership, *London Risk Register*, version 3.0 (London: GLA, February 2014), <http://www.london.gov.uk/mayor-assembly/mayor/london-resilience/risks>, accessed 11 February 2014.
7. HM Government, 'National Risk Register (NRR) of Civil Emergencies', 11 July 2013, <https://www.gov.uk/government/collections/national-risk-register-of-civil-emergencies>, accessed 11 February 2014.
8. Cabinet Office, 'Risk assessment: how the risk of emergencies in the UK is assessed', 20 February 2013, <https://www.gov.uk/risk-assessment-how-the-risk-of-emergencies-in-the-uk-is-assessed>, accessed 8 March 2014.
9. Defined by the Civil Protection Lexicon as a demonstrable ability to respond to and recover from a particular threat or hazard. Cabinet Office, *op. cit.* in note 5.

Figure 1: London – A Resilient City

It ensures that multi-agency capabilities are developed to meet the risks identified in the risk register. These are:[10]

- Underpinning capabilities such as co-ordination, warning and informing the public, and recovery, which are common to all risks.
- Risk-specific capabilities that provide a tailored response to events, such as pandemic flu, which are identified as priorities by the LRF.

The Partnership's strategy outlines how capabilities should be developed. The LRF appoints a lead agency to be responsible for the development of the capability; thereafter the lead agency develops multi-agency plans and training. The plans are based on the legal duties and capabilities of individual agencies in the Partnership. The effectiveness of this multi-agency approach was demonstrated by the response to the roof collapse of London's Apollo

10. Greater London Authority, 'Planning for emergencies in London', <http://www.london.gov.uk/mayor-assembly/mayor/london-resilience/preparing-london/planning-for-emergencies-in-london>, accessed 11 February 2014.

Theatre in December 2013.[11] Police, fire and ambulance services responded, as did the Local Authority and, for the ambulance service, NHS hospitals. Each deployed specialist skills and worked together using procedures developed by the London Emergency Services Liaison Panel.[12]

In summary, capability development under this approach follows five stages:

1. Development of risk assessment and planning assumptions.
2. Appointing a lead agency to work with other responders to identify available/necessary capabilities to then develop the plan.
3. Consultation between the lead agency and other responders.
4. Common training resources for multi-agency capability developed by the lead agency, with individual agencies responsible for ensuring staff are trained to deliver their own role within the multi-agency plan.
5. Testing and exercising.

In addition to the principal duties of the Civil Contingencies Act in preparing such plans, co-operating, and sharing information, the LRF is expected to validate plans and conduct peer reviews.[13] The process allows for the assessment of each capability against a risk. This is based on what agencies identify as their own capability, which is then tested in multi-agency exercises, and the results then considered by the LRF.

From an abstract perspective, combining individual capability assessments to form a London-wide assessment should give an indication of London resilience. In practice, it is more difficult. It is not possible to test every capability under real conditions. The LRF does not have the legal power to inspect the capabilities of agencies in the manner of the Royal Navy's Flag Officer Sea Training processes, for example.[14] Preparations for the London 2012 Olympic and Paralympic Games included an assurance process for civil protection, with the LRF reporting its readiness to the government. The process was based on open and sometimes hard-hitting discussion. The common complaint that whilst the capability was there, the response time was contingent on the circumstances, illustrates the difficulty of measuring the multi-agency capability. Nevertheless, evidence was provided through

11. Gerry Holt, 'Apollo Theatre: West End audience shaken but unbowed', *BBC News*, 20 December 2013, <http://www.bbc.co.uk/news/uk-25461241>, accessed 11 February 2014.
12. The London Emergency Services Liaison Panel, <http://www.leslp.gov.uk/>.
13. Cabinet Office, *The role of Local Resilience Forums: A reference document*, version 1, 4 April 2011, <http://www.epcollege.com/EPC/media/MediaLibrary/Knowledge%20Hub%20Documents/B%20Guidance/B3%20Guidance%20Tools/Role-of-an-LRF-A-Reference-Document.pdf?ext=.pdf>, accessed 11 February 2014.
14. Royal Navy, 'Flag Office Sea Training', <http://www.royalnavy.mod.uk/The-Fleet/Naval-Command-Headquarters/Flag-Officer-Sea-Training>, accessed 11 February 2014.

exercises against planning assumptions and the LRF was able to provide an assurance that the London Resilience Partnership was ready for the Games.

In summary, the LRF measures resilience capabilities against planning assumptions that are based on risks identified in the Community Risk Register. It provides an indication of resilience against the risk of emergencies occurring in a five-year period. These risks are based on the UK civil protection definition: 'detect, prevent and if necessary to withstand, handle and recover from disruptive challenges'.

Resilience and Longevity

London has been a place to live and do business for 2,000 years.[15] Longevity suggests resilience: does London's continued success depend on structures such as those arising from the Civil Contingencies Act or do other factors explain its endurance?

The London Resilience Forum was formed as a result of legislation in 2004. There was no direct antecedent to the forum and the legislation replaced a mix of civil defence and emergency procedures. However, London has always had processes to deal with emergencies, such as fire-fighting duties and legislation to deal with infectious disease. The City of London Corporation, which managed the Great Plague in 1666, is the Port Health Authority for London including Heathrow Airport and ports outside of Greater London including Tilbury in Essex.[16] Air raid precautions, including governance arrangements, were established for the Second World War when large parts of London were badly damaged by bombing. Some of London's resilience can be attributed to its ability to respond to and recover from disruptive events.

Urban areas do not necessarily succeed. An estimated 3,000 medieval villages in England are deserted;[17] 'ghost towns', abandoned in the last century, are found in places as far apart as Antarctica, Australia and the Americas.[18] London has suffered insecurity through Viking raids, disease such as the plague, and disaster such as the Great Fire of London, and yet has recovered and continued. Why has London survived when others have failed?

At first glance, settlements fail because they are no longer viable for their purpose as a place to live or do business. They may be abandoned because

15. City of London, 'City history', <http://www.cityoflondon.gov.uk/things-to-do/visiting-the-city/archives-and-city-history/city-history/Pages/default.aspx>, accessed 11 February 2014.
16. City of London, 'Key statistics', <http://www.cityoflondon.gov.uk/about-the-city/who-we-are/Pages/key-facts.aspx>, accessed 11 February 2014.
17. Wikipedia, 'Abandoned village', <http://en.wikipedia.org/wiki/Abandoned_village>, accessed 11 February 2014.
18. Wikipedia, 'Ghost town', <http://en.wikipedia.org/wiki/Ghost_Town>, accessed 11 February 2014.

of changes in climate reducing the potential for agriculture, as found on Dartmoor, or changes in the original economic purpose of the town, for example, Romney, an important port until its harbour silted in the thirteenth century. Other settlements, such as Pripyat near Chernobyl, have failed because of natural or man-made disaster.

London's history suggests that its resilience does not come from resilience management alone. Its historical economic purpose, based on trade through the Port of London, has also played a major role. The port's advantages come from its geographical position: the Thames estuary gives maritime access to national and international markets; and a crossing point for the Thames, perhaps near London Bridge, gave access to the Roman road network. Economic circumstances have changed, however. Ships have grown since Roman times. This is reflected by a gradual move of port facilities down the Thames. Many of these are now outside of boundaries of Greater London, in Kent and Essex, for example, though still managed by the Port of London Authority. London has adapted to this change in economic activity. Some 36 per cent of the city's employment is now in financial and business services, and London is now 'the UK's leading centre of high value, export oriented employment'.[19]

Perhaps London's longevity is explained by measuring it against another definition of resilience such as Michael Blastland and David Spiegelhalter's 'the ability to thrive when bad things happen'.[20] Bad things in London have included insecurity, disease, flooding and fires (the 'handling disruptive events' definition) but have also included changing economic circumstances (the Blastland and Spiegelhalter definition). London has successfully adapted to these changes through its governance structures and population.

London's location also matters. London's position relative to important European trade routes may explain its longevity using economic and human geographical models.[21] Historians may argue that the continuity of government and the rule of law is another reason for its success.

Measuring London's resilience against risks in the Community Risk Register goes some way to indicating the city's capacity to handle and recover from disruptive challenges. Its long-term resilience is best measured against a wider definition of resilience that includes the ability to adapt to new

19. City of London, 'London's competitive place in the UK and global economies', 20 January 2011, <http://www.cityoflondon.gov.uk/business/economic-research-and-information/research-publications/Pages/londons-competitive-place-uk-and-global-economies.aspx>, accessed 11 February 2014.
20. Michael Blastland and David Spiegelhalter, *The Norm Chronicles: Stories and Numbers about Danger* (London: Profile Books, 2013).
21. Wikipedia, 'Central place theory', <http://en.wikipedia.org/wiki/Central_place_theory>, accessed 11 February 2014.

circumstances. What is most important is that London remains 'a dynamic, globally-focused economy… and a unique place with unique people'.[22]

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22. City of London, *op. cit.* in note 21.

III. Recovery and Resilience in the US Pacific Northwest

Ann Lesperance

Around the world, communities are wrestling with what it means to be resilient enough to recover from a catastrophic disaster. Emergency management agencies have come to recognise that response and recovery are only two phases along the road to resilience and that there is no real dividing line between response and recovery.[1] Some response activities will continue into the recovery phase, and recovery preparations need to begin during the response phase if communities are to limit the damage to the economy – a key driver affecting resilience.

Since its inception in 2007, the Pacific Northwest National Laboratory's (PNNL) Northwest Regional Technology Center (NWRTC) for Homeland Security in Seattle, Washington, has been working with state, local and federal agencies, the private sector, and other organisations to develop approaches that foster resilience and support rapid recovery following an accidental, intentional or natural disaster. This chapter describes the NWRTC's approach to building robust local and regional coalitions, shares some notable successes in improving recovery and increasing resilience, and identifies challenges and issues that still need to be addressed if communities are to be resilient in the face of disasters.

Recovery versus Resilience

The US Federal Emergency Management Agency (FEMA) defines recovery as encompassing 'more than the restoration of a community's physical structures to its pre-disaster conditions. Of equal importance is providing a continuum of care to meet the needs of the affected community members who have experienced the hardships of financial, emotional or physical impacts as well as positioning the community to meet the needs of the future.'[2] Therefore, recovery requires communities to replace, reimburse, retrofit, repair, revitalise, restore, rebuild, reconstruct and reinvest.

Resilience, on the other hand, involves the ability to withstand threats, rapidly recover from events and adapt in order to be more likely to withstand threats in the future.[3] Resilience includes both physical infrastructure and social structure; the latter deals with restoring a general atmosphere of confidence,

1. Federal Emergency Management Agency, National Disaster Recovery Framework (Washington, DC: FEMA, 2011), p.5.
2. *Ibid*.
3. US Department of Homeland Security, Quadrennial Homeland Security Review Report (Washington, DC: DHS, 2010).

hope and collective trust. In both cases, the resilience of infrastructure depends upon its ability to anticipate, absorb, adapt to and rapidly recover from disruptive events. The idea is to minimize any loss to the system by building in contingencies and protecting the individual components that will keep a community functioning during and after a disaster.

All Disasters are Local: An Approach to Engaging Stakeholders

Local emergency responders often work together to create response protocols, procedures and agreements to ensure adequate response. A wide variety of agencies and organisations have a role in resilience and recovery. Recent incidents and exercises have shown that recovery, in particular, will take much longer, involve organisations outside of the typical emergency responder community and be more complex than any other phase of emergency management. For this reason, recovery and resilience planning needs to cast a wide net to ensure involvement from local agencies, state agencies, federal agencies with a local presence, the private sector (businesses and critical infrastructure owners), and other non-governmental organisations (NGOs) such as Volunteer Organizations Active in Disasters and faith-based groups.

For a community to be resilient and able to rapidly recover from a disaster, all these groups must come together to understand the available resources, agree on roles and responsibilities, triage resources, and integrate and practice plans and procedures. This is consistent with FEMA's 'whole of community' approach, which encourages the involvement of volunteer, faith-, and community-based organisations; other NGOs; the private sector; and the public in the emergency management field.[4] The teamwork enables communities to develop collective, mutually supporting local capabilities to withstand the potential initial impacts of catastrophic incidents, respond quickly, and recover in a way that sustains or improves the community's overall wellbeing for the future.

The NWRTC's basic methodology of bringing stakeholders together begins with consensus between those agencies with jurisdiction and/or those able to deliver resources in emergencies. This consensus includes agreeing to provide the necessary resources (staffing, supplies, etc.) to develop planning documents, policies and procedures for implementation. These agencies then establish a core leadership team representing different capabilities and perspectives. Once established, the core team reviews existing plans and identifies places of commonality, differences and gaps.

4. Federal Emergency Management Agency, A Whole Community Approach to Emergency Management: Principles, Themes, and Pathways for Action, FDOC 104-008-1 (Washington, DC: FEMA, 2011).

Through small group working meetings and collaborative working sessions with regional stakeholders, the NWRTC works with a core team made up of professionals from participating agencies (such as local, state and military) to come to a consensus on how to address the differences and fill in the gaps. These core team members help set the direction and focus of the activities on behalf of the broader community. The value of having this small core team is that they are not only respected in their organisations but they also think beyond their organisation and from a broader collective community level. In some cases, members of the core team or other stakeholders are unfamiliar with a particular topic, such as the different response and recovery actions needed following a disaster involving nuclear radiation or the massive data requirements needed to track and resolve issues of recovery. In such cases, the NWRTC hosts knowledge enhancement workshops, bringing together stakeholders with subject matter experts to learn, ask questions and explore possible solutions. Workshops can also help introduce organisations to each other and assist them in identifying and working through potential issues.

Taking such an approach to recovery planning and resilience building has a number of advantages. Involving stakeholders ensures that key information is identified and factored into plans and protocols. Local documentation can serve as a key communication tool to inform state agencies about recovery plans. Such documentation can also serve as a communication tool for federal agencies involved in supporting local planning. Finally, keeping efforts local enables jurisdictions to identify appropriate threats and the recovery approach within the local context, further enhancing resilience.

The Case of the US Pacific Northwest

Two examples of what this method can accomplish for recovery can be found in the Interagency Biological Restoration Demonstration (IBRD) and the Wide-Area Recovery and Resiliency Program (WARRP). IBRD was a joint effort among DHS, the Defense Threat Reduction Agency, and the Seattle Urban Area Security Initiative (UASI). The objective was to work with the inter-agency organisations, including state and local representatives, to reduce the time and resources required to recover and restore large urban areas, military installations and other critical infrastructures following a biological incident.

IBRD involved regional recovery planning; evaluations of private sector and community resilience; holding knowledge workshops and planning to determine how to manage, treat and dispose of waste contaminated with biological materials; determination of the role of social networking in recovery; and the development of a statistical sampling and characterisation methodology. Lessons learned included the need to spread a wide net to ensure all stakeholders can provide input and the value of educational workshops to both build capacity and resolve issues.

WARRP was a collaborative effort by the DHS, the Denver UASI, and the State of Colorado to enhance the wide-area recovery capabilities of the Denver UASI. Additional federal agencies, including the Department of Defense, Department of Energy, US Environmental Protection Agency and Department of Health and Human Services, also collaborated in this effort. The objective was to develop solutions to reduce the time and resources required to recover large urban areas, military installations and other critical infrastructures following a catastrophic chemical, biological or radiological (CBR) incident.

WARRP brought together more than 200 stakeholders to develop a regional recovery framework that would help guide development of local recovery plans; facilitated the consensus of diverse subject matter experts on CBR incidents to identify potential methods for infrastructure sampling and clearance; and provided input to national-level guidance on developing recovery frameworks. The culminating capstone event drew more than 300 emergency management staff from federal, state and local agencies as well as the private sector to discuss the regional recovery framework and unresolved policy issues that require federal attention and action to support effective local recovery and resilience.

Perhaps the best recent example of how the NWRTC approach can be used to increase resilience is the Canadian-US Enterprise Resiliency Experiment (CAUSE-ERE). The DHS and Defence Research and Development Canada jointly supported this effort with the purpose of demonstrating the large-scale integration of newer emergency management technologies and their capabilities during an exercise related to an accidental, intentional or natural disaster. Feedback collected from the emergency management community during the programme would be used to address the readiness and utility of the technologies demonstrated, allowing developers to pinpoint and resolve issues before full deployment, thus increasing the resilience of the participating agencies and communities. The project involved identifying technologies; interviewing stakeholders about their needs for the type of technologies being considered; co-ordinating with the international partners; planning and conducting the exercise; gathering feedback and comments; and identifying lessons learned to make recommendations.

The CAUSE-ERE experiment simulated a magnitude 9 earthquake off the coast of Vancouver, BC. On the US side of the exercise, five technologies were developed with one commercial technology being integrated into the earthquake response scenario:

1. **LiveWall** – This tool facilitates communication among separate groups using interactive video, audio and a shared desktop environment, allowing everyone to participate and collaborate in real time. The tool could provide enhanced point-to-point communication during and after emergencies.

2. **Mobile Alerting** – This system for urban emergency response includes a mobile application, database and command-centre interface. The mobile application provides a user in the field with two-dimensional building layout data. The command-centre interface allows a user to send a search location and path to the mobile device user. First responders could use this tool in search and rescue situations.

3. **Mobile Epiphany**[5] – This rapid application configuration toolset can allow previously complex mobile process applications to be designed by people with no programming knowledge and minimal training. The commercially available tool could be applied in any emergency management activity that involves fieldwork, including providing instructions to a worker in the field or recording and reporting information from the field to a central location.

4. **Real-Time Evacuation Planning Model** – This tool is an evacuation clearance time calculator that works from census and highway data. It is currently being piloted by multiple states and agencies in the South-eastern US.

5. **Situational Awareness Mapper** – This tool increases situational awareness by enabling people in the field to take pictures using a mobile device, tag the picture with metadata, and send it in to a central (cloud) repository. On the dashboard side of this tool, the pictures show up geo-located on a map. Its potential application is in enhancing situational awareness from the field during or after emergencies.

6. **Scalable Reasoning System (SRS)** – This suite of analytical capabilities enables analysts to visually explore large data sets including their provenance and semantic relationships. It can automatically find clusters of topics, temporal trends and geographic references in information. In the emergency management domain, SRS's ability to sort and filter social media could prove extremely valuable in identifying trends, maintaining situational awareness and discovering issues that need to be acted upon or rumours to be confirmed or refuted.

5. This tool was developed by Mobile Epiphany (private developer).

More than two-dozen participants from emergency management agencies used the technologies in the context of the earthquake scenario. They provided a tremendous amount of feedback and had discussions amongst themselves on the merits and deficiencies of the technologies. All but one of the technologies received a high level of interest and several agencies expressed an interest in piloting the technologies that were demonstrated. Based on feedback from the technology developers, the stakeholders and the client, the programme could have benefited from earlier involvement from stakeholders, including on technology selection and usage.

Programmes such as these can help communities build capacity to recover from disasters and grow more resilient over time.

Challenges and Issues

NWRTC's many projects have identified a set of common challenges and issues facing organisations seeking to improve resilience and recovery. With the economy playing such a key role for community sustainability, it is not surprising that many of the issues are associated with economic redevelopment. What opportunities are available to provide citizens with a way to safeguard or recuperate personal finances? How will the repurposing of local land impact federal actions or involve federal agencies? Can the federal government provide incentives to businesses to stay or relocate to an area and accelerate recovery?

With the many stakeholders involved in resilience and recovery, it also unsurprising that another problematic area is effective decision-making. While many agencies realise that a catastrophic disaster will require multi-agency co-ordination for recovery, few have experienced such co-ordination. In a disaster, a wide variety of organisations will have a role in recovery. Which one has jurisdiction in a given area? How will other agencies stay informed or involved? When multiple jurisdictions have specific responsibilities, how can they collaborate for better solutions? How will these efforts improve resilience in the long term? Working with a broad group of stakeholders allows these questions to be discussed and addressed, and increases the chances for a timely and resilient recovery.

Multi-jurisdictional decision-making can also affect the prioritization of clean-up. Who sets priorities for clean-up and restoration? What are the priority decision criteria? What occurs when state and federal clean-up priorities differ from local and private sector priorities?

Public health and medical services comprise another area of concern. The widespread damage caused by a catastrophic event raises questions about the solvency of the health and medical care system in the impacted area. Will government reimburse private medical companies for the medical and behavioural healthcare for the uninsured and underinsured? What about

private insurers? How will the psychological effects, including fatigue, in the public health and medical services community be addressed?

Another key challenge is effectively involving the private sector. Again, many agencies appear to realize that community recovery means economic recovery. Without the full support and engagement of private-sector businesses and critical infrastructure owners, recovery is impossible. Agencies need to meet with representatives from the private sector in workshops or at trade events to learn what businesses need from government to prepare and to recover. What are businesses prepared to do for themselves? What can they not do? For example, workshops in the Seattle area under the IBRD project identified a six-month window for recovery, after which some companies would simply move out of the area or go out of business.[6]

Finally, an ageing infrastructure only increases the need for integrated approaches and systems. These integrated systems include the development of standards for both the infrastructure itself and the response/recovery to disasters. For example, FEMA, the National Fire Protection Association, and the American Society for Testing Materials International are developing preparedness standards that incorporate concepts of resilience.

Summary

Helping communities improve recovery and resilience requires involvement from the local to the federal level to resolve key issues. The effort also requires facilitation, deliberation and consensus building among a wide variety of groups as well as education and standards development. Following this approach can result in plans and processes that reduce the time and resources required to restore communities and critical infrastructure following a catastrophic incident and assist policy-makers and emergency managers to minimize the economic and public health impacts. As was the case with such efforts in Seattle, Denver and with Canada, lessons learned at the local level can inform practice at the federal level and result in better-prepared and more resilient communities.

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6. K S Judd and A M Lesperance, Business Continuity Planning Resources for Small- and Medium-Sized Businesses, PNNL-19067 (Richland, WA: Pacific Northwest National Laboratory, 2010).

IV. Making Cities Resilient: The Approach of the UN Office for Disaster Risk Reduction

Paola Albrito

On a global scale, human losses due to disasters have been declining due to improvements in early warning systems. For the first time, however, annual economic losses from disasters exceeded $100 billion for three consecutive years and are projected to double by 2030.[1] Within the European region, the economic impact of disasters today averages $13.4 billion a year, making it the third most affected region in the world after the Americas and Asia. In fact, the 2011 Global Assessment Report on Disaster Risk Reduction indicates that in OECD countries, the risk of economic losses is now growing faster than their average GDP growth. As a result, disaster risk reduction has become an essential condition for sustainable development, in Europe as well as globally.

This chapter presents reflections on the notion of disaster risk reduction and provides examples of how to build community resilience to disasters, starting at the local level.

UNISDR

The United Nations Office for Disaster Risk Reduction (UNISDR) is the secretariat of the International Strategy of Disaster Reduction and disaster risk reduction community. The disaster risk reduction community comprises numerous organisations, states, intergovernmental and non-governmental organisations, financial institutions, technical bodies, and civil society, which work together and share information to reduce disaster risk. UNISDR serves as the focal point for the implementation of the 'Hyogo Framework for Action 2005–2015: Building Resilience of Nations and Communities to Disasters' (HFA) – a ten-year plan of action adopted in 2005 by 168 governments to protect lives and livelihoods against disasters.

UNISDR co-ordinates international efforts in disaster risk reduction (DRR) and guides, monitors and reports regularly on progress of the implementation of the HFA. It organises a biennial Global Platform on DRR with leaders and decision-makers to advocate risk reduction policies and support the establishment of regional, national and thematic platforms. UNISDR advocates greater investments in risk-reduction actions to protect people's lives and assets including climate change adaptation, more education on DRR, and the

1. UN General Assembly, 'Implementation of the International Strategy for Disaster Reduction: Report of the Secretary-General', 14 August 2013, A/68/320, available at <http://www.unisdr.org/files/resolutions/SGReportEnglish2013.pdf>, accessed 22 January 2014.

increased participation of ordinary men and women in the decision-making process. It informs and connects people by providing practical services and tools such as the risk reduction website PreventionWeb, publications on good practices, country profiles and the Global Assessment Report on Disaster Risk Reduction which is an authoritative analysis of global disaster risks and trends. Finally, UNISDR campaigns to create global awareness of disaster risk reduction benefits and empower people to reduce their vulnerability to hazards. The current campaigns focus on safer schools and hospitals as well as resilient cities (through the 'Making Cities Resilient – My City is Getting Ready!' campaign).

UNISDR relies on diverse partners, such as regional organisations, networks and institutions. At the national level, UNISDR works through officially nominated focal points. These are very often also the National Platforms for Disaster Risk Reduction Coordination. In the UK, the national counterpart is the Cabinet Office with whom UNISDR has a very active and rewarding collaboration.

Making Cities Resilient Campaign: Why Cities are Important

Half of humanity now lives in cities, and cities make up more than 30 per cent of the world economy. Fast-growing cities and urban areas of the world are engines of growth and wealth accumulation. This growth has positive results on social improvements, and cultural, educational and other positive impacts. On the other hand, fast economic growth combined with fast population expansion in urban areas also increases disaster vulnerability as natural defences are removed. Exposure is therefore increased as more people and more and higher valued assets are located in hazard-prone locations.

Cities need to pursue their development in a way that will prevent new risks from emerging, by reducing and applying corrective actions to existing risks and by proactively building resilience among individuals and societies to cope effectively when hazards do strike. In order to raise awareness, commitment and knowledge sharing around the issue of disaster risk reduction in cities, UNISDR launched the Making Cities Resilient campaign in 2010 in Bonn, Germany.[2] Its objective is to achieve sustainable urban communities through actions taken by local governments to reduce disaster risk.

The campaign has been remarkably successful. So far, 1,655 cities have joined the campaign of which 435 are in Europe. There are ten so-called 'role model cities' in the region, which have been particularly proactive in their approach to making their communities more resilient to natural

2. UNISDR, 'A Toolkit for Local Governments', <http://www.unisdr.org/campaign/resilientcities/>, accessed 21 January 2014.

hazards. These cities are Lienz (Austria); Nice and Sommières (France);[3] Bonn (Germany); Venice (Italy); Barcelona (Spain); and Karlstad, Malmö, Kristianstad and Arvika municipality (Sweden). As part of the campaign, city-to-city exchanges between participating cities have been a successful way of ensuring knowledge transfer between local counterparts. These partnered cities are Venice (Italy) with Byblos (Lebanon), Kristianstad (Sweden) with York and Hull (United Kingdom), Lienz (Austria) with Jonkoping (Sweden), and Ancona (Italy) with Gothenburg (Sweden). In addition, a city-to-city exchange between Venice and Dubrovnik (Croatia) is in the process of being formalised. Particularly effective are the Campaign's Champions: the European Champion is Giorgio Orsoni, mayor of Venice, whose city is an exemplar on many levels.

The Local Government Self-Assessment Tool

The Making Cities Resilient campaign has developed several useful tools for local action. Amongst others, these include a handbook for local government leaders on how to make cities more resilient and the *Making Cities Resilient Report 2012*.[4] The so-called '10 Essentials' is a ten-point checklist and the building block for disaster risk reduction, developed in line with the five priorities of the HFA (see Box 1).

The capacity to monitor advances and challenges in addressing DRR actions on the local level is a fundamental dimension of ensuring appropriate measures and support towards building resilience to disasters. With this important consideration, the Local Government Self-Assessment Tool (LGSAT) helps local governments to engage with different stakeholders to map and understand existing gaps and challenges in disaster risk reduction in their city or locality; sets a baseline and develops status reports for cities and municipalities that have committed to the Making Cities Resilient campaign and its 10 Essentials; and complements information gathered through the HFA monitoring system (HFA Monitor) by providing local-level information.

As an initial effort, the reports provide insight into achievements for disaster risk reduction at the local level, particularly organisational structures for engaging a diverse set of actors with different DRR responsibilities, early warning systems and alerts, measures for protecting critical social infrastructure, such as schools and hospitals, and approaches to the risks brought on by climate change. The reports also identify common challenges, suggesting an area for future work such as more city-to-city peer exchanges to share experiences and lessons learned. One of the common challenges reported was that whilst building codes now address the need for greater

3. For the instance, read the Sommières profile at the UNISDR website: <http://www.unisdr.org/campaign/resilientcities/cities/view/2905>, accessed 8 March 2014.
4. UNISDR, *Making Cities Resilient Report 2012* (Geneva: UNISDR, October 2012), <http://www.unisdr.org/we/inform/publications/28240>, accessed 8 March 2014.

resilience in new structures, it is not clear how to mandate that existing properties be retrofitted to withstand new hazards. Another common challenge was the need for more financial resources. One can envision how future LGSAT reports might identify local governments that could join together in working groups to address common challenges or to highlight role model achievements. The initial local reports show enormous promise to do much more than the benchmarking and reporting that was originally intended.

Box 1: Ten-Point Checklist: Essentials for Making Cities Resilient

1. Put in place organization and co-ordination to understand and reduce disaster risk, based on participation of citizen groups and civil society. Build local alliances. Ensure that all departments understand their role to disaster risk reduction and preparedness.
2. Assign a budget for disaster risk reduction and provide incentives for homeowners, low-income families, communities, businesses and public sector to invest in reducing the risks they face.
3. Maintain up-to-date data on hazards and vulnerabilities, prepare risk assessments and use these as the basis for urban development plans and decisions. Ensure that this information and the plans for your city's resilience are readily available to the public and fully discussed with them.
4. Invest in and maintain critical infrastructure that reduces risk, such as flood drainage, adjusted where needed to cope with climate change.
5. Assess the safety of all schools and health facilities and upgrade these as necessary.
6. Apply and enforce realistic, risk compliant building regulations and land use planning principles. Identify safe land for low-income citizens and develop upgrading of informal settlements, wherever feasible.
7. Ensure education programmes and training on disaster risk reduction are in place in schools and local communities.
8. Protect ecosystems and natural buffers to mitigate floods, storm surges and other hazards to which your city may be vulnerable. Adapt to climate change by building on good risk reduction practices.
9. Install early warning systems and emergency management capacities in your city and hold regular public preparedness drills.
10. After any disaster, ensure that the needs of the survivors are placed at the centre of reconstruction with support for them and their community organizations to design and help implement responses, including rebuilding homes and livelihoods.

Source: UNISDR, 'The 10 Essentials for Making Cities Resilient', <http://www.unisdr.org/campaign/resilientcities/toolkit/essentials>, accessed 8 March 2014.

The Role of the Private Sector

In the future, trillions of dollars will pour into hazard-exposed regions, largely determining the outlook for disaster risk. In most economies, only 15–30 per cent of this investment is made directly by the public sector. The way in which the other 70–85 per cent is invested, therefore, has far-reaching consequences for disaster risk accumulation and underlying risk drivers. The private sector, of course, is part of the community and not only has the capacity to either increase or decrease disaster risk based on the nature of its investments, but it also has a vital role in shaping the city's ability to rebuild itself following a disaster. The majority of businesses are located in cities, and if a city is disrupted, so too are businesses. This, in turn, has consequences at both the national and the local level.

UNISDR has been working with the private sector to look at ways to raise awareness and work together more effectively. The Disaster Risk Reduction–Private Sector Partnership (DRR-PSP) is a global partnership between UNISDR and members of the private sector for mobilising resources for reducing the risk of disaster. DRR-PSP members include partners in financial services, telecommunications, construction and materials, and support services. Members of the initiative work among four different DRR-PSP working groups to leverage resources for disaster risk reduction.

DRR-PSP's Making Cities Resilient Working Group is engaged in the development of a pilot instrument called the City Resilience Scorecard, which builds on the 10 Essentials and focuses on vulnerability, economic losses and exposure, as well as avoiding the creation of new risk. By their very nature, businesses are very adept at calculating investment risk. Yet the relationship between business investment practices and disaster risk is still poorly understood. This is precisely what the City Resilience Scorecard attempts to address. Several pilot countries, including the US, New Zealand and Australia are planning to begin testing the Scorecard, while UNISDR is discussing it with the European Commission, particularly with regard to the integration of climate change adaptation and disaster risk reduction, all of which are closely linked.

Case Studies at the Local Level

Despite facing very different resilience challenges, the cities of Copenhagen, Venice and San Francisco provide great examples of effective disaster risk management at the local level.

Recently, the Danish capital of Copenhagen implemented a sweeping climate change plan, based on a prudent cost-benefit analysis and backed by the national government, following a 'one in 1,000 years' flood in July 2011. The city's Climate Plan is designed to limit the impacts of more severe weather and climate change, amongst other things calling for climate neutrality by

2025. The implemented measures are estimated to deliver savings of EUR 3 million over the next 100 years by avoiding economic losses related to future extreme flooding.

On the other hand, the city of Venice – amongst the world's most beautiful cities and a UNESCO World Heritage Site – raises interesting questions about the connection between disaster risk reduction and the value of cultural heritage. A high proportion of the city's economy is tourism-based, and protection of the city's cultural and historic assets is essential to its identity, development and economy. Given the geographical location and infrastructure of the City of Venice, the approach to date has been 'living with floods' rather than 'fighting floods'. The city has put in place a number of measures to address flood risk, the most famous of which is a highly sophisticated flood barrier to limit how high the floodwaters can rise. The local municipality also invests in flood monitoring, forecasting and communications to increase public awareness and preparedness.

Finally, the city of San Francisco, being notoriously prone to earthquakes, is not only considered a leader in sustainability, but has also made great strides in building its resilience to disasters. The strength of the city's resilience is largely the product of its comprehensive institutionalisation of DRR and the participation of a wide range of actors in its various programmes, committees and activities. San Francisco assigns a budget for disaster risk reduction that includes staff and projects. With these funds, San Francisco is able to provide, amongst other things, free disaster response training for interested citizens and free assistance for business continuity planning to NGOs. From a governance standpoint, San Francisco's mayor and city administrator are responsible for co-ordinating the work of city agencies, and their budgets, to ensure that the goal of contributing to the city's overall resilience is embedded in each department's mission. Finally, one of the most innovative programmes initiated by San Francisco is the Neighborhood Empowerment Network, which is a coalition of residents, community and faith based organisations, NGOs, universities, and private and public agencies that builds tools, resources and programmes in order to increase their capacity to make their communities more resistant.

All of these are great examples of how cities can have a profound impact on disaster resilience not only at the local, but also the national level, positively impacting citizens and private businesses. UNISDR is committed to continuing its work on the Making Cities Resilient campaign, and working with local governments and other stakeholders to ensure the sustainable development of cities and communities through disaster resilience and risk avoidance actions.

Paola Albrito is the Head of the United Nations Office for Disaster Risk Reduction (UNISDR) Regional Office for Europe and has covered disaster risk reduction activities in the European region since 2007. She joined UNISDR headquarters in 2004 during the preparations for the World Conference on Disaster Reduction. She assisted the inter-governmental Drafting Committee and Main Committee of the Conference in charge of developing the Hyogo Declaration and the Hyogo Framework for Action 2005–15. Paola holds a Master's in International Relations and Political Science from the University of Turin, which was gained with research conducted at the International Institute of Strategic Studies in London.

V. A Perspective on Organisational Resilience

Charley Newnham and James Crask

This chapter offers a perspective on organisational resilience by discussing three hypotheses:

1. Enterprise resilience is about both short-term and long-term 'survive and thrive'
2. Resilience is generated and diminished by 'doing' and 'being'
3. Visible resilience can be altered, manipulated and leveraged.

'Thrive and Survive'

There are many definitions of resilience. The Oxford English Dictionary explains it in terms of an ability to return to an original state following disruption.[1] Alternatively, socio-ecological system theory offers: 'the capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks',[2] or the 'capacity to create a fundamentally new system when ecological, economic or social structures make the existing system untenable'.[3]

In an organisational context, many managers still think of organisational resilience as the ability to survive a short-term crisis. However, an organisation that returns to its pre-crisis state arguably has not learned how to avoid, mitigate or minimise the underlying cause of the disruption. For organisations, therefore, the more complex definitions offered above are more useful. Enterprise resilience is about the factors that determine an organisation's ability to not just survive in the short term, but to continue to survive over long periods of time in a 'thriving' state.

Stated another way, resilience is about the factors required to ensure an organisation can sustain the delivery of its core objective over a desired period of time. This raises the following questions:

- Is resilience achievable?
- Should resilience include strategic board decisions?
- Are business continuity management or risk management different from resilience?
- If a company goes into administration today, could it have been

1. Oxford Dictionaries, 'Resilience', <http://www.oxforddictionaries.com/definition/english/resilience?q=resilience>, accessed 10 March 2014.
2. Brian Walker, C S Holling, Stephen R Carpenter, and Ann Kinzig, 'Resilience, adaptability and transformability in social-ecological systems', *Ecology and Society* (Vol. 9, No. 2, 2004).
3. *Ibid*.

resilient three years ago?
- Is resilience a simple concept or a complex one?
- How important is organisational culture to overall resilience?

In Chapter II, Hamish Cameron offers some context for these questions. In thinking about London's resilience capability, he uses a definition of resilience built on the ability to respond to and survive sudden shocks, requiring a multi-agency and governmental response.

Cameron also reminds us that London has existed for more than 2,000 years. As a concept, London has been the biggest hub for living, working, government and industry for centuries, suggesting perhaps that London is indeed resilient. This example usefully challenges a common notion, particularly in industry, that resilience is only about short-term survival, and forces consideration of the socio-ecological viewpoint.

The Changing Face of London

The London of today looks very different from the London of 2,000 years ago, when the Romans were in charge. Neither does it have the same features as in 1666, when the particular configurations of industry and infrastructure enabled the Great Fire of London. Its characteristics have changed again since the Great Smog of December 1952, when the lack of visibility beyond a metre ahead closed down all transport except the London Underground, left the ambulance service unable to operate, and resulted in around 4,000 additional deaths.[4] London looked different, smelled different and behaved differently. As a significant hub for living, working, government and industry, London is nevertheless still here. It has survived, adapted and evolved, and it continues to thrive.

Academic research into how and why London has survived, adapted and evolved in the face of changing contexts that include 2000 years of technological, ecological, geographical, industrial and human evolution may help to explain some of the reasons for London's continued survival. However, in the absence of such research it might be suggested, rather more simply, that perhaps London has had, and still has, the basic resources to survive as an entity. It has a population that has continuously provided dynamics and resources to enable adaptation, and this has provided the will of the people and their leaders to require London to survive and to thrive.

In the context of an organisation, the notion of thriving, as well as surviving, is key.[5] Organisations are, essentially, entities established to deliver core

4. Met Office, 'Case Study – Smog: The Great Smog of 1952', <http://www.metoffice.gov.uk/education/teens/case-studies/great-smog>, accessed 10 March 2014.
5. Abraham Carmeli and Gideon D Markman, 'Capture, Governance, and Resilience: Strategy Implications from the History of Rome', Strategic Management Journal (Vol.

objectives, which might be a profit to its owners or a particular area of public service.[6] Those that do not succeed in delivering this aim robustly, in a thriving capacity, are more likely to become less relevant and eventually be subsumed or eradicated.[7] Unless an organisation has completed its purpose at the time of its demise, it would be hard to consider that organisation to have been resilient.

Thus, in the context of an organisation, it can be argued that resilience is about the factors that support or diminish an organisation's ability to survive, adapt and evolve to thrive in both the short and the longer term.

'Doing' and 'Being'

In considering resilience capacity, many organisations focus almost exclusively on the processes put in place specifically to protect the enterprise. Charley Newnham's research in 2011 showed that organisations with a department or manager with 'resilience' in the title often delivered processes focusing on business continuity management and crisis management, with around one third also including risk management in the scope of 'resilience'.[8] Consulting organisations such as PwC would also include other operational functions within 'doing' processes, such as IT resilience and disaster recovery, finance, information security, safety, physical security and sustainability all forming part of a wider governance framework.[9]

PwC's UK Business Resilience team has additionally observed that organisations that have invested in these operational resilience measures have often done less or little work to ensure that the disciplines are well integrated.[10] Operational resilience is maximised when the processes and functions are intelligently and appropriately integrated.

However, operational processes are not the only factors in an organisation that contribute to, or diminish, levels of enterprise resilience. For instance, consider this allegory:

> A CEO calls to his boardroom the heads of various operational resilience functions, including the heads of physical security, information security, IT resilience, business continuity, crisis management and governance. He tells

32, No. 3, March 2011), pp. 322–41.

6. Cambridge Dictionaries Online, 'organization', <http://dictionary.cambridge.org/dictionary/business-english/organization?q=organisation>, accessed 10 March 2014.
7. Carmeli and Markman, *op. cit.*
8. Charlotte Newnham, Gold or Dust? Creating Resilient Organisations: Predicting a leader's propensity for behaviours that create organisational resilience, unpublished thesis (Cranfield: Cranfield University, 2012).
9. See PwC's Operational Resilience Benchmark.
10. Comments by Charley Newnham and James Crask at the RUSI conference, November 2013.

> them that he's been asked to consider organisational resilience by his non-executive directors.
>
> The CEO asks the gathered heads if they are good at their jobs and they are all able to respond, genuinely, that they are excellent at their jobs and so are the people that work with and for the organisation.
>
> The CEO asks them all if they work well together, sharing information, knowledge, intelligence and ideas on an everyday basis. They are all able to reassure him, genuinely, that their areas are extremely well integrated.
>
> The CEO then asks them if that means the organisation is resilient, and whether they would stake their careers on that.
>
> The heads of department look at the CEO and explain that they have no idea how resilient the organisation is. They can vouch for many of the operational resilience capabilities, but there are a myriad of other factors that impact on the resilience of the CEO's company – for example, board-level strategies, management policies, hiring and firing decisions, competitor activity, industry activity and contextual change (such as customer requirements and trends, market technologies and environment) and so on.

This story illustrates that operational processes are vital to organisational resilience, but they are only part of the picture. Organisational resilience is increased or diminished by every decision and action within an organisation. Recent research, such as papers by Resilient Organisations in New Zealand,[11] into the concept of organisational resilience has found a number of indicators that may provide significant insight into organisational resilience, many of which are outside process-driven or operational boundaries. In industry, the use of terms such as 'indicators' are often viewed as somewhat ambiguous but they are a useful means of narrowing the scope and thus providing an approach by which to consider key factors and dynamics for enterprise resilience.

Contemplate, for a moment the following scenario:

> Imagine that you are in London in 1941 during the Second World War. A bomb-raid siren has just gone off. It is the third evening of sirens. The previous two were followed by vicious attacks near to your home and you are immediately worried. You are still on your way back from work, so you pick up speed and walk towards a nearby underground station, wondering as you do whether your family is in a safe place. You meet a friend on the platform and, with them, try to find a space until you hear the all clear. You

11. See Resilient Organisations for links to example academic papers, <http://www.resorgs.org.nz/Content/publications.html>, accessed 10 March 2014.

> can hear explosions in the distance, which seem to be getting closer and closer to where you are sheltering. And then they pass, and it all goes quiet. You are all safe in the station and ready to go home. As you emerge above ground, you see the devastation of the local area. As you run towards your home, your mind wanders to thinking about the immediate consequences. Who has lived and who has died? Is your house still there? Was anyone at home when it happened? You are trying to be hopeful, but even if your family is safe, there are mass casualties, fallen houses, debris to be cleared, and people to take care of, particularly those that have suffered losses.

When asked to consider resilience in light of this scenario, most people do not consider the processes (or operational resilience measures) supporting the raid, such as the mechanism for the siren, the plans for the fire and medical response, the recovery process and the onward support mechanisms for those who suffered financial losses. They consider instead resilience as it relates to the people: the attitudes, the cultural norms, the shared values, available redundancies and capabilities, and the ability to continue within an altered context.

Academic and industry thought leadership have listed these considerations as indicators of organisational resilience:[12]

- Shared values and purpose
- Situational awareness
- Research and development
- Staff (commitment, engagement, behaviours, capabilities and capacity)
- Innovation and creativity
- Social capital
- Understanding of networks and dependencies
- Exercised/stress-tested strategies
- Operational processes designed to protect the organisation.

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12. A Boin, L K Comfort and C C Demchak, 'The Rise of Resilience' in L K Comfort, A Boin and C C Demchak, *Designing Resilience* (Pittsburgh, PA: University of Pittsburgh Press, 2010), pp. 1–12; L Valikangas, *The Resilient Organisation: How Adaptive Cultures Thrive even when Strategy Fails* (London: McGraw-Hill, 2010); M Beer, *High Commitment, High Performance* (San Francisco, CA: John Wiley and Sons, 2009); S McManus, 'Organisational Resilience in New Zealand', graduate thesis, University of Canterbury, New Zealand, 2009, available at <http://www.resorgs.org.nz/images/stories/pdfs/organisational%20resilience%20in%20new%20zealand.pdf>; A Stephenson, 'Benchmarking the Resilience of Organisations', graduate thesis, University of Canterbury, New Zealand, 2010, available at <http://www.resorgs.org.nz/images/stories/pdfs/thesis_benchmarking%20the%20resilience%20of%20organisations.pdf>; C Newnham, 'Gold or Dust? Creating Resilient Organisations – Predicting a Leader's Propensity for Behaviours that Create Organisational Resilience', MSc thesis, Cranfield University, 2012.

Visible Resilience

A common mantra in management circles is, 'If you can't measure it, you can't manage it'. Regardless of its truth, many organisations do rely on metrics and measures (quantitative and qualitative) to prompt action within their management systems. Therefore, it is fair to assume that organisations concerned about their resilience capabilities will value the ability to measure and evaluate both the status quo and changes over time, perhaps in response to investment or the lack thereof.

In many organisations, the effectiveness of processes, and therefore operational resilience (where it is accepted that these contribute to operational resilience), have been measured and/or evaluated for many years by internal and external review and audit approaches. This kind of approach can therefore be lent to operational resilience benchmarking.

However, measuring circumstances and dynamics can be more complex. If a less than perfect answer is accepted, these indicators can be reviewed, measured and explained in a manner that enables an organisation to identify gaps between the organisation's current situation and where it wishes to be, as a mechanism to support more informed decision-making and investment strategies.

If the management mantra is reversed, if it is measured, it can be managed. In other words, if an organisation's resilience capability, in terms of both 'doing' and 'being', is understood, the factors contributing to or diminishing it might be manipulated, changed and leveraged to create the resilience capabilities and attributes that the organisation needs.

Charley Newnham has more than ten years' business continuity and incident management experience, with organisations including British Airways, Alpha and, more recently, a decade at the BBC. She joined PwC in 2013 following the completion of her Master's thesis on the subject of organisational resilience with Cranfield University. Charley now works with organisations on developing strategic and operational resilience policies and programmes.

James Crask developed the UK government's corporate resilience policy and co-ordinated the London Olympic Resilience Project while working for the Cabinet Office in the Civil Contingencies Secretariat. At PwC, James spends most of his time helping clients with the wider concept of organisational resilience, working mainly with large multinationals to develop strategic resilience policies and programmes.

Resilience Issues of Urban Environments

VI. The Impact of Climate Change

Lola Vallejo

There are many immediate threats and hazards to resilience, but it is also important to take a step back and consider the longer-term perspectives. In Chapter IV, Paola Albrito highlights the importance of the link between adaptation to climate change and resilience. This chapter focuses on the characteristics of climate change: what it is and what challenges it poses, in terms of impact measurement and the policy cycle, asking the question, 'Where do policy-makers intervene?' The chapter then considers more deeply the adaptation challenge and the work that is currently being done in this area.

Climate change is one of the greatest challenges to businesses and society. It is already happening and is likely to exacerbate global vulnerability and exposure to risk in the future.[1] The UK has been hit badly by a number of extreme weather events in recent years and these events are likely to become more frequent and severe.[2] When preparing for climate change, policy-makers have to make decisions in the face of a degree of uncertainty. While we cannot know with precision the location and severity of future climate impacts, science can inform on trends and give ranges of possible temperatures, precipitations levels, and sea-level rise. For instance, the UK Climate Projections[3] published in 2009 feature projections on the change in London's summer precipitation; displayed as confidence lines, these take a 'range approach' that looks at a range of possibilities rather than absolute figures. There will always be issues around the possible granularity of such predictions, but this approach does enable policy-makers to 'zoom in' on certain potential impacts and extract some findings that may be more applicable at the local level.

The Role of the Committee on Climate Change

The Committee on Climate Change is an independent, statutory body established under the Climate Change Act of 2008. Its purpose is to advise the UK government and devolved administrations on reducing emissions and preparing for climate change. While the main Committee focuses on the reduction of carbon emissions, the Adaptation Sub-Committee (ASC) focuses on progress in climate change adaptation. The ASC has two main roles. The

1. IPCC Working Group II, 'Climate Change 2014: Impacts, Adaptation, and Vulnerability – Summary for Policymakers', April 2014, available at <http://ipcc-wg2.gov/AR5/images/uploads/IPCC_WG2AR5_SPM_Approved.pdf>.
2. Met Office, 'Too Hot, Too Cold, Too Wet, Too Dry: Drivers and Impacts of Seasonal Weather in the UK', March 2014, available at <http://www.metoffice.gov.uk/media/pdf/4/8/Drivers_and_impacts_of_seasonal_weather_in_the_UK.pdf>.
3. See UK Climate Projections, <http://ukclimateprojections.metoffice.gov.uk/>, accessed 21 January 2014.

first of these is to provide expert advice to government on devising its climate adaptation policy, on topics ranging from the development of the Climate Change Risk Assessment (CCRA),[4] the design of the Adaptation Reporting Power or the Flood Reinsurance Mechanism. More importantly, the ASC will report to Parliament in 2015 on the progress that the government is making on implementing its National Adaptation Programme.

The Climate Change Act has set a five-year policy cycle for the UK adaptation to climate change. The first major policy document published after the Act was the CCRA. This tried to capture the climate change risks that will affect the UK and the level of confidence in both the risks taking place and their predicted severity. Following this, the government published the National Adaptation Programme in July 2013 (see below).[5] The ASC will be assessing the government's progress on its adaptation programme in 2015 and will also write the evidence report underlying the next CCRA, to be published in 2017.

The risks from climate change which may impact communities, businesses, infrastructure and the natural environment are larger and wider than those covered in the CCRA. The CCRA only focuses on domestic impacts from climate change but there are important impacts that may be imported from international effects, many of which are discussed in the 2013 PricewaterhouseCoopers report 'International threats and opportunities of climate change for the UK'.[6]

For the CCRA, the government has made a very strong point of emphasising that there are opportunities as well as risks from climate change. However, the risks represent the majority of the expected impacts. Secondly, the confidence level for many risks is either medium or low, and therefore the level of uncertainty is high. There is definitely scope for more research into the impact that these risks are likely to have on specific types of actors or vulnerable communities, as well as more research into local impacts at an increasingly granular level.

4. HM Government, *UK Climate Change Risk Assessment: Government Report* (London: The Stationery Office, 2012), available at <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69487/pb13698-climate-risk-assessment.pdf>.
5. HM Government, *The National Adaptation Programme: Making the country resilient to a changing climate* (London: The Stationery Office, July 2013), <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/209866/pb13942-nap-20130701.pdf>, accessed 17 January 2014.
6. PwC, 'International threats and opportunities of climate change for the UK', <http://www.pwc.co.uk/sustainability-climate-change/publications/international-threats-and-opportunities-of-climate-change-to-the-uk.jhtml>, accessed 21 January 2014.

Monitoring and Evaluating Adaptation Action

Preparing for climate change (adaptation) or reducing greenhouse gases emission (mitigation) both pose very different challenges. In the UK, there is a very clear target for de-carbonisation, which is to reduce carbon emissions by 80 per cent by 2050. The level of carbon emissions is the all-encompassing metric that acts as a reference point for all sectors. In adaptation, however, there is no such simple national target or metric, which means the ASC has had to devise its own set of indicators to monitor and evaluate progress.

The ASC has designed a two-tier toolkit to achieve this. The first tier uses a number of indicators: on exposure and vulnerability, to monitor trends in risk; on adaptation action, to monitor the uptake of actions that contribute to reduce vulnerability; and on climate impact, to monitor impacts whenever possible (as it requires a long time-series to distinguish any trend or attribution to climate change).

The second tier of the toolkit looks at decision-making analysis and tries to identify 'no-regret' adaptation measures. For instance, water efficiency devices are no-regret measures because they can be useful no matter what future climate holds. Longer-term measures – such as the location of a power plant – are more strategic, with potential implications for decades to come, and so require much more of an important decision-making process.

Summary

This chapter has focused on approaches to monitoring and evaluation for adaptation. In the run-up to its statutory report in 2015, the Adaptation Sub-Committee has built indicators regarding flooding and water scarcity, ecosystem services and the natural environment. The 2014 report will look at risks to health, infrastructure and businesses. Today, there are about sixty indicators, but this number should reach 100 by July 2014. These indicators will then be used for the statutory report to Parliament in 2015.

Lola Vallejo works on infrastructure resilience, coastal change management and business adaptation reporting within the Committee on Climate Change, the independent body advising the government on tackling and preparing for climate change. She previously worked on global decarbonisation pathways as a research co-ordinator at Imperial College London and on climate policies as a consultant in Paris. She holds an MSc in Environmental Technology from Imperial College and an MSc in Finance and Strategy from Sciences-Po Paris.

VII. Radiological Response and the Half-Life of Resilience

Malcolm Sperrin

There are many definitions of the term 'resilience', but the most useful are those that acknowledge a system may develop greater resilience by learning lessons from previous events, such as that of the US Federal Emergency Management Agency (FEMA), discussed in Chapter III.

This is particularly true in the case of radiological CBRN events, where the health risks to the affected populations present unique challenges in the immediate aftermath, and short-term and long-term recovery, not least because the risks are dynamic and differ depending on the phase of the incident and nature of the agent. In this regard, resilience to a CBRN event of this kind can be usefully discussed in terms of its impact on populations over time and geographical distance.

A release of radiation can have an impact on one or more of the following:

- An individual, who may be irradiated, contaminated or simply inconvenienced
- A population, which may be exposed to an elevated risk of radiation-induced disease
- A social community, where normal social functions have to be modified (because, for example, access to usual meeting places and essential services are restricted)
- Organisations, where the organisation has to modify its function to operate in the changed environment
- Local, regional and national responses to a real or perceived threat
- Governance structures, which may need to create or restrict privileges
- Political drivers of national policy
- International agreements
- Drivers of conflict.

There is plenty of scope for discussing each of these potential impacts in depth, but for the purposes of this paper it is sufficient to identify these (and others) as factors in dictating the prevention of, threat from and recovery following a radiation-release event. Such events may be accidental, where schemes such as National Arrangements for Incidents involving Radioactivity (NAIR)[1] apply, or offensive. The primary difference between accidental and

1. See: <http://www.hpa.org.uk/Topics/Radiation/UnderstandingRadiation/UnderstandingRadiationTopics/RadiationIncidents/incid_Nair/>, last accessed 19 December 2013.

offensive release is one of intent but such intent may inform the actors' choice of isotope(s): whereas an accidental release is likely to be of a single isotope intended for specific industrial applications, a malicious incident may involve a combination of radioactive materials with different properties, each requiring a specific response that makes the immediate and long-term recovery more complex. The implications of this are discussed in more detail later in the paper.

Radioactive material used in the nuclear power industry and by the military are governed by strong regulations dictating their management and, arguably, are therefore less likely to be accessible to malicious actors and more robustly protected from accidental harm. Of more concern to the resilience of modern cities to CBRN events is the accidental or deliberate release of radioactive isotopes from smaller quantities of material and equipment used in industries such as healthcare and agriculture.

Vulnerabilities during Carriage

The first area of concern to CBRN resilience this paper will consider is vulnerabilities during carriage, as this is one of the logistical points where material can be accessed, either deliberately or accidentally. Such incidents have occurred in a number of cases, such as when a small canister of iridium-192 was stolen from the back of a van in Lancashire, UK in February 2013, and a cobalt-60 teletherapy source was in a van stolen in Mexico in December of the same year. In both cases, the intent of the crimes was not specifically to steal radiological material – rather just the contents of the van whatever they may be or the van itself – but the incidents highlight the potential vulnerabilities and opportunities for those who may want to acquire such material.

In the case of carriage of materials to and from nuclear power stations, carriage is highly controlled due to the large volume and potential for catastrophic consequences upon accidental or deliberate release. Flasks containing the material have to be designed to withstand extremely large stresses as well as withstanding high temperatures for periods that permit the arrival of emergency services following, for example, a serious motorway crash. Furthermore, there are tight security arrangements covering contingencies including terrorist attack. These arrangements have been visible during the recent extraction of weaponisable nerve agent precursors from Syria, for example.

Such tight controls are not in place for the carriage of smaller quantities of radioactive material used in other industries, however, and the release of smaller volumes of material during carriage is therefore arguably a more realistic scenario. In addition, as many towns and cities have an ancient origin, the transport and logistics routes in and out of the city – the Lines of

Communication, or LoCs, in military terms – can be complex and less than optimal for the transport of hazardous materials.

Many such lines of communication have origins in industry that has long gone but whose logistical needs still define the layout of our cities, determining the position of features such as railways, canals and river crossings, as well as more recent developments such as motorways. The likely consequences of these features on the response to an incident are well understood: planning by the emergency services includes an awareness of communication restrictions including road access, radio and mobile telecommunications and access to back-up capacity and specialist advice. The release of radiation into such an environment does, however, present certain factors – discussed below – that act to significantly complicate safe and efficient control, and makes for a difficult and dynamic process.

Emergency services responding to an event initially assumed to involve trauma but which rapidly is identified as involving radiation release may have limited capacity for providing the effective extraction of casualties to mass decontamination units or the local receiving hospital, particularly if the event happens in a narrow street in the middle of a built-up area where there is insufficient space to erect and perform hot zone triage, treatment and decontamination.

Furthermore, while the response to radiological incidents is practiced as a major incident scenario, the number of individuals playing the part of affected patients in such exercises is usually reasonably low – few exercises realistically practice how to deal with the large numbers of individuals who may be involved in an event taking place close to a densely populated residential block or a crowded shopping centre, for example. Similar difficulties exist with the ability of a hospital to exercise the arrival of a large number of contaminated and/or irradiated casualties and to practice using their facilities for decontamination, triage and active material disposal in realistic quantities.

Triage of Contaminated Casualties

A second consideration in radiological CBRN response is how to provide care to patients with immediately life-threatening injuries, particularly if doing so risks exposing those providing immediate aid with radiation doses themselves and leads to them becoming vectors in the distribution of radioactivity. The first responders on the scene are unlikely to be the specialist HART[2] teams trained and equipped to treat and extract casualties from contaminated areas, and while there are well practiced procedures that set out when

2. HART – Hazardous Area Response Teams, see http://naru.org.uk/naru-work-activities/naru-work-activities-capability-deliverables-hart-programme/national-hart-teams/, last accessed 4 April 2014

ambulance paramedics should 'stand off' from a contaminated scene, it may in practice this is only possible where there is an overt release and, in any case, it may be extremely difficult for a paramedic to stand back and watch someone bleed to death, even when they are aware that they may be putting themselves at risk by doing so. It may also be the case that the radioactive contamination is not recognised until many first responders have approached the incident site. Urgent expert involvement may be required to manage radiation risk, but such expert teams may be not be able to reach the key locations in a meaningful time scale.

A more subtle point relates to the secondary carriage of radiation by the population surrounding the incident. Fragments of dispersed radiological material – shrapnel from a dirty bomb or fragments from material damaged in a crash – may be carried from the scene in the form of deposited dust or as imbedded foreign matter requiring surgical management. The uncontrolled distribution of such material vastly increases the risk profile to the population and makes the subsequent clean-up very difficult to manage. Just how difficult this can be was illustrated by the radioactive trails left by the protagonists following the poisoning of former Russian agent Alexander Litvinenko with the radioactive isotope Polonium-210 in 2006, which included thirteen contaminated sites in London alone, including the stadium of Arsenal Football Club, and required the involvement of fifty-two countries to trace more than 36,000 people who may have been exposed to the radiation.[3]

Managing the 'worried well'

One crucial consideration for hospital and associated facilities following a radiological incident is the risk from a sudden increase in the 'worried-well', who may or may not have been affected by radioactive material. Precise detail will vary with analysis, but for every fatality it is reasonable to consider at least a factor of ten applied to the number requiring urgent medical attention, another factor of ten for those who have minor injuries and yet another factor of ten for those who have no injury but who require reassurance. In the Litivenko incident described above, the statistics were as follows:[4]

3. Jennifer Cole, 'UK Medical Responses to Terrorism', Medical Responses to Terror Threats, NATO Peace and Security Series E: Human and Societal Dynamics, Vol 65, 2010
4. *Ibid.*

No. affected	Risk	Description
1	Dead	Alexander Litvinenko
15	Actually affected	Deemed by the Health Protection Agency/NHS to have a health risk requiring ongoing monitoring
596	At significant risk	Deemed sufficiently at risk to be tested for radiation exposure by the HPA/NHS
7,200	Worried well	5,500 concerned passengers who may have travelled on an aeroplane contaminated by the radiation called British Airways helpline, plus 1,700 concerned individuals called the NHS helpline.

It is easy to see how such incidents may result in many hundreds of concerned people saturating the available medical facilities and making access for those with the most serious injuries even more difficult.

Further important considerations are the spread and possible concentration of radioactive material as a result of the population density in areas such as hospital emergency department waiting areas, and the compromise of hospital imaging systems as a result of contamination. This compromise of a medical facility's equipment is of critical importance. Many departments rely on radiation detection for accurate diagnosis through the use of X-rays and nuclear medicine, and the presence of random active material will at best provide artefacts in the image or possibly make the imaging process impossible, leading to more complex and delayed diagnostic pathways.

Responding to contamination from mixed isotopes

The management of spilt isotopes for medical or industrial purposes is routinely practiced and represents a relatively controlled risk. The release of isotopes for nefarious intent presents a greater problem, however, in that it may be some time before such a release is even detected, especially where the release is dispersive rather than explosive. The problem is magnified considerably if the release comprises a cocktail of isotopes or of fissile material. In these latter cases, the half-lives are very different: the type of radiation includes alphas, betas and gammas and they will be in different forms. This range of isotopes presents a complexity that makes the management of isotopic mixes difficult.

The ability of radiation to penetrate through protective material and also skin depends upon whether the isotope is particulate and also its energy. Gamma rays penetrate many materials easily, but also escape easily, meaning

that their associated radiation dose can be low. Alpha particles, though they penetrate less easily, are more likely to result in a very high radiation dose, particularly when ingested as they are likely to remain in to the gut and cause considerable damage. The health impact from Beta particles is less likely to be acute but may develop over a number of years, requiring long-term health monitoring and surveillance of those affected.

The analysis of the risk from multiple isotopes is a highly complex task, and the risks from a mixture of isotopes is even more so, making protective and control measures a particularly specialist task.

This may result in conflicts of decision as the best course of action for a patient may not be the best course of action for the healthcare system: for example, immediate evacuation of an individual to a healthcare facility may not be an appropriate response if doing so is likely to put that healthcare facility at considerable risk: several of the individuals affected during the Litvinenko incident were healthcare workers at Barnet General Hospital, where he was initially treated. Furthermore, the understandable urge to clear-up an area post incident may need to be delayed while investigations into its cause are undertaken, leading to longer periods of recovery and arguably less 'resilience' if length of recovery is taken to be a resilience indicator.

Dynamic risk assessment for changing circumstances

An isotopic cocktail would require a dynamic risk assessment; firstly because the daughter products will have different radioactive properties, each of which has its own risk profile, and secondly because windborne isotopes will disperse and arrive in a different manner to solid radioactive debris. The operational consequences to this are further complicated as the risk profile will change with time, meaning that it may be advantageous to split the management of the incident into stages that reflect the nature and severity of the multiple challenges. This was clearly seen immediately after the release of the radiation from the Fukushima Dai-ichi nuclear power plant in Japan following the March 2011 tsunami and earthquake, where high dose-rate but short duration exposure was detected prior to the arrival of contaminated solids in the form of radioactive dust.

The resilience of a healthcare and social system is likely to be challenged further by factors derived from the physics and kinetics of isotope exposure. The concept of critical time-frames is well established in the management of trauma but less well known is the impact of delayed radiation effects - often referred to as acute radiation sickness. This was clearly observed following the atomic bombs dropped on Japan at the end of World War II, where the initial peak of traditional blast and heat injuries was followed by a second peak arising from radiation effects such as nausea, erythema and diarrhoea, which are life threatening in their own right, and the increased

risk from the genesis of cancers in the long term. These risks can be offset: in both Chernobyl and Fukushima, potassium iodide was available to prevent the uptake of radioactive iodine by the body, and the increased medical care such casualties are likely to receive in the immediate aftermath and through long-term health monitoring can lead to much earlier detection and treatment of emerging cancers (and other health risks unrelated to the radiation exposure) than would otherwise be the case. Awareness of the treatment pathways following a critical event is crucial.

The analysis of complex technical data, which can appear to be conflicting to non-scientific experts, is of crucial importance to those controlling an incident and the subsequent management of an affected area. Experts with appropriate training are available but are there sufficient numbers to provide comprehensive cover, especially in large-scale or multi-centre events? Such experts may be found in hospital physics departments, in industry and in the military but at present may not be sufficiently versed in resilience to be able to provide information in the form required by those dealing with the incident.

Summary and conclusions

In summary, the resilience of different actors involved in the event and, in particular, the interplay between them needs to be further investigated and better understood. There is likely to be some benefit in informing a population of the risks that might exist following a radiological incident (and, crucially, to have that information ready and to hand before an incident occurs, so that it can be disseminated immediately), since otherwise a lay population will attempt to inform itself, with insufficient understanding to form reasonable conclusions. Such well meaning but ill-informed opinion led to the panic buying of potassium iodide following the Fukushima release, with individuals buying large amounts of ordinary table salt instead of potassium iodine on the basis that they are chemically similar in nature, seemingly unaware that ingesting large quantities of table salt could have proved fatal. In addition, sales of potassium iodide increased significantly, and at inflated prices, without medical advice on the true nature of what was being purchased or appropriate information on dosage.[5]

There is, therefore, an argument for the creation of approved response guides linked to technical appraisals that specifically focus on the long-term health issues of the affected populations – this presents a considerable academic and operational challenge since the deposition and hence risk arising from radiation incidents is multi-factorial, taking into account meteorology, hydrology, the built environment and other disciplines. This is also a factor in the urgent and on-going medical triage and healthcare models, where

5. Jennifer Cole, 'Understanding the radiological risk: lessons from Fukushima', CBRNeWORLD, Falcon Communications, pp. 56-58, Summer 2001

the impact of a broad spectrum of isotopes remains to be comprehensively studied.

This raises the potential for numerous lines of research and investigation, both scientific and operational. Such key areas include:

- Considering the mechanisms needed for responding to multiple challenges. This may be a number of simultaneous events of the same type, or a chemical incident running in parallel with a radiation incident which in turn has arisen from a traumatic event. More research is needed on how these areas overlap and affect one another.
- Further investigation is needed into health risks and their subsequent management following a broad-spectrum isotopic release.
- How to best develop a profession-dependent working knowledge of the threat indicators, such as the theft of isotopes or chemical agents; the information needed by the security services in the aftermath of an attack may be very different from that required by GPs in the area affected, for example.
- The military uses a concept known as Intelligence Preparation of the Battlespace (IPB) where a knowledge of likely incident points, environmental factors and so on inform the optimum courses of action. Developing a similar method for assessing the geospatial risk in the city environment would be advantageous. While some of this exists in Restricted Cabinet Office documents, more open source approaches that can inform planning by all stakeholders is required.
- A better understanding is required of how transition from the threat of an event to the event actually occurring, along with more research on how individual and population risks develop over time.
- Further development of multiple interest command, control and recovery (C2R) is needed to ensure competent organisations are not constrained by individual working practice and to ensure that events spreading over international boundaries are managed for optimal outcome for all parties.

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VIII. The Resilience of City Systems: Interdependencies – Synergistic and Antagonistic – and How We Measure Them

Jeremy Watson

Cities are complex systems of systems that involve many types of interactions: social, economic, technical and environmental. Only by thinking of these as an integrated system can an attempt be made to estimate the resilience of the whole or part of a city. Additionally, many externalities apply – not least national economics and energy, water and food supplies.

The United Nations Office for Disaster Risk Reduction defines resilience as: 'The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.'[1] A mind-map, as in Figure 1, can show some of the considerations involved: disturbances, vulnerabilities and interdependencies on the one hand, and sensing and measurement, and data fusion and analytics on the other. Disturbances can be natural or man-made; vulnerabilities exist across the physical and human infrastructure and built environment systems.

Figure 1: Mind-Map of Resilience Considerations for City Systems.

Work by Jo da Silva at Arup includes a wheel diagram that juxtaposes human and physical system characteristics as they pertain to resilient urban

1. UNISDR, 'Resilience', Terminology, <http://www.unisdr.org/we/inform/terminology>, accessed 11 March 2014.

systems.[2] This embraces the human characteristics of resourcefulness and capacity to learn alongside engineered characteristics such as safe failure and redundancy. It is clear that resilient cities require appropriate co-operation between human and machine actors.

Flows, Nodes and Layers

An entailment diagram can start to show some of the interacting elements that make up the city 'system of systems'. It can demonstrate the different types of 'currency flow' that take place between functional nodes. These flows and nodes must be individually considered in terms of their robustness and redundancy when thinking about the resilience of the overall system.

There are many ways of thinking about systems in cities. One is by considering functional layers, which include:

- Service layers, such as utility networks (electricity, gas, water and communications)
- Flows of resources between service networks and agent or user nodes
- Land use and the geographical aspects of city design, which strongly impact energy use; CO_2 emissions, journey times and commuter experience.

An important further way of considering the elements of city systems is through their functional interdependence. A simple diagram cannot do justice to the real complexities that pertain, but the network approach suggests that a structured method for estimating resilience may be possible through a node and arc diagram (as in Figure 2). Likelihoods of nodal failure against a set of challenges or disturbance types could be estimated and multiplied through the matrix of city element failure rates to yield a vector of resilience metrics. Establishing dependencies is a significant issue, and social network analysis may play a part in helping to provide operational understanding.

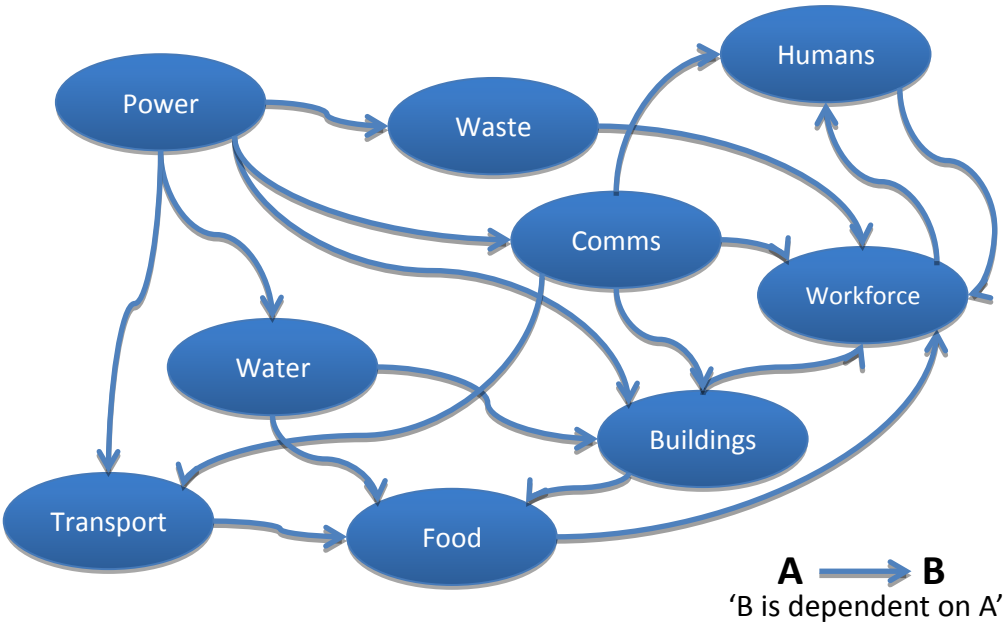
Interdependencies

Views of interdependencies are changing. Initial studies concentrated on the adverse effects of cascade failure interdependence; however, early in the 2000s, the focus started to shift towards seeing interdependencies as opportunities for efficiencies and cost savings. This was recognised by HM Treasury in their establishment of the Engineering Interdependency Expert

2. Jo da Silva, Sam Kernaghan and Andrés Luque, 'A systems approach to meeting the challenges of urban climate change', International Journal of Urban Sustainable Development (Vol. 4, No. 2, 2012); Jo da Silva, Shifting agendas: Response to resilience – The role of the engineer in disaster risk reduction, The Institution of Civil Engineers 9th Brunel International Lecture Series (London: Institution of Civil Engineers, 2012), p. 21, figure 6.

Group for Infrastructure UK, and a joint EPSRC/ESRC call for proposals on 'innovative business models around infrastructure interdependencies'.[3]

Figure 2: Node and Arc Diagram Showing Resilience Interdependencies.



Further consideration of failure cascades led to a realisation that interdependencies in cities and their infrastructure do represent significant risk and pointed to the need to concentrate on decoupling, management and protection of systems from external threats.

Wider interdependencies were recognised and analysed after the 2007 Gloucestershire floods. It was clear that there was key reliance on a critical electricity sub-station built on a flood plain with knock-on effects in water supply and IT. Ultimately, this cascaded to the criticality of the sub-station with respect to the road network and its part in the delivery of temporary flood defences, as demonstrated by the flooding of the M5 motorway.

Why do interdependencies matter so much? For the different types of individual asset failure, consequent system failure modes are important. Do they lead to a graceful degradation of service, or sudden collapse, locally

3. Professor Brian Collins currently chairs the Expert Group, led by Lord James Sassoon, Commercial Secretary in HM Treasury. The 2012 funding call for is available at <http://www.epsrc.ac.uk/funding/calls/2012/Pages/infrastructureinterdependencies.aspx>, accessed 11 March 2014. The EPSRC and ESRC aimed to 'invest up to £7 million to support two multidisciplinary research centres exploring the innovative business models that arise when infrastructure is considered as an interdependent system of systems', *ibid*.

cascading out from a centre? To understand the risk, it is important to understand the logical links in the system of systems, as well as emergent behaviours at system and system-of-system levels. Potential risks need to be understood not only at the single-asset level, but also with respect to their system implications. If the asset is critical (in other words, a key link in a potential causal failure cascade), should redundancy be built into the system in which it forms a critical part?

There are many kinds of interdependencies, two important examples of which are the electrified railway network and the food supply chain to cities. The railway network is a major consumer of electric power, which is supplied by sub-stations disposed around the rail network. The sub-stations are themselves fed by grid links that also supply other consumers of electricity. Grid links to sub-stations and critical sub-stations themselves may, given a systemic failure, cause the loss of rail transport.

People who live in cities are crucially dependent on the food supply chain. Supermarkets may only hold around three days of perishable supplies. These stocks depend for replenishment on complex and often long supply chains and logistics lines, involving multi-modal freight carriage. These supply chains in turn depend on the availability of fuel for delivery lorries.

The Emergence of Pervasive Sensing and 'Big Data'

Since the introduction of CCTV street cameras, ambient monitoring opportunities have grown exponentially, particularly with the widespread adoption of smart phones and G3-connected personal devices, most of which include cameras, accelerometers and GPS functionality. Some enabling factors are:

- Pervasive CCTV
- Traffic flow and speed sensors
- Smart meters for utilities
- Environmental monitors
- Personal digital devices combined with GPS and 3/4G networks
- Social networking, such as Twitter.

The first group of interventions can inform and assist in the case of accidents, crime and road obstructions; the second provide finer-grained information and the possibility of inferring implicit information. The last enable citizens themselves to participate in sensing and monitoring. An example of this is the ability to detect the outbreak of Norovirus through mining informal geo-located comments on Twitter.

Big Data is a philosophy as much as a technical topic. It seeks to encourage the publication of public and private data sets, static and live, on the Internet.

These data sets may be in disparate forms, but with the availability of agent-based and interpretive software, they can be connected or cross-associated ('mashed') to provide new information not previously available. For example, crime statistics may be associated with geographical information services to create 'crime contour' maps. At a more sophisticated level, time-stamped data from different sources may be correlated and fused to yield inferences concerning behaviour. This capability may provide opportunities to anticipate and pre-empt anti-social and disruptive behaviours.

Opportunities for business development and economic growth exist through private sector mashing services, combining proprietary and open data sources for knowledge and value creation. These services may evolve to be generated 'on the fly', in response to user/client web queries. For example, progress towards live Building Information Modelling (BIM level 3) data will make building and district-scale energy mapping possible, including live predictive maintenance information on buildings and infrastructure.

Challenges to City and Infrastructure Resilience

City resilience is challenged by stimuli both from the natural environment and from human activity. Climate change is an important natural challenge. It is almost universally accepted that there is a causal relationship between human activity, CO2 level rise and global warming. Global warming causes extreme weather (such as high summer temperatures in temperate climates), and increases in atmospheric thermal energy may be manifested by strong winds and intense rainfall. Rainfall and strong winds impact cities by inundating buildings and infrastructure, damaging and washing away structures. For infrastructure in the built environment, these effects can be triggers for cascade failures across different but interdependent sub-systems. This climate dependency on infrastructure interdependencies was explored in a 2010 report by the Royal Academy of Engineering.[4] Adding resilience to interdependent networks carries a cost, and careful business consideration is needed to balance this against the criticality of maintaining an uninterrupted service.

Estimating and Enhancing Resilience

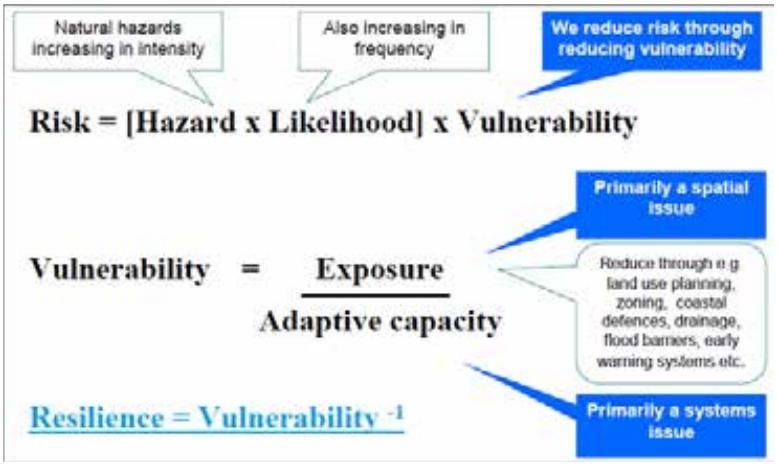
Managing resilience concerns the continuity of operational capabilities of systems and sub-systems under disturbance conditions, with acceptable levels of degradation:

- Sub-systems may be interdependent such that 'cascade failure' is possible
- Sub-systems may be redundant, such that the failure of one is supported by the continuing operation of another.

4. The Royal Academy of Engineering, Infrastructure, Engineering and Climate Change Adaptation: ensuring services in an uncertain future (London: RAEng, 2011).

An estimate of resilience for a complex system can be derived from a probabilistic network analysis of these properties in real systems. In mitigating risk through redundancy, it must be recognised that redundancy costs money, and that while the exploitation of synergistic interdependencies can save money, it may increase the risk of cascade failure.

Figure 3: The Relationship Between Vulnerability and Resilience



In Figure 3, vulnerability is shown to be inversely proportional to adaptive capacity. One way to achieve adaptive capacity is through redundancy, or alternative multi-path approaches to maintaining systems functionality.

The Role of Behavioural Science in Resilience

How the built environment is designed and engineered influences its sensitivity to citizen behaviour. For example, the predictability of the energy efficiency of a building is strongly influenced by whether it has windows that can be opened by the occupants. The deployment of street cameras may reduce crime, and the knowledge that their images are subject to automated processing and interpretation may reduce it even more.

When designing for behavioural outcomes, it must be recognised that the persistence of effects cannot be guaranteed. Responses to interventions are subject to rebound and contrary behaviours. It is found that the installation of low-energy light bulbs results in them being left ‘on’, as perceived savings reduce the onus to switch off. Similarly, in a trial to test occupants’ willingness to reduce heating, subjects were told that a 1° reduction of their room thermostat setting would save £100 per year. At the end of the trial it transpired that more than 50 per cent had increased their thermostat setting by 1°, arguing that £100 was not much more to be cosier.

When introducing a design intervention, a further factor to be considered is the transition dynamic. This follows an ‘S’ curve of adoption versus time,

with a characteristic delay of typically five years for 20–80 per cent adoption. Recent statistics for the adoption of condensing boilers in homes obeys this dynamic, even though regulation is in place to ensure only condensing types are used when replacing old boilers.

Further Research

The topics explored in this chapter suggest key areas for further research, including how to engineer design from objective outcomes; understanding corporate behaviours associated with collaboration for value aggregation; and the role of regulation and fashion alongside technology in gaining momentum in adoption.

There is a clear need for multi-disciplinary research to guide engineering and policy, leading, perhaps, to systems that learn (and maybe question) choices and behaviour.

Conclusion

Cities are becoming more vulnerable as they depend on ever more complex systems of systems. Many of these are interdependent, and subject to cascade failure. It may be possible to map these system interdependencies and estimate their probability through node-arc diagrams to assist the computation of failure. This quantified resilience information can guide a strategy of design for resilience through redundancy.

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Modelling Resilience

IX. Modelling Resilience: The Importance of Geospatial Data

Rollo Home

The Ordnance Survey (OS), the National Mapping Authority (NMA) for Great Britain, has an evolving strategy for the exploitation of 3D geospatial data. Although a public body, as a 'trading fund' it operates within a commercial environment, meaning that product creation has to be backed by a sound business case before it can be approved. In the case of 3D data, city modelling for resilience – encapsulated within the term 'smart cities' – is seen as a crucial business driver. This chapter explores the ideas behind that thinking, explains the importance of 3D geospatial data for urban management, and invites contributions from the community on the assets such a future 3D data product might contain to enhance its utilisation for resilience modelling.

An important role within the OS is to identify the future demands placed on the data produced by it, and to respond to these demands in a timely manner. In essence, this condenses into two questions: What will the decision-maker require in five, ten and twenty years' time to make the informed decisions that are currently being made with the existing products? And how will the technology evolution over that period shape the geospatial data requirement? Underlying these is a more direct question: What needs to be done to keep the OS's data relevant to the user community?

To place these questions within their appropriate context, it is important to outline what the OS actually is. As the NMA, the OS has been charged with the national purpose of 'maintaining the definitive underpinning geospatial framework for Great Britain'.[1] In practice, what that means is that more than 1,200 staff members work to ensure that every significant change in the physical structure of Great Britain is mapped.

The other significant factor is that the OS is a government trading fund. This requires the OS to recover the full operational costs of all its activities. It does not receive subsidy from government (although the government is a significant client); instead, revenue is generated from the licensing of products and services. As the organisation operates as a commercial entity, albeit one with a wider public service remit, product thinking is driven by commercial realities. Therefore, while the public may have an expectation that the OS will map and produce 3D geospatial data and data models, this can only happen if the business drivers that require these data can be

1. Ordnance Survey, 'Our public task', <http://www.ordnancesurvey.co.uk/about/governance/public-task.html>, accessed 11 February 2014.

identified. Resilience modelling, especially within the urban context, has been identified as a key potential growth area for the use of these data.

It has been understood for some time that common geographic information provides a common situational awareness platform that can help with undertaking strategic assessments and scenario planning, as well as enabling options and their consequences to be explored.[2] This can, in turn, feed into all stages of the resilience process (prevention, protection, response and recovery) in order to improve the quality and timeliness of decision-making, and reduce duplication, resources and ultimately costs. The value of this is not, however, as widely understood as might be imagined.

Infrastructure, Interdependency and Data

Over the past twenty years Great Britain's national infrastructure has undergone a dramatic transformation.[3] As a society, we have moved from a moderate dependence on a series of loosely coupled systems and assets to the point where we now live with near-complete dependency on huge networks of distributed goods and services. The modern, complex interdependence that has come to characterise our infrastructure means that a failure of any aspect can quickly cascade across wider infrastructure with unexpected outcomes. Crucial to being able to respond in such an environment is the timely availability of data and a shared operational understanding among groups of infrastructure operators and responders.

There has been a wealth of work in recent years focusing on the response to threats to the critical national infrastructure, predominantly through the lens of responding to civil emergencies.[4] Common across them all is the placement of information sharing at the very centre of ensuring the continuity of essential services during a civil emergency. More recently, there has been growing recognition that different users view the world only in the way they need to in order to supply the service their organisation is responsible for.[5] Thus owners and operators of national infrastructure

2. Patrick Broomijmans, Arda Riedijk, Chris Jacobs, Ronnie Lassche and Henk J Scholten, 'Measurement of the added value of geographic information in disaster management', GSDI 11 World Conference, Rotterdam, the Netherlands, June 2009, <http://www.gsdi.org/gsdiconf/gsdi11/papers/pdf/117.pdf>, accessed 12 March 2014.
3. 'The national infrastructure is the underlying framework of facilities, systems, sites and networks necessary for the functioning of the country and the delivery of the essential services, which we rely on in every aspect of our daily life.' See Centre for the Protection of National Infrastructure, 'The national infrastructure', <http://www.cpni.gov.uk/about/cni/>, accessed 12 March 2014.
4. For example, *The Pitt Review: Learning Lessons from the 2007 Floods* (London: Cabinet Office, 2008), now available from the National Archives.
5. Cabinet Office, *Keeping the Country Running: Natural Hazards and Infrastructure* (London: The Stationery Office, 2011), <https://www.gov.uk/government/publications/keeping-the-country-running-natural-hazards-and-infrastructure>, accessed 18 December 2013.

neither all face the same risks nor tackle issues in the same way. This means that the view of one single organisation very rarely matches that of another; for example, the way in which a local authority references the street light infrastructure against the road network may be different to how the same street lights are referenced by the Highways Agency. The requirement for definitive object referencing (the explicit identification of features using a common reference ID) is becoming more and more important to ensure that all parties are referring to the same infrastructure element.

The 2011 Cabinet Office report 'Keeping the Country Running' advises the use of dependency maps of an area 'as an information and challenge document during risk assessment, pre-event planning and exercising, ensuring visibility of key dependencies during an emergency'.[6] In recent years, geography has underpinned the response to a range of different national and regional emergencies, ranging from flooding and terrorism to pandemic flu – all of which have endangered parts of the UK's critical infrastructure. Planning and responding efficiently to these emergencies with reduced funding and resources is increasingly important, particularly in a financially constrained world.

The OS has been working to use geography to underpin contingency planning through its Mapping for Emergencies service[7] and Exercise Orion.[8] This remains very relevant in the context of a world where danger is as likely to be delivered via a network cable, as it is a flooded river or suspect package. Clearly having a nationally consistent data set for this type of work is important: while location provides vital insight, it is not a limiting factor on where an incident may occur.

Smart Cities

In the context of Big Data,[9] the resilience of cities segues into the concept of smart cities. The smart city is an urban environment that uses information and modern technologies to ensure the critical infrastructure (and its components) and public services are more interactive and efficient, enhancing the experience of the citizen, but within the context of ever-greater resource constraints.[10] This in turn shifts thinking about resilience away from contingency planning towards sustainability. Smart or 'future'

6. *Ibid*.
7. Ordnance Survey, 'Mapping for emergencies', <http://www.ordnancesurvey.co.uk/support/mapping-for-emergencies.html>, accessed 18 December 2013.
8. Ordnance Survey, 'Ordnance Survey and Exercise Orion', September 2010, <http://www.ordnancesurvey.co.uk/blog/2010/09/ordnance-survey-and-exercise-orion/>, accessed 18 December 2013.
9. Russell Jurney, 'Big Data Defined', Hadoop Insights, Hortonworks, 4 April 2013, <http://hortonworks.com/blog/big-data-defined>, accessed 11 February 2014.
10. Department for Business Innovation and Skills, 'Smart Cities: Background Paper', October 2013, Ch 4: What is a Smart City?, <https://www.gov.uk/government/

cities are the discussion point of the moment for good reason: the current model for a city is fundamentally unsustainable.[11]

If we define resilience as the ability to respond to change, then the modern city is under threat from a range of factors:

- **Changing economic models** are reducing employment opportunities in many cities. For example, a shift to online shopping is having a direct impact on many high streets.
- **Physical infrastructure** is under increasing pressure due to population growth (80 per cent of which in taking place within urban areas in the UK[11]) and a changing demographic profile.[12] The demands on cities are becoming acute.
- **Climate change** is placing increasing focus on energy resilience. The requirement to refocus from pure carbon-based production is a challenge for cities.[13]
- **Constrained budgets** require doing 'more for less': reductions in local authority budgets have fallen an average of 12 per cent in the last three years, with some experiencing cuts as high as 20 per cent.[14] The source of that budget – predominantly central government – also needs to take on more of the characteristics associated with resilience.

The traditional response to these issues has been siloed across the various agencies responsible, but the scale of this global problem is producing numbers that should concern us all: the world's current infrastructure maintenance requirement currently outstrips the global capacity to meet that need by a factor of three.[15] It is clear that there is a need to think differently about how we respond to these challenges.

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uploads/system/uploads/attachment_data/file/246019/bis-13-1209-smart-cities-background-paper-digital.pdf>, accessed 12 March 2014.

11. Department for Business Innovation and Skills, 'The Future of Cities', Foresight Programme, <http://www.bis.gov.uk/foresight/our-work/projects/current-projects/future-of-cities>, accessed 11 February 2014.
12. Forum for the Future, Growing Pains: Population and Sustainability in the UK (London: Forum for the Future, June 2010), <http://www.forumforthefuture.org/sites/default/files/images/Forum/Projects/Growing-Pains/Growing%20Pains.pdf>, accessed 12 March 2014.
13. Nick Pennell, Sartaz Ahmed and Stefan Henningsson, 'Reinventing the City to Combat Climate Change', *strategy+business* (No. 60, August 2010), <http://www.strategy-business.com/article/10303?pg=all>, accessed 12 March 2014.
14. Department for Business Innovation and Skills, The Smart City Market: Opportunities for the UK, BIS Research Paper No. 136 (London: The Stationery Office, October 2013), <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/249423/bis-13-1217-smart-city-market-opportunties-uk.pdf>, accessed 12 March 2014.
15. Greg Babinski, 'The Role of Regional Geospatial Coordination for Effective City Management', Geospatial World Forum, Rotterdam, 13–16 May 2013.

An example of the different approach that could be applied is apparent in New York City, where Mike Flowers from the Office of Policy and Strategic Planning is a proponent of Big Data providing new insights on the infrastructure of the city:[16]

> [E]very day we learn something new. Just this morning I found out that there is something that I know about boilers in the city that I didn't know before. It all has to do with where on the floor it is positioned and how below grade it might be within the basement, and then you over lay that with the projected flood area for the 500 year flood zone and there you go – boom! – you have your priority for where you need to go first to make sure that place is resilient to hold on in the event of a flood.

What is interesting about this insight is that Flowers is describing a very simple geospatial query – the locational relationship between water boilers and flood depth. Understanding the relationship between the position of the boiler and the flood risk has enabled the city to focus on high-priority areas during emergencies and has engineered a more effective outcome within a reduced budget.

Does sharing data openly between departments and undertaking some additional analysis on the basis of this constitute a smart city? Probably not, but as with any evolving concept there are a thousand definitions that pertain to any one particular person's area of interest. This may include broadband connections, smart meters, smart grids, intelligent transport networks, intelligent sensors and so on. If the smart cities concept is here to stay, Ordnance Survey needs to define what it means from a corporate perspective.

The term smart cities can be broken down into a number of constituent parts:

- **Smart** to mean the approach to a service (such as transport, utilities or waste management) to enable the transformation of communities into something (more) efficient and sustainable. This means cost savings while providing a better service (the 'more for less' agenda) and a reduction of carbon emissions leading to an overall improvement in the quality of life.
- **City** is generally used not because the concept is applicable only to cities, but because 'everything happens somewhere', and most of it happens in cities. With the concentration of resource demand occurring in the urban environment, the most obvious challenges will lie in the largest cities.

16. *BBC News*, 'How New York is releasing its "big data" to the public', 12 October 2013.

The concentration of the world's population in cities will continue: 2008 saw global urban population exceed 50 per cent of the total world population for the first time ever; by 2030 it is expected that more than 60 per cent of the world's population – almost 5 billion people – will live in a city.[17] Most of that urban growth is concentrated in Africa and Asia but there is also an impact on the UK. Megacities have captured much public attention but the new growth will apparently occur in smaller towns and cities, which often have fewer resources to respond to the magnitude of the change.[18] Thus there are some high-profile pressure points, and the real problems will be felt right across the urban spectrum: in the UK, this will not be a London problem but rather a UK PLC problem, lending perhaps more credence to the term 'smart communities' over smart cities.

Understanding 'Smart'

Assuming all that to be correct, how does 'smart' actually work in practice? At the simplest level it is networked infrastructure: a wireless network of nodes that provide and exchange real-time information. The things to note at this level are the requirement for an appropriate level of detail and coverage of the network, and the importance of real-time feedback and response. An example might be sensors on traffic signals used to monitor traffic volume and flow. That information is fed back to a command centre where revised optimal signal phasing is recalculated and then re-distributed to the signals. Take that a step further and one can start looking at the interdependence of a number of factors: by using observed variances in commuting volumes in different weather conditions, peak flows could be anticipated from meteorological forecasts, leading to a move beyond simple reaction to predicting and responding appropriately ahead of the occurrence.

This example sets out the vision at a very basic level for a 'digital' or 'intelligent' city rather than a truly smart one. Glasgow's future vision of itself as a smart city by 2061 does not make any reference to technology; instead it focuses entirely on the quality of life in the city and the experience of living there.[19]

For a smart city, there are at least two additional criteria:

17. United Nations Department of Economic and Social Affairs, 'World Population Prospects: The 2010 Revision', <http://esa.un.org/wpp/Documentation/WPP%20 2010%20publications.htm>, accessed 12 March 2014.
18. United Nations Population Fund, 'Linking Population, Poverty and Development: Urbanization – A Majority in Cities' <http://www.unfpa.org/pds/urbanization.htm>, accessed 12 March 2014.
19. Glasgow City Council, A Fifty Year Vision for the Future: Future Glasgow 2011–2061, Full Consultation Report (2011), <http://glasgowcityvision.com/uploads/GCC_2061_ A4%20Full%20Version%20Online.pdf%20(display%20copy).pdf>, accessed 12 March 2014. See also Future Cities Special Interest Group, Technology Strategy Board, 'City Councils' Feasibilities Studies', connect, <https://connect.innovateuk.org/web/future-cities-special-interest-group/feasibility-studies>, accessed 12 March 2014.

- A **competitive environment**: this is where the smart network is put to use to generate economic growth (the beginnings of a knowledge economy). At this point the international picture becomes particularly significant, as growth leads to a human resource demand. Cities such as London will be utilising their existing human capital to compete for intellect on a global stage. Depending on a fluid resource is dangerous, however, as by its nature it tends to respond quickly to external enhanced offers.
- There is therefore a requirement to create **sustainable** cities. This is in terms of both environmental sustainability (it is a statement of fact that cities are going to have to deliver more services using fewer resources) and also social sustainability (with social inclusion/participation/stability likely to become increasingly common terms to describe efforts to create an environment in which people want to live and work).

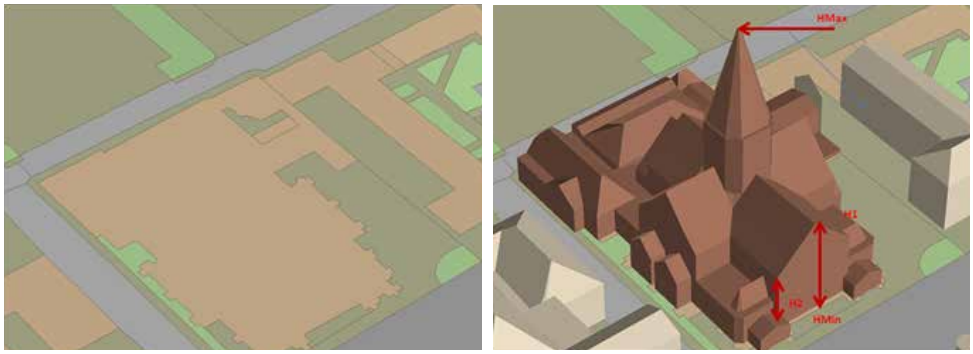
Future Data Needs

From an Ordnance Survey perspective, understanding this context for the future use of OS data is paramount. The differentiation of a smart city is not the technology itself. The technology (the 'intelligent network of nodes') is rather the primary enabler – the basic building block – and, to a large extent, a hidden one. It may not be (and does not need to be) obvious to the citizens of a city as they drive through it that the traffic flow is in part controlled by meteorological data. In respect to data consumption, the manifestation of this change is a move from a user that demands the data from the OS in order to process it themselves to a user that asks the OS for the answers to problems.

For the OS, this means re-engineering products from a simple map (albeit a digital map) to a data model. Rather than simply showing the building on a plot of land (Figure 1a), the key dimensions/elements need to being extracted or mined from the geometry (Figure 1b) and presented in a manner that can be consumed by the client's applications (which may not necessarily be a Geographic Information System, the typical means by which OS data products are currently consumed). This is a shift in focus from pure geometry to derived information, and is exposing an incredible wealth of information 'hiding' within OS data. The information has always existed, but until now, there was an expectation on users to extract only what they needed. Now, the wealth of potential additional information that could be derived from fairly simple geometry by adding the third dimension to create a 3D model is starting to become apparent (Figure 2).

Figure 1: Standard OS City Mapping: 'implicit' geometric information is extracted and provided 'explicitly' or as part of enhanced query functionality.

Figure 2: 3D City Mapping: additional geometries afforded with the use of the third dimension.

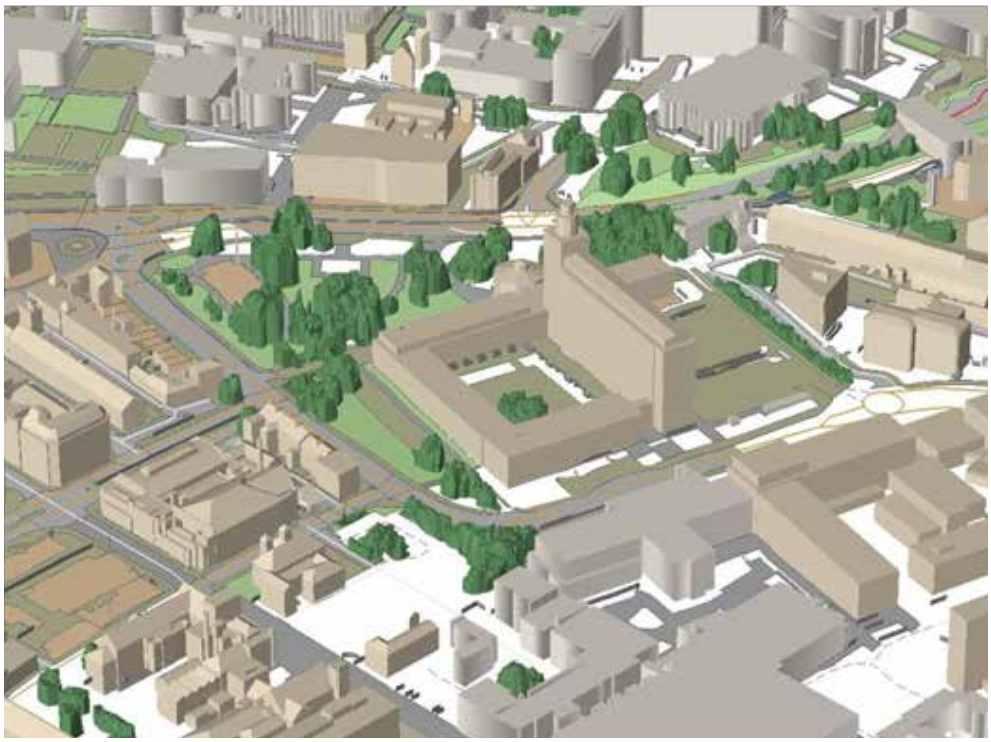


In real terms, what the OS will be adding is the attribution of building height (available from April 2014) and, in the longer term, roof form. This chapter has not touched on true 3D (characterised by verticals and volumes) but the technology behind models such as that illustrated in Figure 3 are well understood.

OS data-captured flow lines are already aligned to the implementation of these data, but the use of these data products is yet to be resolved. What are the actual questions that are going to be asked in future? The appropriateness of the data model to the application is susceptible to nuance, meaning that if the OS is to avoid costly mistakes of bringing products to market without a supporting business model, there has to be a clear understanding of the value/ability of the data to address specific needs. For example, what is the resolution of object definition required? The current unit of resolution within the urban context may not be sufficient. To take this a step further: is true 3D actually needed, or are surrogates of more value (for example, storeys/levels within a building)? The requirement for data on interiors also needs to be discussed.

There are clearly a considerable number of factors that remain to be answered, but the more smart cities as a concept is discussed, the more apparent it becomes that geospatial information (and in particular 3D) is crucial to making the solutions offered work. Nevertheless, there is an apparent lack of discussion on the benefits that geospatial information can bring to the resilience of smart cities not just in the future, but today. As with any modelling exercise, the devil is in the detail: the research needed is not an exploration of *how* to generate 3D geospatial data, but a determination of the specific questions (the *why*) that need to be answered for a city to become truly resilient.

Figure 3: Sample 3D City Model Data Generated by Ordnance Survey.



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X. Resilience and the Advantage of a System of Systems Approach

John Preston, Layla Branicki, Roy Kalawsky and Jane Binner

There are a number of approaches to measuring resilience, each of which involves some analysis of assets, resources and capacities at a city level. If it is considered that resilience, however defined, is a function of various resources in a city then there are three broad approaches to measuring it. The first of these is an additive approach, which involves the counting or summation of resources in particular geographical areas of a city. Examples of this approach include the use of input-output analysis, logistical analysis, 'tick box' audits of resources and capabilities, and the identification of key strategic capabilities. The second is a cumulative approach to resilience where there may be interactions between these resources. Examples would be approaches that identify positive and negative externalities in cities. Finally, there are network approaches to identifying resilience in cities where there are multiple complex feedback effects and emergent properties.

Intuitively, the complexity of cities implies an understanding of resilience that is mindful of the second and third categories: cumulative and network effects. Although additive approaches to resilience are useful, cities are increasingly interconnected and critically reliant on the interdependence between many more previously unrelated and unconnected systems. The term 'system of systems' (SoS) in its more basic form describes a collection of components that are themselves systems designed to achieve a common goal. Examples of such SoS include large-scale critical infrastructures such as water management and treatment systems, ground and air transport management systems, emergency service/response systems, energy supply networks and healthcare delivery systems. Clearly, this represents a very diverse range of systems, each with its own nuances. These systems need not have been designed to work together from the outset, but are increasingly required to work co-operatively together to deliver the services that are expected to exist in a modern city today.

The Concept of Emergence

Moreover, these systems may be under totally independent management and control. This loose coupling of systems only adds to the complexity, creating the need to consider a fresh approach to resilience. City planners are further challenged by the idea that a SoS does not necessarily reach an end state in its lifecycle, because of its need to constantly evolve or change to emerging requirements. One of the important characteristics of any system is the concept of emergence, whereby new properties or behaviours are present that are not present in any one of the constituent systems.

Ideally, the emergent properties are useful or highly desirable. Unfortunately the converse is true as well, where unexpected and undesirable emergent behaviours become evident and, occasionally, these undesirable attributes do not reveal themselves for some considerable time after the SoS has been in service. Managing the evolution of a SoS becomes a critical task and to do it effectively requires the consideration of potential future scenarios and configurations of the SoS.

Conceptualising a city as a SoS means that emergent properties must be considered. Emergent properties of networks are often defined in terms of positive, reinforcing externalities. Smart Cities, where crowd-sourcing behaviour and technologies are used, may be able to autonomously solve collective action problems including emergency response and recovery. However, there may also be negative network externalities. Additionally, cities as SoS are critically dependent on temporal (as well as spatial) network properties: collective behaviours may be hampered, or reinforced, depending on the time of day or night. Finally, we need to consider that emergent properties take place on a long historical scale. Cities are hundreds – often thousands – of years old, and supposedly inefficient institutions may, in actuality, support city resilience. These caveats, which complicate the measurement of city resilience, are considered in the rest of this chapter.

Social Media and Evacuations

Much of the literature on social and other networks concentrates on positive network externalities in emergencies. Research into contemporary disaster management in cities, for example, considers social media (and social capital) to be a positive asset. In the area of city evacuations, John Fry and Jane Binner have formulated a new decision-making framework through which social media can be used to deliver more efficient evacuations.[1] This new approach is flexible and improves upon existing models by allowing incoming information to be incorporated sequentially. Further, the model is the first of its kind to consider the effects of information quality in social media.

Fry and Binner consider both high-quality information and low-quality information regimes (including abuse of information) and overcrowding in network systems. Under a high-quality information regime, the potential benefits of social media increase as the size of potential delays increases. The simulation results show that by not using updated information, as proposed in this study, final evacuation times are increased by 20 per cent and in some cases can be more than doubled. Under a low-quality regime, social media provides noisy information; alternative strategies – including random allocation strategies – may be more effective. To address overcrowding, Fry and Binner formulated a Bayesian algorithm whereby system parameters

1. John Fry and Jane M Binner, 'A decision-making framework to co-ordinate smarter evacuations using Social Media', paper submitted to *Management Science*, 2013.

can be updated sequentially. They also outline situations in which individuals may best proceed by adopting contrarian strategies and evacuating via less popular but technically slower routes. Ultimately their objective remains to create a reliable tool that allows emergency planners to leverage social media to protect the public at large – enabling 'Smarter' evacuations. The chapter's authors are already actively engaged with policy-makers, scientists and businesses to investigate the calibration of the models and the real world implementation.[2]

Negative Network Externalities

As cities become increasingly inter-connected and complex, however, there is the potential for a reversal of 'smartness' through negative network externalities. 'Dumbness' as an emergent property of networks has not been considered, as the research has nearly exhaustively concentrated on positive emergent properties and capabilities. An example of dumbness as an emergent property is when individuals over-use information in solving a collective action problem in a city. In the case of a city evacuation involving cars, where evacuees possess the ability to carry out peer-to-peer communication, for instance, it may seem logical for individuals to share information about uncongested roads with their friends. Individuals underestimate the costs of sharing such information, however, failing to recognise that the uncongested roads quickly become congested as information spreads through the network.[3] The most efficient evacuation, paradoxically, is the one in which individuals are the least networked.

One could also consider cognitive and attention costs of increased 'smartness' in cities. For example, one unintended consequence of the proliferation of smart phones is a decline in attention paid to the real, visceral environment of cities with implications for emergency response. In one recent incident in the United States, commuters on a train did not notice a gunman with a

2. See, for example, Vincent A Schmidt and Jane M Binner, 'A semi-automated display for geotagged text' in John Preston, Jane M Binner, Layla Branicki, Tobias Galla and Nick Jones (eds.), *City evacuations: an interdisciplinary approach* (Springer, 2014); Aom Ariyatum, Jonathan Whittle and Jane Binner, 'Better service design for greater civic engagement' (2013 [preprint]); Jane Binner, Baseerit Nasu, Will Simm, Marie A Ferrario, Jonathan Whittle and Aom Ariyatum, 'Evaluating public confidence in policing services; a new decision support tool' (2013 [preprint]); John Preston, Jane M Binner, Layla Branicki, Maria A Ferrario and Magdalini Kolokitha, 'Multiple attacks on transport infrastructure: an inter-disciplinary exploration of the impact of social networking technologies upon real time information sharing and recovery', *Journal of Homeland Security and Emergency Management* (2011).
3. Global Uncertainties, ESRC and EPSRC, 'City evacuations: preparedness, warning, action and recovery', Final report of the DFUSE project (Game theory and adaptive networks for smart evacuations: EP/I005765/1), March 2013, <http://www.cityevacuations.org/uploads/6/8/1/7/6817950/finalpublic.pdf>, accessed 11 February 2014.

clearly exposed weapon until he had shot a student.[4] There have also been cases reported where people have filmed accidents and disasters rather than attempting to actively help. Such cases are not unknown in cities, nor are they new. The famous case of Kitty Genovese,[5] who was murdered in New York in 1964 in front of numerous witnesses who did nothing to help, shows that the innocent bystander effect existed long before mobile technologies.

Temporal Dynamics of Resilience

An approach that concentrates on city geography (or networks) as static will have little to say about resilience. City dynamics change rapidly as populations move into and out of the city. Commuters can swell and shrink the population of a city considerably in the matter of an hour or two. Immigration and emigration, both intra- and inter-country, can rapidly change city dynamics. As an illustration of this, Nick Jones and Jamie King have demonstrated that the speed with which a warning and informing message would impact on the population changes dramatically throughout the day.[6] A message sent at 8pm, for example, would take only 30 minutes for 50 per cent of the population to become aware of it, whereas a message sent at 11pm would take 11 hours for the same population to become aware. Strikingly, in the Jones and King model, it is old media that is the main carrier of messages, with new media providing only a small part of the initial warning and distribution of the message.

If we are to measure resilience through a SoS approach then temporal dynamics become important. It therefore makes little sense to speak about cities, or areas of cities, as being more or less resilient than others without reference to time.

Inertia

It is important that in a quest for associating resilience with smartness we do not forget the enduring legacy of institutions. Bureaucratic processes are considered to be slow, inefficient and to duplicate resources but these may actually be positive for resilience. In her study on path dependence and institutions, Kathleen Thelen considers that institutions do not particularly suffer from inertia, but rather are constrained by the interlocking actions of other institutions.[7] What may appear to be inertia and silence can often be the prelude to rapid change given different constraints.

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4. Reuters, 'Smartphone users didn't notice gunman killing student on train', 10 November 2013.
5. Wikipedia, 'Murder of Kitty Genovese', <http://en.wikipedia.org/wiki/Murder_of_Kitty_Genovese>, accessed 11 February 2014.
6. Jamie King and Nick Jones, 'Information spreading following a crisis', in preparation, preprint available on request.
7. Kathleen Thelen, *How Institutions Evolve: The Political Economy of Skills in Germany, Britain, the United States and Japan* (New York, NY: Cambridge University Press, 2004).

John Preston has analysed the Home Office's emergency planning division (F6) in the 1970s and 1980s, a period usually considered as a time of inertia for civil defence.[8] Although little was released to the public following the disastrous unveiling of the public information series 'Protect and Survive' in May 1980, the Home Office, constrained by other government departments and opponents of civil defence, was in fact reconsidering the way it thought about population protection and methods of public information. This meant that, by 2001, the government as a whole was in a much better position to distribute information on public protection. Although on the outside there had been 'inertia', internally there was reform and reconsideration.

Furthermore, what can seem to be duplication or inefficiency at a city level may actually increase resilience. The management of a crisis at city level can be characterised as complex, often protracted in its outcomes, and by the need for multiple organisations to work together in planning, response and recovery.[9] It is not surprising therefore that 'joined-up' approaches to crisis management have become part of the dominant logic of city-level emergency planning. It is arguable that this approach 'produces a new grand narrative of control', as claimed by Michael Power,[10] and yet the move to more tightly coupled systems within the city may also produce new and unanticipated vulnerabilities.

It is important to examine the potential impact of a reduction in system duplication or 'slack' upon city-level resilience. When there are attempts to 'join-up' systems, the outcomes are often two-fold: increased attention to shared language, practices and processes; and rationalization for reasons of cost efficiency. However, it is not clear from existing research that a more joined-up city is a more resilient city. For example, Timothy Vogus and Kathleen Sutcliffe argue that, 'one possible explanation for organizational resilience is that resilience is a result of high levels of slack resources'.[11] Whilst they refer to literal slack (such as, duplication of critical national infrastructure provision), they also mean 'conceptual slack' (in other words, the need for multiple ways to define, frame and resolve real-world problems).[12] Karl Weick takes this idea further and argues that even the perceived removal of

8. John Preston, *Disaster Education: 'Race', Equity and Pedagogy* (Rotterdam: Sense Publishers, 2012).
9. Arjen Boin, Paul 't Hart, Eric Stern and Bengt Sundelius, *The Politics of Crisis Management: Public Leadership under Pressure* (Cambridge: Cambridge University Press, 2005), p. 1.
10. Michael Power, *Organized Uncertainty: Designing a World of Risk Management* (Oxford: Oxford University Press, 2007), p. 67.
11. Timothy J Vogus and Kathleen M Sutcliffe, 'Organizational resilience: towards a theory and research agenda', IEEE International Conference on Systems, Man and Cybernetics, Montreal, October 2007, pp. 3,418–22.
12. Vogus and Sutcliffe, *op. cit.*, p. 3,420.

slack can 'lower the threshold at which a crisis will escalate, and increase the number of separate places at which a crisis could start'.[13]

Linked to the notion of slack, research indicates that crisis can act as destabilising influence upon city-level inertia, and yet at the same time, the very reasons for 'inertia' may remain undiminished due to 'geographic advantages, long term investment in infrastructure, and place-dependent business networks'.[14] Inertia, or resistance to change, at the city level may occur for a number of legitimate reasons such as the competitive benefits of business clusters, protection of heritage sites or an earlier logic about what constitutes resilience in planning and practice. Crises have the nasty habit of rendering plans and structures irrelevant and therefore the response to a crisis may somewhat unexpectedly require improvisation and innovation rather than central co-ordination and control.[15] It can also be argued that tightly coupled systems (those with high levels of inter-dependence) can spread rumour, failure and error as effectively as they spread efficiency, learning and shared understanding. The idea that there is one right way to negate or mitigate crisis may, therefore, in itself be a dangerous presumption and, as such, smart strategies that join-up the city may, perversely, lead to stupid outcomes.

Conclusion

In conclusion, cities are becoming smarter, and there need to be new ways to measure this. However, we need to be sure that we are measuring the right things and not conflating aggregation with resilience. Networks can act 'dumb' and cities' resilience changes from second to second. Institutions may seem cumbersome, but may be better than networks at solving collective action problems in the long run. Perhaps what policy-makers should be aiming to measure is not smartness as an aspect of resilience, but 'wise cities'.

This would lead one to consider qualitative as well as quantitative aspects of city resilience. One important facet of the SoS approach is that it attempts to account for a variety of systems that cannot necessarily be described using one methodology. However, it is also important to account for temporal considerations both in the short and the long run. Overall, this would lead to an approach to city resilience that is, by definition, inter-disciplinary.

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13. Karl E Weick, 'Enacted Sensemaking in Crisis Situations', *Journal of Management Studies* (Vol. 25, No. 4, 1988), p. 313.
14. Lawrence J Vale and Thomas J Campanella, 'Conclusions: Axioms of Resilience' in Lawrence J Vale and Thomas J Campanella (eds.), *The Resilient City: How Modern Cities Recover from Disaster* (Oxford: Oxford University Press, 2005), p. 345.
15. Boin et al, *op. cit.*, p. 55.

Fellow, from which the research for this paper was funded under the project 'Mass Population Response to Critical Infrastructure Failure'. John's research on disaster education and public preparedness uses pedagogical theories from education to consider how disaster response can be made more efficient and equitable. He is a frequent contributor to media and public debates and his work has featured on the BBC, Reuters and in the broadsheet press. His most recent book is Disaster Education: 'Race', Equity and Pedagogy *(Sense Publishers, 2012).*

Dr Layla Branicki is a lecturer at Birmingham Business School (University of Birmingham) specialising in the linked areas of resilience, critical national infrastructure protection and the impact of social media on crisis communication. Prior to joining Birmingham Layla was the Strategy, Organisational Learning and Resilience Research Fellow at Warwick Business School. She worked on the first major UK project to examine the existing capacity of organisations, and networks of organisations, to manage emergencies and was a co-investigator on the EPSRC-funded project 'Game Theory and Adaptive Networks for Smart City Evacuation'.

Jane Binner joined the Accounting and Finance Department at the University of Birmingham as Chair of Finance on 1 August. She has worked with a number of stakeholder groups such as the Home Office, Experian and the Boots Group. She brings expertise in analysing the strategic investment decisions of large enterprises through econometric modelling and has conducted research in econometric modelling for more than twenty years. She has extensive academic and commercial experience. She has four books and over sixty publications in the area of computational finance and economics.

Roy Kalawsky is Professor of Systems Engineering and Human Computer Integration at Loughborough University. He is the Director of the Advanced VR Research Centre, which was established in 1995 and undertakes research in the development of advanced modelling, simulation and visualization techniques. The human dimension of modelling, simulation and visualization underpins all of his research. He is also Adjunct Professor, Defence and Systems Institute, University of South Australia, Adelaide and a research member of the Leicester National Institute for Health Research Biomedical Research Unit in Cardiovascular Disease.

XI. Community Resilience Assessments for Localised Mitigation Planning and Visualisation

Paul Kailiponi

The concept of resilience has gained prominence over the past ten years in disaster management studies as a goal for communities in advance of disasters and crisis events. The term itself, however, has many meanings rooted in a number of academic fields. This multiplicity of meanings can have a dual effect on the policy applications of resilience in the UK.

In cases where the functional meaning of resilience is an aggregation of the many disparate definitions, the sheer volume of possible factors can complicate actions taken to build resilience within organisations and communities. A second problem is that even when appropriate measurements of resilience are identified, there is little guidance as to methods that can be used to transform and combine these non-commensurate measures to support resource allocation.

Background to the Resilience Framework Project

This paper will discuss a collaborative effort between the University of Manchester and the Greater Manchester Resilience Forum (GMRF) to create frameworks for measuring resilience to support resource allocation in advance of flood events. Under this collaboration, a measureable framework for localised community resilience will be developed through interviews with local authorities and other disaster management stakeholders. These interviews will lead to objective proxy measurements that are indicative of resilience. The framework will include resilience factor measurements, an assessment of sources for that information, a method of transformation so that the factors can be compared, and a method of combination into a single community resilience score. These community resilience scores will then be attached to a geographic information system in order to provide localised mapping of the analysis to support decision-makers to improve resilience within the Greater Manchester area.

This research utilises the methods of multi-criteria decision analysis to develop the community resilience index, and multi-attribute value functions (MAVF) to transform and combine non-commensurate measurements in an objective way. A second key output from this research is the visualisation of data to support community resilience analysis. Data of social and economic factors are typically aggregated to various administrative zones (such as census output areas and school catchment boundaries). The smaller the level of aggregation, the greater contextual variation is possible within the resilience analysis. This allows for the visualisation of resulting analyses and

can be used to communicate resilience analysis results and provide utility to emergency management personnel interested in using the factor data to support emergency planning.

The first section of this paper discusses the theoretical roots of the resilience concept and their implications for the development of community resilience measures; it then considers UK government literature used as baseline information for local authorities. The paper then reviews practical applications and community resilience frameworks in order to identify common outputs and their ability to support policy analysis and resource allocation by emergency agencies. The MAVF method will be discussed as an alternative method that better fits the needs of emergency managers in delivering services and plans to objectively support disaster planning. A case study of the application of this method to the UK local authority of Wigan within Greater Manchester will then be discussed. The paper will conclude with general findings, including implications of the MAVF approach and how these can be used to support disaster management decision-making in advance of major flood events.

Defining Resilience

The concept of resilience existed in a number of disparate fields for decades prior to its adoption within emergency management. Due to the multi-disciplinary nature of disaster management, many stakeholders in planning and operations will bring with them their own understanding of resilience. As a concept, resilience existed within engineering, psychology, medicine, economics and organisational behaviour prior to its inclusion in the emergency management literature. This has resulted in a degree of confusion as to an appropriate definition of resilience when applied to emergency organisations.[1]

This difficulty in defining resilience can lead to a number of substantive problems. The first issue is the difficulty in measuring resilience in a consistent and coherent manner.[2] A second implication of an aggregated definition of resilience for emergency management is that it can make it difficult to identify clear policy procedures to improve resilience for disaster management organisations.[3] One key purpose of resilience measurement is to aid emergency management personnel in their resource allocation

1. Brian Walker, Crawford Stanley Holling, Stepher Carpenter, and Ann Kinzig, 'Resilience, adaptability and transformability in social–ecological systems', *Ecology and Society* (Vol. 9, No. 2, September 2004).
2. Laurie McCubbin, 'Challenges to the definition of resilience', Annual Meeting of the American Psychological Association (2001), pp. 24–26.
3. Siambabala Bernard Manyena, 'The concept of resilience revisited', *Disasters* (Vol. 30, No. 4, November 2006), pp. 434–50.

and operational decisions for large-scale emergency events.[4] Due to these issues it may be necessary to analyse the different purposes of the resilience concept and identify the degree to which different resilience-measurement methodologies fulfil their intended purpose.

Applied Resilience Frameworks

Some implications of unclear definitions of resilience compared with actual practice can be illustrated by assessing existing resilience frameworks. Several types of resilience frameworks will be discussed in this section along with the connection between the methods inherent in each framework and the stated practical use of the analysis. In order for resilience to have a lasting practical application within emergency organisations, there should be a clear connection between the methods used to measure and assess resilience, and the stated use of the models. Common goals and associated methods of various resilience frameworks are:

- **Descriptive**: A framework that aims to provide descriptive analysis of factors that lead to resilient communities or organisations.
- **Assessment-based**: A process through which an organisation or community can measure different factors of resilience.
- **Proxy-based**: Makes use of existing data as proxies for underlying resilience factors.

Descriptive Frameworks

Descriptive frameworks use resilience as a theoretical concept to guide basic mitigation and resilience-building activities.[5] The most basic form of these models is to identify and define (without measurement) factors that influence resilience. In this way, connecting aspects of the mitigation strategy with the identified factors can develop mitigation strategies. However, the goal of these frameworks is not to suggest marginal improvements to resilience given a wide range of mitigation options. As a result, these frameworks are not able to make statements such as 'the resilience of the community will be improved by y if mitigation strategy x is used'.

Without a statement of the marginal relationship between resilience and mitigation strategies, it can be difficult to make optimal choices between different options where limited resources are available. While an emergency manager may be confident that resilience will improve by initiating a relevant mitigation strategy, they would not be able to differentiate between different options. Descriptive frameworks can be very useful as a method to identify possible mitigation strategies and develop a high-level understanding of

4. Louise Comfort, *Shared Risk: Complex Systems in Seismic Response* (London: Pergamon, 1999).
5. IFRC, *World Disaster Report 2004: Focus on Community Resilience* (Geneva: IFRC, 2004).

resilience within a community, but the approach is less able to objectively measure resilience or optimise mitigation strategies given limited resources. Also, due to the lack of actual resilience measurement inherent in these models, it can be difficult to use such frameworks to compare different communities or to assess improvements over time.

Assessment Frameworks

Assessment frameworks provide a theoretical description of resilience alongside a method for entities to assess the described resilience factors. This concept of measurement is important as it will allow emergency entities the ability to gauge improvements to resilience within their own organisation over time or even between like entities. These assessment frameworks are typically completed through a reflexive process and use primarily subjective assessments. Questions typically take the form of either the presence/absence of factors or the subjective degree to which the organisation adheres to the relevant resilience factor (using descriptive ordinal indicators such as low, medium or high). The measurement of underlying factors must also be gathered by the organisation itself to complete the assessment. Assessment frameworks take one step forward in resilience methods as the approach provides a measureable component of resilience analysis. This can be an effective tool for organisations looking to improve over time using a consistent assessor.

The ability of these frameworks to measure marginal effects of different mitigation options is often dependent on the assessment methods provided for the underlying resilience factors. Where measurement methods are objective and clear it can allow for generalisability between communities. More subjective measurement assessments may be influenced by inter-assessor bias and as such are less amenable to generalisation to different locations or between different organisations.

Proxy Frameworks

Proxy-based frameworks describe a model of resilience that is measured using secondary sources of data. The primary difference between assessment and proxy frameworks is that the data typically used to measure underlying resilience factors are already gathered (usually across a number of time periods) and as such do not require in-house assessment from the community or organisation. This vastly improves the speed at which the assessment can be completed and lowers the amount of additional resources that must be spent by emergency managers in gathering data. A second result of using proxy data is that the data are typically gathered systematically and as such is commonly objective in nature. This greatly diminishes problems of inter-assessor bias and can allow for a high level of generalisation of results both between different communities and over time.

A common technique used in proxy variable assessment is factor analysis, which attempts to divide a set of variables into different categories based on correlation between those variables. This technique has been commonly used in vulnerability studies and is effective in identifying common factors from a set of variables.[6] An issue with factor analysis and related statistical processes is that it is unable to make statements of the marginal effect that any individual factor has on the aggregate concept that is studied. This means that while it is able to state that a set of factors are related to one with another, it is unable to state what difference a change in that factor would have on the aggregate score.

Using alternative methods, it is possible to identify marginal effects of mitigation on resilience using proxy data. In choosing optimal mitigation strategies, an emergency manager should objectively assess the underlying resilience factors, the way in which different mitigation strategies influence those factors and the cost of each mitigation strategy.[7] The main criticism against proxy-based resilience assessment is a lack of appropriate data for the underlying resilience factors. There will often be instances where the required data are not available or the data that is available is a poor indicator of the underlying resilience factor. This can lead to a clear disconnect between the stated meaning of any resilience measurement and the end results of the analysis, ultimately leading to error and low confidence in model outputs.

Each of these methods can provide added value for emergency managers. However, it is assessment and proxy methods that provide actionable information for resource allocation decision-making. Descriptive models often do not attempt to objectively measure resilience components and therefore are unable to state clear trade-offs between different resilience-building activities.

Assessment models move toward measurement, but can be hampered by inter-assessor error, which may limit the generalisability of results. Proxy methods can be effective but are highly dependent on the availability of relevant data and their connection to underlying resilience factors. The method used in the GMRF case study attempts to use a proxy method in order to facilitate emergency managers' request for models to aid in differentiating between different mitigation strategies.

Multi-Attribute Value Functions for Resilience Analysis

In order to create a viable proxy-based resilience model, a process should be used that identifies a set of underlying resilience factors, measures those factors objectively and transforms them so that they can be compared and

6. Susan L Cutter, 'Vulnerability to Environmental Hazards', *Progress in Human Geography* (Vol. 20, No. 4, 1996), pp. 529–39.
7. Kailiponi, 2009

combined to create an aggregate resilience figure. This type of model can be developed using multi-criteria decision analysis (MCDA) tools.[8]

MCDA is used to make decisions where there are conflicting or complex factors that need to be transformed and combined into an aggregate figure.[9] For example, an MCDA might be used by a government to determine how various options for allocating scarce resources will help them to meet key performance indicators, such as how to allocate money across healthcare,[10] future technologies,[11] security,[12] business[13] or education.[14] The common methodological process within all of these is a quantitative representation of decision-makers' preferences alongside a framework to compare and combine multiple factors into a single construct. In the case of resilience frameworks, this process allows a decision-maker to identify objective trade-offs between different factors in order to facilitate policy decision-making.

In this problem, a decision-maker must rank a set of census output areas z according to a set of criteria c_i. The most simplistic method is one that assumes linear preferences for decision-makers across the range of each criteria, and both statistical and preferential independence between model criteria. The MCDA method that adheres to these assumptions is called the 'weighted linear combination' (WLC).[15] For multi-criteria problems it is necessary to transform the model criteria to a common range. A normalisation process can be used to compare dissimilar criteria. Equation 1 shows the normalisation process that transforms criteria values for spatial units (such as census areas).

8. Ralph L Keeney and Howard Raiffa, Decisions with Multiple Objectives: Preferences and Value Tradeoffs (New York, NY: Wiley, 1976).
9. Valerie Belton and Theodor Stewart, *Multiple Criteria Decision Analysis: An Integrated Approach* (Springer, 2002).
10. George W Torrance, Michael H Boyle, Sargent P Horwood, 'Application of Multi-Attribute Utility Theory to Measure Social Preferences for Health States', *Operations Research* (Vol. 30, No. 6, November/December 1982), pp. 1043–69.
11. Roger M Cooke and Louis H J Goossens, 'Expert Judgement Elicitation for Risk Assessments of Critical Infrastructures', *Journal of Risk Research* (Vol. 7, No. 6, 2004), pp. 643–56.
12. Vicki M Bier, 'Choosing What to Protect', *Risk Analysis* (Vol. 27, No. 3, 2007), pp. 607–20.
13. Michael Doumpos and Constantin Zopounidis, *Multicriteria Decision Aid Classification Methods* (Springer, 2002)
14. V H Visschers, R M Meertens, W F Passchier and N K Devries, 'How does the general public evaluate risk information? The impact of associations with other risks', *Risk Analysis* (Vol. 2, No. 3, June 2007), pp. 715–27.
15. Jacek Malczewski, 'On the Use of Weighted Linear Combination Method in GIS: Common and Best Practice Approaches', *Transactions in GIS* (Vol. 4, No. 1, 2000), pp. 5.

The normalisation process requires an assumption of linear preferences across the range of each criterion. The normalised value for each criterion $n_{z,c}$ is the value for each geographic unit $x_{z,c}$ divided by the maximum value from the entire set of geographic units for each criterion $x_{c,max}$.

$$n_{z,c} = \frac{x_{z,c}}{x_{c,\max}} \tag{1}$$

This criteria transformation process creates a common range of $0 < n_{z,c} < 1$ that will allow for the comparison of criteria one to another. An additive multi-criteria function using the normalised range is then used to represent the value of each spatial unit. Equation 2 shows the multi-criteria function where the value of spatial unit z is the weighted k_c sum of normalised data for that spatial unit where $\sum k_c = 1$.

$$c = \sum k_c n_{z,c} \tag{2}$$

Where the assumptions of WLC do not hold, more complex multi-criteria functions should be used. Multi-attribute value functions (MAVF) can be used to create models where the assumptions of WLC are violated.[16] A value function evaluates the desirability of individual criteria and allows for non-linear preferences over the range of that criterion.

Equation 3 shows the common exponential form of a single-attribute value function $v(x_c)$. An exponential function assumes diminishing decision-maker preferences over the range of an attribute that is common for normal goods where: h is used as a scaling constant and R represents the degree to which the criterion becomes more/less desirable over the range of the criteria.

$$v(x_c) = h - e^{-x_c/R} \tag{3}$$

The use of MAVF is an important development for spatial data analyses due to the widespread use of WLC methods.[17] A movement from WLC methods to MAVF allows for possible non-linear preference between resilience factors and more robust elicitation processes when gathering data. In this way, better information can be gathered to support local emergency officials when choosing between different mitigation options.

16. Keeney and Raiffa, *op. cit.*, p. 68.
17. J Ronald Eastman, Weigen Jin, Peter A Kyern and James Toledano, 'Raster Procedures for Multi-Criteria/Multi-Objective Decisions', *Photogrammatetric Engineering and Remote Sensing* (Vol. 61, No. 5, 1995), pp. 539–47; J H Lowry, H J Miller and G F Hepner, 'A GIS-based sensitivity analysis of community vulnerability to hazardous contaminants on the Mexico/US border', *Photogrammatetric Engineering and Remote Sensing* (Vol. 61, No. 11, 1995), pp. 1347–58.

Local Authority Application in Wigan

The collaborative project developed a case study of community resilience through interaction with a local authority in Wigan, Greater Manchester. This area is at high risk of flooding and local officials have expressed concern over their lack of resources to facilitate mitigation and recovery operations in advance of disaster events. The GMRF requested research from the University of Manchester to assess resilience and key infrastructure as outlined in government documents and consulting documents concerning flood preparedness.[18]

These documents call for a multi-criteria approach to vulnerability analysis using spatial data gathered from the Environment Agency, Office for National Statistics and the NHS (although they do not explicitly address a process to aggregate various factors or methods to combine these factors).[19] The choice of exact resilience factor measurements was performed using qualitative interview methods. Four preliminary interviews were performed in the area with emergency management officials in Manchester and Wigan. The goal of these interviews was to identify a set of appropriate proxy variables that could be used to evaluate community resilience to flooding in Wigan town centre.

Proxy Variables for Community Resilience to Flood

The UK Department for Environment, Food and Rural Affairs, in conjunction with the Environment Agency, provides flood vulnerability assessment guidance that can be used by local government officials and emergency managers.[20] The general guidance includes three categories of information that can be combined to create a value of flood vulnerability for a target area. These categories represent hydrologic characteristics of a flood hazard, area vulnerability and people vulnerability. Table 1 shows each of these broad categories and the specific pieces of information that can be used to measure each of these concepts.

18. Such as Environment Agency, Review of 2007 summer floods (Bristol: Environment Agency, December 2007); The Pitt Review: Learning lessons from the 2007 floods (London: Cabinet Office, 2008); H R Wallingford, Flood Risks to People, Phase 2, FD2321/TR2 Guidance Document (London/Bristol: Defra/Environment Agency, March 2006).
19. Wallingford, *op. cit.*
20. *Ibid*.

Table 1: UK Flood Vulnerability Factors

Variable	Data sources
Flood hazard	Environment Agency flood maps
	Hydraulic modeling
Area vulnerability	Ordnance Survey maps
	National Property Database
	Site inspections
Population vulnerability	National census
	Local information

The variety of information that can be used for each category gives flexibility to emergency managers to evaluate flood risks. In order to combine these data, it is necessary to have a common geographic unit of measure for the multi-criteria analysis. The flood hazard, area vulnerability and population vulnerability should be attached to a common geographic unit so that they can be combined into a numerical index representing overall flood vulnerability within that area. Suggested data sets for each category are 1) flood hazard maps created by local Environment Agency offices, 2) Ordnance Survey maps which can show area vulnerability, and 3) census data zones for people vulnerability. All of these suggested data sources are available to emergency managers and are consistently compiled across all of the UK.[21]

Susan Cutter et al propose another set of proxy variables that can be used as indicators of disaster resilience for communities on the east coast of the United States.[22] They divide a total of thirty-six different proxy indicators between five different categories of resilience: 1) social resilience, 2) economic resilience, 3) institutional resilience, 4) infrastructure resilience and 5) community capital. These categories were identified due to the high level of correlation between variables using factor analysis. Aleksandra Kazmierczak and Gina Cavan used a similar method known as 'principal component analysis' to identify vulnerability categories from a set of correlated variables for the Greater Manchester area.[23] They found that the variables that best fit the variation in vulnerability to be economic deprivation, households with children and percentage of people aged 65–75 as explanatory variables for vulnerability across census areas in Greater Manchester. Both of these studies were used as prompts in this project, following initial elicitation in order to limit bias in the interviewed participants.

21. *Ibid*.
22. Susan L Cutter, Christopher G Burton and Christopher T Emrich, 'Disaster Resilience Indicators for Benchmarking Baseline Conditions', Journal of Homeland Security and Emergency Management (Vol. 7, No. 1, 2010), pp. 1–22.
23. Aleksandra Kazmierczak and Gina Cavan, 'Surface water flooding risk to urban communities: Analysis of vulnerability, hazard and exposure', Landscape and Urban Planning (Vol. 103, No. 2, 2011), pp. 185–97.

Initial Proxy Variable Findings

An initial finding from this project was to identify concepts of resilience from local emergency managers and explore possible proxy variables that can be used to measure these factors within Wigan. In the existing government documents on resilience, respondents listed (without prompting) age-based and economic factors as the common factors. This includes different age groups (youth and aged) within the area and indicators of wealth (aged and youth populations are systematically gathered by the Office for National Statistics for various geographic areas). Local managers agreed that information concerning age is objective and conceptually useful as a general indicator of resilience.

Social deprivation indicators used by the Office for National Statistics were identified as appropriate factors but were seen as proxies for other information. In particular, emergency managers found deprivation to have less of an effect on resilience when compared to the number of households in at-risk areas that had relevant insurance. They thought that the existence of savings or access to liquid funds was more useful in rebuilding a community than absolute indicators of wealth. Some appropriate variables that measure this concept would be: 1) average savings, 2) number of households with relevant insurance, or 3) number of benefits claimants in the community.

The research respondents raised a second interesting issue of community spirit and connectedness. The theoretical concept of community spirit is present in previous research (such as Cutter[24]), in which two different concepts underlying community spirit are identified. The first is a self-help concept in that neighbours will help one another to recover from any disaster. The second is the communities' ability to engage with and heed warnings from local officials and emergency workers. However, local authorities were not comfortable with the proxies provided in that body of literature. Community capital proxies that measure inflows/outflows of the population from geographic areas were found to be lacking, as even relatively static communities would not indicate continued interaction between neighbours especially among older populations. Instead, emergency managers identified the existence of community mobilisation, such as community watch programmes, as better resilience indicators. Community engagement with officials was expressed as a key component of resilience, although emergency managers expressed difficulty in community buy-in to resilience building programmes. Possible proxies that were mentioned were crime rates and previous history of accepting local government aid.

These findings will lead to the exploration of different systematically gathered data that can be used to support decision-making for resilience projects in the local area. These findings represent the preliminary stage toward the goal

24. Cutter et al, *op. cit.*

of creating a resilience model that can be used to understand the marginal effects of mitigation strategies using MCDA methods.

Conclusions

Resilience building has become an important concept to local emergency managers in preparing at-risk communities for natural disasters. Emergency managers can have a difficult task, however, in choosing between different mitigation strategies to improve resilience due to the many different fields that use resilience concepts. Many of the existing resilience frameworks are unable to identify marginal improvements to overall resilience given the wide range of mitigation strategies that are available. This research project has proposed using a proxy-based resilience framework using MCDA methods to create a resilience model that can support resource allocation decision-making for resilience building in the UK. The local authority of Wigan in Greater Manchester was chosen as an initial case study for this work in order to identify appropriate proxy measures that can be used to support the resilience model. As a first step localised proxy variables were identified through an interview process with local emergency officials to support value functions in later analysis.

While there was a good amount of agreement between identified factors and current UK government recommendations, there was some refinement of proxy variables that may better capture the theoretical meaning of resilience concepts. Differences were found in proxy variables that measure economic resilience and community capital; specifically, insurance uptake and savings were identified as key concepts that are theoretically distinct from commonly used proxies such as social deprivation and wealth indicators. Community capital was also refined theoretically into concepts of engagement with local authorities and between neighbours in local communities. Possible proxies for these concepts include dependence on local authorities through benefits systems and crime areas within community geographies.

In this research, emergency managers recognised that there may be access issues to these data but it is important to identify these nuances to existing proxy variables for two reasons. The first is to identify potential avenues for additional data gathering that would improve emergency management and planning. A second important aspect to these findings is a refinement of theoretical data that can be used for communication and mitigation identification. While it may not be possible for emergency managers to enact strategies to pull households out of economic deprivation, there may be policy options to encourage basic savings or insurance uptake. Similarly, community capital can be improved through better engagement with local officials.

The next step in this analysis will be to take the set of proxy variables through a MCDA process to transform the factors so that they can be compared with each other and combined into an aggregate resilience score. Each individual factor model will then be used to understand the trade-offs between factors in order to facilitate decision-making between different mitigation strategies. In this way this research potentially leads to an objective resilience model that can be used to make crucial resource allocation decisions at very local levels in the UK.

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Discussion Groups

During the afternoon, the conference broke up into focused discussion groups, each comprising between ten and twenty delegates. The outcomes of these discussion forums are presented over the following pages.

Discussions were without attribution. The information presented here seeks to represent the discussions that took place; there is not always robust academic referencing to support the views offered, but it has been assumed that if comments made by individual delegates were not credible they would have been rejected by the other members of that group during the discussions. Views presented are therefore assumed to be broadly supported by the majority of those present. Where possible, transcripts of the discussion forums were distributed to the participants during the editing process for further comment and clarification.

There was, inevitably, some crossover of subject matter and topic discussion between one group and the next, and where this has occurred, comments have been amalgamated under one heading to avoid repetition.

Discussion Group 1: Methodologies for Resilience Research

Chair and Rapporteur: Jennifer Cole

Key Issues and Challenges

- Resilience research needs to be conducted using mixed methods across disciplines that are not necessarily experienced in working together. Discussing available methodologies jointly, planning research projects together and understanding how research projects can have benefits across all relevant disciplines is a developing area.
- There needs to be a more strongly agreed definition of resilience that is accepted across organisations and agencies. This will help to determine how resilience baselines are set, and which factors need to be included in considerations of resilience.
- Natural science, behavioural science and computer science experts need to work together to make accurate predictions of risk, and risk impact. The behaviour of the population during an incident can be as important to resilience as the physical damaged caused by the event, and both need to be factored in to computer models used to understand, analyse and predict resilience.
- A better understanding is needed of how data can be pushed out to the public in the event of a disaster, and how non-experts are likely to understand or interpret complex information.

Resilience crosses a number of academic disciplines, but the methodologies to measure and model resilience, as well as to collect and analyse data, tend to lie within computer science and mathematics. As an increasingly wide range of software for non-IT experts becomes available, such as that provided by the Epidemiological Intelligence Unit of the US Centres for Disease Control,[1] resilience analysts no longer need to be technical experts themselves, although they can nonetheless benefit from an understanding of data collection, modelling methodology and their underlying principles.

Academic and policy researchers alike need to understand how to set the parameters for data collection, so that the 'right' questions are asked, the 'right' data collected, and they and their colleagues can make sense of data outputs. Natural scientists can measure the likelihood and impact of earthquakes, floods, radiological releases and pandemics, while social scientists can help to predict how people will behave in facing the risk. Understanding earthquake risk, for example, requires a range of experts: geologists, to understand which regions are most likely to be at risk;

1. Centers for Disease Control and Prevention, 'Field Epidemiology Training Program', <http://www.cdc.gov/globalhealth/fetp/>, accessed 29 January 2014.

seismologists, to measure that risk and predict when it is likely to increase or become more immediate; architects and civil engineers, to understand how buildings and structures can to be built to withstand an earthquake; social scientists, to determine likely behavioural patterns of people living in areas prone to risk and the impact of stress after an earthquake event; and medical experts, to determine the resources required to address the human impact. All of these factors need to be fed into computational models if these are to be accurate and useful to risk managers and resilience planners.

If these disciplines fail to work together to frame questions properly, the real issues may be missed or the possible responses limited. Combining understanding, data and modelling across disciplines can provide a more complete understanding. For instance, to determine the historical impact of a flood, the analysis must include a model of the river flood plains, the number of residents that heeded past flood warnings, the action they took, the level of insurance claims that were made, and the number of properties that were flooded again during subsequent flood activity. Such a study would benefit even more from including information on the health impacts on residents in flooded neighbourhoods, economic recovery over a given period of time, and any long-term effects on employment or urban development.

Unpacking 'Resilience'

A key challenge to combined methodologies for the measurement of resilience is the lack of a single agreed definition, accepted internationally and across disciplines. This makes it difficult for resilience researchers to formulate the right questions and design appropriate interdisciplinary research projects.

Another challenge is how to distinguish between short-term and long-term resilience, an area of research that would be assisted by in-depth evaluations of the long-term impacts on individuals and communities of past incidents. For instance, there is a large bank of research on the long-term health impacts of the Nagasaki and Hiroshima atomic bombs,[2] but less on the psychological stress on survivors caused by evacuation and separation from their communities. Working across such data sets may help to determine whether community approaches are the best way to address resilience.

The incorporation of demographic information and expertise may also reveal new insights into resilience. For instance, single people are more likely to live alone in urban rather than rural areas, and hence may feel less a part of a community or support network; this could be a significant factor in determining the different psychological experiences of people facing a

2. For instance, Yukiko Shimizu, Hiroo Kato and William J Schull, 'Studies of the Mortality of A-Bomb Survivors: 9. Mortality, 1950-1985: Part 2. Cancer Mortality Based on the Recently Revised Doses (DS86)', Radiation Research (Vol. 121, No. 2, February 1990), pp. 120–41.

serious incident or event. Such factors need to be better understood, in particular with regard to understanding who 'owns' resilience – the individual, community or city – in order to determine where limited resources can be best focused.

These considerations raise the question of whether or not there is a resilience equivalent of 'herd immunity'. This biological term covers cases where vaccination (or natural immunity) of a significant proportion of a given population prevents diseases from circulating within that herd/community, thus also offering protection to unvaccinated/non-immune individuals who are shielded from the disease by the immunity of others. In resilience terms, this would manifest in a significant proportion of the community displaying resilient behaviour that also affords protection to others who may not follow resilience advice to the same degree. An example might be a significant portion of a housing estate in an area at high risk of flooding choosing to refit impermeable driveways and patio gardens with more effective drainage capabilities; or a significant proportion of a community opting in to flood warning schemes, and then notifying neighbours and friends of severe weather predictions. More research is needed into what proportion of the community would need to 'opt-in' to the resilient behaviour for the entire community to benefit.

As well as defining 'resilience' it is also important to define 'harm', including where and in what form(s) harm manifests and whether impacts are short or long term. Different types of emergencies often cause similar types of harm in terms of large numbers of casualties, or people requiring evacuation and shelter. Focusing on these common consequences may help to determine what resources are most needed, both in generic and specific terms. For example, if 300 people are likely to be 'harmed', what do these 300 casualties require? More ambulances for hospital transfers, or more paramedics and first aiders to treat them at the scene? Long-term follow-up to address psychological damage, or a support network to help make insurance claims and access rehabilitation services? Resilience planning is too often carried out on the basis of listing the assets available but without matching these available assets to the likely harm caused, leading to an approach of 'this is what we have', rather than 'this is what we need to address the consequences'.

Understanding Urban Characteristics

The shifting character of urban environments is an important consideration for resilience, particularly with regard to the role of data technologies. Despite these making it easier to work remotely, and conduct banking and shopping online, the number of people living in cities continues to rise. At the same time, whilst some cities are expanding, others are shrinking. Smaller cities tend to have a greater degree of community, where people know each other and there is community memory. In the context of resilience, how should

we understand city size? Is it a sign of failing or evolving resilience? There is considerable research on why cities have evolved in the way they have but less on which characteristics of that evolution drive or impede resilience, both in terms of the built environment and human behaviour.

In particular, the relationship between the economy and resilience warrants further exploration. It is important to understand the economy not only at the time of a disaster, but also its historical development and the economic importance of the impacted area relative to the wider region. For example, the links between a coastal city and its legacy as a trade port may be important even if the port is no longer central to its economy, or if its main role has shifted from trade to tourism. Such changes may shift the relative importance of the city at the national and even international level, resulting in disruption to normal operations having a greater or lesser knock-on effect across the wider region. There also seems to be little research assessing how businesses moving into or out of a region has an impact on the resilience of the area.

As well as discrete measures of resilience, it may help to design measurements that compare one type of resilience with another, and help determine the relationship between them. For example, the construction of flood defences may lead to a loss of community memory in how to deal with regular flooding. In The Netherlands, better flood management planning and investment in flood defences has meant that serious flooding is slipping out of living memory. Less frequent flooding may have a negative effect on resilience, particularly as, without the comparative perspective that comes from recent experience, moderate flooding may be seen instead as a 'disaster'.

Objectivity has a strong impact on resilience. A community needs to take proportionate action against relevant risks, but 'proportionate' and 'relative' may be measured differently depending on the likelihood or gravity of the risk. This is where an 'all-hazards approach' that measures both impact and likelihood (such as the UK National Risk Register) adds real value. Such an approach also helps communities to conduct cost benefit analysis and maximise the impact of investments.

Considering Communities

How communities practice resilience at the individual, family, group and community level also needs more research. There is insufficient understanding of what types of events communities are vulnerable to. Without this, it may be unrealistic to ask the population to be responsible for their own resilience. A better understanding of the resilience that different actors can provide – such as individuals and communities on the one hand, and regional and national institutions on the other – would help to determine which resources and structures are required at the top level of intervention.

Resilience planning also tends to work on non-linear data, assessing absolute states ('at serious risk', 'at some risk' or 'not at risk') rather than linear data that would assess past impacts and relate them to the current situation. Individuals and communities tend to take more responsibility for resilience when they are exposed to frequent small shocks that provide regular reminders that a larger event with a more serious impact is a credible danger. This helps them to prepare appropriately. For instance, with a recent history of earthquakes,[3] the populations of Los Angeles and Seattle tend to take earthquake resilience seriously. They are well educated on the risks and have a good idea of what to do. If a community has never experienced a disaster, however, how will people know how to react? There may be a potential role for diasporas and immigrants to help build resilience in these cases, particularly by those displaced from their previous communities by the effects of climate change or natural disaster. Such individuals may be better prepared, and more willing to prepare themselves, than a community that has never had to worry.

Experiences of disasters can be passed on from one generation to the next through personal relationships or through formal community memory structures such as museum displays on floods or earthquakes. Such 'memories' may be 300 years old but they are still relevant, and worth keeping alive in the population. How such memories are kept alive, how they help to build resilience, and also what happens to communities that would rather forget unpleasant events are all issues that warrant more research. The (re-) evaluation of models constructed with data from past real incidents would be a valuable research topic to help build understanding of future impacts, as would better understanding of linear trends in resilience. For instance, comparisons of water usage and weather forecasts may aid the development of more predictive models of high water usage and likely shortages.

A difficult issue is the extent to which the government should encourage individuals and communities to take responsibility for their own resilience, while providing a safety net to those who do not or cannot. Such an approach can enable limited resources to be targeted more effectively, and prevent a lack of resilience in one group or region from affecting the wider community. For example, a strong focus on some of the most excluded groups in society may have a very positive effect on health resilience in the UK. In the case of antibiotic resistance – a growing issue that threatens to cause a large-scale health emergency for the UK population – the focus can be on the homeless community (amongst whom high levels of tuberculosis are recorded), sex workers (who are at risk of gonorrhoea), and traveller communities (amongst

3. Seattle has experienced four earthquakes above 6.0 magnitude in the past seventy years, the most recent in 2001. Seattle Office of Emergency Management, 'Earthquake', <http://www.seattle.gov/emergency/hazards/earthquake.htm>, accessed 28 January 2014.

whom measles is endemic due to lack of vaccination). Front-loading resources to target these groups by providing increased access to healthcare and more stringent surveillance could help to tackle infectious disease outbreaks before they impact a broader portion of society. Even a short-term focus on these groups may have a significant impact over and above more general public-health campaigns targeted at a wider audience which has already largely 'got the message'. A resilience challenge here, which may determine both the metric and the measurement of success, is whether the aim is to reduce the spread of drug-resistant tuberculosis and sexually-transmitted infections, or to 'clean up' a certain area of the city where homeless sleepers and sex workers congregate.

Sharing Data with the Public

An important exercise for emergency planners and resilience experts is to consider the type of information the public wants and in what format. For example, following a chemical, biological, radiological or nuclear incident, such as the accidental release of radiation from the damaged Fukushima nuclear power station in Japan, the public is less likely to ask, 'how many milliseiverts above the usual baseline level is the current level of background radiation in Tokyo?' than 'Am I in danger?' and 'What should I do?'. In the case of the Fukushima disaster, the Japanese authorities did need to gather scientific data to provide very accurate information on radiation levels in Tokyo, but the communication of such data to the public, and their interpretation of it, is an important consideration.

During the 2009–10 H1N1 Swine 'flu pandemic, emergency planners in Seattle considered the role of public bus drivers in spreading the disease, and debated whether they should be a priority group for vaccination together with healthcare workers. However, there was a concern that such a strategy could alarm the public, who might think that bus travel would expose passengers to infection, and thus refrain from travelling to work, with consequences for the economy. Such theories are largely unresearched however, and developing a better understanding of behavioural patterns, based on expertise from behavioural psychology, is a valid research area. There is generally an assumption that the public will react irrationally to scientific data, by panicking or believing media and social media sensationalism, but this is not always backed up by empirical evidence.

Data Use and Privacy Issues

Once measurements of resilience are developed, local authorities and/or the national government will need to collect personal data that can be matched against such indicators to help assess resilience needs and allocate resources appropriately. For example, evacuation strategies can be better designed if emergency planners know how many households have their own car or other means of transport, and how many require public transport or other

assistance. The next step is an understanding of the mobility characteristics of those without their own transport: for instance, how many are elderly or disabled, how many can get themselves to traditional pick-up points, such as rail stations or bus depots, and how many are likely to require assistance at their homes? What medical and care support might they need *en route* to evacuation centres and once they arrive there? This type of data may be held by national agencies, local authorities or by private and charity groups supporting the elderly and disabled to live independently in their homes (such as Meals on Wheels), all of which have different data protection commitments. In a real crisis, however, the public may be more willing than usual to give data to the government or accept the sharing of data by non-government organisations. Privacy concerns tend to be thought of in absolute terms, rather than as shifting or fluid acceptances. Research to provide a deeper understanding of how this might be affected by emergencies would be welcomed by resilience planners. Such research would also help to build a better understanding of how, and in what circumstances, the public trusts data.

In terms of resilience, basic parameters still need to be set for the creation of resilience data sets: for instance, data that does not seem relevant can be just as important when an emergency strikes. Resilience experts need to be able to anticipate the kind of information required, particularly as it may be needed to provide a range of answers to different and often complex questions. Collecting too much data can make the information difficult to analyse or prioritise. How frequently the data(set) should be updated is also a challenge: whilst it may be technically possible to keep data up-to-date in real time, this is resource intensive. This in turn raises issues about who should update the data and how quickly its accuracy diminishes. The optimum time frame for updating or refreshing data sets may differ for different end-users of the data.

Finally, how and with whom data needs to be shared should ideally be set out when the data are collected, but setting parameters too inflexibly may cause problems. An organisation that is central to the response when the incident happens may not have been considered important – or may not have existed – at the time the list of sharing agencies was set. A more practical approach might be to state which (types of) agencies the information should *not* be shared with and even, in these cases, to consider the circumstances in which this might be reconsidered.

There are definite advantages to conducting risk assessments on scenarios in which data are shared or not shared, and the impact of these approaches on the emergency response. For instance, exercises that reveal that not-sharing can put lives in danger might lead to more flexibility with data-sharing (and the breaching of confidentiality agreements) should an incident

occur. Enabling different resilience stakeholders to practice and discuss data-sharing scenarios will embed better understandings of what is and is not possible during real events. Data-sharing plans should also be discussed with the public so that their likely reaction can be predicted and understood. This might also help the public to feel more ownership over resilience projects, and give them a sense of being fully included in any plans.

Data Collection Considerations

Regardless of the types of resilience or resilience determinants that are being measured, it is important to know exactly what the data are being collected for. Data collected for collection's sake may not be analysed easily or in a way that provides any particularly useful information. Key considerations at the beginning of any project include: What decision(s) need to be made based on the data collected? Who will make those decisions? How will data support the decisions being made? Is it the absence or presence of a certain determinant that is important? Emergent behaviour is important to understand in a real emergency: how data about this can be collected and analysed requires further research.

Researchers and policy-makers also need ways to determine quickly if the data they need (or are interested in) is already available elsewhere or available in a slightly different format that can be modified to meet their needs. This again raises data protection concerns. For instance, what are the implications of private resilience companies having access to resilience data collected as part of the national census? Are those identified as vulnerable by such data protected from aggressive marketing of resilience products and services?

An additional consideration is the issue of data loss (either the data itself or the system through which it is accessed), and its impact on resilience. Data losses tend to happen at the local rather than national level, and there does not seem to be much modelling of different scenarios that can help to determine the impact of the loss of certain data, or whether different data sets are more vital in some response scenarios than others. Collecting data on a number of resilience indicators in a systematic way over set time periods will enable better comparison of the state of resilience and help to identify positive or negative trends. An indicator of flood risk increasing, for example, may not be an increase in the level of rainfall from one year to the next, but rather the number of times in one year, compared with previous years, in which flood water comes within a certain distance of the top of the flood defences. It may be the increased frequency of near misses that indicates that the flood barrier is no longer offering sufficient resilience. Collecting regular data against a number of agreed baselines will help to improve scenario modelling of individual risks on an annual basis as long as the correct data are being collected.

Suggested Research Topics

1. Emergent behaviour during disasters, including the collection and interpretation of such data, and the role of this information in shaping the response.
2. The psychological impact of disasters on different types of communities, including inner-city estates and rural communities, in order to understand how the demographics of a community affect the impact of an event.
3. The proportion of the community that needs to 'opt-in' to resilient behaviour for the entire community to benefit.
4. The reasons for cities' particular evolutions, and the characteristics that drive or impede resilience, both in terms of the built environment and urban human behaviour.
5. The way that resilience is practiced at the individual, family, group and community level.
6. The way in which memories of adversity are reproduced or forgotten; and how community memory can help to build resilience.
7. The impact of emergencies on privacy concerns in order to better understand how, and in what circumstances, the public trusts data.

Discussion Group 2: Historical Perspectives on Resilience

Chair: Lindsey McEwen

Rapporteur: Laura de Belgique

Key Issues and Challenges

- Can historical lessons in resilience be applied in the context of modern-day resilient cities?
- The study of historical resilience is interdisciplinary and available research material may be in the form of written records rather than more easily analysable data formats.
- How can we identify the nature of information or data that might already be archived?
- Historical methods of resilience may not be compatible with modern lifestyles.
- The integration of science and narrative as a resource base for decision-making remains a particular challenge.

Past populations have always faced risks such as floods and disease, and so countries and communities should be able to learn resilience lessons from their histories. Researchers of historic resilience (who come from varied professions and academic backgrounds, and are part of external communities themselves) seek to explore whether people were more resilient in the past and if so, why. This includes establishing what historical factors made people more or less resilient, and what can be learnt from different settings, for example, by digging deeper into present urban communities in contrast to historic rural settings. Against this backdrop, the characteristics and values within historical factors, as well as the nature of the available data used for past analysis of resilience, need to be studied. This involves identifying what data on historic resilience might look like, where it can be sourced, and how it might be gathered and analysed. The strengths and limitations of different data sources, and their integration, also need to be evaluated. This includes establishing whether there are remaining records or other forms of research that could be turned into data about historic resilience.

Historical Perspectives on Resilience: Exploratory Scene-setting

Historic resilience can be framed in terms of different forms of capital and its impact on resilience. It needs an interdisciplinary focus, drawing on the environmental sciences, social sciences, heritage studies, and media and memory, with a wide range of skills and diverse set of narratives. As with present-day risk analysis, historical resilience of individuals or groups can be framed in a variety of ways including infrastructural, institutional,

psychological/emotional, economic, technical, social, and adaptive/coping, along with the changing nature of community capital. For example, resilience planning and recovery often underestimates considerations of emotional/psychological resilience, such as the incidence of memory loss after a traumatic event, or the stress and emotional memories experienced by flood victims.

In exploring 'historic resilience', it is important to note that the concept of 'community' is itself contested. Definitions of community are frequently envisioned in historic terms. For example, nineteenth-century rural communities that were tied to the land might have moved around very little and may have been relatively self-sufficient for resources. There may have been no real need for residents to travel any great distance in order to access resources if they were living in sustainable communities. This is a very different scenario to contemporary inhabitants of urban settings, who experience long commutes to work and are dependent on globalised food and resource supply chains. In the twenty-first century, urban locations may have many 'communities', some of whom may be perceived as 'hard to reach' by official organisations but which have their own networks. In other settings, residents may be transient for various reasons and never really settle into a geographic community of any kind. This has implications for research into community, risk and resilience that compares the historic with the present and future.

In considering historic resilience, a distinction also needs to be made between the histories of communities living with routine, expected events (such as annual or seasonal floods) and those communities that experience episodic, clustering or trending extremes with major, unexpected impacts. In the UK, mitigation strategies for dealing with risk have also undergone major changes over time. This has involved a scaling down from a national-scale, top-down focus on infrastructural solutions ('technological era') to a more bottom-up model that focuses on involving local communities and individuals, and a varied distribution of risk management (working with official organisations), in an effort to create a more integrated, multi-method approach.

The nature of historical resilience can be evaluated at individual or group levels. There is anecdotal evidence that resilient groups at risk from environmental hazards have declined in number over time. This has involved the backward movement of some urban risk groups along the dependency continuum from 'The government will protect us' to 'We are all responsible for our safety'.[1] Evidence exists that people may have been more resilient to previous conditions of extreme climate change or sporadic environmental

1. Don Riley, (2007) 'Improving public safety: From federal protection to shared risk reduction', Assembly Floodplain Management 2050, Gilbert F White National Flood Policy Forum, Washington DC, 6–7 November 2007.

changes. For example, during the UK's 'little ice age' of 1650–1850, winters were so severe that the River Thames completely froze at regular intervals.[2] Historically, populations may have also been more resilient in their daily lives than we are today. Limited electrical appliances were less at risk of being damaged or damaging others through flooding; and basic building techniques such as stone floors rather than carpets were generally more sustainable and resilient. Furthermore, a resonating sense of community may have been more powerful amongst historical communities: individuals were more inclined to take action to protect themselves and their neighbours.

The twenty-first century evidence for 'reduced resilience' can be explained through a number of social, economic and cultural factors, including the changing nature of 'community'. Historical research into the impacts of floods and other disasters has provided useful insights into resilience. For example, records from the 1947 floods around the River Severn have shown that the authorities in Gloucestershire in fact circulated information on thirteen ways to salvage bedding and upholstery in rural and urban areas.[3] Today's culture of risk aversion and dependency on the state can be pervasive and reinforced by the media. This mentality is particularly common amongst young adults, a key group of concern for 'reduced resilience'. Furthermore, the culture of salvage and reuse has been replaced with a focus on instant gratification. At the same time, technological changes can have significant benefits for some sectors of at-risk groups, creating new or potential tools for contemporary risk management. Relationships with nature and the environment have also changed over time. For many present-day risk groups, there has been a disconnection with the land and its seasonality and rhythms, such as knowing detailed local water geographies, and the potential risks of excess and deficit.

The Nature and Value of the Historic Risk-Resilience Archive

A historical resilience approach to data needs to emphasise both the importance of being able to draw on the documentary evidence of past risk and resilience, and also on the role of people's memories of past hazard events and their impacts, together with associated local/lay/indigenous knowledge(s) for resilience. Here, inter-generational or vertical strategies for communication and exchanges of local knowledge about 'living with risk' need to (re)connect with horizontal communication and exchanges within risk groups/communities as present-day hazard events play out. For example, the ESRC Sustainable Flood Memories project explored the links between flood memory, local knowledge and resilience in the aftermath of the 2007 floods

2. Jean M Grove, *Little Ice Ages: Ancient and Modern*, Vol. 1 (London and New York, NY: Routledge, 2004).
3. Records from the Tewkesbury Borough Council Planning Department.

on the River Severn.[4] This project found that flood memories interweave a whole variety of emotions and lay knowledges – such as around childhood memories of how to deal with risk, and the importance of community/friend networks – and reasons for active forgetting and active remembering.

This poses important questions: who are the people who actively forget hazard experiences, what are the reasons for this, and does this process make them less resilient? Intergenerational communication around risk for resilience involves strategies for children exchanging knowledge with their grandparents, and younger community members engaging in risk heritage discussions with their 'community' elders, who, for various reasons, may be spatially or physically disconnected. 'Looking back to look forward' can be critical in resilience contexts. For example, the AHRC Living Flood Histories Network explored how the arts and humanities might have alternative approaches to the understanding of floods and resilience in the context of environmental change.[5] This research highlighted the value of narrative and historical approaches that recognise and draw on the flood archive.[6]

Historic Resilience Data and How it Might be Gathered

Any exploration of historic resilience needs to identify the nature of information or data that might be already archived. Evidence from official government archives such as reports, county records and church records need to sit alongside and indeed integrate with individual, family and community records and other more informal archives. Such archives might include photographs, diaries and oral history accounts of extreme events. In addition, historic resilience may be evidenced in the built landscape, such as the way houses were constructed or their positioning in relation to risk.

Analysis of the evidence in archives brings the associated issues of whose voice was archived and the power dimension of official archives.[7] In oral

4. ESRC, 'Sustainable flood memories and the development of community resilience to future flood risk: a comparative study of three recently flooded communities', 2011–12, <http://www.esrc.ac.uk/my-esrc/grants/RES-062-23-2783/read>, accessed 31 January 2014.
5. Arts and Humanities Research Council Researching Environmental Change Network, 'Learning to Live with Water: Flood Histories, Environmental Change, Remembrance and Resilience', <http://www.glos.ac.uk/research/csfc/lfh/Pages/default.aspx>, accessed 31 January 2014.
6. Lindsey J McEwen, Iain Robertson and Mike Wilson, 'Editorial - Learning to live with water: Flood histories, environmental change, remembrance and resilience', Journal of Arts and Communities (Vol. 4, No. 1–2, 2012), pp. 3–9; Lindsey J McEwen, Dave Reeves, Jethro Brice, Fiona Kam Meadley, Karen Lewis and Neil Macdonald, 'Archiving flood memories of changing flood risk: interdisciplinary explorations around knowledge for resilience', Journal of Arts and Communities (Vol. 4, No. 1–2, 2012), pp. 46–75.
7. Jacques Derrida, Archive Fever: A Freudian Impression, translated by Eric Prenowitz (Chicago, IL: University of Chicago Press, 1996).

histories of extreme events, the voice of the public can be perceived by some official organisations as anecdotal and conflicting. While memories can alter with time, anecdotes can act as valuable ways of communicating local knowledge. Narrative data (historic and present day) allows previously unheard voices to be brought to the table in discussions around changing resilience. Various issues need to be considered when working with historic risk and resilience data, including how narrative can be used as data, and how narrative resources can be integrated into present and future expert knowledge systems (for instance, for local decision-making). As well as having value in its own right, historical qualitative or narrative data can provide the context for joining up and understanding often fragmented historical data, including numeric data. The issue about the use of historical data (both qualitative and quantitative) and its integration is not a new one, but the integration of science and narrative as a resource base for decision-making remains a particular challenge.

In protecting and gathering historical data about communities and their risk-resilience, individuals researching their family histories may have a particularly valuable role in vertical exchanges of lay knowledge. This capital sits alongside the potentially important information exchange roles of local 'hub' people in communities with local knowledge. These might be amateur researchers in local history societies or those active in campaigns that require local historic investigation of past environments and human-environment relations. In past engagements around flood risk, amateur photographers and local cine-/photography clubs have had a role in capturing and sharing images of local impacts of and recovery to historic extreme events.

Resilience Learning and Archives

Various questions around risk and historic resilience could potentially draw on the historic data archive on risk-resilience. These include:

How can we understand changes in dependence in different sectors within the urban population over time?

These shifts in dependence can be perceived as influenced by the relative power balance between the state, resourceful communities and the 'dependent subset' in risk groups. Historically, life would have been valued differently in societies with different life expectancies, resources etc. For example, people's perception of dying has changed from when death was more common and life expectancy was shorter. Resilience would have been equated with day-to day-survival, linked to dealing holistically with varied stresses. Survival would also have been a shared 'community' endeavour as well as an individual one, for instance, in the face of famine and disease (the last peacetime famine in England was in 1623–24). There have also been changes in resilience related to place and trade-space. For example,

historically if the economy was bad, people had limited choice but to move, leading to waves of migration and immigration.

What does it take for a city to recover from a major disaster?
For example, this might focus on exploring the nature of recovery after the Second World War in Bristol and Coventry. This includes researching the importance of the 'spirit of the city' in recovery in terms of both people and infrastructure. It poses questions as to the extent to which a city should be rebuilt after a disaster. For example, following the bombing of Bristol's port, the town struggled to regain its *raison d'être*; the port was integral to the creation of the town. Present-day Bristol provides an interesting model of the resilient city due to its sustainability, its mixture of cultures and its relationship with water.

Is the city resilient? What leads to continuity in habitation in major cities despite major disasters?
The continuation of a population may be less important than the continuation of the state. For example, London continues to exist despite major disasters in its history (including the Plague and the Great Fire of London) because it remains a good place to make money, with considerable opportunities, skills and a great port. There is also something symbolic about London as a city. This longevity, persistence and resilience may be attributed to the importance of legal systems, government structures and economic security, as well as property rights. This issue of different forms of rights represents a changing dimension of resilience, in terms of intellectual property as opposed to physical property. Differences exist between data 'rights' in recovery – such as those pertaining to intellectual property and cloud-sourced data which are hard to protect – compared to historic legal rights to physical property.

What is the changing role of the state and key organisational players in disaster response?
This includes, for example, the changing role and resources of the military in dealing with civil contingencies. Comparisons can be made with the major risk situations that have occurred historically – for example, during the 1947 flooding of the River Severn, the army used amphibious vehicles called DUKWs, which were readily available after the war, to ferry children to school and keep the normality of everyday life going. Such a role may not be economically feasible in peacetime, when vehicles would need to be replaced for a purely civil contingencies role, with no guarantee they would be used or needed regularly.

How have physical environments changed in relation to risk mitigation and management?
This includes researching the changing perceptions of the impact of structural resilience measures with design limits where risk is not totally removed.

Changing land use and land management practices, and their influence (and perceived influence) on both the nature of risk and resilience can also be investigated. Here, local investigation of map sequences (how maps change over time) and local records (which might give insight into what caused the change depicted on the map) can be a powerful resource, and an effective tool for multi-stakeholder engagement.

What are the changes in how information on risk and resilience is portrayed in the media?
This includes how stories of impact and recovery are promoted and shared in different forms of media, and whether the dominant discourses are of resilience or dependency. In the recent historic past, some official organisations in risk management have relied on information transfer through leaflets and more passive forms of engagement. For some risk groups, information exchange and learning for resilience has been transformed by use of social media. Indeed in some cases, the ethos has changed to co-production of knowledge, and risk-resilience information-sharing amongst wider knowledge communities (for instance, between earthquake victims in Japan and UK flood-risk groups).

How do the major extremes in the historic record play out on the ground in terms of human-physical interaction?
Historically, the climate has not been stable. In local and regional archives, there is evidence of the impact of past extremes on scales not represented in some present instrumental records (for instance, the 1607 storm surge in the Bristol Channel and Somerset Levels). Constructed models of an event of low probability (such as the 0.001 per cent chance, or thousand-year event) are different to how scenarios might have played out in historic real-life situations.

Some Conclusions and Areas for Future Investigation
Can lessons in resilience learned from history be applied in the context of modern-day resilient cities? The consensus of this discussion group was that historical insights and frames of reference around different forms of capital and resilience have considerable potential value as an evidence base for thinking about, and managing issues of, urban resilience in the UK in the twenty-first century. The data needs to allow the framing of historic resilience in different ways, beyond just the institutional and infrastructural, including the emotional and psychological.

There are several ways forward in investigating historic resilience and data. These involve bringing different research disciplines, professional and local community expertise into the mix. Explorations of resilience might be by environmental historians, cultural geographers, historians, local heritage researchers and those working in media, memory and storytelling – ideally

working together. A first step would be to establish what has already been researched about the resilience of historic communities (rural/urban) but not necessarily in applied risk settings. Further, it is important to explore how historic data in its different forms – including narrative data – can be brought into existing knowledge systems and the evidence base for decision-making around risk and resilience. This is not just for official bodies and government but for those working with local communities and for local communities themselves. A key question is who should have the responsibility to collect and share this historic data: government or at-risk groups, or both working in partnership? With distributed risk management, both sets of needs arguably need to be satisfied in order to enable co-learning for resilience. There are several potentially productive areas for research investigation and advancement, but also in the (re)view of extant resources through a new resilience lens.

Suggested Research Topics

1. A better understanding of the nature of the data available for historical resilience analysis, including extant records and associated research, and information that is not currently in a suitable data format but could be reworked.
2. Considerations of emotional/psychological resilience, since these are frequently underestimated in resilience planning and recovery.
3. How the impacts of historic floods were mitigated in order to provide useful insights into resilience.
4. The reasons why some communities seem to actively forget hazard experience: what are the reasons for this and does this process make them less resilient?
5. The (re)view of extant resources through a new resilience lens.

Discussion Group 3: Key Stakeholders in Predicting Resilience

Chair and Rapporteur: Andy Marshall

Key Issues and Challenges

- There is no clear structure for determining who the key stakeholders in building resilience should be, past the Category 1/Category 2 distinctions of the Civil Contingencies Act 2004 and the Local Resilience Forums. In particular, private sector organisations that fall outside this structure, but which have a lot to contribute, are difficult to engage.
- It is not well understood or structured which organisations hold information of relevance to resilience, and what they do with the information they have.
- It is unclear who, if anyone, systematically analyses resilience information that has been collected by different organisations and sectors.

In order to determine which organisations are key stakeholders in the resilience of a city, it is important to consider the different stages involved in building resilience, so that the essential roles at each stage can be determined. For instance, resilience depends on the ability to make predictions about the risks facing the city, the likelihood that they will occur within given timeframes or other parameters, and their possible impact. This may require extremely early consideration of resilience requirements: for example, architects and civil engineers may need to be involved in initial planning or rebuilding individual structures and areas of the city to be resilient to more than one type of threat, and may need time to consider how this can be best achieved.

The discussion group agreed that potential stakeholders are often overlooked, and that local city councils need to work harder to prevent vulnerabilities from emerging. There are numerous factors that have been identified as useful indicators of how a community will fare in the face of an emergency, all of which need to be considered in resilience planning and management. A list of some of these factors includes:

- Adaptation to prevention
- Affluence
- Age demographics
- Awareness of risk
- Characteristics of the community (permanent, transient, temporarily created by circumstance)

- Communication
- Culture
- Exposure to risk
- Health demographics
- Level of networking (social, inter-community, media)
- Level of training and exercising (of general public as well as emergency services)
- Religion
- Tolerance of risk.

Inclusive or Exclusive?

How to deal with the sheer number of potential stakeholders in resilience is a major issue, as including as wide a range of stakeholders as possible has advantages and disadvantages, as does restricting the number to a more easily manageable group. The US has an estimated 80,000 different organisations responsible for resilience at local, state and federal levels, but there is no common network or structure available for the US to deal with the challenge of how many to include. Rather than just including large companies that can afford to take big risks at huge costs, it would appear to be a better strategy to allow a larger number of modestly-sized companies to take many smaller, less costly risks, some of which, in time, will justify more substantial commitments. Companies should thus steer clear of grand, imperial strategies and instead devote themselves to launching a swarm of low-risk experiments, coined by Gary Hamel and Liisa Välinkangas as 'stratlets'.[1] Thousands of ideas will produce dozens of promising ones that may yield a few successes. Note, however, that the understanding of whether fragmentation of resilience strategies provides stronger resilience is very poor as there is no single or central point of failure, and there may be a lack of coherence across resilience strategies. The concept of stratlets failed during Hurricane Katrina and Superstorm Sandy, for example, as the scale of the emergencies surpassed the capabilities available to deal with them. The variety of many low-risk ideas is an insurance against the unexpected. Most experiments fail, but it is the performance of the overall portfolio's experiments that matter.[2]

In the UK context, there seems to be confusion over who are the 'go-to' organisations dealing with resilience, particularly as the Local Resilience Forums have no permanent presence and responders' membership may at times be transitory (although the chair should always be available). Without a single 'go-to' organisation, where does the empowerment or enforcement for resilience lie? With regard to resilience data in particular,

1. Gary Hamel and Liisa Välinkangas, 'The Quest for Resilience', Harvard Business Review, September 2003, p. 9, <http://rhesilience.com/blog/wp-content/uploads/2012/07/23 HBRQuestforResilience-gary-hamel.pdf>, accessed 14 March 2014.
2. *Ibid*., p. 1.

this raises questions over who is able to – or might be interested in – analysing resilience data that has been collected.

The discussion group questioned the benefit of 'city operational centres', such as the one in Amsterdam, and central authorities for resilience. The Amsterdam operational centre's objectives are to increase response capacity and medical relevance along with strategies and choices necessary to allow operation in a global environment.[3] Its strategic plan suggests alternate ways of engaging with local stakeholders and communities in order to provide relevant and quality medical care. It generates ideas about how interventions could relate to more informed populations in a world where shifting disease patterns require more complex medical responses. Other strategies are aimed at ensuring that this centre thrives in a multi-polar world. The Amsterdam centre has been described as a blueprint, thus questions were raised about how standard such response mechanisms should be at an international level. Is it appropriate or practical for there to be the same response in Rio as in Amsterdam, for example? It is unlikely that a one-size-fits-all policy is appropriate in resilience planning.

Aggregation of Multiple Data sets

There are a number of organisations that hold information important to resilience. As well as understanding what these are and how they might be able to share information, it is also important to know how they can, or cannot, act on such information. For example, the Local Resilience Forum has no permanent presence: it is a group of stakeholders that come together, often only once every six months, to discuss resilience issues. The group has no statutory rights, and no real power to implement anything it discusses. The discussion group felt that Local Resilience Forums (LRFs) need to have more power to implement actions that will increase resilience, rather than just being a discussion forum. While this is far from a novel suggestion, the fact that it is still raised in any discussion relating to LRFs should certainly be noted. It was also felt that resilience must come out of incident response as well as pre-incident planning. It is important to determine quickly who has been impacted and who needs to know in order to be able to provide the most appropriate help and to keep the impact of the incident to a minimum.

Second-Hand Information?

It was also felt to be worth noting that information available to LRFs has largely been gathered by its constituent organisations for their primary roles, rather than specifically to inform resilience planning, and so may not give a complete picture. Other organisations, such as insurance companies

3. Medecins Sans Frontieres-Operational Centre Amsterdam, Strategic Plan 2011–2014 (Amsterdam: MSF-OCA, 2011), <http://association.amsterdam.msf.org/sites/default/files/AzG-SP-11.pdf>, accessed 14 March 2014.

and others from the private sector, have pools of data that may be highly relevant (such as flood risk data), but this cannot be given to the LRF due to data protection laws. It could potentially be given to the public directly, however, as part of programmes to encourage members of the public to take more responsibility for their own resilience – however, the public does not necessarily act on or take notice of such information.

More research is needed on how the public can be encouraged to take more of a role in resilience, since it is a key stakeholder. It has a 'need to know' with regard to resilience issues so that individuals and families can take appropriate resilience measures against the risks likely to impact their local communities. This depends on their engagement with the issue, however. The BBC was seen as a key stakeholder here, with a potential role in predicting as well as responding, particularly by disseminating early warning and informing messages. The BBC may also have an important role in countering or diffusing inaccurate messages being passed via social media during incidents.

A second important issue concerning the role of the public in resilience was the extent to which members of the public would be happy to have their information shared for resilience purposes. Public levels of trust are important and can be influenced by who owns the data and actual or perceived notions of what they will do with it. Supermarkets sell data on their 'clubcard' customers to a wide range of organisations with little complaint from those customers, but would there be resistance if customers thought the same information was being passed to the local authority or the government to enable resilience planning?

Summary and Conclusions

Information sharing between key stakeholders and potential key stakeholders presents serious barriers to resilience; ways to overcome these barriers should be a research focus. It is important to focus on the role of the data analyst: which organisation should they 'belong' to, where will they pull information from, and what are the aims for which the data are being analysed? Analysts need to be part of the process of data sharing from the early stages of resilience planning, in particular to ensure that data are shared selectively and appropriately, rather than 'dumped' into a data repository that will be difficult to analyse in any meaningful way. There are multiple stakeholders and multiple levels involved in analysing and predicting resilience, and how to aggregate all the available information and data together will be an increasing challenge.

Suggested Research Topics

1. The need for a central depository for resilience data and information that has been collected so that a wide range of data can be made

readily available to resilience practitioners and researchers. This is particularly important as data may not have been collected for resilience purposes, and may come from a wide range of organisations. The role of a skilled analyst who understands how this data can be interrogated will be important to the overall resilience picture, and training such analysts (or providing them with the appropriate skills) will be a key role for academia.

2. A better understanding of whether internationally standardised resilience mechanisms are more or less efficient than more locally focused initiatives. There is an obvious need for a link between top-down and bottom-up approaches but there is currently less clarity on the point at which these need to meet and integrate.

Discussion Group 4: Health Demographics and Future Resilience

Chair: Kathryn Humphrey

Rapporteur: Christopher Sheehan

Key Issues and Challenges

- Silos continue to exist within the healthcare sector, and between the healthcare sector and other relevant government agencies, in particular with regard to information sharing
- Increased NHS cuts and privatisation of some services is exacerbating the above challenges; and monitoring of what is happening is being made more difficult
- There is too much focus on short-term solutions at the expense of long-term planning. One-year planning cycles hinder longer-term thinking
- There is a limited understanding of the long-term risks emerging in healthcare and how these might therefore be addressed.

The aim of this discussion group was to consider what factors are the most important in terms of the UK's health demographics and future resilience.

Throughout the discussion, a number of points were made regarding silos and siloed information. A number of participants felt that the NHS is overly departmentalised and, while Public Health England has some good solutions to healthcare resilience, it can be hard to share these across all stakeholder agencies. Similarly, Social Services' duty of confidentiality regarding data – and tendencies to adhere more strictly to data protection laws than needs to be the case – leads to a tendency to look at separate areas of data without linking them together. This often makes it difficult to take action quickly.

It was agreed that, increasingly, our definition of 'health' is changing. There is a shift away from seeing health as meaning 'conditions that require hospital treatment' to including a greater emphasis on areas that have previously been considered the remit of social care rather than the NHS. However, the lack of appropriate information sharing is preventing the necessary coming together to be actioned appropriately.

The issues associated with siloed information were felt to be worsening as a result of increasing private provision of public and social healthcare: for instance, the growth in private care homes has led to additional barriers to information and data sharing, particularly as data becomes tradeable, and therefore a profitable commodity. Public attitudes towards the sharing

of health data need to better understood: the public routinely share very personal information on social media, so why is there such concern about sharing anonymised health data between government organisations tasked with improving resilience, when it is for the public's benefit? Participants felt that a mutual resilience committee between departments (within and across organisations) to discuss such issues would be of benefit.

Strategic Action at the Local Level

The current information silos also have a vertical as well as horizontal effect. Health policy is set by central government at the strategic level but the group participants did not feel that there is always sufficient openness regarding the decisions being made or the reasons behind them. The general public in particular often does not understand why decisions are made, though conversely it was also felt that priorities are sometimes guided too much by the general public rather than the specialists. In both cases, instilling the general public with a more complete understanding of the underlying issues and reasons for the decision that have been made may be of benefit – although actually achieving this is very difficult.

The lack of an efficient feedback system presents another challenge. New policy may be generated and implemented, but without an effective system

Box 1: The Need to Break Down Silos

The challenge siloed information could present to resilience was offered through the following scenario:

Imagine that following an industrial accident or terrorist attack at a chemical factory, a chemical plume is spreading across an area populated by approximately 10,000 people. The public are told to stay inside and the area is isolated. Family members are separated from one another and vulnerable people are separated from both their family members and their healthcare providers.

Ambulance personnel have Personal Protective Equipment and are trained to operate while wearing it. They could be sent into the area to carry out some social care activities in place of district nurses and care assistants and social workers. However, they currently have no specific training for this, and it is unclear if information on vulnerable people and their conditions could be shared with the ambulance service in this way.

Group participants felt that there are no practical plans in place to address situations such as this (based on actual test exercises).

in place through which to evaluate and, if necessary, improve the policy, it is difficult to see the policy's real impact.

There was also concern within the group that, at present, policy and structure are trying to change too rapidly and that policy 'chases the latest trend' and looks for 'single, snap solutions', rather than focusing on longer-term improvements. A longer-term approach, looking out to 2020 and beyond, may prove more effective. However, before a more long-term approach is taken, a better understanding of the current situation is needed. This was described as 'Before we start getting ahead of the curve, we need to understand the curve', and needs to involve more bottom-up thinking and a better understanding of the cost (in terms of life and money) of not acting, as well as of instigating change. An example of this was that 'winter comes around every year but we always seem shocked'. Participants described how there always seems to be a rush in the run-up to winter to get necessary resilience measures in place, rather than focusing on long-term policy that might help to address the vulnerabilities better. The 'flu jab was given as a good example of a long-term policy that genuinely reduces vulnerability (of individuals and the health service) to winter, and more approaches of this type would be beneficial. Some members of the group felt that addressing long-term planning by using the 'treat/transfer/terminate/tolerate'[1] model for long-term planning favoured in risk management strategy would be of benefit in helping to determine priorities.

Redundancy and Spare Capacity

There was also concern that in general, resilience is being affected by spending cuts. Redundancy and spare capacity in the system appears to be being stripped away, leaving very little (if any) contingency for a health emergency that seriously tests the national system, such as an influenza epidemic with more severe symptoms that the 2009–10 H1N1 outbreak. This would be a particular challenge should the emergency affect healthcare staff, further reducing the availability of doctors and nurses who may themselves fall ill and so be unavailable to treat patients.

If addressing such resilience challenges in future will, by necessity, involve needing to do 'more with less', is current research focused in the most appropriate place to understand and address this challenge? For example, while it is well known that there is an increasing number of ambulance call-outs (4 per cent increase per year), the group did not feel that it is sufficiently understood whether the reasons for this are that the need to call out an ambulance is genuinely increasing (due to unavoidable factors such as, an ageing population or an increase in population size; or avoidable factors,

1. Glasgow Caledonian University, Risk Management Strategy, <http://www.gcu.ac.uk/media/gcalwebv2/theuniversity/supportservices/financeoffice/Risk_Management_Strategy.pdf>, accessed 20 January 2014.

such as increased alcohol abuse), or because there is an increasing tendency to call out ambulances for minor problems. If the latter is true, what is driving people's decisions to call out ambulances for situations they would not have in the past?

One research area that would benefit from greater investment is trend analysis, particularly considering the increasing importance (and existence) of Big Data. The more future trends in health, particularly in non-communicable diseases such as heart disease and diabetes, can be predicted, the more effectively they can be planned for and the more resilient the healthcare system will be. At the moment, trend analysis tends to be carried out at the global level, whereas more granularity at the local (or even individual) level might pay dividends. There are potentially some very simple quick fixes in this area: for example, the UK does not currently record the reason for death on death certificates, whereas many other countries do, meaning that it is difficult to quickly identify trends in the cause of death.

Some of the group felt that there is a significant issue with a short-termist approach that tends to fund solutions before the problem is fully understood. It was acknowledged that it may sometimes be necessary to start to move forward with only partial information, otherwise nothing will get done, but there also needs to be a mechanism to allow backpedaling to enable changes to be made when more information becomes available. Research funding can often be too inflexible, preventing researchers from changing direction quickly if early research suggests this is needed. Researchers may need to make a separate grant under a new funding call in order to begin to explore the new findings in any depth, rather than being able to redirect their current funding.

Participants also felt that current funding mechanisms present challenges in implementing bottom-up approaches. Some felt that there is too much red tape involved in procuring funding to mitigate health resilience challenges. Some smaller NHS trusts or hospitals miss out as they lack sufficient resources to make the necessary bids. Referring back to challenges of instigating long-term plans, funding is often provided on a yearly basis only, with no opportunity for long-term investment which, some participants felt, actively kills progress. In addition, funding does not give sufficient consideration to seasonal variation: the example given was that in summer, there is a drop in emergency department admissions and so funding is reduced; in winter, when admissions increase again, there is a rush to apply for additional funding, followed by a reduction in funding the following summer, and so on in continuous cycle. In addition, the funding structure has been broken and reconfigured regularly with little thought, leaving the structure overly complex and confusing.

Community Resilience in the Health Context

The lack of traditional, old-fashioned communities and community structures is felt to be having an impact on health resilience. Some members of the group felt that increases in visits to GPs may be due to lack of 'community diagnosis'. Whereas in the past individuals would have turned to family, friends and other trusted members of a tight-knit community (including district nurses, midwives, family doctors and local pharmacists) for advice and reassurance over minor ailments, the lack of social support networks leaves them with no-one but the GP, or even accident and emergency departments, to turn to. Some members of the group felt that an increased use of digital technology may help here: for example, medical apps such as heart-rate monitors may help to provide reassurance to heart disease sufferers on the current state of their condition. Such technology is often used in other areas – accelerometers embedded in clothing that enable athletes and their coaches to tell when one leg is being favoured over the other was one example given – but these are not being used as well as they might be in routine healthcare to make the most of limited resources.

Modern technology, as well as the approaches to using such technology, could have a large impact on health resilience. A large data system shared by many stakeholders may well help to identify symptoms early (especially rare ones, which GPs and consultants do not experience often enough to build up personal expertise on), improve diagnosis and also highlight potential pathways to illness, flagging up certain lifestyles and lifestyle practices that may increase a patient's risk of a certain disease and helping to steer them away from the risk at an earlier stage. Linked databases could also help to reposition shared resources to the areas of greatest need, for example by directing resources generally needed after flooding to areas affected by floods, to help ease the conditions that lead to stress and depression.

Summary and Conclusions

Some members of the group felt that existing problems are getting worse, with insufficient attempts to address them, rather than new and novel problems arising. A vicious circle exists where, due to incomplete information, there is a reluctance to try new solutions until there is more confidence that they will work but there is not enough evidence to provide the necessary level of confidence, meaning that new solutions are less likely to be tried.

There is a need to develop better understanding of where the long-term risks lie and how these can best be mitigated; the tendency to focus on short-term 'quick fixes' is failing to address the underlying problems. Increased data sharing across vertical and horizontal silos, along with more willingness to listen to and to include bottom-up thinking in strategic planning decisions will help to improve the current situation.

Suggested Research Topics

1. A longer-term approach, looking out to 2020 and beyond, as more effective than short-term policy change.
2. The linkages between medical and social care in providing and promoting 'health' more holistically. Addressing issues at a social level may help to reduce stress on the NHS and on hospital accident and emergency departments in particular.
3. The potential advantages of a health resilience committee between departments (within and across organisations) to discuss shared issues and how to address them.
4. How resilience can be achieved with fewer resources in the future than are available today if the NHS continues to shrink in absolute or relative terms.
5. Trend analysis: the more future trends in health can be predicted, the more effectively they can be planned for and the more resilient the healthcare system will be.

Discussion Group 5: Smart Citizens – The Human Element in the System of Systems

Chair: Ashley Truluck

Rapporteur: Philippa Morrell

Key Issues and Challenges

- What will cities look like in the future?
- How will data technology evolve?
- Increased reliance on IT and networked systems may decrease resilience if the city is unable to operate when the systems fail.
- City resilience depends on many interrelated factors, some of which are better networked (and easier to network) than others
- Is the role of the citizen as an operator of future networks sufficiently understood?

This discussion group explored two interrelated issues with regard to the resilience of cities: the nature of current and growing threats, and the data requirements and collection methodologies required to address these in the future.[1] Discussions were confined to UK cities. The group noted that the consideration of future threats requires some vision of both what a future city will look like and how data technology will evolve.

Perceived Present Threats to Resilience

The resilience of the UK's increasingly large and diversely populated cities is strongly influenced by human factors, in particular those associated with, or related to, population growth and overcrowding. Examples of this include a shortage of both domestic and office space, which can lead to price inflation and, in extreme scenarios, the pricing out of some groups leading to civil unrest or even conflict. In addition, a high concentration of people in one space or on crowded mass transport systems offers a single target to terrorists seeking to undertake a mass casualty attack, and will speed the rapid spread of contagious disease during a pandemic or bio-terrorism event. The impact of climate change is another threat: the increasing pressure on water supplies and the interruption by flooding to services perceived as essential are climate-change impacts that are particularly likely to affect cities.

Cities act as a complex cauldron of political and extreme views. This can cause difficulty in establishing optimum social and governance structures, including those for local government, hierarchical structures between local

1. The discussion group on the day was amalgamated from what had been intended to be two separate groups, 'Future Requirements for Data Capture' and 'Resilience Determinants, as it was felt that the topics covered would be likely to overlap.

and national government, and the provision of social services and emergency services. Cultural attitudes to resilience, as well as memories of facing adversity together, can impact strongly on the way a society acts in the face of an emergency. Is it sufficiently well understood whether the multinational nature of typical UK city populations dilutes the traditional British 'stiff upper lip' attitude to adversity or enriches the scope of the community for dealing with the unexpected? This was felt to be a good topic for a separate study.

Economic resilience was identified as another important topic. Cities have become hubs of a globally integrated, services-based society, which makes them potentially more vulnerable to global economic trends (such as fluctuations in the global stock market) than has been the case in the past.

There are also technological aspects to consider. Information technology is changing and transforming the ways individuals communicate with each other and with authority. This can have potentially destabilising effects, as the Arab Spring illustrated. Rumours and 'non-events' can be easily reported and fanned via social media, which may require public communication spaces to be increasingly 'managed' if this threat is to be mitigated. At the same time, the ability to harness social media and aggregate multiple data sources provides the authorities with instant information on, and ways to respond to, events.

Most importantly, while IT systems can provide cities with better understanding and control of their operations and development, autonomous systems and computer-based technological solutions risk increasingly distancing humans from the decision-making loop. The implications of this may not yet be fully understood, although some assumptions are discussed further below.

Interrelationships between Resilience Factors

Some of the factors discussed above are interrelated, and are well integrated and networked. Others stand alone, or may be stove-piped. For example, to evacuate 3,000 people, computer models need to predict how the group will behave emotionally and psychologically in any given situation, particularly when they are interconnected by social media, as well as where the nearest exits are, and how long the evacuation will take. Interconnected factors such as political structures, cultural norms, religion and education all need to be considered in terms of their impact on individuals and the governance structures they follow, particularly in times of emergency. Increased utilisation of Social Network Analysis tools may add value in the future.

In all issues concerning city resilience, the common denominator is the city population, suggesting that measurable resilience aims and outcomes could be determined by a common 'disaster education' programme. A population that has been taught the same things will be more likely to react in a more

uniform and predictable fashion when faced with experiences that they feel well prepared for and familiar with.

Opportunities and Weaknesses in the Networked Society

In order to consider future data requirements, it is necessary to visualise what a city might look like in a decade's time. This requires the identification of growing trends, particularly those driven by IT. For example, everyone is increasingly using various communication forms and is increasingly networked. This produces strengths and weaknesses with regard to resilience.

The strengths include the speed of communication, which may be valuable in providing early warnings – both in terms of providing an early indication of an incident to the authorities, and in early dissemination of warning and information messages to those likely to be affected. The ability to talk to one another over a variety of platforms and media enables better inter-service co-ordination and also enables those with more complete and accurate information to counter rumours swiftly and prevent misinformation from spreading. In addition, duplicated communication paths increase redundancy – or may create a single shared point of potential failure, such as a common dependency on the electricity supply to recharge batteries or operate at all.

Whilst the evidence suggests that emergency situations do not produce mass panic, there is nevertheless the danger that mass interconnection might lead to misinformation by misinformed or malicious actors.[2] An additional concern is that the greater the proliferation of various communication networks, such as commercial, government, public and social, the more dependent the user will become on them. Thus, they become an Achilles' heel and lead to system vulnerability, wherein individuals become unable to act on their own initiative when access to the system is restricted.

Given a growing dependence on cyberspace – both institutionally and socially – how individuals and groups are likely to behave when faced with the loss of essential systems, due to accidental loss or cyber-attack, requires further investigation. Once again, education will be a key factor in increasing resilience in this regard, such as through an increased and shared awareness of the risks and consequences of the use and misuse of IT networks. The commonly used term 'cyber-defence' implies that it is possible to defend against all attacks, which is unrealistic and could lead to a false sense of

2. Numerous academic studies of panic in emergencies consistently show that concerns over mass hysteria and mass panic are unfounded. For instance, see John Drury and Chris Cocking, *The mass psychology of disasters and emergency evacuations: a research report and implications for practice* (Brighton: University of Sussex, 2007); and John Drury, Chris Cocking and Steve Reicher,'Everyone for themselves? A comparative study of crowd solidarity among emergency survivors', *British Journal of Social Psychology* (Vol. 48, No. 3, 2009), pp. 487–506.

security. It may be more practical to accept that attacks are inevitable and that the real challenge is being sufficiently prepared to be able to work through them.

Nonetheless, the advantages are seen to outweigh the disadvantages. The availability of Big Data now and in the future is likely to confer resilience advantages overall. Once this is accepted, important factors to consider include the development of open systems, in which all the disparate systems use a common interface that enables data to be shared across systems via agreed common standards. In addition, ways to validate the information being received from and by the population are needed. This will help to manage data and, by extension, help to manage behaviour likely to be influenced by it.

The Future City

'Smart cities', as covered in Chapter IX, which take a systems approach to harnessing the power of IT and Big Data to monitor, analyse, control and regulate the operation and survival of the city as an economic and social entity are likely to be an increasing feature of the future landscape. The future city is likely to be a 'system of systems' (SoS), constituting a number of sub-systems which will be the likely determinants of future resilience, such as economic or business systems that drive the wealth and prosperity of the city; governance or city services that form the operational activities and co-ordination of service delivery provided by the city authorities; citizen systems, which include all systems geared to supporting the wellbeing of the population, such as public safety, health and education; communication systems, particularly transport, postal and telecommunications; utilities providing and distributing water and energy, for example; and infrastructure. The latter would include the provision of 'smart' buildings for living and working.

The vast volumes of data upon which these sub-systems rely, plus the ability to network this data, will increasingly require integration of these disparate sub-systems into a coherent whole. This can be explained by the 'office block analogy', described in Box 1.

The smart office block analogy is an ideal. Practical considerations mean that such a vision will be seen only in new builds initially, as retrofitting older buildings will take time and will cost money. The use of smart phones to remotely action many of the automated systems described above is a more likely scenario that is in fact not far from reality already.

Much will depend on how the personal communication revolution progresses and social media platforms develop. Every citizen is potentially a communication and/or surveillance hub. If intelligently harnessed and

networked, new technology will be able to give citizens a direct role in monitoring, policing and regulating their own city environment – and thus obviate the need for elaborate 'built-in' systems such as those envisaged in the smart office block. The most likely outcome will be a diverse and pragmatic mix of public and private systems.

Box 1: The Smart Office Block: The Smart City in Microcosm

In the next decade or so, the future office block will be a mini SoS, a smart city in microcosm. It will have its various IT business systems plumbed in and interconnected with wider systems; automatic sanitation and waste disposal systems will be linked to city services; citizen services such as safety and security monitoring and surveillance systems (including iris/voice recognition 'automatic concierge' facilities) will be fully networked; and temperature, humidity and health-monitoring systems will be autonomous.

Communications systems will interconnect the whole building and provide a link to other city services. The building will have water and electricity plumbed in from the city utilities' smart grid and will be monitored continuously to ensure optimum usage and to minimise its carbon footprint.

Most importantly, the building infrastructure will have been designed *ab initio* with all this in mind.

Summary and Conclusions

Future cities do not necessarily need everything designed in and fully networked. Some diversity will provide system redundancy and make the future city more resilient. The issues of affordability (and the influence of a single-system monopoly on costs) also need to be considered. Of particular importance is the role of the citizen in such a future city: it will be a system of systems but citizens will need the technical wherewithal to 'opt-in' and become their own data collection and dissemination nodes. For this to work, such a system will need to be fully transparent, with open standards and light-touch regulation.

With more data and increased networking, individual systems may become more vulnerable due to their reliance on IT and the power supply that enables it. Everyone needs to accept that no system will ever be completely invulnerable: what is needed is ways to mitigate the risk as much as possible. This involves educating private citizens on the responsible use of data systems and social media just as much as training the various professionals on the use of their functional IT systems.

Suggested Research Topics

1. Does the multinational nature of large city populations dilute the ability of the city to cope with adversity, or enrich the scope for dealing with the unexpected.
2. The potential of social media, both as an enhancement and as a threat to resilience.
3. Social Network Analysis, in order to understand interconnected factors such as political structures, cultural norms, religion and education.
4. The ways in which individuals and groups are likely to behave when faced with the loss of essential systems, given the growing dependence on cyberspace – both institutionally and socially.
5. The development of open systems so that data relevant to resilience can be shared via common interfaces across different systems and via agreed common standards.
6. The role of the citizen within a fully networked smart city, as a hub for the collection and dissemination of data, and as a remote controller of automated systems.

Conclusions and Summary

Research Themes Identified in the Presentations and Discussion Groups

Perspectives on Resilience

Chapter I: John Tesh
There is a need for more research exploring why some cities survive in the face of persistent threats and hazards, while others do not. Cities such as Venice and Tehran should be used as case studies to help understand how urban environments and their populations adapt to cope with adversity. More research into how risks interact and the consequences this leads to will help to predict how overlapping risks will affect environments in future.

Chapter II: Hamish Cameron
Historical research into why some settlements have prevailed and thrived while others have been abandoned may throw light on the drivers of resilience and causes of failure, with particular focus on whether failures have been due to a single disruptive event or gradual decline. This is particularly important as long-term resilience appears to be more correlated to economic success than the ability to withstand a single disruptive event such as a severe flood or terrorist attack.

Chapter III: Ann Lesperance
More understanding is needed of how government might provide support to, and incentives for businesses, so that they are more likely to stay in, or relocate to, areas following resilience challenges in order to aid recovery. How this is likely to impact on long-term resilience. In addition, how best to provide insurance and support to individuals and communities who did not take out available insurance requires more research.

Chapter IV: Paola Albrito
Further research is needed on the relationship between public sector and private sector investment in resilience, particularly as future trends will continue to put critical infrastructure in the hands of the private sector. This needs to explore new ways to engage and involve individuals, as well as businesses and organisations.

Chapter V: Charley Newman and James Crask
Academic research into how and why London (and other cities) has survived, adapted and evolved throughout 2,000 years of changing contexts would help to explain how resilience is affected by technological, ecological, geographic, industrial, cultural and population changes. Developing values against which resilience can be assessed will help organisations determine how well they do (or do not) measure up.

Resilience Issues of Urban Environments

Chapter VI: Lola Vallejo
There is scope for more research into the impact that climate change risks are likely to have on specific actors or vulnerable communities, as well as more research into increasingly granular local impacts. More understanding is needed on how already vulnerable communities may become more vulnerable to climate change in future.

Chapter VII: Malcolm Sperrin
The resilience of different actors likely to be affected by CBRN events and the interplay between them needs to be better understood, in particular with regard to the changing dynamics during the immediate response and short- and long-term recovery. This will be affected by the isotopes involved and how they disperse though a modern urban environment and will be particularly complex if a mix of isotopes has been released.

Chapter VIII: Jeremy Watson
Further research is needed into how to engineer design from objective outcomes; gaining better understanding of corporate behaviours associated with collaboration for value aggregation; and the role of regulation and fashion alongside technology in gaining momentum for the adoption of resilience strategies. Developing systems that not only learn from past decisions but also question choices and behaviour may help to drive resilience forward.

Modelling Resilience

Chapter IX: Rollo Home
A better understanding of what data and models created from the data will be used for will ensure that the modelling developed will have the best utility. For example – is an extremely detailed 3D model of a building actually of more value than a model that simply shows how many storeys the building has and the height of each storey? More discussion is needed to determine the benefits that geospatial information can bring to resilience.

Chapter X: John Preston, Layla Branicki, Roy Kalawsky and Jane Binner
Multi-disciplinary research is needed into the right indicators to measure in order to understand resilience, including qualitative as well as quantitative measures. Systems that appear overly complex may in fact offer greater resistance as they may be more adept at collective action and have fewer points of failure.

Chapter XI: Paul Kaliponi
There would be benefit in further research into proxies for resilience variables, such as insurance uptake and savings for economic resilience

instead of more commonly used proxies such as social deprivation and wealth indicators. Understanding such proxies may help emergency planners to help support community resilience strategies better through, for example, finding new ways to enable insurance uptake or encourage savings. The trade-off between different factors affecting resilience also needs to be better understood.

Discussion Groups

Discussion Group 1: Methodologies for Resilience Research
Emergent behaviour during disasters, and amongst different communities, needs to be better understood, as does how data on this can be collected and how they can be used in shaping the response. There may be a level at which resilient behaviour by a proportion of the community provides 'herd immunity' for the rest, and this may be affected by how individuals, families and wider communities approach resilience.

The impact of emergencies on privacy concerns, and the extent to which the public may be more willing to accept data sharing in certain circumstances needs further research.

Discussion Group 2: Historical Perspectives on Resilience
A better understanding is needed of the nature of data available for historical resilience analysis, including information that is not currently in a suitable data format, and of how these data can be applied to resilience studies.

Further consideration needs to be given to emotional and physical resilience, along with how the impacts of historic events were mitigated. Why do some communities seem to actively forget hazard experiences while others choose to actively remember?

Discussion Group 3: Key Stakeholders in Predicting Resilience
A central repository for resilience data and information is needed so that a wide range of resilience data can be made available to researchers and practitioners. There is a need for skilled analysts who understand how to interrogate these data for resilience purposes.

Research is needed into whether internationally standardised resilience mechanisms are more or less efficient than more locally focused initiatives and at what point top-down and bottom-up approaches best meet and integrate.

Discussion Group 4: Health Demographics and Future Resilience
The linkages between medical and social care in providing and promoting health resilience need to be better understood, in order to ease pressures

on the healthcare system as well as to improve public health as resources become scarcer.

Trend analysis would help to identify health trends and predict future health, enabling more efficient resilience planning. This may require a longer-term approach than is currently favoured, and better sharing of information and available data across organisations and government departments.

Discussion Group 5: Smart Citizens: The Human Element in the System of Systems

Research is needed on how immigrants to a community, particularly those with past experience of dealing with resilience challenges, impact on the resilience of the community as a whole.

Better understanding is needed of how individuals and communities cope with the loss of systems and services they consider to be essential under normal circumstances.

Social network analysis, the use of social media, and the role of the citizen within a fully networked smart city will aid understanding of resilience networks and structures, including the negative impacts such technology may have, as well as its positive influence.