

The background of the cover is a photograph of a large, modern airport terminal with a high, arched glass and steel roof. Sunlight streams in from the windows, creating a bright, airy atmosphere. The floor is a polished, checkered tile that reflects the light. Several people are walking through the terminal, some carrying luggage. In the foreground, a man in a dark suit and tie is walking towards the camera, carrying a briefcase. In the background, there are signs for 'Customer Service Center' and 'Concourse C E F Gate 81-811'.

INFRA
STRUCTURE
RESILIENT
2005

CONFERENCE HANDBOOK

Resilient Infrastructure

Rotorua, New Zealand

8th-9th August 2005

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Resilient Infrastructure 2005

Congestions around ports. Pressure on the energy network. Gridlock on Auckland roads. Wellington airport fog-bound again. Concern over storage capacity for liquid fuels. Emergency communications at full stretch...

Resilient Infrastructure 2005 is the first New Zealand event to look at the ability of communities as a whole to survive disasters and disruptions. It deals with building resilience into our built and human infrastructure, including natural, economic and social capital.

The event brings together national and international perspectives on how to protect physical lifelines, improve social resilience and ensure business and economic activity can continue after a natural disaster or a major human-induced disruption.

Importantly, it will focus on the interactions between lifelines, social dynamics and economic activity and explore the myriad of interdependencies, as well as areas of commonality.

Disasters and disruptions can take many forms: in just a few years New Zealand has experienced major flooding (Horowhenua-Manawatu 2004, Bay of Plenty 2005) increasing restrictions within transport systems and a threatened outbreak of Foot and Mouth Disease. Internationally we have seen the long term devastation from the Indian Ocean tsunami, terrorism, and epidemics of influenza.

It is a matter of vital importance to government, business and the public-at-large that the flow of services provided by the nation's infrastructure continues unimpeded in the face of a broad range of natural and man-made hazards. Whenever these facilities are damaged, disrupted, or simply unable to deliver the required services, the impact on society can be disastrous.

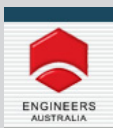
Resilient Infrastructure 2005 brings together leading specialists to help explore and understand these issues, to examine the interactions and identify new and emerging responses. Case studies and examples of best practices will draw these ideas together and illustrate a way forward.

Organiser



The Centre for Advanced Engineering (CAE) exists to broaden New Zealand's technical knowledge for the benefit of all New Zealanders. CAE has done this successfully and consistently since its foundation in 1987. Today CAE is at the forefront of the application of engineering knowledge and new perspectives and solutions. As an independent non-partisan body, CAE is uniquely positioned to pioneer, integrate, broker knowledge and raise awareness.

In collaboration with:



Established in 1919, Engineers Australia has provided the national focus for the development of all aspects of engineering as well as representing the interests of Australian engineers and the communities they serve. Its objectives are to: raise the professional standing of the engineering team; enhance professional development through graduate development programmes; cultivate partnerships with industry; and be the voice of Australian engineering and increase engineer's community visibility.



The Institution of Professional Engineers New Zealand (IPENZ) is the professional body which represents professional engineers from all disciplines in New Zealand. Its aim is to develop and improve the professional practice of engineering in New Zealand for the benefit of its people and industry, supporting its increasing diversity of application and disciplines, and its globalisation.

Major Sponsor:



Supporting Sponsors:





A Message from the Chairman of CAE...

Like most developed countries, New Zealand depends on a complex system of networks and infrastructure to support our economy and society at large. Modern infrastructure is increasingly advanced but is vulnerable to major pressures and occasional disruption.

New Zealand must address the need to make its infrastructure strong and resistant to external events. If we do not, we risk the possibility of outages that contribute to a phenomenon known as “cascading failure.”

If this occurs, New Zealand’s economic and social wellbeing will be severely threatened and network providers will be exposed to a range of risks and liabilities not seen before.

We must confront the key question: How can we plan for infrastructure that is robust and able to withstand major external pressures? In other words, how do we make it resilient?

CAE is proud to announce New Zealand’s first international event to plan for the safeguarding of infrastructure systems and the social and economic activity they support.

Resilient Infrastructure 2005 promises to be a watershed of critical assessment and innovation in infrastructure planning and risk assessment. It will be of direct benefit to any organisation or professional concerned with infrastructure provision and the delivery of essential services.

The need for resilience in our built infrastructure is an issue of utmost importance. We must acknowledge the growing complexity of infrastructure management and protect our communities from the economic and social decline that can occur after a major disruption.

I look forward to participating in these discussions with you.

A handwritten signature in black ink that reads "Francis Small".

**Francis Small,
Chairman, CAE**

About CAE

CAE's Mission

To advance New Zealand's economic growth and social progress through broadening national understanding of emerging technologies and facilitating early adoption of advanced technology solutions.

Objectives

- Establish collaborative frameworks to address New Zealand's emerging technology issues;
- Advance engineering and technology-related knowledge;
- Stimulate the uptake of advanced technology; and
- Raise awareness of the benefits of technological advance.

CAE at a Glance

- is a not-for-profit organisation, established in 1987
- has a well-established, proven record of achievement
- is based at the University of Canterbury campus
- is concerned with issues of national and international importance
- is helping to develop new solutions through advancing engineering knowledge and practice
- is helping inform and educate New Zealand communities about technology matters

How CAE Operates

Established as a not-for-profit organisation in 1987, CAE was built on a vision to raise this country's technical knowledge for the benefit of New Zealanders. CAE plays a strong integrating role within New Zealand's engineering and technology sectors, undertaking major projects that seek to build this country's technological capabilities in areas of national importance.

Collaboration and the dissemination of knowledge are the cornerstone to achieving that goal. CAE's organisational strength lies in its ability to facilitate expert groups and provide the knowledge transfer capability to build upon the findings of specific project activity.

Historically, CAE activities have involved strong participation and financial support by industry and the engineering profession. Much of its work has been directed at projects that go "beyond" conventional engineering practice so as to create new perspectives on emerging technology trends to New Zealand. Its strategy is to be seen as a neutral, far-sighted commentator on technology and engineering-related matters

A particular focus of CAE activity are industry-led approaches and technical studies relating to energy supply and demand for New Zealand. CAE's strategic imperatives are:

- Broad industry participation with a primary mission of facilitating culture change and innovation in the delivery of energy solutions.
- Independent comment so as to hold credibility in the political environment. Managing conflicts of interest with assignments as necessary.
- Maintaining a broad perspective on the entire energy sector to ensure balance and objectiveness.
- Reinforce technical capability with incorporation of economic analysis via appropriate partnering organisations (especially the Auckland Business School at the University of Auckland).

CAE's Programmes

CAE's work programme is focused on the following five key areas – areas that we judge as being vital for New Zealand's economic growth and sustainable development:

Oceans:

New Zealand is claiming exclusive rights to the fourth largest area of ocean in the world. Enormous national assets are at stake, including minerals and hydrocarbons, fish and other biological assets, along with potential in areas such as biotechnology and ocean tourism. Our vision is to see New Zealand recognised as a world leader in oceans management.

Infrastructure Systems:

Critical to New Zealand's economic growth and our communities' vitality is the renewal and extension of our built infrastructure. CAE is a leader in developing a more thorough understanding of the future infrastructure needs of New Zealand and the vulnerability of local infrastructure to natural hazards. The use of systems approaches to improve understanding of the connections and inter-dependencies that govern infrastructure investment forms the basis for ongoing activity within this area.

Risk Management:

Risk management is now widely used as a decision making tool. Through bringing together systems thinking and risk assessment techniques developed from engineering practice, CAE projects offer integrated approaches to solving complex issues. We are also helping to communicate risk management outcomes in ways that are meaningful to the practitioner and non-specialist alike.

Technologies For Sustainability:

CAE seeks to advance environmental sustainability in New Zealand by improving best practice and levels of resource stewardship and technology application. Our focus is on stimulating collaborative action on the identified knowledge gaps in sustainable management practice, and raising awareness of the underlying technology and science opportunities.

Emerging Technologies:

CAE is acting as a catalyst for enabling New Zealand organisations to achieve world-class delivery or best practice. We do this through providing channels into specific areas of expertise, and research relevant to current industry capability. Our aim is to bring together ideas and new opportunities for collaboration, and to lift industry/university linkages to new levels of research excellence and investment.

Contacting CAE

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Acknowledgements

CAE would like to acknowledge and gratefully thank the following individuals for their contributions and assistance in organising this event.

New Zealand

John Lumsden	Consultant
Pat Helm	Department of Prime Minister and Cabinet
Roger O'Brien	O'Brien Consulting, CAE Director
David Dunsheath	Business Continuity Planning Ltd
Brice Glavovic	Massey University
Dave Brunsdon	Kestrel Consulting
Erica Dalziel	University of Canterbury
John Mander	University of Canterbury
David Elms	University of Canterbury
Andrew Cleland	IPENZ
Sarah Norman	Ministry of Civil Defense & Emergency Management
Kieran Devine	Transpower
Hans Brounts	Transpower
Francis Small	CAE Chairman

International

Bruce Howard	Engineers Australia
Peter May	Engineers Australia
Michael Dureau	Warren Centre
Anne Kiremidjian	Stanford University
Tom O'Rourke	Cornell University

CAE Team

George Hooper	Executive Director
Sue McKenzie	Office Manager
Charles Hendtlass	Information Services
Scott Caldwell	Projects Coordinator

Programme

Day 1, August 8 2005

8.30	Arrival and registration, tea and coffee (Registration Desk opens 7.30)
SESSION 1: Infrastructure Resilience <i>Session Chair, Dr Francis Small (CAE Chairman)</i>	
9.00	OPENING: The Case for Change <i>Basil Morrison, President, Local Government NZ</i>
9.20	KEYNOTE: Building Resilience into Infrastructure Management <i>Professor Tom O'Rourke, Cornell University</i>
10.05	KEYNOTE: Risk, Vulnerability and Sustainability for Critical Infrastructure <i>Dr Adrian Gheorghe, Swiss Federal Institute of Technology</i>
10.50	Morning tea and coffee
11.10	Economic Resilience <i>Dr Alan Bollard, Governor, Reserve Bank of NZ</i>
11.40	Infrastructure Resilience <i>Tom Pinzone, GHD, Australia</i>
12.10	Social Resilience <i>Professor Bruce Glavovic, Massey University</i>
12.40	Lunch
SESSION 2: Protecting our Future <i>Session Chair, Dr George Hooper (CAE)</i>	
1.30	KEYNOTE: Developing a Risk-based Approach <i>Pat Helm, Department of Prime Minister & Cabinet</i>
2.00	Making Organisations Resilient: Understanding the Reality of the Challenge <i>Dave Brunsdon (Kestrel Group), Erica Dalziel (University of Canterbury)</i>
2.30	An Economy for Future Infrastructure Resilience <i>Kelvin T Sanderson, Managing Director, Business and Economic Research Ltd (BERL)</i>
3.00	Afternoon tea and coffee
3.20	Natural Hazards, Infrastructure and Risk <i>Professor Russell Blong, Benfield Australia</i>
3.50	CASE STUDY: Managing New Zealand's Flood Risk Local Government NZ/CAE Study <i>Graeme Martin (Otago Regional Council); Marilyn Brown/Dr Terry Day (NM Associates/CAE)</i>
4.20	End of Day 1
Conference Dinner <i>Commencing at Te Puia Village (5.30 pm) followed by dinner at the Millennium Hotel (8 pm)</i> <i>Guest speaker: Hon David Cunliffe MP</i>	

Programme

Day 2, August 9 2005

8.15	Arrival, tea and coffee
SESSION 3: Infrastructure Vulnerability <i>Session Chair Mike Dureau (Executive Director, Warren Centre, Australia)</i>	
8.40	KEYNOTE: Understanding Infrastructure Complexity <i>Professor Anne Kiremidjian, Stanford University</i>
9.20	New Zealand Infrastructure Vulnerabilities The New Zealand Electricity Grid: Resilient Infrastructure <i>Kieran Devine, General Manager System Operations, Transpower NZ Limited</i> Resilient Infrastructure: The View From Telecom New Zealand <i>Steve Fuller, General Manager Service Delivery, Telecom New Zealand</i> Infrastructure Vulnerabilities – An NGC Perspective <i>Stuart Dickson, Strategic Asset Manager, NGC</i> Water – A \$40 Billion Dollar Issue <i>Peter Whitehouse, NZ Water & Wastes Association</i>
10.30	Morning tea and coffee
10.50	New Zealand Infrastructure Vulnerabilities (cont'd) New Zealand Infrastructure Vulnerabilities: A CCIP Perspective <i>Chris Roberts, Manager, Centre for Critical Infrastructure Protection</i> Infrastructure Vulnerability: <i>Bruce Johnson – Ministry of Transport</i>
11.25	Safeguarding Australia <i>Kevin Murray (Transgrid Australia)</i>
11.55	Protecting Critical Infrastructure Systems <i>Professor Ian Buckle, University of Nevada</i>
12.25	Lunch
SESSION 4: Safeguarding Livelihoods <i>Session Chair, Basil Morrison (President, Local Government NZ)</i>	
1.15	KEYNOTE: Community Response to Loss <i>Professor Brenda Phillips, Oklahoma State University</i>
1.55	Conceptualising Infrastructure for Safeguarding Communities and Livelihoods <i>Professor John Handmer, Centre for Risk and Community Safety, RMIT</i>
2.25	Case Study CAE TBC
2.55	Afternoon tea and coffee
3.15	Prepared for Emergencies? A Resilient UK and meeting the Challenge to London's Resilience <i>Eve Coles, Centre for Disaster Management, Coventry University</i>
3.45	Measuring and mitigating long term social and economic consequences of major disruption events <i>Dr Graham Leonard et al, Institute of Geological & Nuclear Sciences</i>
4.15	Raconteur (Wrap-up) <i>Chris Laidlaw</i>
4.40	End of Day 2



True partnership with our customers

Benfield is the world's leading independent reinsurance and risk intermediary. Our customers include most of the world's major insurance and reinsurance companies as well as global corporations and government schemes all around the globe.

Whether tackling risk management issues, analysing and assessing exposures or seeking to access reinsurance or other forms of contingent capital, Benfield will work in partnership with you to craft the best possible solution for your business.

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Earthquake Commission

Proud Sponsor of

Resilient Infrastructure 2005

Resilient infrastructure is an integral component of a resilient community and crucial in New Zealand - a country on the move.

The Earthquake Commission's insurance cover, research funding and public education also play a vital role in building resilience, enabling New Zealanders to recover quickly and get on with their lives after natural disasters.

We are delighted to further contribute to this ongoing effort by sponsoring "Resilient Infrastructure 2005".

For more information about EQC see our website at www.eqc.govt.nz

The background of the advertisement is a black and white photograph of a snow-covered landscape. In the foreground, there are snow-laden bushes and trees. In the background, a large electricity pylon stands prominently on the left, with power lines stretching across the scene. Another pylon is visible in the distance to the right.

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□ The national grid is the backbone of our energy infrastructure, providing efficient transmission of electricity from generation to power distributors across the nation. ■ At Transpower, our task is to maintain this vital power network and ensure it has the capacity to meet the growing demands of businesses and households throughout New Zealand.

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Biographies of Contributors

Professor Russell Blong



Emeritus Professor Russell Blong has postgraduate degrees in geography, geomorphology, and engineering science and extensive experience in modelling natural hazards and their consequences in Australia, New Zealand, South East Asia and the South Pacific. His particular interests lie in earthquakes, tsunamis, floods, volcanic eruptions and hailstorms. He is the author of several books and more than 200 academic and industry papers.

At Macquarie University Russell was the founding Director of Risk Frontiers funded by a consortium of insurers, reinsurers and reinsurance intermediaries. From 1998-2000 he was President of the International Society for the Prevention and Mitigation of Natural Hazards (the Natural Hazards Society). On his retirement from Macquarie in 2003 he joined Benfield Australia to work as a member of a natural catastrophe team.

Dr Alan Bollard



Alan Bollard is Governor of the Reserve Bank of New Zealand, which is responsible for carrying out monetary policy, overseeing the financial system and providing New Zealand's currency.

Prior to his appointment as Governor in 2002 Dr Bollard was secretary to the Treasury, which manages the Crown's finances and is the Government's principal economic advisor. He is a former chairman of the New Zealand Commerce Commission, the regulatory authority responsible for the Commerce Act and the Fair Trading Act, and has also served as Director of the New Zealand Institute of Economic Research. He has wide experience as an economist in a variety of positions in the United Kingdom and the South Pacific.

Marilyn Brown

Marilyn Brown is a resource management consultant and a director of NM Associates Ltd - Architects and Planners. She has "over 20" years' experience as a planning professional (much of it in private practice) often encountering issues relating to "difficult', hazardous' or just plain "challenging" environments. Her practice is Wellington based, working on projects throughout New Zealand.

Marilyn's past experience includes several years working in environmental impact assessment in California, and in regional and local government here. She was co-author of a CAE document published last year "Natural Hazards and the Built Environment". Her work on the Flood Protocol continues that theme, and carries through consideration of the implications of risk environments for the practice of resource management, and sustainable management.

David Brunsdon



David is the National Engineering Lifelines Co-ordinator and has been Project Manager of the Wellington Lifelines Group since its establishment in 1993. He is also the immediate past-president of the New Zealand Society for Earthquake Engineering, a member of the National Urban Search and Rescue Steering Committee, and a member of the Building and Research Advisory New Zealand (BRANZ) Board.

David spent two years following the 1989 Newcastle, Australia earthquake assisting with the

recovery process. This, along with seeing first-hand the impacts of the Kobe, Japan and Chi-chi, Taiwan earthquakes, has generated a passion for improving Civil Defence and emergency Planning for response and recovery in New Zealand. In 2003 he and colleagues in Auckland and Christchurch established Kestrel Group Ltd, a consulting practice specialising in risk and emergency management planning.

Professor Ian Buckle



Ian Buckle is the director of the Center for Civil Engineering Earthquake Research and professor of civil engineering at the University of Nevada, Reno.

In the ten years prior to taking up his appointment at Reno, Dr Buckle held appointments as the deputy vice chancellor of research at the University of Auckland in New Zealand, and deputy director for the National Center for Earthquake Engineering Research at State University of New York at Buffalo. In addition to his role as a teacher and researcher at Reno, Dr Buckle is currently

President of the Consortium established by the National Science Foundation to manage and operate the George E. Brown Jr. Network for Earthquake Engineering Research (NEES). He is also the director of the Large-Scale Structures Laboratory at Reno, which houses a multiple shake table facility, one of the fifteen NEES Equipment Sites established by the National Science Foundation in 2004.

A graduate of the University of Auckland, his primary research interests are in the performance of bridges and infrastructure systems subject to extreme events including earthquakes and sabotage.

Eve Coles

Eve Coles is Senior Lecturer in Risk and Emergency Management at the Coventry Centre for Disaster Management, Coventry University. She began her academic life as administrator/researcher for the Disaster Prevention and Limitation Unit (DPLU) based at the University of Bradford where she helped organise and run the annual DPLU International Conferences on disaster management and emergency planning.

She is a Fellow of the Institute of Civil Defence and Disaster Studies and a Fellow of the Royal Society of Arts. She was formally Editor of 'Emergency', the quarterly journal of the Institute of Civil Defence and Disaster Studies. Her research interests include Emergency Planning in Local Authorities in the United Kingdom, with particular interest in professional qualifications and core skills and competencies of local authority emergency planners, the introduction, management and effects of benchmarking and 'best value' on local authority EPU's and the use of the Internet as an information and communication resource in management of emergencies and disasters.

Dr Erica Dalziell



Dr Erica Dalziell is a lecturer in risk management and engineering systems in the Department of Civil Engineering at the University of Canterbury.

Erica is leading a six year research programme funded by the Foundation of Research, Science and Technology (NZ) looking at the ability of organisations to prepare and respond and recover from major hazard events.

Erica has a PhD from the University of Canterbury in the application of risk assessment methodologies to road network reliability. Between her PhD and returning to New Zealand, Erica spent four years in the UK where she worked as a risk management consultant and with JP Morgan Chase

Dr Terry Day

Educated in both Canada (BA, MA) and New Zealand (PhD, University of Canterbury), with work

experience in central government in Canada in a range of roles in research, science policy, environmental monitoring, water resource management and organisational policy and planning. Involved in management of local government here in New Zealand. Now consulting on management, organisational and technical issues for central and local governments and private firms.

Kieran Devine



Kieran has had over twenty five years of experience in various roles in the electricity industry both in New Zealand and overseas, involving design, construction, manufacture and operational engineering, and operational and tactical management.

He has held a variety of positions with Electricorp and ECNZ, including General Manager Generation, and recently with Beca Carter Hollings and Ferner.

Currently Kieran is General Manager, Service Delivery for Transpower, and is responsible for all Construction, Maintenance and Regional Operating on the New Zealand Electricity Grid, together with the provision of Information Technology, Telecommunications and Procurement Services for Transpower.

Stuart Dickson

Stuart Dickson is Strategic Asset Manager responsible for NGC's gas transportation assets. The asset management group is responsible for asset optimisation, integrity and risk management, setting service levels, capital expenditure and long-term asset management strategies. Stuart has first-hand experience in pipeline emergency management and is a member of the National Gas Outage Contingency Plan (NGOCP) working group.

NGC owns and operates 2300km of high-pressure gas transmission pipelines and 2500km of gas distribution networks throughout the North Island.

Stuart joined NGC in 2000 as the Transmission Asset Manager. Prior to that Stuart worked in the air separation and industrial gas industry for ten years including engineering and operations roles with Air Products PLC in the UK, and BOC Gases in New Zealand including, most recently, the role of Operations Manager at Glenbrook.

Steve Fuller

Steve is General Manager Service Delivery for Telecom New Zealand Limited, the major telecommunication provider in New Zealand. With over 4 million people living in New Zealand using a full range of wireline and wireless (voice and data) services, Telecom delivery of reliable service is paramount. The Telecom network is managed by Steve Fuller, General Manager Service Delivery, which involves the deployment, maintenance, operation of all technology.

Steve has 28 years experience in the Telco industry working in senior management roles for the last 10 years. His current role sees him responsible for the complete operation of Telecoms network infrastructure for Voice, Data and Mobile services.

Dr Adrian Gheorghe



Based at Switzerland's Federal Institute of Technology, Adrian Gheorghe is a specialist in energy, environmental and industrial risk assessment and critical infrastructure management at a local, regional and global level. His current work includes the generation of advanced models for comparative risk assessment and decision support systems to manage complexity-induced vulnerability.

Dr Gheorghe's scientific interests are diverse, including vulnerability and network management, management science (systems engineering, cost-benefit analysis, dynamic

modeling and optimisation), through to hazard assessment, energy economics, climate change, artificial intelligence, application of space technology and development of decision support systems. He is an editorial board member for the International Journal of Critical Infrastructures.

Associate Professor Bruce Glavovic



Dr Glavovic has a multi-disciplinary education and nearly 20 years of work experience in private consulting, government and academia. Currently the Programme Co-ordinator of the Resource and Environmental Planning Programme at Massey University, Dr Glavovic's work focuses on making sustainable development work in practice.

This work is clustered around several themes: negotiation, collaboration and consensus building processes; integrated environmental management (with a particular focus on coastal, ocean and water resources); and understanding poverty-environment linkages and driving forces. He has been responsible for a wide variety of teaching, training and capacity building programmes on varied topics in environmental science, planning and policy analysis.

Professor John Handmer



John Handmer is a geographer specialising in social science hazards research, including economics. He has worked on research projects in Australia, USA and Europe, where he spent six years at the Flood Hazard Research Centre which specialises in economic assessment.

At RMIT he directs the Centre for Risk and Community Safety, which was established as a collaborative venture between RMIT, EMA and the Australian National University. The centre's programme is dedicated to improving community resilience and sustainability through providing the evidence base for policy and practice. He is one of four research leaders for the bushfire co-operative research centre (CRC), focusing on vulnerability and adaption issues for bushfire-prone communities, and tools for the assessment of fire damages and the benefits of mitigation.

Pat Helm



Patrick Helm is a policy advisor with the Department of the Prime Minister and Cabinet. His current responsibilities include crisis management, critical infrastructure, emergency services, risk analysis, and national security issues. In the past decade he has managed a range of government projects involving risk methodologies, and has been closely involved with work to improve the assessment and control of natural, technological, and other hazards/threats in New Zealand. His career includes 5 years with Physics and Engineering Laboratory, DSIR; a secondment to the Ministry of Foreign Affairs; a diplomatic posting in Washington; and other secondments. He has interests in risk management, systems analysis, national security issues, and strategic planning.

Bruce Johnson



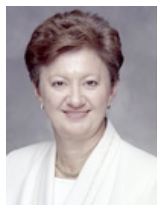
Bruce Johnson spent 20 years in the Royal New Zealand Navy as a seaman officer and warfare specialist. His last naval appointment was a 2-year secondment to the Domestic & External Security Group within the Department of the Prime Minister and Cabinet. In this role he focused on national counter terrorism preparedness and intelligence, which included chairing the National Working Committee on Terrorism.

More recently he was the General Manager of Maritime Security with the Maritime Safety Authority. During this time he was responsible for working with relevant government agencies, industry, and other stakeholders, to develop and implement a national mari-

time security structure to comply with the International Ship and Port Security Code which came into effect on 1 July 2004.

Reporting to the Secretary for Transport, Bruce is currently the Ministry of Transport's Group Manager for Safety and Security. This Group has principal responsibility for making the transport system safer and more secure through developing, implementing, and monitoring national policy and systems. He has a Master of International Relations degree from Victoria University.

Professor Anne Kiremidjian



Anne Kiremidjian is Professor of Civil and Environmental Engineering at Stanford University, where her research has focused on earthquake hazard characterisation, structural damage modeling and loss estimation, risk analysis of transportation systems, reliability analysis of industrial systems and damage detection algorithms.

She was the founder of a leading US company providing catastrophic risk assessment and software development and recently founded a company focusing on the development of structural monitoring systems based on embedded micro sensors and wireless data transmission. In 2003 she received the C. Martin Duke Award for Excellence in Lifeline Earthquake Engineering Research from the American Society of Civil Engineers.

Dr Graham Leonard

Graham is a Natural Hazards Scientist and Volcanic Geologist with the Institute of Geological and Nuclear Sciences in New Zealand, as a member of the mapping and social research teams. His particular research interests are in measuring, characterising and mitigating the impacts of natural hazard events and developing effective response to warning systems. He also conducts mapping and research in volcanic geology and related hazards. Graham is secretary of the IAVCEI Cities and Volcanoes Commission and his most-recent work focuses on understanding community resilience and vulnerability to flooding, tsunami and volcanic processes. This research aims to understand motivators of preparedness and factors that influence resilience. It also explores reduction of vulnerability through physical and planning-based mitigation, and reduction of residual risk through theoretical and applied development of effective warning systems that include monitoring, planning, training and education.

Basil Morrison

Basil has been President of Local Government New Zealand since 2000 and was elected as a Regional Councillor for Environment Waikato in 2004. Basil has had over thirty years' experience in local government including fifteen years as Mayor of Hauraki District Council.

Basil's involvement in local government and community organisations is considerable, which was reflected in his being awarded the Companion of New Zealand Order of Merit in 2004. He is a Conservation Authority member, Controller of the Thames Valley Civil Defence Organisation and Chair of the Waikato Civil Defence Emergency Management Group, board member Asia Pacific Regional of the United Cities Local Government and an Executive Member of the Commonwealth Local Government Forum.

Kevin Murray



Mr Kevin Murray is the Acting Chief Executive and past General Manager Network of TransGrid. TransGrid is a New South Wales / Australia State owned transmission company.

With 82 high voltage substation and 13,000kms of transmission lines, TransGrid is responsible for a significant amount of the States critical infrastructure. Kevin has been responsible for developing security strategies and response plans for TransGrid. In recent times these have been aligned with Commonwealth and State Guidelines.

Kevin, as a professional engineer, has had over 30 years experience in the maintenance and management of high voltage electrical infrastructure.

Professor Tom O'Rourke



Tom O'Rourke is one of America's leading authorities on infrastructure engineering and hazards reduction and is a Professor of Civil and Environmental Engineering at Cornell University. His research includes the lifelines (infrastructure) aspects of the collapse of the World Trade Centre, infrastructure rehabilitation after major loss, and systems effects such as the cascade failure across north-eastern America in 2003.

Professor O'Rourke has served on the peer reviews for projects associated with highways, rapid transit, water supplies and energy distribution systems and has participated in numerous earthquake reconnaissance missions. More recently he was elected a Fellow of the American Association for the Advancement of Science, and served as president of the Earthquake Research Engineering Institute, 2002-2003.

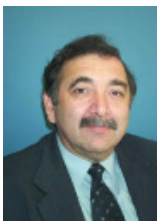
Professor Brenda Phillips



Brenda Phillips is a subject-matter expert at Oklahoma State University in underserved populations in disaster situations. She teaches both undergraduate and graduate emergency management and is among the first faculty in the world to teach emergency management online. Her work has been funded by the National Science Foundation, US Geological Survey and Natural Hazards Centre and has been published in numerous journals and technical publications.

Dr Phillips has been invited to present her work to the Australian Emergency Management Institute, the FEMA Higher Education Annual Conference, the US National Academies of Science, the Annual Hazards Workshop in Colorado, the Flood Hazard Centre (United Kingdom) and at several national offices in the People's Republic of China.

Tom Pinzone



Tom Pinzone is a consulting civil engineer with over 30 years professional experience. He is a Director of GHD and leads its Transportation Business Sector. In recent years he has been very closely involved with the development of major urban areas including both renewal and rehabilitation schemes and urban fringe land releases such as Sydney's Rouse Hill, Edmonson Park, City West and Green Square development areas and The Palm projects in Dubai. Tom has directed GHD's teams for many recent transportation projects and BOOT/PPP schemes including Sydney Olympic Stadium, Sydney Superdome,

Sydney Light Rail, sale of Federal Airports, Victoria's Rail Privatisation, Epping to Chatswood railway and Sydney's North West Transit Study.

Tom was responsible for research and analysis and co-authored the 2000 and 2001 Report Cards on Australia's Infrastructure and the 2003 NSW Infrastructure Report Card for Engineers Australia and was project director for the 2004 Queensland Infrastructure Report Card. He is currently leading GHD's team for similar report cards for Australia's other States and Territories.

Chris Roberts

Chris has over 30 years of IT, commercial and audit experience with extensive experience in IT consulting, computer and information security and information technology assurance. He has also worked extensively in the areas of e-fraud, other IT related investigations, and computer forensics. He is widely experienced in both the private and public sectors and has provided specialised assistance to a wide variety of Government, State Owned Enterprises, financial and other private sector organisations.

Between 1992 and 1995, Chris was head of an independent consulting practice provided specialised service in the areas of institutional strengthening, systems assurance, policy development and technical training. He worked extensively with international AID organisations such as USAID, CIDA, UNDP, SIDA and the World Bank sponsoring projects for various government's ministries, departments and state-owned enterprises.

Chris is currently the Manager of the Centre for Critical Infrastructure Protection in the Government Communications Security Bureau and tasked with providing warnings and undertaking research related to the protection of critical information infrastructure in New Zealand.

Kel Sanderson



Kel was experienced in applying economics to real world developments like food processing location in NZ, and regional development in Tanzania when he became BERL's first fulltime consulting economist in 1970. His role in BERL now ranges from 'big picture' conceptualising to straight information and data analysis in BERL project teams.

In 1974 Kel went offshore to gain his development 'spurs' with UNDP/FAO in East Africa. He then ran BERL strategic development teams in Malaysia and Belize, Central America working for NZAid and UNDP/World Bank, before strategic and triple-bottom-line was cool! He returned in 1984 in time for 'The Re-structuring'. In the 1990s he assisted to establish the Federation of Maori Authorities business network, FoMA.

His strength is sound analysis within the 'big picture', applied to issues and developments in industries, regions, and fun facilities, like stadia, airports, films, and even a Len Lye centre.

Peter Whitehouse

Peter Whitehouse is currently manager Advocacy and Learning at the New Zealand Water and Wastes Association. Peter has had a long involvement in infrastructure issues, notably energy.

He previously held an executive role at Business New Zealand that involved close dialogue with Ministers and senior officials in both the public and private sector. Much of that dialogue revolved around the critical role that resilient infrastructure plays in achieving a sustainable level of economic growth.

Peter was an active member of the government appointed Winter 2001 taskforce charged with dealing with the critical electricity supply situation that had arisen. This gave him an excellent understanding of the severe consequences when an important input to society is threatened.

Peter was until recently a long-serving member of the executive board of the Major Electricity Users Group and remains a member of the Electricity Commission's Security Advisory Group. He has worked closely with CAE, notably in examining the opportunities offered by our Exclusive Economic Zone and in considering the options for the country in the post-Maui era.

Presentation Notes

(in order of presentation)

Resilience in Infrastructure Management

T D O'Rourke, Cornell University

Abstract

Extreme events are caused by natural hazards, severe accidents, and pre-meditated human threats. Infrastructure resilience requires that appropriate measures are taken to assess and reduce the potential for problems resulting from the interaction of extreme events and interdependent, critical infrastructure systems. This paper identifies key characteristics of modern infrastructure, and illustrates their influence on complex network operation by means of case history examples associated with the 2001 World Trade Center Disaster, the 1983 New York City Garment District Incident, and the 1989 Loma Prieta earthquake. Conclusions are drawn with respect to the causes of damage, factors affecting the spread and constraint of damage, and factors that contribute to both the resiliency of urban infrastructure and the attendant services necessary to respond effectively to extreme events. Lessons learned for the managers of infrastructure systems are summarized.

Making Organisations Resilient: Understanding the Reality of the Challenge

Dave Brunsdon (Kestrel Group), Erica Dalziell (University of Canterbury)

Abstract

Organisations play key roles within our society. They have the responsibility for managing, maintaining and operating our infrastructure, creating our economy, and providing employment and essential goods and services for our communities. An organisation's ability to respond effectively to adverse events depends on their structure, the management and operational systems they have in place, and the collective resilience of these.

New Zealand organisations have been through considerable structural change over the past two decades. This has occurred at all levels from central through to local government and the private sector. Some organisations have in fact been through several cycles of restructuring in the pursuit of different philosophies. This process has seen the evolution into smaller and more independent organisations and business units. Their focus on short-term economic efficiency has however had a detrimental effect in terms of planning to be resilient in the face of major emergency events.

This paper provides a past/ present/ future perspective of New Zealand by presenting reflections on the impacts of corporatisation during the '80s and '90s, a view of the current situation and suggestions on where future emphasis should be placed. The view is expressed that relatively few organisations (public or private) in New Zealand are currently making appropriate levels of commitment and investment in the vital element of 'readiness' or preparedness to respond to and recover from major emergency events. In addition to highlighting the challenge that this situation represents, some practical strategies for increasing organisational resilience are suggested, along with key areas where greater resource commitment should be made.

Introduction

Organisations play key roles within our society. They have the responsibility for managing, maintaining and operating our infrastructure, running our economy, and providing employment and essential goods and services for our communities. The ability of an organisation to respond effectively to adverse events depends on their structure, the management and operational systems they have in place, and the collective resilience of these.

The ability of key organisations to continue to function in the face of unexpected events will have a large influence on the length of time that essential services are unavailable, and on the duration of recovery for the community as a whole. There is a need therefore to be able to critically evaluate the consequences that hazard events may have on organisations.

New Zealand organisations have been through considerable structural change over the past two decades. This has occurred at all levels from central through to local government and the private sector. Some organisations have in fact been through several cycles of restructuring in the pursuit of different philosophies. This process has seen the evolution into smaller and more independent organisations and business units. Their focus on short-term economic efficiency has however had a detrimental effect in terms of planning to be resilient in the face of major emergency events.

Recent flood events and multi-agency simulation exercises have highlighted specific organisational challenges to be addressed in order to maintain a sustainable response to major emergencies.

The Concept of Organisational Resilience

To understand the impact of hazard events, we need to evaluate how key organisations are

going to perform during and after these events. This requires not only understanding the degree to which they might be impacted, but also their capability for responding and recovering from these impacts. This requires understanding the ‘*resilience*’ of organisations.

What does it mean to be a *resilient organisation*? Resilience definitions refer to the ability of a material or system to absorb change gracefully whilst retaining core properties or functions:

Resilience:

- *the ability to rebound to original shape/form after deformation that does not exceed its elastic limit;*
- *the ability of a system to recover easily and quickly from adversity.*

Resilience may be broken down into two key components: vulnerability and adaptive capacity. These components are illustrated in Figure 1. In the centre of the diagram the shock represents an event that pushes an individual, community or an organisation from one state of relative stability or equilibrium into another. The ease with which an organisation is pushed into this new state is a measure of their *vulnerability*, while the degree to which they are able to cope with that change is a measure of their *adaptive capacity* (Dalziell and McManus, 2004). The resilience of the organisation is a function of the area under the curve, relating to both the magnitude of impacts experienced by the organisation and the time it takes for that organisation to recover.

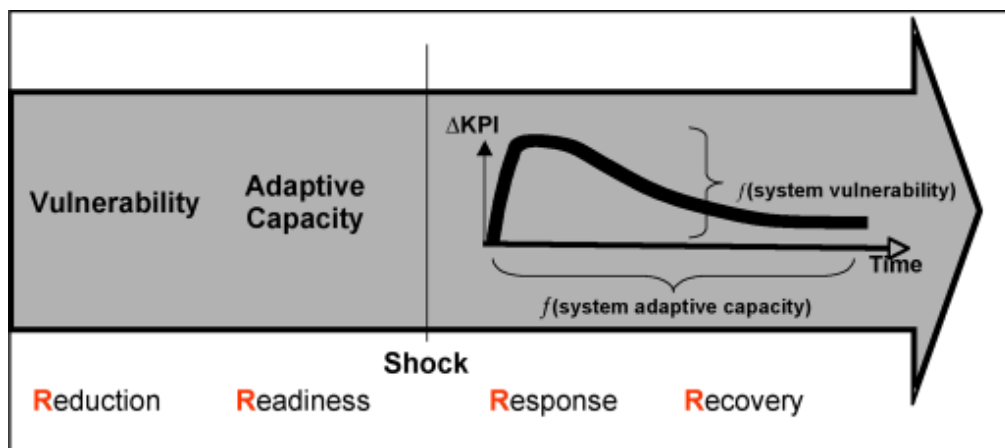


Figure 1: Severity and duration of impact on KPIs as a measure of system resilience, where resilience is a function of the area under the curve.

This generic framework highlights several opportunities for improving an organisation’s resilience:

- 1 Reducing the likelihood that recoverable limits will be exceeded (risk management).
- 2 Moving the boundaries which define the recoverable limits for the organisation (business continuity planning).
- 3 Reducing the response time to recognise that change or action is needed (situational awareness).
- 4 Improving the speed and capability of the organisation for responding to change (creativity and responsiveness).

Resilience Management brings together existing risk management and business continuity planning into a common framework; combining a strategy of managing identified risks with an ability to respond effectively when a crisis actually happens; irrespective of whether or not that event has been previously identified as a risk.

How to Evaluate Resilience?

A significant challenge to evaluating the resilience of organisations is the complexity of organisations, and the ever-changing context within which they operate. This is the subject of a six year research project underway in New Zealand (Resilient Organisations, 2005). The research explores:

- The decision-making context of risk management and business continuity planning within organisations;
- Their ethos towards preparing for extreme events;
- An organisation's potential to be adaptive and even prosperous in crisis situations;
- Perceptions within organisations around their levels of manageability and control over unexpected events;
- The criticality and resilience of inter-organisational relationships and how these are managed by organisations;
- The role of an organisation in the wider community, and how expectations of performance after a major event align with those of the wider community.

The research includes ten in-depth case studies of different organisations to evaluate their resilience to unexpected events. An early challenge identified was the need to get organisations thinking beyond the typical 'disaster' scenarios. In New Zealand, quite understandably, focus tends to concentrate on natural hazards such as flooding or earthquakes. The research uses four *consequence scenarios* to encourage organisations to explore different aspects of their resilience. These consequence scenarios are:

- **Regional Event:** Significant *physical damage to buildings, contents, and resources*, coupled with severe disruptions to *lifeline services* such as transportation, electricity, water and telecommunications. An example of this type of event may be a major earthquake or flood.
- **Societal Event:** A nationwide event resulting in *extended staffing absences*. In this event all physical infrastructure is intact, but staff are either unable or unwilling to be at work. Examples may be an influenza or SARS pandemic.
- **Localised Event:** An *organisation specific incident* resulting in loss of life, severe disruption to normal operations and *reputation impacts*. The intense focus of media and regulatory agencies requires the organisation to focus on managing stakeholder perception as well as the physical response and recovery from the event. Examples may be a fire or explosion in a key building, or a hazardous spill affecting the immediate locality.
- **Distal Event:** Impacts *business flow* through key suppliers or customers. This consequence scenario is designed to explore the ways an organisation may be impacted through its networks of *inter-organisational relationships*. Examples may be failure of a key supplier, major disaster of another large urban centre, or an international shortage of key resources.

Knowing that organisations are an important component towards creating more resilient communities is one thing; effecting change to encourage organisations to increase their resilience is another. Creating a compelling business case for investing in greater resilience is inherently difficult when the return period of the event is significantly longer than the planning horizon of the organisation. Key requirements towards achieving more resilient organisations are:

- The development of simple yet effective frameworks that organisations can use to evaluate their resilience.
- A common language and terminology to enable dialogue and debate within organisations about their resilience priorities, and to facilitate communication between organisations about common issues and interdependencies in their resilience strategies.
- Metrics for evaluating and benchmarking resilience. Metrics are needed so that organisations can demonstrate and value their resilience strategies, and create a business case for

improving resilience. These metrics must be both meaningful to decision makers within organisations, and directly relevant to the overall goals and objectives of the organisation.

- The sharing of case studies and lessons learnt to raise awareness of the need for, and demonstrate best practice in, Resilience Management.

The Current Nature of Organisations in New Zealand

Organisations across most sectors in New Zealand today can best be characterised as being more independent than in previous decades, with a greater number of organisations in any given sector. This broad characterisation typically encompasses business units within local authorities and central government agencies as well as private companies. This profile is also considered to reasonably well represent most western countries.

This context derives from two decades of restructuring in the quest for economic accountability and independence. The focus across both the public and private sectors has been to produce smaller business units with an emphasis on autonomy and self-reliance in order to produce economically efficient organisations and competitive sectors.

Issues and Implications for Resilience

This modern organisational environment has potentially significant implications for organisational resilience, particularly in terms of preparing for and responding to adverse situations. These could be rapidly occurring events such as earthquake, sabotage or biosecurity breach, or unfolding events such as a pandemic.

The emphasis on larger numbers of functionally independent organisations has essentially produced a large number of ‘silos’ – units that whilst they may be economically efficient in the day-to-day operating context, typically lack sufficient connectivity and critical mass to enable a co-ordinated and collective response to adverse events.

This inherent vulnerability can be offset by a conscious effort to actively link across the individual elements – but there are few signs of this in evidence in many sectors. Conversely, some organisations within critical infrastructure sectors such as energy and telecommunications have been reluctant to plan collectively for emergency events lest this be seen as colluding in terms of their governing legislation. This misplaced anxiety has hindered a much-needed collaborative approach.

Some of the key issues and the corresponding implications are discussed below.

(1) Loss of strategic level operational experience, system knowledge, and central technical expertise and resources

There has been a progressive loss of strategic and operational experience through the restructuring process, including significant amounts of system knowledge. In the infrastructure sectors, this further reduces the institutional ability to recognise the onset of multi-system failure situations, particularly when compounded with ageing physical infrastructure in some utility sectors.

The disestablishment of the Ministry of Works and Development (MWD) in the late-1980s brought to an end the central capability for high-level independent strategic technical advice on infrastructure and built environment issues to Government. In addition to strategic planning advice on energy issues in conjunction with the then NZ Electricity Department, MWD provided significant input into the development of design standards across the range of infrastructure and built environment categories. As the Government’s technical arm, MWD also placed emphasis on key public facilities being designed to meet functional and operating requirements which in many cases went beyond minimum regulatory requirements.

The physical works arm of MWD also provided a central plant and workforce resource capacity, which although less economically efficient on a day-to-day basis, would prove invaluable in times of major disaster. No equivalent central capability or arrangements currently exist.

At local government level, there has been a significant movement of utility asset managers into the consulting arena. While this has added to the loss of in-house technical knowledge, some of the positives include the ability to apply that knowledge to a range of other organisations.

General staff turnover also contributes to a loss of operational knowledge. One of the observations made in the lead up to the recent Foot and Mouth Disease simulation organised by the Ministry of Agriculture and Forestry was that of the more than a dozen government agencies involved in an exotic disease response, less than 20% of the relevant people had been involved in the last such exercise held only two and a half years previously.

(2) Contractors as the critical delivery arm for response and recovery

The associated trend to reduce the direct staff base of organisations has seen the outsourcing of many functions that are not deemed to be 'core' functions. This has resulted in a heavy (and in some cases, total) dependency upon external contractors to deliver key functions. Examples range from facility security, communications services database management and inspections (eg. AgriQuality for MAF) through to the full service delivery functions for some lifeline utility asset managers (including professional technical services as a separately contracted element).

Despite the criticality of many of these functions to the principal, asset manager or community, it is observed that inadequate attention is typically given to the likely effectiveness of the response to major emergencies by contracting agencies. This requires consideration of how the functional relationships would operate in adverse circumstances, rather than just focusing on the actual contract requirements themselves. In turn, this requires a time investment by both the principal and the contractor.

Documents defining these relationships need to spell out both the expectations and specific performance/ delivery requirements for contractors in such situations. As well as considering major natural hazard events which directly and physically affect wide sections of the community, these expectations and requirements need to cover the aspects of a response which involves the principal as lead agent (eg. Ministry of Agriculture and Forestry for biosecurity and Ministry of Health and District Health Boards for pandemic).

(3) Leadership and accountability across the public/ private interface

Two utility failures of quite different scales highlight the lingering expectations by the general public of technical leadership and co-ordination from 'City Hall'.

In the 1998 Auckland CBD power crisis, there was disappointment in some circles regarding the lack of technical leadership that Auckland City Council could provide to the response process (Newlove et al, 2003). With the ownership of the assets (and hence the technical problem) sitting with the then Mercury Energy, Auckland City Council personnel had difficulties in identifying and locating the basic data they needed in order to make informed decisions about the management of the Auckland City CBD. This in turn meant that the Mayor of Auckland City was widely perceived as being powerless in this situation – wholly understandable in terms of the devolved ownership arrangements, but of little consolation to the business community and the many others affected.

A subsequent major gas leak in Wellington City in 2000 also highlighted the lack of specific responsibility for utility co-ordination in local incidents. It took four hours after a significant gas leak was first noticed to establish which of the two distribution companies actually owned the ruptured main. Amongst other things, this highlighted that no single agency has responsibility for co-ordinating utility response for this level of incident. If the same incident had occurred ten years previously, co-ordination would have been provided by the City Council from 'City Hall' – as at that point in time, Council was the owner and operator of energy supply assets as well as water and wastewater services.

The key point from both of these examples is that while the public understands at a conceptual level the modern forms of asset ownership and the associated day-to-day operating implications, the ultimate accountability for managing the response will philosophically remain with elected members of local and central government.

The Civil Defence Emergency Management Act (CDEM Act, 2002) provides an appropriate balance in this regard – while the Act frames the duties and expectations of lifeline utilities, local government (via CDEM Groups) and central government (via the Ministry of Civil Defence & Emergency Management) have a responsibility to encourage and monitor the engagement of lifeline utilities in terms of risk reduction and response readiness.

Moving Forward – Focusing on Readiness

The Resilient Organisations research programme represents a longer term strategy for improving the resilience of New Zealand organisations. But what can be done right now to address the resilience issues of our key organisations with specific response roles?

Recent flood events, along with recent multi-agency exercises and the early case studies that are the subject of the Resilient Organisations research programme, have highlighted that greater levels of effort need to be put into *Readiness* (or preparedness) measures by agencies with designated response roles.

Priority areas that could form the basis of organisational action plans to enhance the readiness aspect of the resilience of organisations are outlined below.

Comprehensive Resource Planning

Specific planning is required for adequate levels of appropriately skilled and trained response personnel (comprising technical and support; in-house, contract, other agencies) to enable a sustained ('campaign') response.

Agency emergency response planning has commonly tended to focus on only those parts of organisations with 'front line' response obligations. The reality is that the full depth of most organisations will be called upon in the event of a major emergency event, requiring the mobilisation of general support staff to enable a 24/7 operation to be sustained in the crucial early stages of a response. 'Support staff' in this context includes a range of knowledgeable and experienced people who don't necessarily appreciate the valuable contribution that they would make in an adverse situation, and are not specifically trained to operate in that mode. This is particularly the case in some government agencies.

Sharing Resourcing, Knowledge & Experience Across Silos

Organisations and sectors need to drive their own risk-based response arrangements and capability development. But as the preceding points have illustrated, the key aspect that is missing relates to linking the efforts across individual organisations and sectors, particularly with regard to the sharing of resourcing, knowledge and experience. Much greater emphasis should be given to the inputs that could/ should be provided by *other* supporting agencies (both for specific roles and general resource assistance).

Within the public sector, Government needs to consider fostering the transportability of readiness and response planning skills amongst key departments and agencies. There also needs to be a more comprehensive process by which to apply response lessons from one organisation or sector to another. This should include more active encouragement for sharing of response resources, both actively during planning and preparation and in response situations.

Understanding the Processes for the Delivery of Contracted Services in an Emergency

In many situations involving the delivery of critical functions by contractors, there is a need for specific dialogue and definition around expectations and responsibilities by both parties to extreme events.

Readiness in this context should see contractors demonstrate their ability to perform their core contracted function on which the principal depends, as opposed to dependence upon broad 'motherhood' or 'best endeavours' contract clauses. It is important that this ability to perform be demonstrated via a constructive and dynamic engagement rather than simply as a static audit process. Whilst the contractual 'stick' will no doubt need to be wielded in some cases in order to obtain the time commitment of the involvement of a contracting organisation, the

spirit of a 'carrot' should be used in order for both sides to constructively understand how they will deliver their respective functions in an adverse event.

How Much Effort is Required?

Disasters can wipe out literally years of economic progress in small economies (whether viewed *organisationally*, *regionally* or *nationally*). Enhancing resilience for organisations and from a national perspective therefore has the aspect of minimising the extent of unforeseen losses, and needs to be justified in this context.

Two key questions for New Zealand around the 'level of effort' topic and readiness include:

- What form and extent of training and skills maintenance is appropriate for 'low probability but high impact' events across the range of organisations?
- What is an appropriate level of investment? Should there be more of a direct link between the level of investment from year to year and the overall estimated cost for extreme events (to an individual organisation and to the country)? Could this be expressed as a percentage of the possible (foreseeable) economic impact where it is possible to cost the impacts of representative or maximum credible events?

It is the view of the authors that a national level discussion should be held around these questions, which apply across a range of agencies and sectors.

Concluding Observations

In this paper we have covered the *past*, the *present* and outlined some thoughts for making progress in the *future*. The point that we have tried to make is that the key to generating more resilient organisations is to put in more focused efforts in the future than we have in the past.

Today's organisational environment features larger numbers of functionally independent organisations than in the past. The resulting focus of the business unit 'silos' on short-term economic efficiency has had a detrimental effect in terms of planning to be resilient in the face of major emergency events. Efficient and effective response and recovery processes require integration *across* organisational units and *between* agencies. This integration is achievable, but requires an increase in the level of organisational effort in terms of specific planning and resource commitment commensurate with the increasing numbers of organisational units involved.

Conceptually, the solutions for capability building to overcome this inherent vulnerability are relatively straightforward. However the first step, that of commitment, is proving elusive. It could be said that we are suffering from 'one silo too many'. In many sectors, the levels of awareness, planning and investment for events outside of the 'normal envelope' do not appear to have increased to offset these fundamental structural changes. There is now a need to play 'catchup' given all of the structural changes that have occurred over the past two decades.

The real issue for many organisations seems to be a lack of understanding of the full scope of response, including the expectations of other agencies, and extending right out to community level. Once the scope and scale of a potential response is mapped out, the necessary extent of readiness activities and hence the level of commitment required becomes reasonably apparent.

Work in these areas will require some quite fundamental shifts in organisational commitment, both within and across organisational (and in many cases, contract) boundaries – and in both the public and private sectors.

References

Civil Defence Emergency Management Act, 2002.

Dalziel, E. P., McManus, S. T., 2004. *Resilience, Vulnerability and Adaptive Capacity*:

Implications for Systems Performance. International Forum for Engineering Decision Making (IFED); Switzerland. December 2004

Newlove, L., Stern, E., Svedin, L., 2003. *Auckland Unplugged: Coping with Critical Infrastructure Failure.* Lexington Books, Lanham, Md.

Resilient Organisations, 2005. *Research Programme website:* www.resorgs.org.nz

An Economy for Future Infrastructure Resilience

Kelvin T Sanderson, Managing Director, Business and Economic Research Ltd (BERL)

Abstract

This paper explores the relationship between the physical form of the economy, and its likely resilience to potential future infrastructure failures. The basic forces of economic location tend to result in urban areas with high density centres. These high density centres encourage growth of higher value added industries, increase employment opportunities which results in high levels of employment participation, and thus high GDP generated per capita and per hectare. The accessibility due to high density results in high usage of public transport (PT) and active modes of transport, which justifies a high investment in creation of resilient infrastructure.

This pattern is found to be occurring in recent times in the inner city of Wellington, and to some extent in inner Auckland.

These cities when contemplating growth can either pursue growth of a single CBD, or encourage growth of satellite CBDs. It is concluded that the spread of CBD capacity around a network would increase infrastructure resilience

The overall conclusion is that sound development of higher density cities will generate in future an economic base from which New Zealand can afford to invest in the creation of the knowledge, the software and the hardware of resilient infrastructure.

Introduction

This paper generates a high level view of the shape of an economy necessary to support future resilience of infrastructure.

The emphasis in this paper is on the physical form as it affects the nature and shape of the economy and economic behaviour. It will initially consider the interacting factors of location economics; urban density; infrastructure; and how they influence the shape of the economy.

The paper will consider whether higher density is likely to support infrastructure resilience in future, by considering what has happened in the past, and what is beginning to happen now.

Finally it will consider whether our main cities could strive for network resilience by developing networks of high density centres.

The paper does not discuss the economic shape of the economy although undoubtedly the management of the monetary and financial structure, the flexibility of the labour market, and the fiscal and national debt structures will all contribute to maintaining the economy in a strong position to resist or recover from future shocks due to infrastructure failures.

Physical shape and nature of the economy

There is an interaction of forces that create the physical shape of the economy and its strength. These are the economics of location of activity; the effects of location on urban density; and the economics of infrastructure provision and urban density. These three interact to have a major influence on the shape of the economy, and people's economic behaviour.

The economic forces of location result in land uses that generate a high economic rent to the land being located at the centre of the production plain. This principle, generated in relation to agriculture, follows through to imply that urban development will develop at the centre of the production plain.

The same location effect means that the high-value uses, like high-density commercial, resi-

dential and mixed use will be located at the centre, and lower value uses like bulky manufacturing and storage will be located at the periphery of the urban area.

The economics of provision of infrastructure is such that the extent of the infrastructure, and the level of the services provided is higher, and the unit costs are lower with higher urban density.

These three forces appear to interact, allowing expansion of high-level services, particularly business services provided from the centrally-located urban area. It is the higher density urban area that generates the range of business services, creative services and industry that results in a strong economy. There appears to be a feedback interaction here between the increasing dense urban area and its hinterland. The high density urban area also generates behaviour that reduces per capita demand for infrastructure as the workplace, the personal services and the community facilities are all in close proximity and within walking/cycling access.

The higher density urban areas can support a higher investment in infrastructure per hectare (because of the density) and per person because the industry profile here is high up the value chain, and GDP generated per capita is high. Creating resilient infrastructure is likely to require more knowledge, and investment than short-life and temporary infrastructure.

The conclusion from the consideration of the interaction of these physical factors is that, looking to the future if infrastructure is to be more resilient, we should, especially in our large cities look to increase density, increasing the strength of our economy to support higher investment in resilient infrastructure.

Interactions between infrastructure and urban density past and present

In the past, two of our cities illustrate very different interactions between infrastructure and density. Wellington expanded by developing public transport infrastructure, especially rail, supported by road along the two settlement valleys to the north. Settlement grew centred on the rail stations, and the people commuted to feed the growth of the CBD, and its density. On the other hand Auckland has built an expanding web of motorways that has seen low-density urban area expand, generating high congestion at the centre of this motorway web. Overall urban density has increased little, and in fact official data indicate that in 1910 urban density was 20 people per hectare, and in 2003 urban density was 20 people per hectare.

More recently Auckland has decided in the Auckland Regional Growth Strategy (ARGS) of 1996 that future growth should be concentrated on high density compact-built nodes around the region. Actions of the market have seen some increase in density in the very centre, and in some of the nodes, like Botany town centre, Panmure and Albany. The integration of high density nodes with an effective infrastructure network has not yet been achieved.

The present situation in Wellington has seen substantial increase in density in the centre, and with it, changes in industry profile and people's behaviour. The residential population density in the six Census Area Units (CAUs) of inner Wellington in 1991 and 2001 shows that highest level of the average urban density reached has increased from about 33/ha in 1991 to about 40/ha in 2001.

This increase has been accompanied by a change in industry profile with a definite move from employment in 'bulky' industries of manufacturing and construction, to employment concentrated in the business services and cultural, recreational and personal services.

The business services industry includes finance, and a broad range of professional and other services, including some of the creative industries. As such these industries in the cities not only generate their own high-value production, but they also add value to the goods produced in other parts of their hinterland and the country as a whole.

The profile of industry employment in the inner cities generates a higher level of average GDP per employee than the average profile for all industries in the country. It is probable also that the productivity of the individual employees, at least in some industries, may be higher in inner cities than at other locations. However even taking the assumption that the average GDP

per employee is the same across each industry, wherever that employment is located, then the profile of employment by the residents of inner Wellington City in 2001 would generate an average GDP per employee about 20% greater than for the New Zealand average.

It could also be expected that the inner city component of each industry would have employment productivity higher than the national average for that industry. This would be as a result of the sharing, matching and learning mechanisms as identified in research of the agglomeration effects on productivity.

With the higher density and greater range of types of employment opportunities the population employment participation rate has increased dramatically. In New Zealand as a whole, about 47% to 48% of the total resident population are employed. In the more-urbanised cities, this employment rate is higher, and in Wellington City, in 1996 the rate was about 54%, presumably reflecting specific demographics and range of employment types available. In the inner city Wellington the CAUs, the employment rate increased with the population density increase 1991 to 2001, and it would appear that a 'maximum' rate is about 70% of resident population in a New Zealand urban situation. This high employment rate makes for a very strong urban economy.

The increased urban density and increased access to places of employment has caused a major change in travel to work behaviour. There has been a modal shift from cars to public transport (PT) and walking, cycling etc (or active modes) in both inner city Wellington and in inner city Auckland.

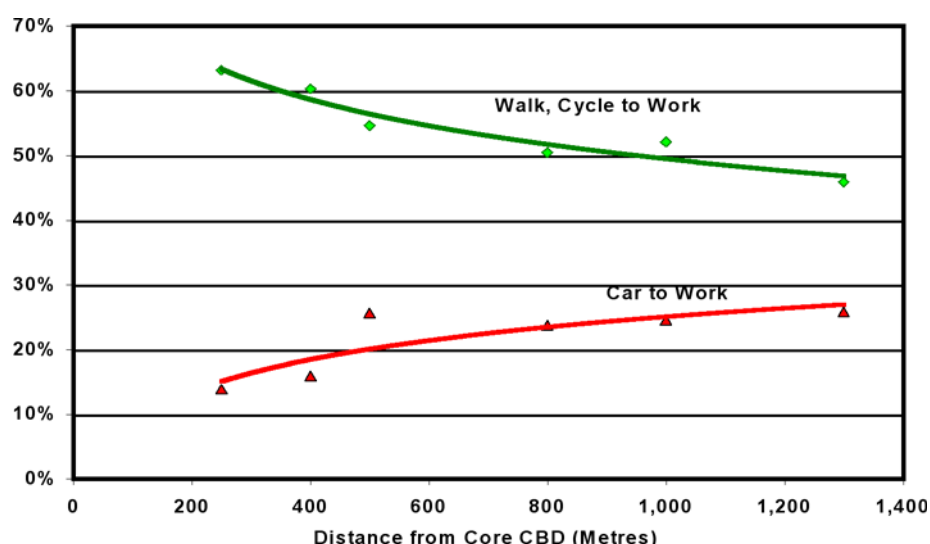


Figure 1: Inner Wellington Travel to Work Behaviour 2001

There are over 50% of each population who walk, cycle etc to work, however in Wellington the people a little further from the centre, say 1000 metres out also use this mode at a level of above 50%, but in Auckland at that distance, something under 30% walk or cycle to work.

This use of active modes is very much higher than in the suburban situation of lower urban density, where perhaps 6% of residents use active modes in their travel to work.

These observations of recent change in inner Wellington and Auckland city indicate that if urban densities are increased in New Zealand, we can expect industry profiles and urban behaviour to change resulting in higher value industries and services, higher labour participation rates, and higher use of active transport modes. These all result in future in higher GDP per capita and much higher GDP per hectare of urban area. The urban areas will therefore in future be able to invest in higher quality, resilient infrastructure.

Expansion of higher density CBD capacity through networks

The fundamental choice facing a city considering its long term aspirations as to population size

and density, is whether to pursue ever-growing population size and density within its boundaries, or whether to expand its CBD function in future by encouraging growth of satellite CBDs. The trade-off is between the benefits from agglomeration of an ever-growing population, and generating an equally large CBD capacity in a planetary system, requiring effective access among them.

In terms of infrastructure resilience, the spread of CBD capacity around a network would spread the risk, so that should one location, either the 'sun' or one of the 'planets' suffer infrastructure failure the remaining functional 'planets' can maintain and expand their capacity to bring about recovery of the network's capacity.

A city that has explored this question in some detail recently is Sydney. Sydney was developed around reasonably comprehensive public transport, with suburbs feeding workers into the CBD. This is not dissimilar to the development of public transport and settlement nodes along the two valleys, or corridors north of Wellington City. In Sydney, the suburbs have tended to become 'cities' but generally with a shopping mall function, rather than a CBD function. Public transport development has not kept pace, people have increased their mobility with higher car ownership, and traffic growth is becoming unsustainable.

Against this background a research effort *Sustainable Transport in Sustainable Cities* was launched in 2000. It was a \$4 million project and the findings were released in 2002. It was completed by the Warren Centre for Advanced Engineering at the University of Sydney. The main conclusion of this study was that the long-held urban form assumption of agglomeration at the central Sydney CBD is unsustainable. Instead the conclusion was that Sydney should become a City of Cities.

The general picture is similar to what Wellington and Auckland are beginning to experience. Some of the findings may open opportunities for Wellington and Auckland to increase the scale of their CBD functions on a regional basis utilising the satellite concept, rather than central agglomeration. This is consistent with the Auckland Regional Growth Strategy, but there appears to be difficulty in obtaining the necessary commitment to actual development of substantial compact-built nodes there. In Wellington the satellite approach is more likely to be implemented as public transport in Wellington has grown integrated with the urban form. There is the basic behaviour pattern that could be rejuvenated if the PT system among the satellites was lifted to Twenty-first Century standards.

The satellite 'CBDs' would be regional centres based around higher-order jobs, community services, administration and major retailing centres, as well as sub-regional centres, industrial estates, and high-technology parks. They would have a range of housing and built-form environments, cultural, recreational, environmental, and social services assets. These CBDs would be inter-linked by a completed, effective regional transport network that also linked into the national transport network.

The fundamental is that these centres would have a relatively high urban density and land use planning integrated with multi-modal transport provision. They would be designed for a high level of accessibility by their residents, employees, businesses, and communities. The infrastructure within them would be of high density and therefore high usage. Similarly the links between them would be high usage and therefore could sustain the investment necessary to bring them to Twenty-first century standard, and to be resilient.

The overall conclusion is that sound development of higher density cities will generate in future an economic base from which New Zealand can afford to invest in the creation of the knowledge, the software and the hardware of resilient infrastructure.

Natural Hazards, Infrastructure and Risk

Russell Blong, Benfield Australia

Everyone talks about risk, but does anyone understand it (or should that be them?). Financial risk, market risk, operational risk, risk to reputation Very few people have a good grip on more than one of these. I think I have a good grip on natural hazards risk, but won't be surprised one day to discover that this is more apparent than real.

AS/NZ 4360 is not a bad starting point for whatever sort of risk assessment we are talking about. The best part of the standard is the Likelihood – Consequence diagrams in an appendix, but abandoned in the latest version (a step backwards in my view). The Likelihood – Consequence matrix needs to be quantified, but at least it makes us think through two fundamental aspects of risk in a reasonably rigorous way.

In an ideal world, we might try to quantify the risk in terms of annual exceedance probability (AEP) producing a curve that shows the financial loss that could be expected or exceeded for a given return period (Figure 1). AEP curves are the product of complex models which take into account the probability of a hazard occurring, the exposure of assets to the hazard including site conditions and construction characteristics, and the vulnerability of the assets to a specified level of ground shaking, wind speed, hailstone size, ash fall thickness, water depth or whatever. Most importantly of all, the models take into account the considerable uncertainties in all of the above estimates. In principle, an AEP curve could also be worked out for deaths, accident-days or other measures of risk or risk resilience.

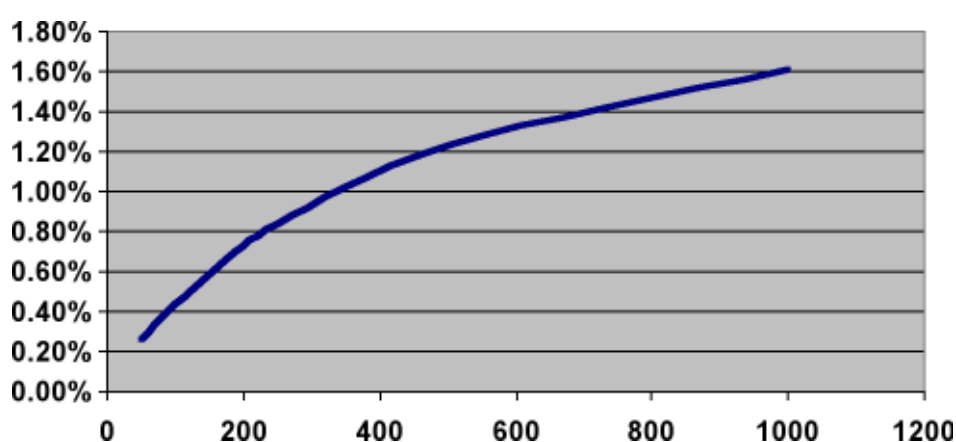


Figure 1: Annual Exceedance Probability curve showing damage expressed as a percentage of asset value destroyed for given return periods in years (on the x-axis).

In many countries regulators maintain that insurers and others must demonstrate that they would remain solvent in the event of a 250-year loss or whatever. Figure 1 allows an insurer to ponder what proportions of a specified loss would be held as cash reserves or protected by insurance or reinsurance or ignored because “it won't happen while I am manager”.

Figure 1 might also encourage the asset owner to get involved in risk reduction by increasing the resilience of some assets. Figure 2 illustrates the extent to which potential losses can be reduced; here, a portfolio of assets exposed to flood has a loss of about \$100 million or greater once in 250 years. Removing all the assets with floor levels below the 20-year average recurrence interval flood (or flood proofing them) reduces the 250-year loss to about \$65 million or greater. Or, a group that retains \$25 million in capital to pay for occasional flood losses can reduce the probability of having to pay this amount for damage from once in a few decades to once in a couple of hundred years simply by managing the locations of assets. It really looks pretty straightforward for the manager of any asset portfolio!

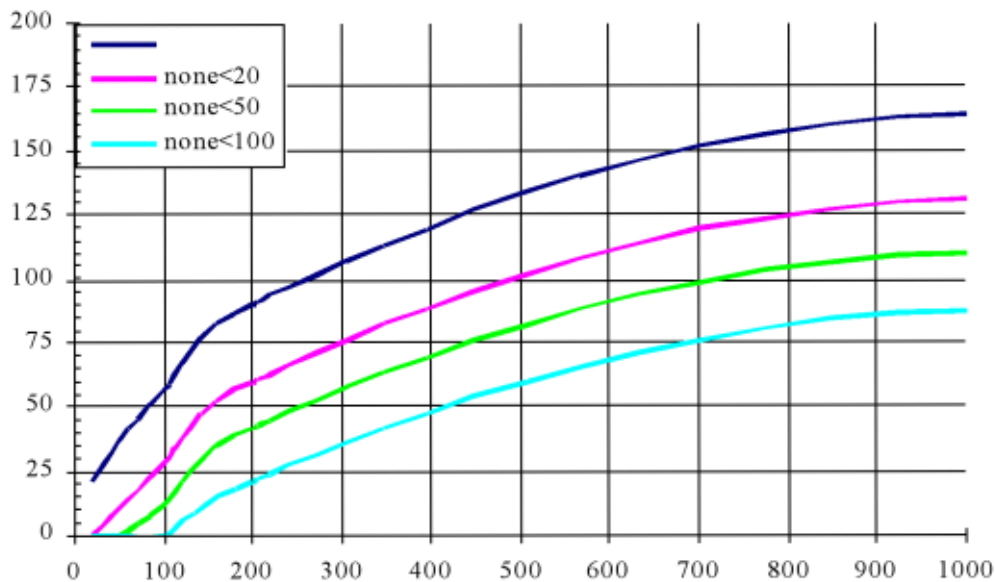


Figure 2: AEP curves for a portfolio of assets with randomly selected locations in a city (uppermost curve). Y-axis shows flood damage in \$millions. X-axis in years. Other curves indicate the change in damage for given return periods by shaping the portfolio to exclude all properties below the 20-year, 50-year and 100-year average annual recurrence interval floods.

Using the sort of asset portfolio management implied in Figure 2 would seem to be good business for insurers and reinsurers as they will pay fewer flood claims and, at the same time, encouraging for the remaining policy holders who will subsidise fewer flood losses. However, for those living in flood-prone environments and now without insurance the situation is trickier; no insurance may mean no mortgage. In the short-run, denial of flood insurance may be a terrible social policy impacting hard on some floodplain dwellers, but in the long-term it may encourage more prudent land use planning policies that benefit everyone and increase the resilience of the nation's infrastructure. Things could be even more interesting for asset managers, bank managers, communities, shareholders and those at risk if one major insurer puts in the hard work of risk rating asset by asset for flood (or earthquake) and a major competitor does not.

In principle, it is a relatively straight-forward exercise to undertake asset-by-asset risk rating for a number of natural perils including flood, earthquake, wildfire, landslide and wind. This implies that the owner of a portfolio of assets can readily enhance portfolio resilience.

The examples given here are rather monochromatic as they focus on individual perils. Life becomes much more complex when we consider several natural perils at a time including those for which we do not have well-tested exceedance probability models. If we have two perils (say flood and earthquake) each with a loss to an asset portfolio of \$100 million or more once in 250 years, the anticipated loss becomes \$100 million or more once in 125 years. If we then put some serious thought into unmodelled perils (say volcanic eruption and extra-tropical storms) we quickly realise that a loss of \$100 million or more might occur more frequently than once in 100 years. If we are serious about protecting our assets against a one in 250-year loss we may need much more than \$100 million of cover, or work harder at making the asset portfolio more resilient to natural hazard impacts.

We also need an holistic approach to risk – an approach that embeds natural hazards risk as just one facet of a risk assessment process and places these risks in a register that has identified, considered and reviewed the likelihood and consequences of the whole gamut of enterprise-wide threats and opportunities.

Managing New Zealand's Flood Risk Local Government NZ/CAE Study

*Graeme Martin, Otago Regional Council; Marilyn Brown,
NM Associates Ltd; Terry Day, T J Day & Associates*

Abstract

Flooding is a natural phenomenon critical to the development of river systems and their catchments. The extent of negative and positive impacts of flood events to our natural, social and economic environments will largely be determined by our ability to avoid or mitigate risk in a manner which fully acknowledges the long term need to respect catchment dynamics as we address community aspirations. While not a new perspective: our observation is that increasingly our patterns of development and settlement are continuing on a basis which fails to respect this need. Communities are increasingly at risk where we attempt to emphasis flood prevention rather than catchment management, and where we either ignore risk, or treat it superficially.

Reduction of risk associated with flooding may be achieved by

- acknowledging catchment dynamics and risk environments therein
- pro-actively addressing environmental sustainability within catchments
- promoting sustainability through land use and development practices
- avoiding development in areas most significantly at risk
- promoting environmental enhancement , and
- working within catchment processes.

The protocol sees many opportunities for improved flood risk management. Its risk management methodology can be readily adapted to the governance systems of local authorities and current law.

Introduction

Flooding has significant impact on the social and economic well being of regions and the nation. Floods at all scales continue to be important regional events around New Zealand. Some, such as occurred recently in the North Island, become significant national events, costing many hundreds of millions of dollars.

New Zealand's active geology and weather systems, with the added spectre of climate change, will result in floods continuing to impact on New Zealand's people, communities and economies. The historic use of flood prone lands, coupled with increasing community demands for access to and production from these lands (also matched by increased expectations for risk protection), show that there is a need to reassess flood risk management in a strategic, comprehensive manner.

The determining factors of floods are well known. Rainfall and snowmelt provide the input that is concentrated by catchment characteristics into river and stream flows, which are modified as the flood moves downstream. These flows in turn modify physical character by erosion and deposition of debris and sediments, and the ecology by the modifying habitat through for example the transfer of nutrients and pollutants. In urban environments control of runoff, channelisation, and flood protection works place reliance on infrastructure and it's capacity to adapt to changing runoff regimes..

Natural processes, and on-going environmental modification, give catchments their dynamic character. Like communities everywhere we impose patterns of land use and settlement within catchment environments. Many of parts of these environments may be risk prone: hazard to

our lives and livelihood occurring where communities are affected by inundation, erosion, and deposition, land instability, water quality effects, contamination and a host of associated other effects.

Flood impacts have many dimensions, such as:

- *Social*, including during and after the event: personal stress; demands on social and medical services.
- *Economic*, including: repairing/replacing infrastructure loss or damage; loss of income; loss of income production (such as loss of production lands); loss of property; cost of cleanup, repair and replacement
- *Environmental*, including loss of habitat and ecosystems, loss of infiltration capacities and cost of pollutant clean up (sewage, chemicals, debris); increased deposition within offshore environments, loss of amenity values; loss of heritage and cultural resources.

While a range of mitigation/control techniques exist, traditionally the most common one is based upon protecting people and property by building “flood control” infrastructure. This approach, common world wide, seeks to reduce flood risk through engineering solutions by confining, restricting, slowing or expediting flood flows. Risk response built around many decades of protective works is also received wisdom for most communities: e.g. immediate call for more protection following each storm event, disappearance of more coastlines, coastal erosion. This remains the major flood management approach, and is very much the public view on how this risk is to be managed.

The intent of the local government flood risk management project is to assess the case for, and to develop the contents of an improved approach to flood risk management. This is being done by identifying the need for reassessing current practice, by identifying issues likely to impact on the application of this approach, and of the implications of implementation. Understanding natural systems and the impact of human interventions upon these (and *vice versa*) underpins all approaches to sustainability and risk management that underpin this approach.

Risk Factors Requiring Resolution

Flood risk in New Zealand is characterised by the following identified factors:

- Existing stopbanking with a design or operating limit that has in many (or most) cases no explicit public provision for larger (greater than 1% to 5% AEP or 1:100 to 1:20 year return period) river flows to be safely discharged.
- Existing stopbanking that may perform insufficiently well because of riverbed aggradation, degradation, overloading of natural foundation materials or tree growth.
- The flood performance of river systems being impaired by bridge crossings, culverts, banks or other structures built by utilities or private individuals.
- Existing stopbanking that through land use and community changes might not afford appropriate protection levels aligned for today's land uses and community expectations.
- Higher value land uses (intensive farming, dairying, horticulture, cropping, and lifestyle, residential, industrial) on flood plain areas that, for today's community expectations, have inadequate or no formal flood protection or flood mitigation measures.
- Changing patterns of land use within catchments influencing the hydrologic regime and water budgets.
- Changing weather patterns with attendant changes in precipitation regimes.
- Lack of clarity in the roles and responsibilities between and within central and local governments, and the difficulty in gaining long term political support and establishing accountabilities.

Flood Risk Management – Developing a New Protocol

A risk management approach makes considerable sense as it implants a sensible framework for decision making (e.g. sequential steps of establishing context, identifying risks, analysing and ranking risks, and treating risks, wrapped in an interactive monitoring and review process, with appropriate communication and consultation). This is a well established process. What is not well established is how to apply it to encourage the best public risk management solutions. The Protocol sets out a framework to do so.

The Protocol, which is first being cast to provide direction to regional and unitary council management, seeks to establish a continuous and holistic approach to the analysis, assessment and reduction of flood risk, as consistent with risk management methodology. It acknowledges that many current practices and governance functions are of a risk management type (such as those under RMA, CDEM, asset management plans, catchment plans, etc) but sets a wider framework for these techniques to be applied.

Setting the context to which this methodology is applied is the critical task. Just what is the right context, how can this be understood by councils and appropriate approaches developed, how to gain support for a common methodology and how to gain the confidence and support of central government, are key issues to be addressed in order to improve the management of flood risk.

The draft Protocol tackles these questions by setting out a series of elements, supported by principles that need to be considered in the assessment of risk. These elements point councils towards understanding and respecting natural processes and the implications of human interventions, in a catchment context of social, economic and cultural aspirations. The protocol framework (Figure 1) demands iterative analyses and the consideration of a range of risk treatment options. These can be either structural (such as flood banks) or non-structural (such as administration systems that are catchment based, improved resource management practices, environmental and landscape enhancement etc). None of these elements are new in themselves; however linking these in a managed manner is a significant challenge for local government.

Implementing the Protocol will require:

- Adoption of a corporate risk management culture within which councils can ensure the right culture exists.
- Understanding of the catchment contexts for community aspirations for environmental, social, cultural and economic objectives, integration of these objectives, setting programme objectives and measuring progress against these. Flood risk management is to be an integral aspect here.
- Adoption of a common approach to flood risk management across the local government sector that while allows local communities to find their own solutions.
- Recognition from central government that the local government Flood Risk Management Protocol provides the best approach to protecting community interests and forms the basis of their relationship for effective flood risk management.

Resource Management for Risk Management

The challenge of building awareness of risk environments, and measures to avoid or mitigate flood hazards within them, while also promoting the sustainable management of natural and physical resources, is a complex one.

Cornerstones of this quest include;

- acknowledging catchment dynamics and associated hazards/risks
- adopting use, development and protection practices to promote the environmental sustainability of catchment resources

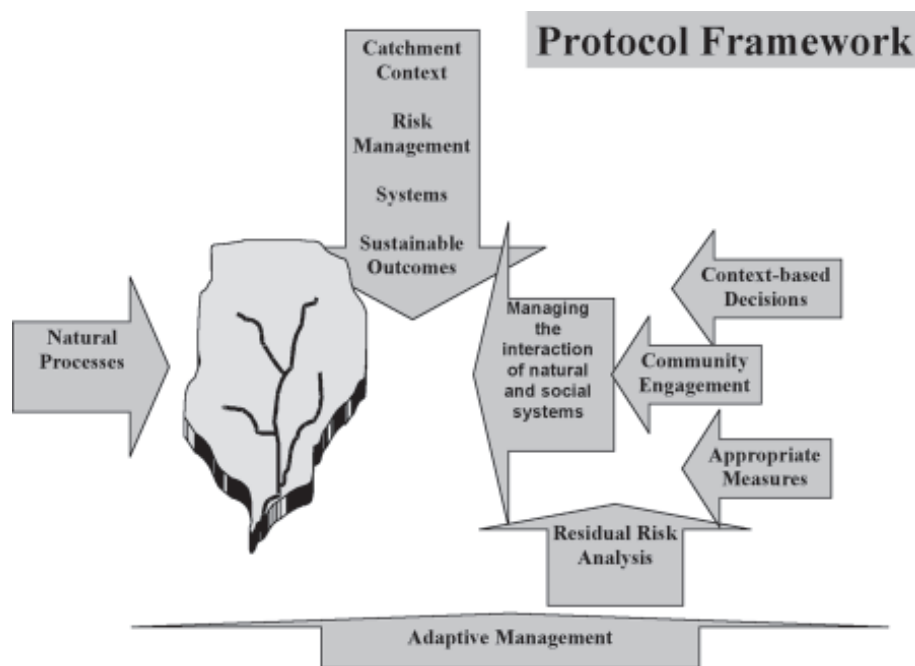


Figure 1

- factoring types and densities of development to types of risk environments
- avoiding development in areas most significantly at risk
- promoting environmental enhancement.

In the implementation context risk management processes and techniques should enable consideration of ‘whole of environment’ structures (e.g. the management framework that is regional and district plans by way of strategic environmental assessment), and on a location or ‘context specific’ basis (e.g. the environmental effects of structural works, or of increasing densities of floodplain development, considering cumulative impact).

The flood protocol acknowledges that much of what is risk management is affected by strategic planning and resource management decisions, and that risk environments fundamentally involve land/water/coastal regimes. Such regimes are integral to plans, policies and implementation initiatives available under RMA (New Zealand’s principal environmental statute).

Governance functions and processes under the RMA offer various pathways to evaluate risk, and risk environments as associated with other environments, on a catchment basis via

- policy initiatives promoted by way of risk identification/management within regional policy statements
- preparation of regional plans that are context based rather than ‘resource based’
- preparation of combined regional/regional coastal/district plans, or combined district plans, thus enabling plan provision and associated objectives, policies, and methods (including rules) in explicit response to flooding as a cross boundary matter
- regional and district plans with positive integration across the hierarchy of RMA functions and documents to note particularly flood risk, associated hazards, contributory factors, avoidance and mitigation strategies.

Issues for Risk Management as Sustainable Management

In considering ways and means to promote improved risk management indicators of improved practice are:

- A diversity of response, ideally promoted on a ‘whole of catchment’ basis, with governance

systems and planning instruments aligned geographically to catchments and subcatchments

- A shift in methodologies from an emphasis on floodplain management to regimes that give improved awareness of (upstream) resource values, estuarine and coastal processes
- Consideration of cause and effect for flood hazard management should acknowledge encompassing issues for land and water resources, potentially by means of evaluation of a series of sustainability indicators. including water quality and quantity characteristics, response of rivers to natural, climate and anthropogenic changes, interface between catchment and coastal regimes, changes in investment ratios in at risk compared to lesser risk environments.
- Resource recovery as an integral component of sustainable management. The loss of natural and physical resources within catchment environments is a significant resource management effect associated with flood hazard/events, avoidance and mitigation
- Risk management strategies offer opportunities not only for watershed/floodplain management but also for improved conservation /landscape and amenity values. They may also contribute significantly to realisation of environmental strategies e.g use of native species planting for river protection, channel and erosion control will provide enhanced ecology and habitat values to riparian corridors.
- Risk environments include cultural environments. Not only does flooding pose risk to communities and environments generally there is also the threat to integrity and survival of heritage resources, including potential damage and loss of marae, urupa, waahi tapu, heritage structures and cultural landscapes.

Implementation options and techniques

Flexible methodologies are promoted, since matters appropriate in any given situation will vary across the wide spectrum that are catchment environments. For the methodologies chosen there will also need to be an implementation strategy – to be brought into effect on a short-term, medium-term and long term basis. The strategy might also involve incremental changes such as trialling of mechanisms, say on a selected small, catchment or subcatchment basis, prior to more general adoption.

In the evaluations of growth management options and processes contributing to “second generation’ RMA documents and strategies, the Protocol recognises the significant opportunities that currently exist to more fully address risk environments in promoting sustainable management of natural and physical resources.

More immediate, or perhaps interim, risk management may include

- Mechanisms to assist peak flow and stormwater management
- Minimising new development in most vulnerable areas.
- Relocation of strategic facilities away from vulnerable locations

A strategic long-term approach would be to identify for flood risk environments those appropriate to

- **Adaptive management** Predominantly extensive built environments in which catchment processes are affected (usually adversely) by past infrastructural response to risk, and/or necessitating specific mitigation of environmental effects. Adaptive management recognises that structural response to flood hazard is unlikely to be a viable option for communities in the long term, either socially or economically. Mitigation measures are aimed at building resilience within communities, while fully promoting risk awareness.
- **Restoration management.** Measures to enhance the integrity of riparian systems, and associated natural values, to improve and sustain essential inter-relationship of catchment processes. May include wetland creation, rain gardens etc. Promotes remediation of natural systems over structural response.

- **Protective management.** Measures which emphasize the sustainable management of natural and physical resources to effect risk management. Protective management has as its underlying philosophy implementation systems which create least modification, and include protection and enhancement of biodiversity, natural and amenity values, water quality. Promotes risk avoidance as a primary objective.

The methodologies may be applied within varied time frames individually to catchments, or to parts of catchments, as allied to varying types of risk environments. Using this over-arching risk management methodology specific provision can then be implemented to plans and policy documents, and associated implementation strategies.

While there is a considerable body of knowledge about catchment processes, and integrated management, there are opportunities for improved sustainable management through targeted environmental outcomes and specialist implementation techniques. In particular via enhanced regional plan and/or combined regional/district plan initiatives.

Summary

Local government is evolving traditional approaches to floodplain management as the importance of catchment systems are recognised, as it ensures that a range of treatment options are considered, and as it seeks to understand the long term implications of managing for sustainability. The “new” protocol sets flood risk management as its premise and seeks to provide a common basis for councils to approach this key responsibility. Risk management methodology is a fundamental component of this approach in providing a useful system but primarily a critical perspective, with which to assess flood risk.

Reference

Centre for Advanced Engineering 2005. *Discussion Document - New Zealand Protocol for Flood Risk Management*, Christchurch.

The New Zealand Electricity Grid: Resilient Infrastructure?

Kieran Devine, General Manager System Operations, Transpower NZ Limited

Introduction

The national electricity grid in New Zealand is at a key point in its growth and development. In the pre-1913 era the electricity system in New Zealand was a series of small power stations, private generation and distribution networks. In the period 1914 to 1934 the Government took over both the ownership and the responsibility of building New Zealand's first 110kV high voltage transmission lines. During this period North Island power stations were progressively connected into a single transmission network. The period 1935 to 1950 resulted in substantial demand for electricity, compounded by war time power shortages, which resulted in substantial managing of load to meet available supply. The post-war period resulted in the Government rapidly expanding the national grid. The key feature during this period was the introduction of the higher 220kV transmission voltage as the backbone transmission system for New Zealand.

The period from the mid-1980s to today has seen substantial change in the ownership structure and the regulation of the industry as well as the introduction of competitive forces and market structures to create a more competitive industry. One of the key features during this period has been the increased reliance by society on a robust, reliable and resilient electricity system to meet New Zealand's expectations of economic growth.

The 1920s saw the introduction of the 110kV grid system for New Zealand. Forty years later, in the 1960s, saw the beginning of the 220kV grid system for New Zealand. Another forty years on, will the 2000s see the introduction of a 400kV backbone grid system to power New Zealand into the future?

The New Zealand Electricity Grid; what is it?

The electricity grid in New Zealand is a complex transportation system that connects approximately 70 power stations each with a capacity greater than 10 MW, with approximately 1.9 million customers. It has two relatively simple objectives. The first is to provide customers with security of supply via access to electrical energy from a variety of generation stations. The second is to allow a customer to access the lowest cost source of electrical energy, from a wide variety of power stations using the transmission grid as the transportation network.

The transmission grid in New Zealand is owned by Transpower New Zealand Limited. Transpower is a state-owned enterprise (SOE) and is charged to be as profitable and efficient as a comparable business that is not owned by the Crown. It is also required to be a good employer and to be an organisation that exhibits a sense of social responsibility. These are Transpower's principal objectives as set by its owners, the Government of New Zealand.

The transportation of electricity from generators to customers in New Zealand transverses two electrical network systems. Most large generators are directly connected to the Transpower's high voltage transmission network, whereas nearly all customers are connected to approximately 30 low voltage distribution networks. Performance of both systems working together is vital to ensuring a secure supply of electricity to final consumers. This paper will only discuss Transpower's high voltage national grid electricity system.

The Transpower electricity grid in the North and South Islands are integrated, joined by a High Voltage Direct Current (HVDC) link between the two islands. The system is managed from two national co-ordination centres in Hamilton and Wellington, with three regional control centres in Christchurch, Haywards and Otahuhu. The actual transmission assets are summarised in the table below:

TRANSPOWER'S OPERATIONAL ASSETS AS AT 30 JUNE 2004	
Length of HVAC and HDVC Transmission Lines	11,733 km
Number of Substations (includes cable stations)	172
HVAC Transmission Line Voltages – kV	220, 110, 66, 50, 33
HVDC Transmission Line Voltages – kV	350, 270
HVDC Link Capacity (with 2 cables on Pole 1)	1,040 MW
Length of each Cook Strait Cable	40 km

The actual transmission grid consists in excess of 15 million identifiable assets. The individual failure of any one of about a third (4 to 5 million) of these assets could result in the failure of a major item of plant, such as a transmission line or part of a substation.

Resilience Philosophy

By its very nature in New Zealand, the transmission grid is designed to connect Kaitia to the Bluff via the High Voltage Alternating Current (HVAC) networks in both islands and the HVDC cables across Cook Strait. The transmission lines that make up the national grid cover some of New Zealand's rugged (and most beautiful) country. The 45,000 structures (25,000 steel lattice towers and 20,000 wood/concrete structures) that support the transmission lines are exposed to just about every natural hazard that New Zealand has to offer. The main hazards are climatic: storms, particularly lightening and flooding. The 172 substations are susceptible to earthquake damage due to the concentration of large heavy items, particularly transformers that are closely coupled with long thin fragile cylindrical ceramic structures, insulators. These combinations make earthquakes a significant hazard for substations.

The foremost, and probably under-rated, hazard is the volcanic risk to transmission systems. It is interesting to record that it is economically and commercially possible to insure the transmission grid substations against the risk of natural hazards. In a commercial sense it is uneconomic to insure the transmission system. This is driven to a large extent by the volcanic hazard from Taupo north. Therefore the transmission lines in New Zealand are uninsured and Transpower and its shareholders carry the risk of a substantial transmission failure caused by natural hazards, particularly volcanic activity. The culmination of a very large number of discreet assets physically distributed across the total length of New Zealand, with a relatively high proportion individually capable of initiating substantial system failure, and the potential for relatively high impact natural hazards, has resulted in an investment, maintenance and operating philosophy of building resilience into the system. The resilience is built in not only by design and a prudent level of maintenance, but by preparing particularly well to rebuild or replace reasonable large sections of the transmission system in the result of catastrophic failure. This is particularly so with the actual transmission towers where, given the geological nature of New Zealand, it is impossible to fully protect the transmission line structures from all possible natural hazards.

Therefore, Transpower has in excess of 40 specifically designed temporary tower structures spread throughout New Zealand that are capable of being erected within a matter of days following a failure of a permanent tower structure. Routine testing of both the assets, processes and the crews who would erect such structures, ensure rapid response when required. This has been proved on several occasions over the last three years where tower failures have occurred due to extreme climatic conditions, such as wind gusts toppling towers on the HVDC line in the South Island, floods and slips in the Manawatu/Poverty Bay, along with the man made hazard of logging contractors flattening multiple structures.

Planning

While it is not possible to design individual assets with the necessary resilience, it is possible at the macro level to plan, via asset redundancy, sufficient resilience into the grid to meet the security that is expected of the electricity supply system by customers. In the industry this is

known as “N minus x” security planning, where x is an integer from a normal level of 1, to (in extremely critical situations) 3 or perhaps 4. X refers to the number of failures of a substantive asset that can occur whilst still providing a secure transmission of electricity. N is the overall number of substantive assets used to deliver electricity to the customer.

In terms of long term investment planning the standard criteria that has been used in New Zealand is known as N minus one, (N-1). This security planning criteria is currently being articulated by the industry’s regulator, the Electricity Commission as N-1 with all available assets in service, to meet the long term economic load growth forecasts. Currently these load growth forecasts are for medium growth at 2% per year, and for high growth, 2.4% per year. The N-1 security standard allows a consumer to see no impact for failure of any one substantive asset in terms of the quality and continuity of electricity supply.

For example, the largest generator or the largest transmission line supplying a particular customer can fail and the customer would see no impact. While there has been substantial discussion about introducing probabilistic measures into the security criteria, the current implementation of the long term planning security criteria is deterministic. Short term operational planning leading up to real time is fully deterministic, as the outcome is binary - the lights are either on or off!

As a result of tight supply situations in Christchurch, Blenheim/Nelson, Northland and Auckland, a working group of industry stakeholders; the Ministry of Economic Development, the Electricity Commission, all major generator/retailers, the affected distribution companies, Transpower as both the Grid Owner and System Operator, have developed real time operational security criteria that meet the expectations of all major stakeholders.

The basic security criteria of N-1 is enhanced by planning to meet the prudent peak demands forecast for the forthcoming period, together with allowing for the extended outage of the largest generator in the area. An N-1 criterion then also allows for the real time failure of the next largest item whether it is a generator or a transmission line.

Prudent forecast levels agreed with the industry working group usually represent several years of long term economic growth, for example, in the current planning period for the 2005 winter in the Christchurch area the prudent forecast represents approximately 11% growth above the previous year’s maximum loads, (due to clean air regulations in Christchurch, resulting in a substantial investment in additional electric heating, particularly heat pump technology). The equivalent prudent load forecast increases for Nelson/Blenheim is 8% for the 2005 winter, with an equivalent 6% for the Auckland and the Northland area.

It is important to note that the short term operational security criteria, which can be characterised as “N-2 plus”, compared with the N-1 minimalist long term planning criteria, has resulted in substantial additional short term investments, including standby diesel generators being installed, to meet the operational security criteria.

Clearly an issue the industry must deal with is the different demands of long term planning criteria and the short term operational security criteria. These are clearly incompatible over the medium to long term and are only being accommodated in the short term by a series of potentially uneconomic tactical investments that will be left stranded when substantive long term investments in either transmission or substantial generation occurs.

Investment

Decision making on substantial new investments to the core transmission grid have always been contentious, particularly who pays and how much.

In 2003 Transpower voted against the industry developed multi-party contractual arrangements proposed under the Electricity Governance Board (EGB), because Transpower believed that it would not be able to get a decision within reasonable timeframes on the necessary enhancements to the core grid.

The industry regulator that has replaced the proposed EGB, the Electricity Commission, now is

the decision body. It is likely the first major decision for the Electricity Commission will be on Transpower's proposed 400 kV transmission line from Whakamaru to Auckland. Experience to date suggests the decision will be no less contentious than the previous transmission investments.

Grid Performance

Despite the number and complexity of the assets that make up the transmission grid, it has very high reliability and availability. The basic measure of availability in transmission assets is a concept known as circuit availability. The circuit concept involves all the assets that make up a single transmission line, including the substation equipment that is required to connect that line onto other lines. The HVAC circuit availability that Transpower has achieved over the last ten years has been at or very close to 99%. Due to the complexity of the HVDC link, and in particular the complexity of the thyristor and mercury valves technologies, the long term availability of the HVDC circuits has averaged approximately 95% over recent years.

However, circuit availability is not a true representation of the service that the customer can expect from a meshed high voltage transmission grid, where each major node in the grid can be connected by multiple paths (transmission circuits) to other nodes and a variety of energy sources. The concept of "system minutes of interruptions to supply" is common amongst transmission network service providers internationally. A system minute is defined as "the energy in MW minutes not supplied from the system to consumers, divided by the system maximum demand in MW for the year". For the year ending June 2004, 3.6 system minutes of energy was not supplied to consumers. The equivalent un-audited figure for the year to June 2005 is 3.4 system minutes. This represents supply reliability to the consumer in New Zealand of 99.993%, from the high voltage national electricity grid transmission system.

Transpower NZ Limited, as well as being the asset owner of the electricity transmission grid, is also contracted to the industry via the regulator the Electricity Commission as the System Operator. The rules and regulations that govern the System Operator have one clear objective that supersedes all others. It is clearly stated that the System Operator is not permitted to allow the electricity system to get into a state where the concept of cascade failure could occur. Cascade failure is where the failure of any one substantive asset in the electricity system whether it be a generator, a transmission circuit or a load, causes another element of the electricity system to overload and fail thereby causing a "domino" type effect. The last occurrence of "classic" cascade failure in New Zealand occurred on Waitangi Day 1987, when a bus fault caused by a small item of faulty equipment, "blackened" the North Island from Taupo north. Because of the very disruptive nature of cascade nature the System Operator has substantial powers, including load shedding where an event is anticipated, to ensure the power system never enters a state where a subsequent failure could cause cascade failure.

Clearly issues over recent years on the East Coast of the USA and Canada, Sweden, Italy, London and southern England and South Australia, have raised the issue; could New Zealand's transmission system fail in a similar way?

Substantial amount of analytical work has been undertaken subsequent to the major failure in the US and Canada which has analysed past system failures using "chaos theory" techniques. The results of that analysis are shown in the attached chart for the New Zealand system for a variety of outages that have occurred over the last 20 years. The graph shows a very strong correlation between the size of outage and the likely frequency of an outage of that size (return period) for the New Zealand power system (Ancell et al, 2005, p.7), (Fairley, 2004, p.16). The results for an equivalent analysis of the US system show almost identical results. The slope of the curve in New Zealand is 1.6; the slope of the curve in the US is 1.7. The conclusion that can be drawn from this analysis is that failures of electricity transmission grids worldwide are inevitable, and their return periods are predictable. Extrapolation of the data for the New Zealand indicates a return period for a blackout the size of one system minute, (a city like Hamilton for an hour), could be about 25 years.

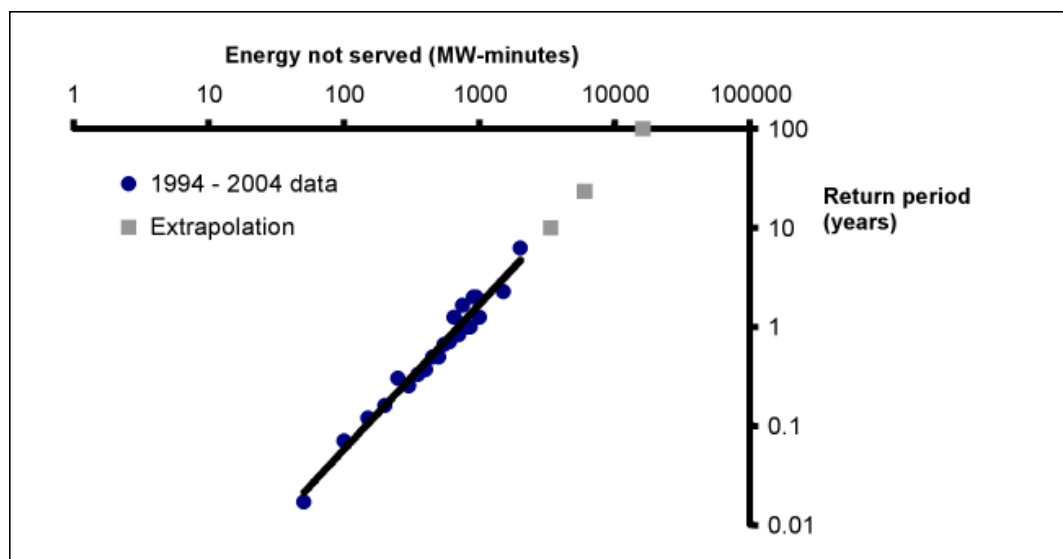


Figure 1: Expected time between blackouts of given size in New Zealand 1994 - 2004

Implications of this analytical evidence and the practical experience of many years on both the New Zealand and/or similar transmission grids around the world indicate that outages large and small will occur for a wide variety of reasons, and that emergency planning and management is essential to ensuring the level of security and resilience that consumers require of the electricity system.

Emergency Management

The industry has a wide variety of emergency management procedures and planning tools that collectively add substantially to the security and resilience of the underlying assets. Because of the dependence in New Zealand of hydro generation, the medium term risk of running out of water for hydro power stations is a risk that constantly faces the New Zealand power system. The Electricity Commission, together with its regulator functions, is now tasked with managing this dry year reserve risk. The Electricity Commission is required to agree with the industry a variety of warning and alert levels based on the time of the year and the state of the hydro storage.

The Electricity Commission has also committed the New Zealand consumer to pay for a dry year reserve generation station, the Whirinaki open cycle distillate-fired gas turbine station in the Bay of Plenty, to provide additional energy reserves to minimise economic impact during times of hydro shortage. In addition to these medium term plans, Transpower as both Grid Owner and System Operator has a variety of management plans to manage a wide variety of “incidents” that occur within the electricity system.

Failure of grid assets in the short term is usually covered by the N-1 security policy to ensure customers are not affected by the failure of any single asset. The ability to rapidly by-pass damaged transmission assets with purpose designed temporary structures is a key feature of ensuring resilience in the New Zealand grid transmission system. A wide variety of procedures and arrangements are in place to deal with catastrophic circumstances such as “system black” circumstances caused by cascade failure. Specific generators are tasked with being capable of “black start” performance which ensures they are capable of self-starting without any external power supplies to power their control systems, pumps, etc. The “black start” systems are required to be regularly tested, usually on a monthly basis. Recently the System Operator has co-ordinated a real time live test of the “black start” capability of a generator in the centre of the North Island to be able to liven deadened lines and transformers into the Auckland area. The requirement for these real time live tests is now an obligation on all affected parties of the industry. In addition, a variety of “desktop” type exercises are managed to ensure the co-ordination required between many elements of the energy industry in New Zealand have the ability to recover quickly, and in a planned fashion from any substantive disruption to the

electricity supply system.

Conclusion

The title of this paper posed a question – is the New Zealand electricity grid a resilient infrastructure? Clearly from the information that has been provided, the assets on their own are not adequate to deliver the level of security and reliability that both the industry participants and the consumers expect of an electricity supply in a first world country in the 21st century.

However, the assets, the systems and processes, and the people in the industry are integrated into an infrastructural delivery system which has historically shown that New Zealand is well served by a transmission grid that has first world reliability standards.

As noted in the introduction, New Zealand stands at a historic 40 year stepping point in development of the New Zealand grid. The original 110kV grid was introduced in 1920, forty years later in 1960 the 220kV grid was introduced. It is proposed to introduce a 400kV grid system in the 2000s, roughly forty years after the 220kV grid. The plans are in place to ensure the New Zealand electricity grid remains a resilient infrastructural delivery system.

All that remains is to continue to deliver on the promise of a first world electricity supply system to meet New Zealand's objective of climbing back up the economic league table to be in the top half of the OECD rankings.

References

Ancell, A., Edwards C., Krichtal V., 2005. "Is a large scale blackout of the New Zealand power system inevitable?" Paper, EEA Conference, June 2005

Fairley, Peter, 2004. "The Unruly Power Grid", *IEEE Spectrum*, August 2004, pp.16-21

Resilient Infrastructure: The View From Telecom New Zealand

Steve Fuller, General Manager Service Delivery

Abstract

Pre-1980 most utilities were owned by the Government or Territorial Authorities. In many cases they had a monopoly and hence competitive pressures like providing customer service (including resilience options) did not apply. In some cases resilience was provided by over-engineering. Key changes in this environment since the 1980s were the privatisation and consequent competition of many Lifeline Utilities, increasing centralisation of the operation of individual utilities (with consequent loss of local expertise) and greater outsourcing of functions.

The growing demand for communication services is clearly evident in all areas of business, society and personal lives. Communications at home, at work and on the move is required and the expectations of performance and content is ever increasing. Hand in hand with these expectations is the expectation of resilience.

Any communications network that touches every part of New Zealand will carry varying degrees of resilience within. While the central core components will be engineered to a high level of robustness, it is economically undesirable to carry this same level of engineering to all parts of the network, and hence the country.

Telecom's IP (Internet Protocol) network codes voice and data traffic as packets of information together with the IP address of the recipient. The packets are then able to select the fastest of many routes to the destination, where they are reformed in sequence. Such a transmission protocol takes advantage of a multiple diversity of routes to achieve excellent resilience. An IP network typically achieves very high availability performance, down to outage figures of only a few minutes a year. This is achieved through a combination of redundancy, diversity and rapid restoration.

Redundancy is achieved through investment in core routers having processor redundancy and a virtual-router function, routers being dual-homed, multi-layered security and the employment of "low-touch" infrastructure.

Rapid restoration is achieved through technology capability, effective assurance systems, proven processes and highly trained people. Key infrastructure components and links are monitored 24 hours a day, 365 days a year, and if momentary degradation is detected then automatic switching occurs. This execution is conducted within milliseconds and is transparent to the service.

Geographic diversity is provided over all core links between main network components; a ladder network of core fibre optic links is interconnected by rungs to provide multiple routes between nodes. All routes are geographically separated to be immune from a single event affecting both links. In the event of damage to any link automatic re-routing occurs, with no break in communications.

In addition, Telecom supports its high-availability network with engineering services designed to the same, if not higher levels of availability. All tier one sites have mains power split over two essential supplies plus back up engine-alternators with many days fuel capacity and a priority fuel supply. Sufficient back up power is available for the continued operation of the infrastructure therefore eliminating the immediate dependences of other utility providers. Civil engineering of both the structures and the contained infrastructure is designed to withstand the expected bounds of predicted earthquakes.

Finally, business continuity planning, disaster recovery procedures and crisis management exercises complete the picture in regards to infrastructure resilience in a communications network.

While sufficient steps can be taken to ensure internal resiliency (ie, within the direct control of the infrastructure owner) there are many external factors that pose a risk. Third party disruption to structures and cables has been, and remains, a considerable threat.

Infrastructure Resilience is primarily driven by market demand and the needs of society. To illustrate this point consider the scenario of a customer with dependent IT systems in 2 cities. Options available to achieve network resilience include buying capacity over links provided by two providers, buying diverse capacity from a single provider, or requiring the providers to swap capacity on each other's network. Irrespective of the combination, the level of the resiliency within each of the chosen routes is dependent on the above mentioned factors.

Telecom is well aware that customer expectations of resilience will change with time. Telecom experiences these rapid changes in expectation now due to the rapidly evolving nature of the technology and the use it is put to by customers. For example, 24 months ago very few customers had a fully IP network with all their applications integrated onto a single IP infrastructure. Today, with the flexibility of IP, many customers have voice, data and video services all operating over a single platform. They have also removed their distributed server farms for their many applications and put them into centralised data centres. All these changes mean that the customers are much more reliant on the network to deliver resulting economic benefits to them.

Customers and Telecom need to think about service delivery and network infrastructure design in a different manner to that of the past, to ensure improved resiliency. Thought is needed in regards to the impact of a single failure and the consequences on business and necessary steps to mitigate the risk. For example, with an all-IP network each business site needs to be assessed under failure conditions with appropriate diversity solutions in place. To manage this risk consideration must be given to geographical diversity and/or media diversity.

Remember resilience expectations change over time. What was a satisfactory trade-off between cost and benefits last year will almost certainly not be satisfactory next year. As businesses automate more of their processes their reliance on technology increases, the business impact of any technology failure also increases, so the resiliency offerings must increase over time.

This dilemma is the responsibility of both the infrastructure provider and the user.

Infrastructure Vulnerabilities – An NGC Perspective

Stuart Dickson, Strategic Asset Manager, NGC

NGC owns and operates 2300km of high-pressure gas transmission pipelines and 2500km of gas distribution networks throughout the North Island. It also operates and manages the Maui pipeline, and provides easement management services for other high-pressure petrochemical pipelines.

Natural gas has been an important energy source in New Zealand for three decades, but over the last few years the security of supply has become more critical due to the increased reliance on gas fired electricity generation. Until recently the gas supply security focus has been on field reliability, because of the Maui field dominance. With Maui declining and being replaced by several diverse fields, and the possibility of imported LNG or CNG, gas supply security will improve and there will be a greater focus on transportation security.

Auckland is the most critical region for gas supply with the greatest demand, highest rate of growth and a reliance on gas for electricity generation. Although there are currently two pipelines feeding Auckland from Rotowaro (near Huntly), they do not provide full N-1 security because of the relative pipeline capacities of the 14" and 8" pipelines. This issue is even more marked between Taranaki to the Auckland area where the two pipelines are 30" and 8" diameter. NGC is currently designating a pipeline route from Rotowaro to Auckland to for a third pipeline to meet the ongoing capacity and security needs of Auckland.

Gas transmission pipelines are generally independent of other infrastructures, running predominately in easements through private land. Sections of pipeline run in road corridors and also rely on road bridges for six river crossings. There is a significant reliance on the Telecom network to provide control and information via the SCADA system. Downstream of the transmission system, gas distribution networks are entirely dependent on the transmission system's security.

Over the past three years the vulnerability of the gas transmission pipeline has been demonstrated through two significant events. In 2002, gas supply to Wellington and the Hawkes Bay was interrupted for 24 hours after a bulldozer ruptured the 8" transmission pipeline at Himatangi (an unlooped section of the pipeline). Last year, the February floods caused a bridge washout that damaged the gas transmission pipeline feeding the Hawkes Bay and resulted in a 5-day loss of gas supply. Third party human factor is the greatest cause of pipeline failure, either through ignorance of the pipeline or failure to locate the exact position. This threat is increasing as urban development and land use intensity increases.

When a pipeline is ruptured, the linepack (gas stored in the pipeline) provides some supply resilience and, by implementing the shedding of large loads, usually enables critical supplies to be maintained while the pipe is repaired. The usable linepack is however linked to capacity and reduces over time as spare pipeline capacity is used up. If load shedding is not sufficient and gas pressure in a network is lost, the reinstatement process is time consuming with the need to purge pipelines and recommission all customers.

The gas pipeline infrastructure in New Zealand faces greater resilience challenges that many other countries due to the concentration of gas production facilities, the population distribution and difficult terrain. All natural gas originates in Taranaki and is transported to three main population bases – Wellington, Auckland and the Bay of Plenty. This results in a very linear infrastructure, rather than the grid-like network of pipelines that service the markets in USA, Europe and parts of Australia. The pipeline routes include difficult terrain with river crossings, earthquake fault line crossings and steep hills. While there are many engineering and operational steps taken to minimise the threat to supply security, the only real solution is to provide diversity via an alternative pipeline.

Providing the right level of security balanced with the lowest service cost is an economic challenge. In many areas, there is no pipeline redundancy. Following the flood related gas supply loss to the Hawkes Bay in 2004, the government and affected businesses questioned the appropriateness of a single gas supply into the region. The cost of providing an additional pipeline to a small market such as the Hawkes Bay is too high to be justified and would result in uncompetitive delivered gas costs. In these circumstances it may more efficient for industrial consumers to achieve N-1 security through alternative fuels (such as dual fuel boilers).

For larger load regions, especially where there is strong demand growth the issue of security and capacity are interrelated. As the gas demand grows, the pipeline system needs to deliver increased security as well as increased capacity. Increasing the capacity through additional pipelines achieves both of these objectives. Investment decisions are, however, rarely straight-forward with large cost steps required to meet incremental demand growth. The regulatory framework needs to support the investment decision. In particular, it is important that optimisation rules support resilience requirements by allowing N-1 where appropriate.

In Australia, the regulatory framework results in some inefficient investment decisions, such as sizing new pipelines for existing demand only to avoid the access regime. The negative impact of regulation on investment decision continues to be a source of frustration for gas transmission companies there. In New Zealand, Transpower face regulatory hurdles to investment through *ex ante* investment scrutiny by the Electricity Commission and *ex post* investment scrutiny by the Commerce Commission.

In conclusion, gas transmission resilience is facing growing pressure from increasing throughput demand, industry security expectations and competition from alternative fuels as gas prices rise post-Maui. It is therefore vitally important that the right economic and regulatory environments exist to enable the right investment decisions to be made.

Water – A \$40 Billion Dollar Issue

Peter Whitehouse, NZ Water & Wastes Association

Abstract

Water is essential to both our life and the economy. This paper argues whilst this is the case, water is undervalued and taken for granted. This has resulted in underinvestment in essential infrastructure and a failure to develop effective national strategies.

The approach to water is changing and this is driven, among other things, by concerns over flood risk and stormwater management and growing public awareness of water quality issues. The development of resilient infrastructure strategies faces a significant barrier in the form of public attitudes to water, many still believing it is a “right”. Systemic barriers are presented by the tensions inherent in the central and local government relationship.

A new paradigm needs to be developed that reflects the true value of water, is integrative in approach and fully engages all stakeholders. This new thinking must also include the development of a more effective infrastructure funding mechanism.

Introduction

Water – we are hearing about it a lot lately. There’s plenty of it, sometimes way too much in the wrong place. Much of it is out of sight underground. It’s taken for granted by most of us and few Kiwis could put a realistic value on it although it is essential to life and our economy. There is no uniform infrastructure or national strategies. But water issues are just as critical as transport and energy policies that, unlike water, have dedicated state agencies running agendas that capture national resources.

There is evidence that this is starting to change, not before time. Catastrophic flooding, most recently in the Bay of Plenty, claims about deteriorating water quality from agribusiness runoff, drinking water under the spotlight with an E-Coli case in Marlborough, proposed new national standards, questions over the effectiveness of some treatment facilities, and major debate over water use in the Waitaki catchment are currently the subject of public discussion and debate.

In dollar terms we are dealing with a resource that is of considerable significance. Although methodologies to value water are not particularly well developed, a 2002 White and Sharp investigation calculated the economic value of water in the Manawatu-Wanganui region as \$2.6 billion. Based on that value, an extrapolation presented at the NZWWA conference earlier this year suggests a value of \$35-\$45 billion for New Zealand’s fresh water assets¹.

The perception problem

Despite this obvious value and despite the increasing prominence of the issues, far too many people still seem to struggle to understand the value of water as an asset and the need to more accurately and transparently reflect that value.

Certainly, words like ‘markets’ and ‘privatisation’ sit uneasily with what some think is “God given”. This concern ignores the provisions of the Local Government Act 2002 which specifically prohibits local government from selling their water assets. It also ignores the reality that it is becoming increasingly clear that property rates and uniform annual charges are an inefficient way to provide capital for securing both a reliable and safe water supply and providing mitigation measures to better prepare for extreme weather events. As one overseas water executive noted, “God may give us water, but he doesn’t give us pipes and pumping stations.”

A recent case graphically illustrates the ambiguity with which water is perceived. The Auckland

¹ MED, 2005. Cited in Calman presentation to NZWWA conference, April 2005.

City-owned water and wastewater provider, Metrowater, revealed \$62 million in retained earnings. This news produced a flood of letters to the editor and press releases from councillors, mainly pillorying Metrowater for having the temerity to make a profit. Some went so far as to suggest that because water was a “right” Metrowater’s services should be strictly non-profit, while others called on the Council to direct Metrowater to divide the \$62 million up and refund individual consumers.

Unfortunately, what was missed in all this was the meaning of the phrase “retained earnings”. It was not 100% profit – part had been paid to Auckland City as a dividend and I understand an even more significant part has been used in ongoing infrastructure upgrades.

This example serves to illustrate the point that public perception presents a significant barrier to achieving “resilience” in the water area.

(I would note in passing that much of the angst generated by the Auckland situation is related to the fact Metrowater introduced water metering and more latterly wastewater metering. Metering has also been introduced by United in Papakura. Critics claim this is a forerunner to privatisation but ignore the fact that the evidence is now irrefutable – metering and pricing water services are a very effective way to conserve the resource. Metrowater and United have seen demand levels remain constant while the other supply authorities in the Auckland region have seen steadily increasing consumption.)

Water Use

So what is it used for? Work done by Lincoln Environmental in 2000 showed that:

- 77% of water allocated is for irrigation (including stockwater), 16% is for community, municipal and domestic uses, and 7% is taken up by industry;
- 58% of water allocated is allocated from the Canterbury region. The North island accounts for 17%; and,
- 19% of the current allocation has been allocated since 1990. The significance here is that the majority of water allocated was allocated under regimes that predate the RMA.

(Note hydro-electricity data and other non-consumptive uses were excluded from the analysis)²

Clearly water is an extremely important and valuable resource economically. It is also, in the form of streams, rivers and lakes, an extremely important community asset. Unfortunately, there has also been a marked unwillingness by both central and local government to seriously address the allocation issues. The Lincoln University study noted, for example, that while the Canterbury region uses more freshwater than any other region in the country, none of the four councils studied had an approved water plan.

Similarly, an OECD environmental performance review of New Zealand carried out in 1995/96 specifically recommended the implementation of robust demand management practices, the introduction of pricing mechanisms that addressed the user pays principle, and greater co-operation between regional councils in sharing costs and expertise.

The issues surrounding water are thus not simple or inexpensive to resolve. A number of conflicting demands have to be met. An engineering solution is often only part of the solution – community and political aspirations are also a critical part of the mix.

Unlike Australia this country has an abundant overall supply. The problem is that at the regional level difficulties regarding the allocation, delivery, quality, and flood management of that supply are beginning to emerge. And Australia has a clear head start in implementing solutions.

Project Aqua, and the subsequent debate over the allocation of the water from the Waitaki catchment, has highlighted the question of what is the most appropriate way to deal with conflicting demands. There, the debate is predominately about the relative importance or value

² Op cit

of electricity generation versus the water demands for land that has been converted to high value agricultural and horticultural uses. Elsewhere there are different factors constituting the same problem.

Physical Infrastructure

In a July 2000 report, “Ageing Pipes and Murky Waters: urban water issues for the 21st century”, the Parliamentary Commissioner for the Environment estimated that about \$5 billion will be required over the next 20 years to upgrade water, wastewater and stormwater infrastructure³. A subsequent report, “Beyond Aging Pipes”, noted that submitters on the original report indicated widespread support for a new approach to pricing water. The Commissioner also noted considerable community disquiet over privatisation and made a number of specific recommendations on how it could be ensured the necessary policy was put in place to support this critical infrastructure area⁴.

However, again only limited advances have been made in improving what the Commissioner described as, *“the fragmented nature of water systems management”*.

We now have the preliminary outcomes of the latest government efforts to address water issues – the Water Programme of Action. Five reports have been released, a number of interesting suggestions are made, but throughout the reports there is repeated evidence of an underlying problem that I would contend continues to obstruct the introduction of an efficient and effective process to ensure we achieve and maintain resilient water infrastructure.

I refer here to the dichotomy between central and local government. On the one hand local government wants central government finance for infrastructure development or remediation – but resists being told what to do with the finance. On the other hand central government says it recognises significant problems exist at the local level, but seems unwilling to provide clear leadership.

Let me illustrate the problem by a couple of quotes from one of the reports:

“Central government involvement was generally supported if it involved providing guidance, support and funding. Interference in the management of water at the regional level was not supported”.

and

“Central government has an overview role to ensure regional councils are doing their job adequately, but councils don’t want to have to report to central government”⁵

While the reports acknowledge infrastructure development has failed to keep pace with water demand and while the phrase “integrated approach” is often used, it is clear that unless this fundamental issue of the respective roles of central and local government is resolved resilience will remain elusive.

I do not have the time here to discuss in any depth why this tension between roles exists. It is, however, worth noting that the advent of the RMA saw the demise of a number of institutional frameworks in the water area, and the Local Government Act amendments of 2002 introduced a number of concepts that while purportedly were intended to improve local government performance may, in fact, have introduced further obstacles to an integrated approach to infrastructure development.

There is little point in looking to the past for solutions, or engaging in a culture of blame. There is a clear and urgent need to develop new ways of thinking about how we address our

³ Parliamentary Commissioner for the Environment, June 2000. Ageing Pipes and Murky Waters, pp23.

⁴ Parliamentary Commissioner for the Environment, April 2001. Beyond Ageing Pipes, pp 12-19

⁵ MfE/MAF, 2005. Report of the Sustainable Development Water Programme of Action Local Government Workshops, pp 16,17

infrastructure problems. I doubt many would seek a return to strong central planning and over reliance on local solutions has clear limitations.

As I noted at the outset there are currently a number of issues surrounding water and if we take a broad interpretation of the word they are all “infrastructure” issues.

By way of example, let us briefly consider two of them - water quality and flood management.

Water quality, particularly drinking water, is clearly an important issue. The majority of the reticulated drinking water in this country is, however, of a high standard. The problems are appearing in areas that often have both a limited funding base for necessary improvements or face growing population pressures, often from tourism.

New drinking water standards are likely to be introduced soon. \$150 million has been allocated to assist with their implementation. Without debating here the appropriateness or otherwise of a “one size fits all” approach by officials to the new standards, it is clear a combination of aged assets and capacity limitations in a number of jurisdictions, will make widespread adoption of the standards a potentially very expensive exercise. It may, in fact, not even be achievable without funding assistance substantially beyond that currently available.

And those problems are not just limited to drinking water. The same areas are often at risk from flood damage. A history of underinvestment and inadequate forward planning are now starting to reveal significant infrastructural deficits.

One unsurprising area that is at last being given a degree of high level attention is of course that of flood management. As we heard yesterday afternoon, in response to clear shortcomings with the regional approach, the Government has now commissioned the development of a recommended Flood Risk Management “Protocol”.

The associated report from the Centre for Advanced Engineering, “Managing Flood Risk: The Case for Change”, calls for, “...an effective national risk management framework wherein roles and responsibilities are clear, programmes are fully integrated, and the relationships amongst the organisations are well managed, providing individuals and their communities with a strategic, seamless service”. The report also notes that, “the current fractured dialogue amongst these (the various agencies) brings little progress in the reduction of risk to communities, flood risk being but one risk.”⁶

Strong words perhaps, but appropriate. Water, be it in terms of flood management, in managing conflicting demands or in implementing drinking water standards, requires an integrated and well managed approach. In parts of the country communities and their local agencies are dealing with the issues well. Nowhere is there any great sense of urgency or national priorities. This needs to change.

Conclusion

I would conclude by recommending to you several key principles we need to consider if we wish too arrive at a point where we can say we do have a resilient infrastructure environment. They are not new – they will be familiar sentiments to many of you who have considered how we might improve that environment:

- we need to develop new models of effective and efficient asset management;
- the public must be fully engaged – this is not just an engineers game;
- it is essential to price the true cost of water and water services;
- we need to carefully consider the role of public funding – it must be allocated strategically and not used to pick winners or attract voters;
- equity needs to be promoted over the long term; and,
- we need to encourage both technical and institutional innovation.

⁶ Centre for Advanced Engineering, May 2005. Managing Flood Risk, the case for change – Consultation Draft

New Zealand Infrastructure Vulnerabilities: A CCIP Perspective

Chris Roberts, Manager, Centre for Critical Infrastructure Protection

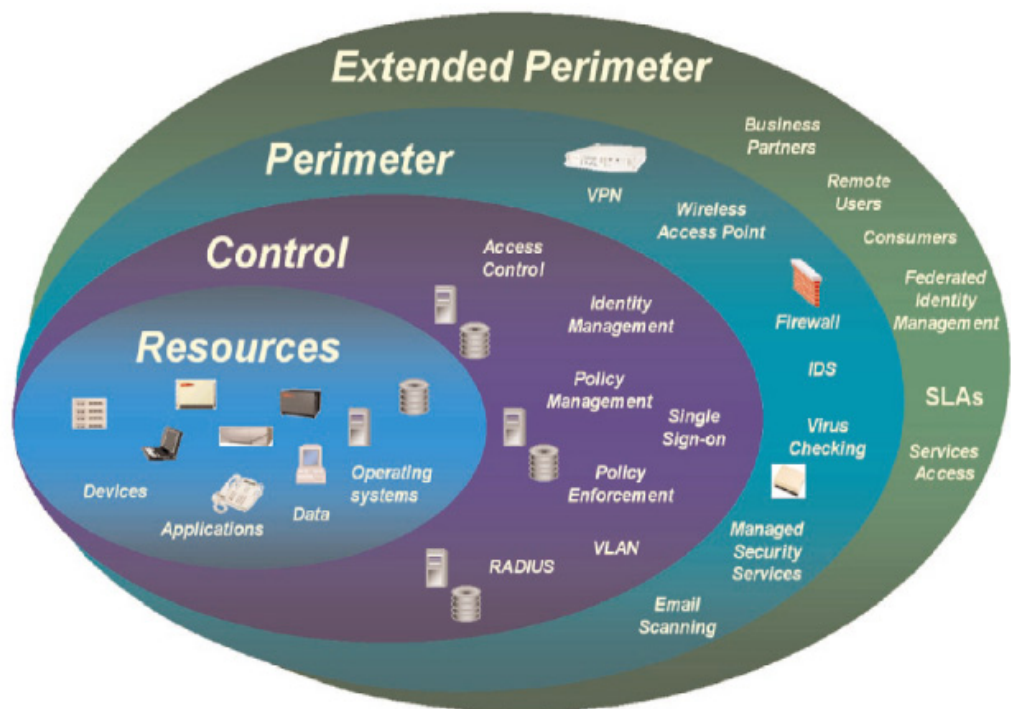
Background

A new mega structure is emerging from the convergence of energy, telecommunications, transportation, the Internet, markets and e-commerce. Moreover, some of these critical infrastructures are seeking new ways to improve network efficiency and eliminate congestion problems without seriously diminishing reliability and security (IEEE Security and Privacy, May/June 2005)

Today's electronic environment is characterised by:

- Increasing dependence on the Internet and telecommunications systems;
- Convergence of technologies;
- The extension of corporate perimeters; and
- Remote control of critical systems.

Each of these characteristics brings special challenges to an organisation, in particular a critical infrastructure organisation. The consequences of a systemic failure have never been greater.



Source: Avaya Corp, based on Burton Group's Layered Security Model

Since commercialisation of the Internet, there has been one key constraint - applications could not communicate directly. The WWW is interactive, **not** batch oriented, reflecting the immediacy expected in transaction processing and response times.

Technology has now evolved to allow integration of diverse applications. This requires a Service Oriented Architecture (which incorporates Web Services standards and other common Internet technology). However, dependence on the Internet brings with it all the risks, vulnerabilities and threats that exist in today's cyberworld.

Threats and Risks

Hackers are now targetting applications directly and often ignoring operating system and organisational technology infrastructure attacks. While operating system and border security operates with varying degrees of success, application security in the web environment is generally poor.

This situation motivated a group known as the Open Web Application Security Project to define the most common problems with applications and provide guidelines on secure programming (www.owasp.org). These include:

- Applications issues are not only caused by poor programming, techniques and management;
- Poor business logic often exacerbates the security problem; and
- Technology cannot help an organisation significantly if its applications are written badly.

Apart from well-designed and written systems, organisation security depends on robust and secure enterprise and security architectures. While we know how to build better systems, there is often reluctance to incur the direct costs associated with secure systems. One useful way to demonstrate the value of secure systems is a robust enterprise and security architecture.

Enterprise Architecture

The individual components of an enterprise architecture provide increasing levels of detail about the enterprise, including:

- Objectives and goals;
- Processes and organisation;
- Systems and data; and
- The technology used.

Enterprise architecture has been depicted in several models including the Zachman model, the Institute for Enterprise Architecture Development (IFEAD) – Extended Enterprise Architecture Framework and the Lockheed Martin Corporation model developed for the US DOD.

The questions arise, is enterprise architecture necessary and why is it important?

Enterprise architecture has a number of benefits including:

- Providing guidance on the development of systems and services;
- Establishing standards and practices adopted by everyone in the organisation;
- Ensuring consistency across projects;
- Enhancing the overall quality of deliverables;
- Reducing overall complexity and cost and
- Improving security.

Security Architecture

Security architecture is an element of enterprise architecture that had been excluded in earlier models and concepts of enterprise architecture. It first appeared as a distinct element in the Lockheed Martin model (2002). In this model, security is part of the technology perspective.

Unfortunately security is often not specified in architectural designs and security issues are often not clearly addressed in the architecture specifications. In addition a purely technical perspective often ignores the relationship to the security management framework and the concept of business risk.

Architecture Standards

A number of architectural standards have been developed and are gaining acceptance. These include:

- IEEE Standard for Architectural Description;
- ISO Reference Model for Open Distributed Processing;
- Software Engineering Body of Knowledge;
- IEEE Recommended Practice for High Level Architecture Federation Development and Execution Process;
- IEEE Architecture and Reference Working Group; and
- Open Group – Architecture description and Markup Language.

A Suggested Approach

A suggested approach to the question of enterprise and security architecture is:

- Assess and prioritise the risks;
- Acknowledge that risk evolves over time requiring regular re-assessment;
- Adopt a philosophy of protect, detect, react, forecast together with “defence in depth”;
- Ensure security is incorporated in any architectural design;
- Recognise interdependencies with providers, customers and suppliers; and
- Develop and regularly test the Disaster Recovery and Business Continuity Plan DRP/BCP).

Summary

- Enterprise and security architectures are fundamental to continued secure operations;
- Architecture standards are emerging;
- Web Services provides integration for diverse applications; and
- Applications are a major source of security breaches.

Architectural Standards

IEEE 1471-2000 Standard for Architectural Description

IEEE Standard 1471-2000 is IEEE’s Recommended Practice for Architectural Description of Software-Intensive Systems description (AD) to conform to the standard.

ISO Reference Model for Open Distributed Processing; ITU-T Rec. X.901, ISO/IEC 10746-1 to ITU-T Rec. X.904, ISO/IEC 10746-4

Commonly referred to as *RM-ODP*, provides a framework to support the development of standards that will support distributed processing in heterogeneous environments. It is based, as far as possible, on the use of formal description techniques for specification of the architecture.

Software Engineering Body of Knowledge

The purpose of SWEBOK Guide is to provide a consensually-validated characterization of the bounds of the software engineering discipline and to provide a topical access to the Body of Knowledge supporting that discipline.

IEEE P1516.3 Recommended Practice for High Level Architecture Federation Development and Execution Process.

One of the new standards projects started in 2002. IEEE P1516.3 will give the HLA user community a definition of the processes and procedures to use in developing and executing federations. It will provide a higher-level framework into which low-level management and systems engineering practices native to HLA users can be integrated and tailored for specific uses.

Open Group - Architecture Description Markup Language (ADML)

The Architecture Description Markup Language (ADML) is an XML-based representation language for architecture. It was originally developed by the Micro-electronics and Computer technology Consortium (MCC) as part of MCC's Software and Systems Engineering Productivity (SSEP) project.

IEEE P1484.1 Architecture and Reference Model Working Group

This standard specifies a high level architecture for information technology-supported learning, education, and training systems that describes the high-level system design and the components of these systems. This Standard covers a wide range of systems, commonly known as learning technology, education and training technology, computer-based training, computer assisted instruction, intelligent tutoring, metadata, etc.. This Standard is pedagogically neutral, content-neutral, culturally neutral, and platform-neutral. This Standard (1) provides a framework for understanding existing and future systems, (2) promotes interoperability and portability by identifying critical system interfaces, and (3) incorporates a technical horizon (applicability) of at least 5-10 years while remaining adaptable to new technologies and learning technology systems. This Standard is neither prescriptive nor exclusive.

Infrastructure Vulnerability: Presentation Synopsis

Bruce Johnson – Ministry of Transport

The evolution of New Zealand's transport system has been characterised not only by the country's remoteness from many of its trading partners, but also by its relatively low population density. International air and telecommunication links have helped overcome the country's isolation, but there is an almost total reliance on sea transport for overseas trade and nearly all cargoes passing through New Zealand ports require some form of inland transport.

The transportation industry uses multi-modal transportation networks as a means to increase efficiency, improve timeliness and expand profitability in a highly competitive environment. The rapidly growing multi-modal concept supports the movement of cargo by container using two or more modes (ship, air, rail, and/or truck).

Today the proliferation of information technology, along with the increased use of automated monitoring and control systems and the reliance on the open marketplace for purchasing and selling infrastructure commodities and services has increased the prevalence and importance of cyber and logical interdependencies. This is an increasingly important consideration for transport as the sector becomes more and more reliant on IT systems.

In recent years the emphasis on aviation and maritime security has intensified, with legislative frameworks being developed and new operational measures being implemented in both sectors. This focus on security has not occurred to the same extent in the land transport sector. The Ministry of Transport recently commissioned a stock take of how well New Zealand is prepared to respond to either natural or man-made hazards involving threats, or actual damage, to critical land transport infrastructure. The review identified a number of transport vulnerabilities that will need to be addressed in the future.

At the most basic level, strengthening our resilience to hazards in the transport sector requires the joint effort of central and local government together with the private sector and communities. Transport infrastructure service providers can ask themselves a number of relatively simple questions. Does another infrastructure affect yours directly or indirectly? Do dependencies on other infrastructures hinder your response and recovery efforts? What backup systems or other mitigation mechanisms are in place to reduce the impacts? This information will at least begin to provide a foundation for making justified, cost-effective infrastructure operation and management decisions to ensure the security and reliability of interdependent systems.

Safeguarding Australia

Kevin Murray, Chief Executive, TransGrid

Introduction

This paper is prepared on the basis of the knowledge and experience of the author in managing high voltage electricity transmission infrastructure. Specifically, the author is the Chief Executive of TransGrid, a New South Wales State Owned Corporation responsible for providing the high voltage electricity transmission connection between generating stations and electricity distribution companies.

To provide this service TransGrid has 12,500 kilometres of transmission lines and 82 high voltage bulk supply substations. As a bulk carrier of electricity it has long been recognised that the effective management of this infrastructure is necessary as electricity is an essential service for industry, commercial and domestic users and in many cases is a vital input for other essential services such as water, sewage, health, transport and communications.

In order to achieve the required high level of reliability expected of a bulk supplier of an essential service, it is necessary that the infrastructure be managed within a total asset management framework. For TransGrid this translates into the key components of infrastructure planning, asset maintenance, asset replacement, asset security, emergency response, business continuity and risk.

Planning

The fundamental resilience or reliability of a network is in the very first instance determined by the approach and policy applied to planning the network i.e. who is responsible for planning, how is it co-ordinated and what is the policy in terms of redundancy (or backup). In Australia planning is undertaken at a national level by the National Electricity Management Market Company (NEMMCO) and at the State level by the Jurisdictional Planning Body which in several cases is the State's Transmission Network Service Provider (TNSP).

NEMMCO is responsible for:

- Statement of Opportunities for the National Electricity Market - this is a document that is produced annually and provides information on the projected supply-demand balance to meet demand in the National Electricity Market for the upcoming 10 years. It is intended as a mechanism by which the market is given signals on the future need for generation plant
- Annual National Transmission Statement - this is a document that is produced annually to provide details on the major national transmission flow paths, economic and other indicators for these flow paths and identify possible upgrade options for these flow paths.

In NSW, TransGrid has been nominated by the Minister to be the Jurisdictional Planning Body. In this role it is required to prepare and publish an Annual Planning Report that records the results of joint planning undertaken with Distributors, considers load forecasts submitted by the Distributors, reports on proposals for future connection points and forecasts network constraints.

TransGrid is expected by the NSW jurisdiction to plan and develop its transmission network on an "n-1" basis. That is, unless specifically agreed otherwise by TransGrid and an effected network owner or major directly connected end-use customer, there will be no inadvertent loss of load for the outage of a single circuit or transformer, during periods of forecast high load.

When the NSW network planning criteria of n-1 under peak load conditions is factored in with NEMMCO's main network security and constraint requirements it results in the network being highly resilient to loss of network elements or loss of generators - particularly so outside of peak load conditions.

Asset Management

Given the redundancy that is built into the network the next priority in achieving resilience is to ensure that the assets that make up the network are effectively managed to the extent that a fault on a network element does not result in cascading failure of other network elements. A simple example is the failure of an insulator string on a transmission line and an ensuing slow operation of a circuit breaker may cause high loadings on other network elements and subsequent tree contacts and over heating of clamps with poor conductivity - the result as has been evidenced overseas can be a total system shutdown.

In TransGrid the management of assets is undertaken within a Total Asset Management framework and is communicated in a 5 yearly Network Management Plan. The Plan specifically describes and details the planning and service delivery strategies and the resulting capital investment strategy. It also describes the management support systems such as quality, health and safety, environment and emergency management.

In terms of asset management, the Plan and supporting policies details the specific strategies and maintenance programs for each of the network asset categories e.g. transmission lines and transformers. The Plan also details the different measures used to assess and monitor the performance of the assets including technical performance assessments, quarterly asset performance reviews and benchmarking studies.

Some of the key elements of TransGrid's Asset Management model are described in more detail as follows:

- Policy and Strategy Development - asset maintenance policy and asset replacement or refurbishment strategies are developed by asset functional cross-section working groups made up of design, maintenance and asset management personnel. The policies are reviewed and updated annually and take account of factors such as safety, defects, maintenance history, condition monitoring information, new technology, cost, equipment criticality and benchmarking. In the case of the asset replacement strategies these are subject to full business case analysis and are also reviewed by an independent regulator.
- Compliance - a key target for the organisation is that at least 95% of the maintenance plan as derived from the maintenance policies is required to be completed each year with the uncompleted maintenance required to be completed as first priority in the following year. Technical Performance Assessments (or audits) are conducted on compliance with the maintenance policies and achievement of the maintenance targets. The Assessments also include a visual inspection of the assets to ensure that not only is the work being done, but that it is effective.
- Performance Monitoring - monthly, quarterly and annual reviews are undertaken of key performance indicators such as reliability, availability, forced outages, significant failures and asset defects. The national Regulator has also included a penalty/incentive payment for service performance in TransGrid's revenue determination.

The aforementioned process has resulted in TransGrid's asset maintenance operating costs being reduced by 40% since its establishment in 1995 without any decrease in the reliability or availability of the network. More significantly however is that the service performance of some key network elements such as transformers and reactive plant have been improved. There has also been a significant reduction in high impact explosive failures which can have significant safety, environment, reliability and co-lateral damage implications.

Network Security, Emergency Response and Business Continuity

TransGrid's infrastructure is subject to security risks emanating from a number of threat sources, all with variable likelihood and consequences. Incidents may range from unauthorised access (children wishing to retrieve lost objects), vandalism and criminal acts through to sabotage and terrorist acts. To reduce the likelihood of these threats being realised TransGrid has developed and commenced the implementation of a Security Upgrade Plan based upon the principles of deter, detect, delay, report and respond.

These treatments have been applied to TransGrid's infrastructure following a risk assessment of the assets, which then ranks assets into Critical, High, Medium or Low risk categories. Treatments at critical substation sites include high security perimeter fences and gates, closed circuit cameras, monitored intrusion detectors, access control, movement activated lighting and signage.

In the event that despite the level of redundancy in planning, well established and good industry practice in terms of asset management and high levels of a security a catastrophic failure, natural disaster or determined attack on our assets occurs then it is essential that a well prepared and rehearsed emergency response is able to be activated to mitigate the impact of the event.

TransGrid has in place Corporate and Regional Emergency Response and Business Continuity Plans. These Plans have direct linkages to NEMMCO's Plan and State Government Jurisdictional and State Emergency Management Plans and Legislation. The Emergency Response Plan has 5 levels of emergency with Levels 1 to 3 primarily being incidents that are within the control and capacity of the TNSP.

A Level 4 Incident is an incident, which goes well beyond TransGrid's area of operations, the overall system safety and integrity is in jeopardy and/or the impact is such that it requires a coordinated response from multiple industry participants. Level 4 incidents are coordinated by NEMMCO.

A Level 5 Incident is a Level 4 Incident in which the incident has escalated to a point that the Government reasonably believes that it needs to intervene. The Government may invoke its powers to employ energy rationing or the State Counter Disaster Plan.

At least annually NEMMCO, industry participants and the jurisdictions participate in a joint simulated emergency exercise to practice the Plans and to identify any improvements.

In addition to the aforementioned systems and processes for protecting TransGrid's high voltage infrastructure the Australian and New South Wales Governments have produced guidelines for protecting critical infrastructure from terrorism. The guidelines describe the requirements for critical assets to be assessed for risk and then depending upon the risk assessment to be classified into defined levels of criticality. The level of criticality then sets not only the level of permanent security but also the level of interim security. The level of interim security is dependent upon the national counter terrorism threat levels, which can be varied from time to time.

The Guidelines also require owners of critical infrastructure to establish an organisation security committee and for this Committee to oversee the risk assessment, conduct audits and to prepare and test response plans.

Protecting Critical Infrastructure Systems

Ian Buckle, University of Nevada Reno

Abstract

Today, life-safety is no longer the sole requirement of successful design for extreme events but is augmented by other performance criteria such as functionality and minimal economic loss. This realization has led to the concept of *performance-based seismic design* which is a relatively new development in the design and construction of civil infrastructure. Nevertheless substantial progress has been made in this direction particularly with respect to the performance of individual components of the built infrastructure, such as buildings and bridges. But the real potential for performance-based design comes when these concepts are applied to systems and subsystems of the infrastructure, such as transportation networks. The concept applies to system performance under both service load conditions and extreme events.

This paper describes current efforts to apply performance-based design to the earthquake performance of highway networks in the United States. In recent years, a major review of performance criteria for bridges has been undertaken and a move towards performance-based, multi-level seismic design of bridges has begun. In a parallel exercise, a risk-based methodology has been developed for assessing the performance of highway systems taking into account the seismic fragility of bridges and their interconnectivity, and estimating congestion and delay times. These efforts have opened the door to performance-based seismic design of highway systems, in which system-level performance criteria, such as maximum permissible traffic delay times and minimum restoration times, are targeted for highway systems immediately following earthquakes of different sizes. This paper explores the feasibility of such a design approach and potential applications for resource allocation and emergency planning.

The methodology extends to other critical infrastructure systems, such as mass transit, water supply, telecommunications and to other extreme events, natural or manmade.

Introduction

Earthquakes remain one of the world's major problems. They occur frequently and result in high death tolls, thousands of injuries, and crippling economic losses. On average, there are more than 1,000 earthquakes of magnitude 5 or greater every year worldwide, 100 M6 or greater, 10 M7 or greater, and one M8 or greater earthquake.

A single large earthquake is capable of causing losses in excess of \$100 billion to the built and human environment, more than twice the loss in the 1994 Northridge earthquake, the most costly U.S. earthquake to date. The Northridge earthquake was catastrophic, not because of lives lost (approximately 60) but because the economic loss exceeded \$40 billion, the affected region was overwhelmed, and interregional assistance was essential for recovery.

For many years earthquake engineering research around the world has focused on saving lives and minimizing the number of injuries, but, we now recognize that earthquake prediction is not the key to risk reduction, and that the protection of human lives is a necessary but not sufficient goal to minimize the social and economic impacts of a major earthquake. Recent data from U.S. natural disasters (Figure 1) show that, despite the advances in earthquake engineering to date, and other natural hazard mitigation programs, economic losses due to natural hazards in the U.S. are escalating at an alarming rate, particularly over the last 25 years.

In a recent report by the Earthquake Engineering Research Institute of the United States (EERI 2003), it is argued that the prime factor for these increasing losses, is the continued population growth of the United States and the corresponding economic investment necessary to sustain the nation's quality of life. Population and economic growth in turn lead to an esca-

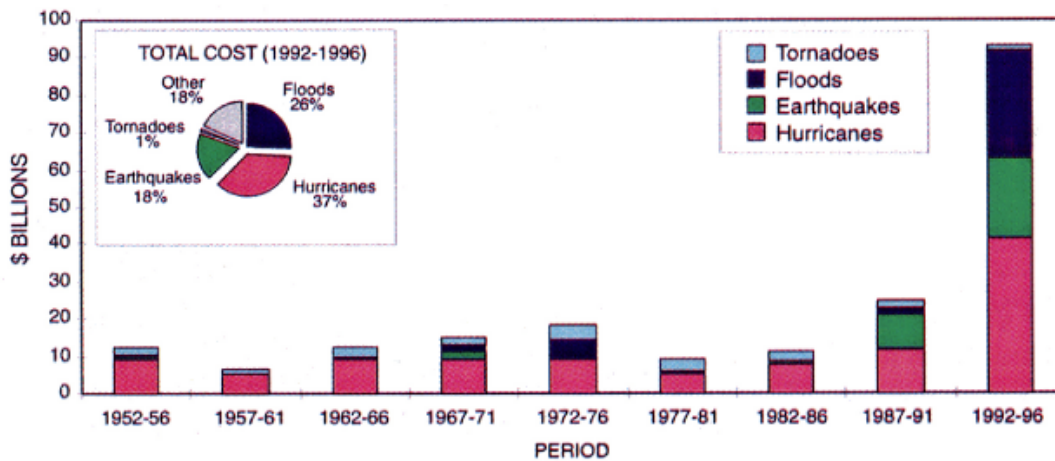


Figure 1: Direct Costs of Structural Repair and Replacement for Natural Disasters in the United States, 1962-1996 (van der Vink et al., 1998)

tion in the extent, complexity, and interconnectedness of the built environment (homes, schools, office buildings, factories, industrial plant, highways, bridges, mass transit systems, dams, reservoirs, waste water systems, electric power and telecommunication systems). This growth results in an ever-increasing number of lives at risk and a rapidly expanding inventory of construction that is exposed to earthquake hazards.

Although new construction is typically less vulnerable to damage than older construction because of advances due to NEHRP and other programs, the exposure of the nation to catastrophic loss continues to grow because of the following factors (EERI, 2003):

- The primary objective of building codes and regulations is to protect the lives of occupants, rather than avoid future economic loss. Whereas new facilities are expected to protect human life, they also present significant economic risk to their owners and society-at-large. Furthermore, despite recent advances, current building codes are based on incomplete knowledge about structural and foundation performance, resulting in the construction of facilities that while code-compliant, may have significant vulnerability.
- The knowledge of earthquake hazards and their impact is still evolving, and we continue to design and construct new facilities without fully understanding the potential hazards.
- The cost of using current technology to rehabilitate older construction is often high, as is the cost of improving new construction to minimize risk. Decision makers either do not completely understand the risk, or do not perceive adequate economic incentives to warrant the investment and lack the decision-making tools necessary to identify these incentives.
- The growing interconnectedness of society, enabled by extensive transportation systems and modern communications, greatly expands the impacted area of a damaging earthquake far beyond the epicentral region. Global trade, commerce, and defense, may all be affected if a critical link in a communications or distribution network is taken out of service by an earthquake. A local disaster can quickly become a national one, which in turn leads to an escalation in financial loss not seen in earthquakes of a decade ago.

The time has come to focus on controlling the economic and social losses from future earthquakes, in addition to life-safety, to prevent a socioeconomic catastrophe. Gaining this control can likely be achieved by addressing each of the above bulleted items in turn but in this paper we address only the last bullet: that of growing interconnectedness and the vulnerability of our transportation systems and other critical infrastructure. We do this by presenting a case study in recent developments to understand and protect highway systems

A case study in critical infrastructure systems: highway systems

The seismic performance of highway systems in recent earthquakes has been less than satis-

factory. In the last decade, numerous highways have been closed due to earthquakes in California, Costa Rica, Japan, Turkey and Taiwan, and although life-safety was generally preserved, public frustration with closures and restricted access has been widespread.

Just as with many other lifeline and infrastructure systems, highways are rarely designed for seismic loads and there are no known codes or specifications for the seismic design of highway systems. Instead most of the progress that has been made towards reducing the vulnerability of these systems has been directed towards the performance of bridges, essential components of most highway systems. But despite the widespread use of seismic bridge codes and specifications, many of the highway closures in recent earthquakes have been due to bridge damage and collapse.

Historically, the United States and many other countries have used a single-level earthquake to seismically design bridges and other structures. This earthquake, usually called the *design* earthquake, is intended to represent the largest earthquake that could reasonably be expected to occur during the life of the bridge. Inherent in such a statement is the notion of 'uniform risk' since the design level is intended to be an earthquake with the same probability of exceedance from one region to another, rather than using the maximum historical event for each region, which may have a very low probability of occurrence.

The *Standard Specification for Highway Bridges* in the United States (AASHTO 2002) adopted this uniform risk approach following the 1989 Loma Prieta earthquake, and uses a level of hazard that has a 10% probability of exceedance in a 50-year exposure period. This corresponds to an event with a return period of about 500 years (actually 475 years). In more recent years the exposure period has been adjusted to 75 years, corresponding to the assumed life of a normal highway bridge. The probability of exceedance was then raised to 15%, so as to maintain, approximately, the same return period (500 years).

At the same time as adopting this uniform risk approach, a corresponding set of performance expectations were included in the philosophy of the AASHTO specifications (AASHTO 2002). These are given in Art. 1.1 of the specification and summarized below:

- Small to moderate earthquakes should be resisted within the elastic range, without significant damage.
- Realistic seismic ground motion intensities and forces are used in the design procedures.
- Exposure to shaking from large earthquakes should not cause collapse of all or part of the bridge. Where possible, damage that does occur should be readily detectable and accessible for inspection and repair.

A set of basic concepts for seismic design was derived from this philosophy (Art. 1.3, AASHTO 2002), and these are summarized below:

- Hazard to life to be minimized.
- Bridges may suffer damage but have a low probability of collapse.
- Function of essential bridges to be maintained.
- Ground motions used in design should have a low probability of being exceeded in the normal lifetime of the bridge.

Characterized by a lack of specificity, these criteria were nevertheless a significant advance over the then prevailing requirements for seismic design.

By contrast, little has been achieved by way of assessing the performance of an inventory of bridges interconnected by a network of roads, and subjected to the same earthquake. Nor have other components of highway systems (retaining walls, slopes, tunnels, culverts and the like) been systematically studied and their contribution to system vulnerability determined. Applications of seismic risk assessment procedures to water supply systems and other utilities have been developed, but until very recently their application to highway systems had not been attempted.

Bridges are critical components of highway systems and with few exceptions are designed to single-level performance criteria. Furthermore, the overall impact of bridge vulnerability on the performance of complete highway systems is not generally known, due to lack of data on the other components of highway systems and a credible methodology for performing such an analysis. Improving the performance of bridges, and the systems of which they are part, is urgently required. Performance-based design and seismic risk assessment procedures appear to offer a way forward.

Performance-based design of bridges

The assumption is made in single-level design (and retrofit) that if performance at the design event is satisfactory, it will be satisfactory at all other levels, both smaller and larger. Such an assumption is generally not true, as seen in recent earthquakes in California, Costa Rica, Japan, Turkey and Taiwan. It would be true for smaller events if elastic performance was required at the design event, and it may also be true for larger events, if the design event was sufficiently large and a generous degree of conservatism used in the design. But under the design event, inelastic performance (damage) is explicitly intended (in most bridges), and provided life safety is preserved, the consequential restrictions on access are considered to be tolerable.

However, these restrictions become unacceptable, if they were to occur on a more frequent basis such as during a smaller earthquake. Since this is a nonlinear problem, assurances regarding performance during smaller earthquakes cannot be obtained simply by scaling performance at the design event and thus explicit design (or at least a design check) should be made at this level, to gain this assurance.

Similarly, performance during a larger event cannot be estimated by scaling upwards and relying on reserve strength. Without explicit quantification, this approach is unreliable because it is based on engineering judgment and an experience database that is thin and largely unverified, especially in the central and eastern United States (CEUS).

The argument is thus made, that to avoid adverse performance, such as seen in Loma Prieta, Northridge, Kobe and Taiwan, explicit consideration of bridge performance during at least two levels of earthquake (and perhaps more) should be undertaken. Furthermore, the expected level of performance during these earthquakes should be stated with a greater level of specificity than has been the case in the past, and assurances given that these performance levels will be met. This argument leads to the consideration of performance-based engineering for the seismic design and retrofit of bridges.

Performance based engineering (PBE) has been defined as consisting of the selection of design criteria, structural systems (layout, proportioning and detailing), and the assurance and control of construction quality and long-term maintenance, such that at specified levels of ground motions, and with defined levels of reliability, *the structure will not be damaged beyond certain limiting states or other usefulness limits*. (SEAOC 1995). This definition has been paraphrased from that developed for buildings in the SEAOC Vision 2000 Project where PBE was explored and its potential for improving the seismic performance of new buildings was clearly demonstrated.

Application of the design phase of PBE requires several fundamental issues be addressed. These include:

- Selecting the ground motions (hazard levels) and corresponding damage states (performance objectives)
- Developing analytical methods for the verification of damage states and performance objectives.

The first of these bullets requires that ground motions be known with a degree of confidence (i.e. the 500-yr seismic design coefficient for a given bridge in a given site class, is known within acceptable limits), and that realistic and meaningful objectives can be defined. The second bullet requires a level of sophistication in analysis that can be implemented with ease and reliability. Further, the relationship between damage states and performance objectives (such as crack width to lane closures) must be not known with a degree of certainty.

Hazard levels and performance objectives for bridges

Factors to be considered when selecting hazard levels and setting performance objectives include:

- How many earthquake levels should be used? Ideally it should be many, but in practice two or three levels should be sufficient to assure that the desired range of performance is achieved. These might be *small, moderate and large* if three events are favored, or *small and large* if only two events are considered. In the latter case, they might also be referred to as *frequent and rare* events.
- How many different kinds of bridges should be considered? It is unreasonable to expect that all bridges should have the same performance criteria for the same earthquake. More important bridges for example, might be expected to perform to a higher level than less important bridges. Temporary bridges and those under construction might also have specific criteria. Setting aside these special cases, two or three categories should be again be sufficient, and these might be based solely on *importance*, although it might be preferable to use *expected performance level* as the differentiating parameter.
- How should these performance requirements be specified? It is not a simple matter to measure performance and therefore to be able to specify it. One measure might be the number of days a bridge is closed for repair following an earthquake, or has restricted access (lane reduction or weight reduction or both). Another measure might be the extent of damage as given by residual displacements or offsets, crack widths, extent of spalled concrete and exposed rebar, number of misaligned or unseated bearings, settlement of approach fills, distress to expansion joints and vehicle barriers, and the like. Neither measure is particularly satisfactory and in practice both are used to complement each other. In this case both a performance level (PL) and a damage level (DL) is used to set the performance criteria.

If dual events are considered (rather than three levels) and two bridge types identified, the above performance criteria may be formatted in a 2 x 2 matrix with the rows assigned to the earthquake level and the columns to bridge type. Elements within the matrix are the required performance and damage levels. Table 1 shows such a performance criteria matrix.

Four performance levels and four damage levels are shown in Table 1 corresponding to two earthquake levels and two bridge types. If more hazard levels and/or more bridge types are to be considered, the number of performance and damage levels (PL, DL) would, in principle, increase. But in practice duplication among the PLs and DLs is common and the number of separate and distinct levels may not even be as many as shown in Table 1.

EARTHQUAKE	BRIDGE TYPE 1 (e.g. Standard Bridges)	BRIDGE TYPE 2 (e.g. Important Bridges)
Frequent Earthquake	PL1 DL1	PL2 DL2
Rare Earthquake	PL3 DL3	PL4 DL4

where PL1 through PL4 is Performance Level 1 through 4
and DL1 through DL4 is Damage Level 1 through 4.

Table 1: Performance criteria matrix for highway bridges.

Component vs system behaviour

Seismic design provisions for the construction of new bridges and the retrofit of existing bridges, based on the above principles, have been developed in the United States (ATC/MCEER

2003, MCEER/FHWA 2005) and are under consideration for adoption. However even if adopted, the improvement in bridge (component behavior) that is to be expected overtime will not assure, unequivocally, that highway systems in the US will not be compromised in a future earthquake. This is because bridges are but one component of the system and interaction between components can, and do, occur in surprising ways.

Furthermore expert opinion suggests that a highway system may be more resilient than its individual components, leading to the conclusion that not every component needs to be protected to the same high level in order to achieve a high level of protection for the system as a whole. This may be seen in Figures 2 and 3 where restoration curves for a single bridge are compared with those for a highway system. These curves were developed by experts exercising engineering judgment in 1985 and published in the landmark ATC-13 report (ATC, 1985). For example it may be estimated from Figure 2, that it will take about 9 months (270) days to restore a 'conventional' highway bridge to 100% capacity following an earthquake with intensity MMI IX. In contrast it will take only about 3 weeks to restore a freeway/highway system back to 100% capacity for the same ground motion (Figure 3).

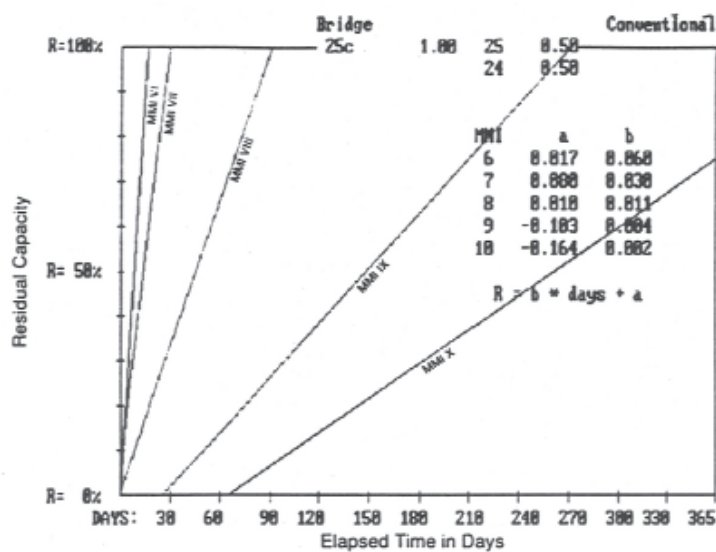


Figure 2: Restoration curves for conventional highway bridges (from ATC, 1985)

This observation (now 20 years old) has since been confirmed in the field during the immediate recovery period following damaging earthquakes in urban areas¹. It therefore has very important implications on how and where to protect highway infrastructure and this has led to exploring the feasibility of applying performance based design to highway systems.

Performance-based design of highway systems

The methodology described above has opened the door to implementing performance-based seismic design for highway systems. As for bridges, the goal of such a design approach is to satisfy certain specified performance criteria following earthquakes of different sizes, but in this case, the objectives are set for a highway network or subset thereof. Following the approach for bridges, successful application will require two issues to be addressed:

- Establishment of realistic and meaningful performance objectives at various hazard levels; and
- Verification of the performance objectives.

Performance objectives for highway systems might simply be related to changes in total system travel times for emergency traffic should a small, medium or large earthquake occur in the region. More stringent criteria might be imposed for small and more frequent earthquakes, than for the large and rare events. Alternatively, performance might be measured by system

¹ The Los Angeles freeway system was at near full capacity months before all of the collapsed bridges were replaced following the 1994 Northridge earthquake. Capacity is defined as 'vehicle miles traveled per day'.

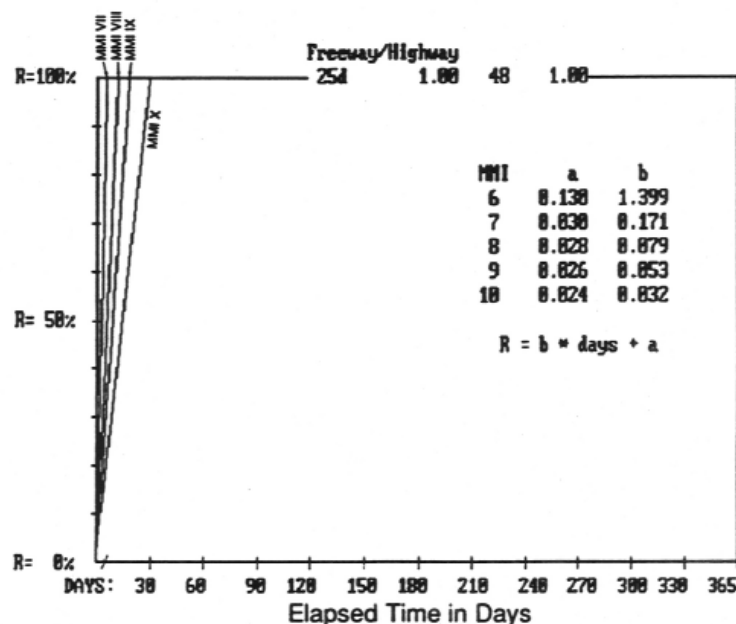


Figure 3: Restoration curves for freeway/highway systems (from ATC, 1985)

restoration time, which is the time required to restore a system back to full capacity (or some fraction thereof) following an earthquake. For small earthquakes this might be less than a day, but for larger events restoration times might be measured in months. Table 2 presents a possible set of criteria based on maximum acceptable restoration times, using two sets of times corresponding to 80 and 100% restoration respectively.

System performance can be verified using the risk assessment methodologies such as those developed specifically for highway systems by Werner et al., 2000. In this way more intelligent allocation of resources can be made with respect to either seismic retrofitting of highway structures, or the deployment of emergency response measures. For example, bridges might be retrofitted in order of their impact on overall system performance, such as the total travel time for emergency vehicles, or the time required to restore 80% of the network capacity. It may be found that retrofitting 10% of the deficient bridges in an inventory may be all that is necessary to get a system back to 80% of its pre-earthquake performance. Such a result could have a profound effect on the allocation of resources to bridge retrofit programs.

As with the performance-based design of bridges, consequential issues arise when considering application to highway systems. For example, the uncertainty in the ground motion needs to be reduced and the relationship between component damage states (e.g. bridge column crack widths) and overall system performance (e.g. travel times to emergency care facilities) needs to be better understood. Nevertheless the above tools show great promise and deserve further study.

Conclusions

Economic losses due to natural hazards have escalated rapidly in the last decade in the United States. As a consequence, life-safety is no longer the sole requirement of successful design for an extreme event but is augmented by other performance criteria such as functionality and minimal economic loss. This realization has led to the concept of *performance-based seismic design* which is a relatively new development in the design and construction of civil infrastructure. Nevertheless substantial progress has been made in this direction, particularly with respect to the performance of individual components of the built infrastructure, such as buildings and bridges. But the real potential for performance-based design comes when these concepts are applied to systems and subsystems of the infrastructure, such as transportation networks.

In recent years, a major review of performance criteria for bridges has been undertaken in the US and a move towards performance-based, multi-level seismic design of bridges has begun.

EARTHQUAKE	HIGHWAY SYSTEM TYPE 1 Standard Operating Requirements	HIGHWAY SYSTEM TYPE 2 Essential Operating Requirements
Frequent Earthquake (FEE)	$T_{80} \leq 2$ days $T_{100} \leq 7$ days	$T_{80} < 1$ day $T_{100} < 1$ day
Rare Earthquake (SEE)	$T_{80} \leq 30$ days $T_{100} \leq 90$ days	$T_{80} \leq 7$ days $T_{100} \leq 30$ days

NOTES:

1. A 'highway system' may be a subset of a larger highway network, subdivided according to operational requirements.
2. Two classes of operating requirements are defined: standard and essential. 'Essential' requirements are more rigorous than 'standard' requirements.
3. System performance is measured by time required to restore network to given percentage of traffic capacity before earthquake.
4. T_{80} and T_{100} are times required to restore system to 80% and 100% of capacity before earthquake, respectively.

Table 2: Performance criteria matrix for highway systems based on restoration times

In a parallel exercise, a risk-based methodology has been developed for assessing the performance of highway systems taking into account the seismic fragility of bridges and their interconnectivity, and estimating congestion and delay times. These efforts have opened the door to performance-based seismic design of highway systems, in which system-level performance criteria, such as maximum permissible traffic delay times and minimum restoration times, are targeted for highway systems immediately following earthquakes of different sizes. This design approach has potential applications to resource allocation and emergency planning.

The methodology extends to other critical infrastructure systems, such as mass transit, water supply, telecommunications and other extreme events, natural or manmade.

References

- AASHTO, 2002, *Standard specifications for highway bridges, Division I-A: Seismic design*, 17th Edition, American Association of State Highway and Transportation Officials, Washington DC.
- ATC, 1985, *Earthquake damage evaluation data for California*, Report ATC-13, Applied Technology Council, Redwood City, CA, 492pp.
- ATC/MCEER, 2003, *Recommended LRFD guidelines for the seismic design of highway bridges, specifications and commentary*, Report MCEER/ATC-49, Applied Technology Council/ Multidisciplinary Center Earthquake Engineering Research Joint Venture.
- EERI, 2003, *Securing society against catastrophic earthquake losses*, Earthquake Engineering Research Institute, Oakland, CA, 62pp.
- FHWA/MCEER, 2005, *Seismic retrofitting manual for highway structures, Part 1 – Bridges*, in press, Federal Highway Administration, Washington DC, and Multidisciplinary Center Earthquake Engineering Research, Buffalo, NY.
- Werner, S.D., Taylor, C.E., Moore, J.E., Walton, J.S., and Cho, S., 2000, *A risk-based methodology for assessing the seismic performance of highway systems*, Technical Report MCEER-00-0014, Multidisciplinary Center Earthquake Engineering Research, Buffalo, NY 265pp.
- van der Vink, G., et al. 1998, *Why the United States is becoming more vulnerable to natural disasters*, Eos, Trans. AGU, 95, pp533-537.

Community Response to Loss

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Abstract

Overview

In considering strategies to foster resiliency within our critical infrastructure, it is appropriate to reflect on what is usually included and what—or who—is not. Infrastructural assessments historically review transportation (aviation, bridges, dams, roads, rail, transit, waterways), utilities (water, energy, telecommunications), waste (solid, water, hazardous) and at times, schools, recreational facilities and hospitals. Although concerns over the physical infrastructure weaknesses are appropriate, they tend to emphasize policy and funding as solutions (ASCE 2005). Such assessments and remediations typically miss the *social infrastructure*, a gap addressed in this session. Healthy and resilient communities require a consideration of intangible, social infrastructure dimensions such as economic vibrancy, culturally appropriate housing, and equity across groups (NHRAIC 2001). Further, we must attend to losses that are rarely considered even in social science research: the losses faced when hazards and related policies undermine connections to place, culture, livelihoods and families (Phillips and Stukes 2003).

Who is “The Community”?

To start, we must begin with the notion of “community,” a term that suggests a collective set of persons connected by a sense of place. However, disaster researchers and social scientists point out that the term implies a homogeneity that does not exist. Accordingly, this presentation asks who constitutes “the community”, what their losses might be, their expected responses to such losses, and the ways in which practitioners and researchers might further understand and support diverse community participation in building resilient social and physical infrastructures. Researchers have found that communities, given the opportunity to do so, can respond to loss in creative and resilient ways. The challenge before us, then, is how to harness the capacities and resources within communities in ways that help build more resilient social *and* physical infrastructures. Establishing strong linkages between physical and social infrastructural development should result in practical, community-appropriate applications that mitigate disasters, build resilient communities, and subsequently safeguard livelihoods.

The Problem

Brief case examples will illustrate how communities experience and respond to infrastructural failures. These case examples will examine both vulnerabilities and capacities of affected communities. In doing so, they lay a foundation for subsequent presentations in this session:

- Communication capabilities have been overwhelmed during massive events, overloading available cell and land lines for use by emergency responders. One emerging U.S. policy designed to target this problem cuts off cell phone access by the public during extreme events. Yet, for persons who are deaf and dependent on text messaging during emergencies, this policy further limits their access to potentially life-saving information.
- The Indian Ocean Tsunami seriously damaged two key bridges leading into the most devastated areas along the Indian coastline. Affected fisherfolk had to respond to massive loss of life and injuries without assistance for between 3-7 days. Although NGO’s and the government have subsequently rushed in to provide relief, local emergency response training programs remain seriously limited (Hyrapiet 2005).
- Many populated coastal areas in the U.S. and other countries face massive environmental devastation. Although engineers and scientists have targeted many areas for restoration, the public remains underrepresented in discussions and actions. What innovative solutions might they bring for water, waste and sewage treatment facilities?

- Disaster programs often target official businesses for relief funds. But what happens to the hidden and informal economies predominantly used by women and the poor?
- After Hurricane Andrew in the U.S., organizations offered home rebuilding programs, but used Anglo-dominated cultural building practices in areas dominated by Latin American immigrants. How did those practices affect group resilience?
- Relocation of entire communities is often recommended as a cost-saving strategy. Yet what is the impact on the social resiliency of communities who must re-locate?
- What is the role of outsiders when massive and widespread devastation to critical social and physical infrastructures occur as seen in the Indian Ocean tsunami? How can devastated communities be appropriately supported and involved as they rebuild?

Involving Communities

Social science disaster researchers believe that communities contain untapped reservoirs of resiliency, resources and strengths. Consequently, it seems axiomatic that we should involve affected populations in guiding practitioners and officials to build disaster-resilient communities. How might we insure that we develop and connect community-appropriate and resilient social and physical infrastructures? Social science disaster researchers urge that we engage communities as visible, meaningful partners in the process of building disaster-resilient communities. The benefits of doing so include generating a fuller range of socially and culturally appropriate options, a higher investment of stakeholders in selecting strategies, and a broader support base for implementing solutions. Involving communities empowers stakeholders and has the potential to build a sense of commitment to building resilient social and physical infrastructures.

Accordingly, the presentation presents strategies and action agenda items to connect social and physical infrastructures through community involvement. In *Holistic Disaster Recovery*, authors suggested a variety of techniques that might be used to involve the public including public meetings, issue presentations, panel discussions, workshops, field trips, live call-in radio, meetings with elected officials, best and worst views and charettes. In addition, new technologies and technologies to reach various publics will be discussed as well. Limitations of the available techniques, especially as they apply to community diversity, will be considered.

Finally, while involving the various publics is the “way of the future in emergency management” doing so remains challenging (Handmer 1999). This presentation identifies the usual challenges to involving the public including information dissemination, hurdles to public participation, the dynamics of intergroup problem-solving and the roles of officials. Using research and writings from participatory approaches, the presentation encourages those present to join the challenging but ultimately worthwhile process of incorporating our communities into the hazard mitigation process of building resilient infrastructures. Case examples of practitioners overcoming the challenges of including those most marginalized in hazards contexts are presented as sources of inspiration (as one guide, see Enarson et al. 2004; Davis 2005).

References

- American Society of Civil Engineers (ASCE), 2005. “Report Card for America’s Infrastructure.” <http://www.asce.org/reportcard/2005/index.cfm>. Accessed July 13, 2005.
- Davis, J, 2005. “Disaster Training for the Deaf Community.” International Association of Emergency Managers *Bulletin*, Volume 22, No. 5, page 8.
- Enarson, E, et al., 2004. *Working With Women At Risk*. Available at the Gender and Disaster Network web site in English and Spanish, http://online.northumbria.ac.uk/geography_research/gdn/wot/latest/additions.htm. Accessed July 13, 2005.
- Handmer, J, 1999. “Final Report of the Australian Disaster Conference 1999: Disaster Prevention for the 21st Century.” <http://www.ema.gov.au/agd/ema/emaInternet.nsf> . Accessed July 13, 2005.

Hyrapiet, S, 2005. Personal Communication.

Natural Hazards Research and Applications Information Center (NHRAIC), 2001. *Holistic Disaster Recovery*, Public Entity Risk Institute and NHRAIC, Boulder, Colorado. Available online at http://www.colorado.edu/hazards/holistic_disaster_recovery Accessed July 13, 2005.

Phillips, B, and Stukes, P, 2003. "Freedom Hill is Not For Sale." Presentation at the International Research Committee on Disaster Annual Session, American Sociological Association, Atlanta, Georgia.

Conceptualising Infrastructure for Safeguarding Communities and Livelihoods

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Summary

The contemporary world of critical infrastructure can seem all-encompassing. But key systems supporting people and communities are often overlooked because they seem intangible – or are simply not within the purview of those charged with formal responsibility for infrastructure protection. Such systems include aspects of local capacity and contingent systems that emerge in a crisis, as well as local economic dynamism and livelihood security. Livelihood security takes many forms but it is arguably a fundamental component of resilience for all forms of crisis. If this is the case, we need to know what supports it and conversely what undermines it. These questions are examined in two contexts (there are many possible contexts, but for convenience only two will be used in this talk): countries like New Zealand, and those more like Pacific Island states.

The fundamental issue of livelihood security

The single critical element underlying resilience is probably livelihood security - consider the situation of those with limited or no access to money, food, shelter, support networks, etc. Resilience is here defined to include the capacity to recover or bounce back from disasters or other shocks. We want to prevent disasters, but in an era of increasing uncertainties a generic capacity to recovery may be especially valuable. “Livelihoods” can be defined in many ways. For our purposes we will focus mainly on rich countries like Australia but also consider Pacific Island countries. In poorer countries many people prefer investments in livelihood security to those directed at the hazard (e.g. flood levees). Livelihood support may come from our own work (formal or informal, subsistence or cash employment), government, kinship or charitable support, remittances from relatives working overseas, local or overseas pensions funds, and so.

If we accept the importance of livelihood security, then an important question concerns what supports and what undermines it?

Local communities

“Community” is a term with multiple definitions. However, it is hard to escape the implication of uniformity in a “community”, as well as idea of exclusion of those outside the “community”. These and other concerns have led some researchers to question and even to reject the concept. However, it has become an important focus of policy and emergency management action. Today, community is defined in terms of place or neighbourhood with an emphasis on small scale and local. I recognise that communities bounded by place will not be uniform in makeup - and this has implications for community resilience. There will be a range of linkages, dependencies, capacities and attitudes to crisis. One important point is that during crises emergent groups and linkages may transform a community’s capacity to cope, at least in the short term. The membership of the emergent “community” of interest may be different to that before the crisis. Those who are excluded may find themselves without some important coping mechanisms.

Even though our focus is local, some of the systems critical to local livelihoods may be global, and not simply local or national.

The contemporary world of local critical infrastructure:

Critical infrastructure and the communities it serves need to be considered within, or as part of, contemporary societal attributes and trends. There are many of these and making the point can seem like a statement of the obvious. Which ones are particularly important in the context

of our interest today? A short list would include the globalisation of business and for many people, livelihoods; closely related to this trend is the increasingly universal provision of infrastructure for profit rather than for national development or as part of the role of government; the strong move to “zero margins”, in the name of (short term) efficiency; and the shifting of responsibility for difficult problems away from government and onto those at risk through privatization and the use of the concept of “community” (shifting costs from the private to public sphere). In some cases these trends mean that the “infrastructure” supporting neighbourhoods may defy spatial definition due to its international nature.

Situating critical infrastructure within social trends highlights that more is involved than physical infrastructure and the internet – important though these are. Livelihood security requires an additional range of support systems that are often overlooked. These include the less visible wiring of society and local economies. This is of course especially the case in poorer countries. The physical and obvious are very important and they have dedicated organisations to ensure they function. Nevertheless, failures – usually short term) of our physical infrastructure and communication hardware are frequent, and we generally cope with these and recover rapidly if not completely. To the extent that the vulnerability of these systems is a function of financial and management decisions and style, we may have as much to fear from ourselves as from external threats. Recovery from failures of many less visible systems may be far more problematic. These include:

- The **informal networks** and systems that support individuals and communities – a fractured or otherwise disfunctional community is unlikely to show resilience in the face of disaster;
- We are accustomed to stability and some certainty under **the “rule of law”**. Litigation and political changes in direction may undermine this certainty and paralyse some businesses and emergency services;
- **Health systems** – both its reliability and surge capacity. It can be undermined through gross negligence, contamination of medicinal supplies, or the collapse of medical indemnity insurance for example. Surge capacity in a major epidemic would require the community to become an active part of the system;
- **Food and water** – maintaining supply and safety. It is not enough that official believe that the food is safe, the community needs to believe it. The UK’s BSE experience is salutary;
- Loss of confidence in our **commercial system** either through massive fraud or negligence, or through closures which damage local economies;
- Emergency (and **crisis**) **management systems** including insurance, compensation and recovery - continuity planning and expanding our capacity for very large incidents is under-developed in many sectors;
- Much of our business and community activity depends on the **availability of insurance** - and that has been under threat;
- Training, expertise, **access to resources** in crises including emergency management and disaster aid;
- Place, identity, **trust, and sense of security** and community.

Securing livelihoods and local economic activity:

A first step is to establish what we really want to achieve and what is realistic given our limited resources and attention? Is it to secure local economic viability – or to ensure local livelihoods from whatever sources are available such as welfare or remittances? Some writers argue that disasters provide opportunities to move towards a more sustainable local economy. However, some apparently positive changes introduced following disaster – such as massive external investment and shifts in economic control - may make local economies less robust and threaten locally generated livelihoods. This question needs to be considered in the context of the issues raised earlier: the globalisation of business and its extension to all forms of utilities in particular may undermine local efforts to secure critical infrastructure.

Some aspects of security may be enhanced by the global networks embedded in communities, and these may support livelihoods in both rich and poor countries through the transfer of funds and expertise. However, there is a tendency to concentrate on formal critical infrastructure systems and to ignore the informal (some of which are set out above). Both are essential, and should receive attention in critical infrastructure planning. In some countries and some circumstances, informal systems may dominate – occasionally because official systems are very limited and unreliable, or because they simply cannot deal with the types of issues involved. For example, fear and anxiety over terrorism has fractured some communities, businesses and emergency services. Resolving such problems, becomes fundamental to community and livelihood function.

Challenging measurement and performance issues exist in all areas of critical infrastructure, however these difficulties are magnified for the less visible and informal elements given that most attention has gone to the physical or otherwise visible. For example, the details of resilience may be inherently unknowable – especially in the case of complex communities undergoing constant change. Even if they could be determined with precision the assessment could be dated immediately as circumstances shift.

After disaster productive assets may need rapid restoration, but economic flows are likely to be the primary generator of local livelihoods. An emphasis on assets during disaster planning or recovery – know as “Thing theory” - can damage the local economy rather than assist it for two basic reasons: the financial benefits are likely to go to large companies from outside the affected area; and it takes funds away from helping local enterprises through training, grants and loans. It also ignores the informal sector which may be the major part of a local economy especially in poorer countries.

In this context New Zealand and Australia are far more vulnerable to disruption if we model our management approach on that adopted in the UK or USA. They have immense reserve capacity because of their size and location which we do not share. With the constraint of eliminating safety margins mentioned above, it seems unlikely that we will be able to develop more robust systems. Instead, we could develop an enhanced contingency capacity and resilience for major emergencies. Doing this in an environment where much emergency management is arguably under-resourced for its day-to-day work will require identification and attention to the full range of elements or systems underpinning our communities; and the building and harnessing of community capacity.

Some examples:

- **The Pacific:** for many island people access to their subsistence gardens is the key to survival, with remittances from relatives working elsewhere often abroad providing important cash income. Maintaining livelihoods requires some transport and communication capacity to enable markets to function and to keep in contact with distant relatives – these facilities need to be global as well as national. We could also argue that clean water is essential as well, as disease undermines local capacity to work the gardens. Equally important is access to gardens and motivation to maintain them – making the case for the rule of law or absence of conflict at least, which in turn suggests support for local informal and formal networks based on kinship, and often church, youth and women.
- **Rich countries:** a major challenge is to avoid undermining local economies during recovery by for example, providing goods from outside the local area. Maintaining local commerce – including farms - is often an important challenge. Decisions may be needed on how to handle marginal industries or facilities, especially in rural or remote locations where such facilities may be key to local economy viability. Communities and sectors without insurance, for example for bushfires or earthquakes, or for professional liability, may find decline unavoidable. Imaginative reinvention is occasionally a possibility, as is wholesale relocation. Fear and anxiety – self induced or brought on by political and media hype - can damage community functioning and result in shifts in food consumption and recreation creating potentially long term community and commercial damage. In crises we depend on flexible adaptive emergency management, with almost unlimited surge capacity. Developing and maintaining this is difficult without strong community support and involvement.

Prepared for Emergencies? A Resilient UK and meeting the Challenge to London's Resilience

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Abstract

In April 2005 significant changes came to the United Kingdom (UK) with regard to the way major emergencies and disasters are handled, when the Civil Contingencies Act (2004), was implemented. Until then the legislative framework that underpinned emergency planning in the UK was a patchwork of acts that began with 'The Civil Defence Act (1948)' and had developed through a series of *ad hoc* measures introduced over the last fifty years. Only when the fuel crisis and the floods in the millennium year of 2000 and the foot and mouth (FMD) crisis of 2001 exposed serious weakness in the capability to deal with wide area emergencies, plus the government's own capacity for dealing with crisis, did policy makers begin to take notice. The resulting policy, a 'Resilience Agenda', in the form of a two stranded approach focussing on a Capabilities Programme and the CCA (2004) sadly faced its first big test on July 7th 2005 (7/7) when suicide terrorism came to London. This paper will focus on the 'Resilience Agenda', critically evaluate its terminology, structures and arrangements for dealing with major emergencies (particularly those special arrangements in place for London) and present some preliminary observations regarding their effectiveness in light of the 7/7 events.

Introduction

In April 2005 significant changes came to the United Kingdom (UK) with regard to the way major emergencies and disasters are handled, when the Civil Contingencies Act (2004), which had received Royal assent in November 2004, was implemented. Until then the legislative framework that underpinned emergency planning in the UK was a patchwork of acts that began with 'The Civil Defence Act (1948)' and had developed through a series of *ad hoc* measures introduced over the last fifty years. Also, incorporated into the new act, the old 1920 'Emergency Powers Act' (a piece of legislation designed to give governments the power to declare a 'state of emergency' in the event of industrial unrest) has taken on a new significance since 9/11 (Turney, 2002). Particularly when considered in conjunction with the increased threat from terrorism and chemical, biological, nuclear and radiation attack (CBRN). The resulting policy, a 'Resilience Agenda', in the form of a two stranded approach focussing on a Capabilities Programme and the CCA (2004) sadly faced its first big test on July 7th 2005 (7/7) when suicide terrorism came to London.

For the UK the new millennium brought with it some events that increased the degree of uncertainty faced by policy makers, challenged emergency management arrangements and raised issues regarding their appropriateness. The background to the current situation has been documented elsewhere (see Norman and Coles, 2002, Coles 1999 and Coles 1998) and describes a number of policy reviews undertaken in the last fifteen years. Furthermore, they describe how UK researchers have long recognised that the emergency management system was in need of restructuring. (see for example Parker and Handmer 1992, Rockett 1993, Coles 1999, Norman and Coles 2002). Only when the fuel crisis and the floods in the millennium year of 2000 and the foot and mouth (FMD) crisis of 2001 exposed serious weakness in the capability to deal with wide area emergencies, plus the government's own capacity for dealing with crisis, did policy makers begin to take notice. The degree of uncertainty being faced was such that the Deputy Prime Minister ordered an immediate review of emergency management arrangements, (the fourth in twelve years), and an extensive consultation process. The subsequent terrorist attacks of 9/11, Bali and Madrid have further emphasised the *ad hoc* nature of the UK system and added impetus to the need to restructure.

The resulting policy, a 'Resilience Agenda', in the form of a two stranded approach focussing on a Capabilities Programme and the CCA (2004) sadly faced its first big test on July 7th 2005 (7/7) when suicide terrorism came to London. This paper will focus on the 'Resilience Agenda',

critically evaluate its terminology, structures and arrangements for dealing with major emergencies (particularly those special arrangements in place for London) and present some preliminary observations regarding their effectiveness in light of the 7/7 events.

Comfort (1995) notes that designing policy for future events crucially depends upon the degree of certainty or uncertainty faced by the architects of such policy. It appears that the terrorist events in the USA of September 11th 2002 (9/11) (and more recently the events in Bali and Madrid) have served as a 'wake up call' for western governments and have increased the degree of uncertainty faced by policy makers. She further suggests that strategies to cope with the "*risk of future adverse events*" (p174) depends upon accuracy, the capacity to re-organise existing resources, skills and knowledge and the ability to develop systems that cross organisational and jurisdictional boundaries.

Britton (1998) when discussing recent changes to emergency management policy in New Zealand pointed out that if emergency management was to meet the challenges of reducing uncertainty and ensuring public safety then a major policy shift was needed. The shift, he suggested was in the need to anticipate risks better rather than rely on being prepared to respond to hazard impacts once they occur. He went on to identify several factors that he saw as critical to changing mind-sets, including government willingness to maintain progress and follow through in the face of what he calls the "*tyranny of the immediate*" (p); the ability of local government to develop effective risk management tools that will assist in allowing informed choices to be made and the willingness of the emergency services to take note of evidence based research and implement education and training programmes in a timely fashion. All of which seem to be particularly appropriate for the UK case.

Rosenthal and Kouzmin (1997) have added to the debate on policy stating that disaster impacts (whether natural or man-made) are compounded because "*policy makers have prepared neither themselves nor the public for appropriate responses once tragedy strikes*" (p277). Interestingly, as early as 1991 Parker and Handmer noted that "*the British approach is characterised by a lack of policies, especially explicit national policies providing unambiguous signals*", a position that has remained unchanged until now (see Norman and Coles, 2002, Coles 1999 and Coles 1998).

Resilience

'Resilience' has become a very popular term in much of the post 9/11 emergency management dialogue and political rhetoric, yet it is not a new concept as far as risk is concerned. Douglas and Wildavsky (1982) discussed the concept of risk from a cultural perspective, observing that the management of risk posed a dilemma of the polar opposites of anticipation and resilience. They described resilience as "*the capacity to use change to better cope with the unknown: it is learning to bounce back*" (p196) and noted that "*anticipation emphasizes uniformity*" and that "*resilience stresses variability*". (p197) A later study by Wildavsky (1988) further developed the notions of anticipation and resilience with regard to devising effective courses of action by public authorities to cope with uncertain, catastrophic events. He saw anticipation as "*predicting hazards, specialized protections, centralisation and detailed standards*", whilst he viewed resilience as "*trial and error, general capabilities and decentralization*" (p244). He concluded that the most beneficial strategy for coping with risk and its outcomes is one of finding a balance between anticipation and resilience. More recently Kendra and Wachtendorf (2003) have applied the term to the creative actions of organisations they observed in the aftermath of 9/11. They argue that such creativity is an important element of resilience being a significant feature of the emergency response and suggest that planning and training should enhance creativity at all levels of responding organisations.

Again Britton (1998) points out that an emergency management policy like the one adopted by UK policy makers does have the capability to create resilience in communities but only through *a recognition of the risks in the wider hazard-scape, and the essential resources required to reduce their consequences* (p3). He suggests that resilience can also be developed through a proactive emergency management strategy that helps communities choose a level of risk appropriate to their circumstances, but warns that "*knowing that simply reducing losses from*

future disasters is too narrow a goal” (p3). Finally, Rosenthal and Kousmin (1997) note “...that a key question regarding the necessity of a response to threatening inputs bears on the dilemma of restoration versus adaptation or innovation as the appropriate functional requirement” (p283) echoing again the anticipation versus resilience argument.

The Resilience Agenda

‘Resilience’ then, has been a term adopted by UK policy makers in an attempt to describe the way in which they would like to reduce the nation’s susceptibility to major incidents of all kinds by reducing their probability of occurring and their likely effects and by building institutions and structures in such a way as to minimise any possible effects of disruption upon them. (Cabinet Office, 2002) It has been stated that the ‘resilience agenda’ is seeking to do three things; build a comprehensive capability for anticipating major incidents, ensure that planning for response and recovery is geared to the risk and promote a ‘culture of resilience’ including business continuity thus helping to reduce the disruptive effects of disaster. (*ibid*)

The Capabilities Programme

As one of the first measures put in place post 9/11 by UK policy makers the Capabilities Programme can be seen as an attempt to develop the strategies outlined by Comfort (1995) noted above. It uniquely covers all areas of the UK including the devolved administrations of Scotland and Northern Ireland and is seen as part of the core framework through which the Government is seeking to build resilience across all parts of the state. It is however, a complex and confusing picture of inter and intra departmental domains and responsibilities and arguably appears to be a clear example of how to further extend complexity in what is already a complex, tightly coupled system of interactions and interdependencies.

Essentially the programme is an audit of current infrastructure and resources with the scope of the programme ambitiously extending to the full range of responses and to the full range of contingencies likely to face the UK in the first decade of the 21st century. The aim is to ensure that a robust infrastructure of response is in place to deal rapidly, effectively and flexibly with the consequences of civil devastation and widespread disaster inflicted as a result of conventional or non-conventional disruptive activity (CCS, 2003). The programme consists of a total of seventeen capability “workstreams” which fall into three groups (see Fig 1):

- Three structural workstreams, dealing respectively with the central (national), regional and local response capabilities;
- five concerned with For instance Utilities would come under the Department of Transport, human infectious diseases, Department of Health, mass evacuation, the Home Office and so on.the maintenance of essential services (food, water, fuel, transport, health, financial services, etc);
- nine functional workstreams, dealing respectively with the assessment of risks and consequences; chemical, biological, radiological and nuclear (CBRN) resilience; infectious diseases – human; infectious diseases – animal and plant; mass casualties; mass fatalities; mass evacuation; site clearance; and warning and informing the public. (*ibid*)

At national level each of the workstreams are the responsibility of a designated lead government department¹, a peculiarity of the UK system. The Civil Contingencies Secretariat (CCS), part of the Cabinet Office is the coordinating department at the centre of the programme. There is a complex set of reporting structures for the programme that are described elsewhere (Coles 2004, 2005)

The CCS admits that as yet the programme has no defined end-point or outcome. On the one hand this can be seen as desirable as all good risk management programmes should be ongoing and cyclical, emphasising constant monitoring and evaluation. The fact that the CCS is even considering an end-point is worrying. On the other hand the lack of identified deliverables

¹ For instance Utilities would come under the Department of Transport, human infectious diseases, Department of Health, mass evacuation, the Home Office and so on.

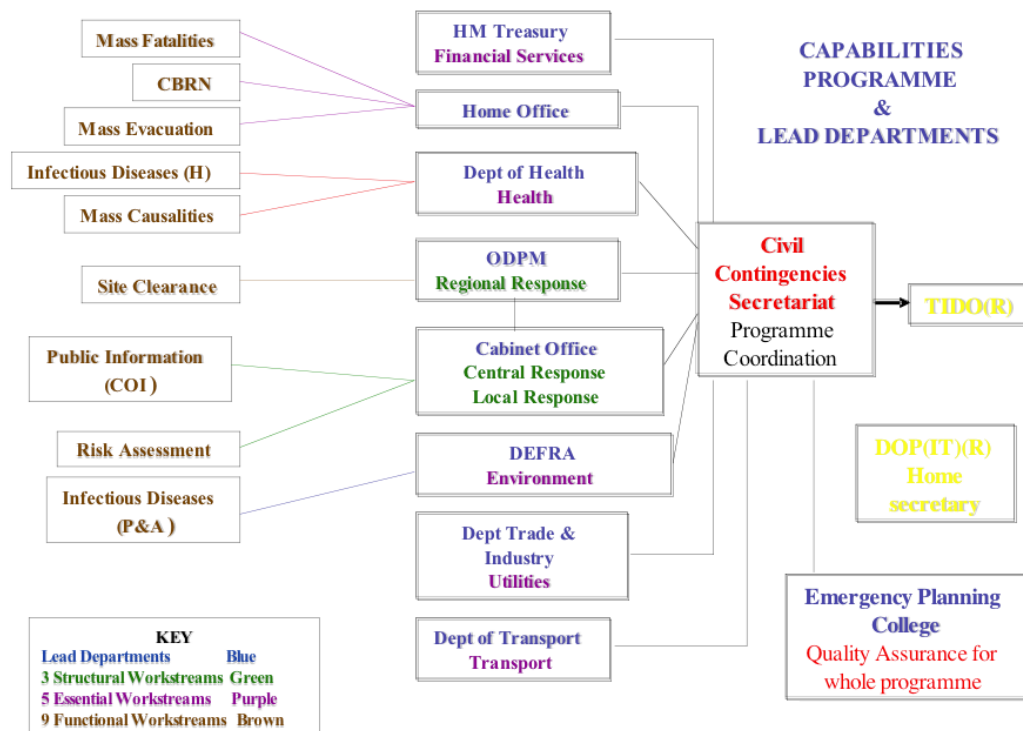


Figure 1: Capabilities Programme and Lead Departments

can present problems for those tasked with implementing the programme. The CCS (2003) has said that an important part of the first phase of the work is to identify the current level of resilience in each of the areas covered by the workstreams this enabling Ministers to decide what increased level of resilience they wish to achieve in each area, and then to plan and if necessary to allocate additional resources to achieve this. An on-going programme of testing and exercising is also a part of the assessment. One of the components of the central response capability workstream is the development of a cross-government programme of exercises and training, which might go some way to redressing the crisis management problems exhibited by government during the fuel and FMD crises. This all raises the important issue of who decides what the optimum level of resilience is and how is it going to be maintained.

The programme has not been without its critics and many issues have been raised regarding its capacity to learn the lessons of the past and improve resilience. Firstly among these is the concept of a 'Lead Government Department' particularly after such a framework was seen as a possible contributory factor in the FMD crisis (Anderson 2002). Also, Broderick (2003) points out the likelihood of delay, departmental prevarication and 'blamism' as possible consequences of the capabilities approach. Departmentalism is also a problem identified by Rosenthal and Kouzmin (1997). Secondly the complex nature of the approach has been challenged by Broderick (2003) with regard to the process of designating response authority/responsibility when more than one Lead Department is involved in an emergency. Thirdly, the issue of decision making in times of crisis has been raised. This again interlinks with the issue of 'Lead Departments' and raises matters of interpretation and dispute about who should control the response (Rosenthal & Kouzmin, 1997). A final criticism of this capabilities based approach is its lack of clear definition within the CCA (2004) and that the responsibilities of the regional tier within the programme are particularly vague and poorly explained.

Civil Contingencies Act 2004 (CCA)

The CCA (2004) is a recognition by policy makers that the legislative framework that currently governs emergency management in the UK is both outdated and outmoded. It is essentially an enabling Act in two parts which encompasses and repeals much of the current legislation regarding civil defence and civil protection and the old 1920's Emergency Powers Act. It is accompanied by Regulations and Guidance that are currently in draft form and going through

a public consultation process. The Act includes;

- A working definition of an emergency
- Provision for identification of risks and the development of a community risk register
- A duty to plan for civil emergencies
- A duty for responders to share information
- A categorisation of responders
- A duty for first responders to have business continuity plans in place
- Provision for advice and support to the business community
- Provision to declare a state of emergency on a regional basis
- Provision for warning and informing the public
- Provision for the appointment of regional coordinators
- Provision for the Minister of State to draw a Regulatory framework for dealing with emergencies

The creation of a new Act has been broadly welcomed by all concerned with the management of emergencies in the UK, however there are some criticisms of it particularly for its lack of clarity and comprehensiveness, because it is focussed mainly at the local responder level and omits any coherent references to a regional or national tier; will place an unfair burden on local responders in terms of administration and funding; makes no reference to military assistance to civil authorities; creates a complex structure that is not well designed for the job it has to do; does not contain any reference to 'Lead Government Departments, exempts central government from the duty to plan and raises grave concerns regarding the declaration of emergency powers (Broderick, 2004). The draft Regulations detail how each of the duties within the Act are to be discharged and the Guidance provides a framework for this purpose.

Emergency Planning Arrangements in England and Wales

The arrangements for responding emergencies in the UK are as complex as the events they seek to manage and include structures at local, regional and national level. The organisational framework is provided in Figure 2. In July 2001, during the consultation period of the most recent review, responsibility for emergency planning moved from the Home Office to the Cabinet Office; under the auspices of the 'Civil Contingencies Secretariat' (CCS) with the declared aim to *"... to improve the UK's resilience to disruptive challenges at every level"* (Home Office, 2001:1).

The CCS (2005:7) draft publication 'Responding to Emergencies' suggests the *"...the local responder is the basic building block of the response to an emergency"*. The Police, Fire, National Health Service (which includes Acute Hospital Trusts, Primary Care Trusts and Ambulance Trusts), local authorities and the Environment Agency (also the Coastguard in coastal areas) are considered to be the main agencies providing or contributing to the local response to disasters² and are all classified as first responders. Support for the emergency services and local authorities is provided by a number agencies and organisations such as volunteers (Women's Royal Voluntary Service (WRVS), Salvation Army), industry and commercial organisations, the Health and Safety Executive and assistance from the military and these are classified as second responders. Each of the first responders is directly responsible to a government department. Police to the Home Office, Fire Service to the Office of the Deputy Prime Minister (ODPM) and so on. Local authorities can seek advice from central government through either CCS or a

² Disasters are normally managed using three nationally agreed operational levels of response: Operational (Bronze) Level, Tactical (silver) Level and Strategic (Gold) Level. These three levels are recognised by organisations normally involved in a response to a disaster and allows a common framework for all responding organisations. A Strategic Co-ordinating Group can also be formed to focus on the provision of resources, prioritisation of requests and forward planning for the successful resolution of the incident and return to normality (Home Office, 1997:16).

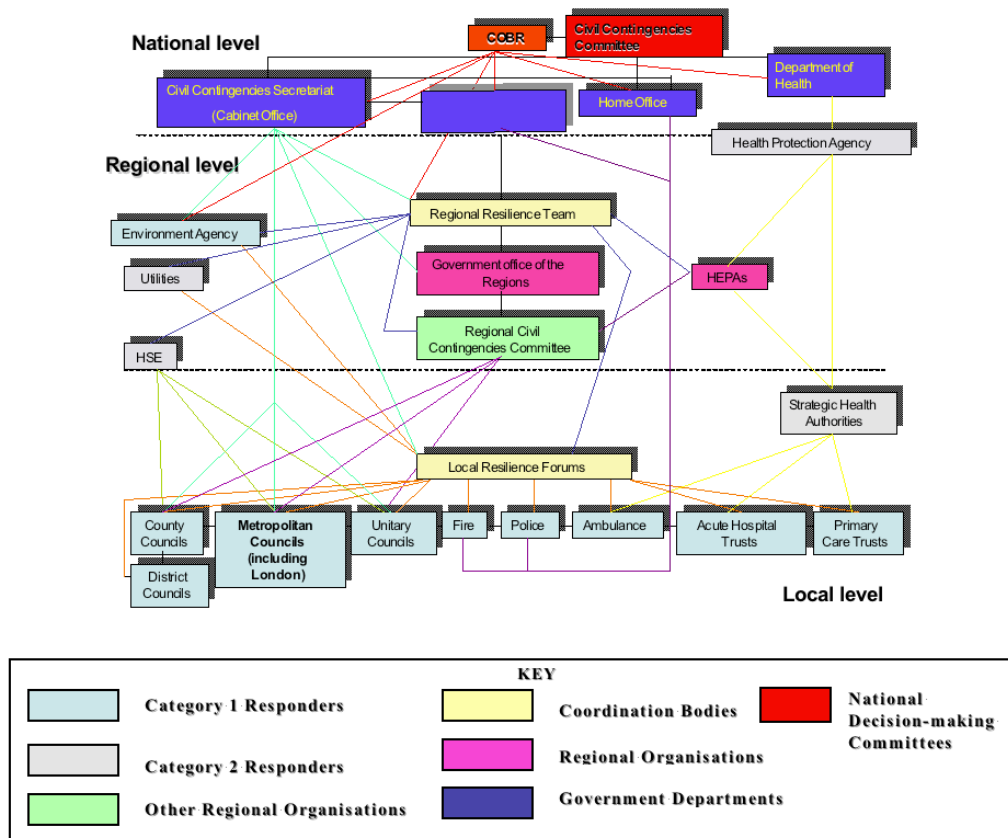


Figure 2: Emergency Planning Arrangements in England and Wales

nominated Lead Government Department (LGD) if more appropriate to the type of incident, for example a radiation emergency. The Local Resilience Forum (LRF) is the coordinating body of the local response and is tasked with keeping the Community Risk Register under the terms of the CCA.

Emergency Planning Arrangements in London

The emergency planning situation in London mirrors the complex nature of emergency planning in the rest of the UK. The city is divided into thirty-three boroughs (forming the greater London conurbation) that are governed for the most part by independent local councils. More importantly, unlike any other major city in the UK it is in a unique position with regard to arrangements for emergency planning because it is also the seat of government and as such is seen to be under a greater threat of disruption from terrorism and chemical/biological/radiation/nuclear (CBRN) attack. This creates a hierarchy of power in the capital that is firmly rooted in five hundred plus years of history and rests overwhelmingly in Whitehall. For although the responsibility for and function of emergency planning resides at local level with the thirty three local authorities and the London emergency services in reality should a major event of the type and order of 9/11 take place then the co-ordination of arrangements for dealing with it would undoubtedly be assumed by central government. Indeed this is exactly what happened on July 7th 2005. Consequently at national level London is a special case and seen to be at greater risk. As such it has a member of government, the Minister for London Resilience to oversee its preparedness and response for major emergencies. However, the national framework for response is still applicable to London (with the local variations) and the arrangements and responsibilities of central government remain the same as they do nationally.

Essentially the framework for response in London is the same as that nationally, with the same roles and responsibilities for the first responders. However, a number of organisations and fora exist in London some of which were created to promote a pan-London response to disasters. The main organisations include: London Emergency Services Liaison Panel (LES�P), London

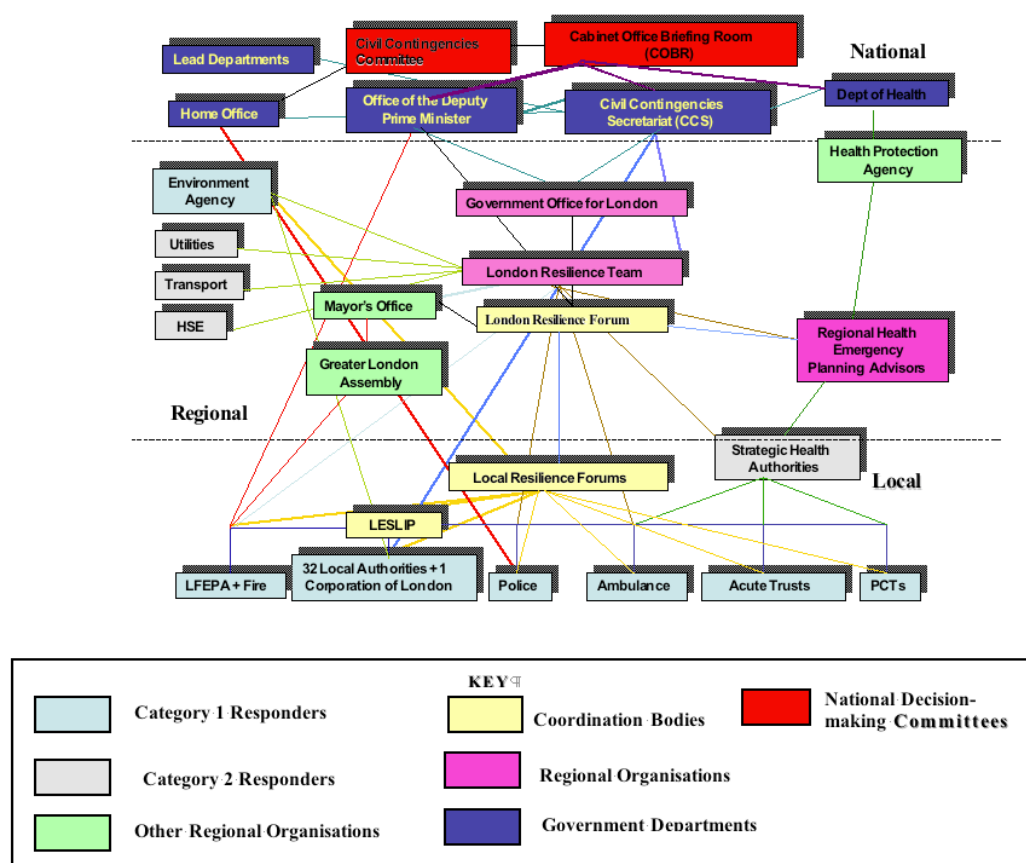


Figure 3: Emergency Planning Arrangements for London

Fire and Emergency Planning Authority (LFEPA), The London Resilience Team, the Office of the Mayor of London, the Greater London Authority, and the Government Office for London. Although there is still some confusion regarding the roles and responsibilities of some of these organisations during an emergency the focus here will be on the London Resilience Team (LRT) and their role in developing the Strategic Plan for London. A detailed description of the other organisations can be found in Coles (2005)

The London Resilience Team (LRT) is a pan-London group that sits within the Government Office for London. It was the first of the Regional Resilience bodies being established after the 9/11 attacks in 2001. Initially, LRT was viewed as a temporary subcommittee tasked with assessing the state of 'resilience' of emergency management within the capital. The results from the assessment were compiled into a report produced in March 2002. It made 142 recommendations for change but, due to its security sensitive nature was classified "*confidential*". Only participating practitioners and organisations with clearance were privy to the report, which is still the case in 2005. LRT is now a permanent group mainly staffed by secondees from the organisations represented on the London RRF, its purpose to ensure London is prepared for a "*catastrophic*" incident (Kowalczyk, 2002). (p16)

LRT has however recommended a number of general changes to the emergency management arrangements for London. These recommendations include a new and more formal command and control centre structure, with a 'diamond' level of command for catastrophic incidents. A new regime for strategic management in London has also been developed which includes a strategic pan London emergency plan (recently completed and published in 2005) and clear protocols for the roles of organisations involved in the response to a 'catastrophic' incident. Furthermore, organisations have received individual recommendations to improve future performance of their emergency management responsibilities (*ibid.*).

Effectiveness of Arrangements in London - July 7th 2005

Preliminary observations of the response to the events of 7/7 indicate that the new arrange-

ments in place for London, particularly the pan London strategic emergency plan, were reasonably effective. It is obviously still very early to have any official deconstruction of the response but it appeared to be timely, efficient and effective in all sectors as evidenced by news reports and personal videos taken by those caught up in the events. Indeed in a joint statement both the Minister for London Resilience and the Mayor of London have praised all responders saying:

“London responded well to last week’s horrendous attacks thanks to the quick response of the emergency services, transport operators and health service staff. London’s councils also rose to the challenge providing a family assistance centre and a temporary mortuary in a very short space of time. The response showed the benefits of the well-prepared and well practiced plans that were in place to help the Capital respond to such an incident”. (<http://www.londonprepared.gov.uk/resilienceteam/index.htm>)

Quite clearly, because of the nature of the emergency, government intervened early and activated a full national response in the form of COBR and the Civil Contingencies Committee with the Prime Minister leaving the G8 summit Scotland to chair the meetings in London. Statements were made in Parliament and every official website is carrying information regarding assistance for those affected. If there is to be any criticism levelled at the new arrangements then it must be at the apparent lack of planned recovery strategies for those involved. The time taken to set up the Family Assistance Centre, the lack of information for the relatives of those reported missing and the amount of time taken to identify the dead have all left a cloud over an otherwise effective response. The formation of the Identification Commission is a new and until now untested strategy that will no doubt provide some lessons for the future. The London Resilience Forum has already met to take stock and identify any early lessons that need to be incorporated into future plans. It can only be hoped that real learning takes place, is embedded into future practice and the lessons made available to all who would benefit.

Conclusion

The arrangements for dealing with major emergencies in the UK have been in a state of flux for the last five years. The flooding of 2000/2001, the fuel crisis and the FMD outbreak of 2002 were directly responsible for the changes taking place now. The subsequent terrorist attacks of 9/11, Bali and Madrid further served to highlight the inadequacies of the old arrangements and added impetus to a change that is nearly complete. Although the new arrangements for emergency planning will not be fully embedded until April 2006 when the last of the duties under the CCA (2004) become fully implemented, the events of 7/7 have gone some way to demonstrating that the new arrangements have some degree of robustness.

With regard to regional and central government the emerging picture was overwhelmingly one of confusion in 2002. Now however the changes being implemented under the CCA (2004) seem to be taking affect and roles and responsibilities are becoming clearer. When mapping the co-ordination arrangements for Greater London in 2002 some difficulties were encountered. These were not with the complexity of the arrangements but rather with their haphazard nature and the confusion found at all levels that surrounded them. Arrangements now are much more co-ordinated and uniform throughout the country and particularly in London where LRT has taken a leading role in preparedness. It is worth reiterating here that London is the seat of government in the UK where responsibility for emergency planning rests at local level. Clearly the 7/7 bombings showed that unlike New York City, some degree of control was assumed by central government. Such a dichotomy creates a duality of tensions that are firmly rooted in the power base that has existed in London for over five hundred years.

Finally, the move of the responsibility for civil protection from the Home Office to the dedicated Civil Contingencies Secretariat in 2001, the introduction of the CCA 2004, the Civil Contingencies Regulations 2005 and the Guidance on Response and Recovery have been or are the instruments for a change that will have taken more than six years when complete.

References

- Anderson I (2002) Anderson Report, "Foot and Mouth Disease 2001: Lessons to be Learned", The Stationary Office, London
- Britton N (1998) Safeguarding New Zealand's Future: Emergency Management's Role in Shaping the Nation Foresight,
- Broderick J (2003) Appendix 4 Note to the Joint Committee on the Draft Civil Contingencies Bill The Stationary Office, London
- Cabinet Office (2001) The Future of Emergency Planning in England and Wales: Emergency Planning Review, London
- Cabinet Office (2003) The Capabilities Programme
<http://www.ukresilience.info/contingencies/capabilities.htm> , accessed 02/04/2004
- Civil Contingencies Secretariat (2005), Draft The Civil Contingencies Act 2004 (Contingency Planning) Regulations 2005, Cabinet Office, London
- Civil Contingencies Secretariat (2005) Responding to Emergencies: Draft Guidance on response to and recovering from hTMEmergencies: the proposed replacement for 'Dealing with Disaster' <http://www.ukresilience.info/ccact/responding.pdf>, accessed 12/07/2005
- Coles E L & Smith D (1997), Turning a Job into a Profession: the Case for Professional Emergency Management in the UK, Presented at the 4th International Emergency Planning Conference, Prague, 20th - 22nd October
- Coles E (1998) What Price Emergency Planning? Local Authority Civil Protection in the UK *Public Money and Management*, Vol 18, No 4, pp 27-32
- Coles E & Norman S (2003) A Resilient United Kingdom: Fact Fiction or Fallacy? presented at European Congress on Sociology, Murcia, Spain, 22nd – 26th September
- Coles E (2004) A Resilient United Kingdom: A systems perspective on the policy agenda to reduce United Kingdom national vulnerability Proceedings of the 2nd International Conference Post-Disaster Reconstruction: Planning for Reconstruction
- Coles E & McGough S (2005) 'Emergency Risk Management in the United Kingdom and the Case of Management Arrangements for London Post 9/11' in Public Risk Management of Cities in Western Countries (in preparation)
- Comfort L (1995), 'Risk and Resilience: Interorganizational Learning Following the Northridge Earthquake of January 17, 1994' in Journal of Contingencies and Crisis Management, Vol. 2, No. 3 (September), pp 174 – 188
- Comfort L K et. al., (1999) Reframing Disaster Policy: The Global Evolution of Vulnerable Communities, in *Environmental Hazard*, November
- Douglas M & Wildavsky A (1983) Risk and Culture. An Essay on the Selection of Technological and Environmental Dangers, University of California Press, Berkeley and Los Angeles, California, USA
- HM Government (2004) Civil Contingencies Act 2004, The Stationary Office Limited, London
- Home Office, (1997) Dealing with Disaster, Brodie Publishing, Liverpool, 3rd Edition
- Home Office (2001) The CCS: What it Means, Home Office, England
- Kendra J M & Wachtendorf T (2003) 'Creativity in Emergency response to the World Trade Center Disaster' in Beyond September 11th : An Account of Post-Disaster Research Special Publication No. 39, Natural Hazards Research and Information Center, University of Colorado, USA
- Kowalczyk Z (2002) Personal Communication

- London Prepared, London Resilience, <http://www.ukresilience.info/londonprepared/resilienceteam/index.htm> accessed 13/07/05
- Norman, S.A., Coles, E., (2002) 'Order out of Chaos: A Critical Review of Co-ordination Strategies between the London Boroughs and Central Government', Paper presented at 15th World Congress of Sociology, Brisbane, Australia, July 7-13
- Norman S & Coles E (2002) 'Order out of Chaos?, A Critical Review of the Roles of Central, Regional and Local Government in Emergency Planning in London' in *International Journal of Mass Emergencies and Disasters*, Vol No pp
- Norman, S.A. (2002) Co-ordination of Emergency Management Strategies between first responders in London and Central Government: A Critical Assessment, Unpublished MSc by Research Thesis, Coventry University, Coventry
- Parker D & Handmer J (1992) eds. Hazard Management and Emergency Planning: Perspectives on Britain, James & James, London
- Parker D & Handmer J (1992) 'Improving Hazard Management and Emergency Planning' in Hazard Management and Emergency Planning: Perspectives on Britain, James & James, London, pp261 - 274
- Rocket J P (1994) 'A Constructive Critique of United Kingdom Emergency Planning' in Disaster Prevention and Management, Vol. 3, No. 1, pp47 - 60 MCB University Press, Bradford, UK
- Rocket J P (1998) We Can't Know What We are Doing Because We Can't Know What It Is , paper presented at the 'Hazards and Sustainability: Contemporary Issues in Risk Management Conference', Centre for Risk and Crisis Management, Durham University Business School, May 26th – 27th
- Rosenthal U & Kouzmin A (1997), 'Crises and crisis management: toward comprehensive government decision making' in Journal of Public Administration, Vol. 7, No.2 (April), pp277 -292
- Turney S (2002) Personal Communication
- Wildavsky A (1988) Searching for Safety, Transaction Press, New Brunswick, NJ, USA

Measuring and Mitigating Long-term Social and Economic Consequences of Major Disruption Events

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Abstract

To plan appropriate response measures that minimise the social and physical impacts, it is important to understand both the socio-economic effects of extreme events, and the way in which communities understand, perceive and prepare for such hazards. Effective survival and recovery from disasters depends not just on physical impacts, but also on the capability of people to effectively confront losses and to adapt to the adverse circumstances presented by an often protracted processes of recovery.

This paper discusses how we measure and mitigate social and economic impacts, and community responses, to a range of hazard events through four case studies: the 1960 Chilean tsunami in New Zealand; impacts of the Ruapehu 1995/96 eruptions; the 2002 'weather bomb' Coromandel flooding; and the June 2005 debris flow in Matata.

Disasters shatter essential assumptions and beliefs that communities and individuals rely on for psychological health, often in a compounding way due to recurring events. It is difficult to effectively quantify direct impacts, let alone model indirect effects and characterise intangible social costs and benefits. Making educated risk-acceptance decisions requires accurate event information and cost estimates. Even the best-informed risk-acceptance decisions are made at a point in time different to that at which the next hazard impact occurs – often to people not involved in the acceptance decision-making process. Understanding the social environment is crucial in determining how well individuals and communities make decisions, adapt to stress, change and emergencies.

Introduction

To plan appropriate response measures that minimise the social and physical impacts of extreme events, it is important to both understand their socio-economic effects, and to understand how communities understand, perceive and prepare for such hazards. Effective survival and recovery from disasters depends not just on physical impacts, but also on how the social environment is affected and manages to support the complex and protracted processes of recovery (Cutter, 2001; Paton et al., 2001). Understanding the social environment is crucial in determining how well individuals and communities make decisions (e.g., to prepare), adapt to stress, change and cope with emergencies.

Disasters shatter essential assumptions and beliefs that communities and individuals rely on for psychological health, often in a compounding way due to recurring events. This paper discusses how we measure and mitigate some social and economic impacts, and characterise community responses, to a range of hazard events through some case studies:

- 1 The 1960 Chilean tsunami in New Zealand.
- 2 Volcanic impacts of the Ruapehu 1995-1996 eruptions.
- 3 Flooding in the 2002 'weather bomb' in the Coromandel.
- 4 The May 2005 debris flow in Matata.

These studies also highlight aspects of direct, indirect and intangible costs and benefits that are difficult to quantify or characterise, or simply are not being adequately recorded. Inadequate recording of disaster event costs and benefits is a critical issue for estimation of risk, and is recognised worldwide (e.g. Mileti, 1999).

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Sustaining improved preparedness: The 1960 Chilean tsunami and warning

On 22 May 1960 at 19:11 universal time a magnitude 9.5 earthquake in southern Chile generated a tsunami that swept across the Pacific. Despite warnings in Chile, Hawaii and Japan, there was major loss of life there. The tsunami struck New Zealand without warning, with no loss of life, but with widespread damage to coastal facilities. Two days after the initial tsunami a large aftershock in Chile was warned Pacific-wide and resulted in the broadcasting of a nationwide warning on radio in New Zealand. This led to the evacuation of several east-coast towns. Newspapers of the day reported that thousands of people were evacuated, making this the largest ever evacuation in New Zealand's history. (summarised from Johnston et al., (submitted))

Almost the entire population of Whitanga, Waihi Beach, Whakatane, Ohope, and Opotiki moved to higher ground for several hours, and in many other communities, people from coastal fringes moved inland. Schools in low-lying coastal areas were closed, and children sent home or to higher ground. However, there were widespread reports of people ignoring the warnings and moving to the coast to get a better view of the approaching tsunami (Figure 1). Had a large tsunami arrived this would have been disastrous for large numbers of the "spectators". After the event there was much discussion in the newspapers of the need to improve both warnings and public awareness of the threat. These issues are still relevant today.



Figure 1: Spectators on Gisborne Wharf observe the arrival of a wave in the 24th May, 1960 tsunami. Public awareness of tsunami impacts waned from 1960 to 2004. Photo courtesy of Gisborne District Council.

Almost immediately following the 1960 event, arrangements were made for New Zealand to receive warnings from the Pacific Tsunami Warning Center. These arrangements were formalised in 1965. Following the tsunami, a range of management tools were made available in New Zealand. These included wave-travel-time maps and public-education resources. However, over the following 40 years, up to the 2004 Boxing Day Indian Ocean tsunami, public awareness of New Zealand's tsunami risk, and the propagation of these management tools, has waned (Johnston et al., 2003). This is despite New Zealand's continued participation in the Intergovernmental Oceanographic Commission International Co-Ordination Group For The Tsunami Warning System In The Pacific and vulnerability to tsunami increasing by orders of magnitude over the same period, due to increasing coastal development. The June 2005 tsunami warning in the USA 'Pacific Northwest' highlighted issues with hardware reliability and response planning effectiveness in their warning systems. Their systems are significantly more advanced in development than those in New Zealand, and yet are still in need of modification.

Increasing vulnerability, and community heterogeneity: Ruapehu 1995/96 eruptions

A sequence of eruptions from Mt Ruapehu began on 18 September 1995 and continued through to early November (Figure 2). Early eruptions through Crater Lake generated lahars down several rivers and valleys occupied by ski lifts. As the lake disappeared, subsequent eruptions were drier and more sustained, and deposited ash up to 250 km from the volcano. Volcanic ash falls produced the most widespread effects (Johnston et al., 2000), affecting some 20 communities, large areas of agricultural land, disrupting air and road transportation, affecting water and national power supplies, and disrupting the winter-sports industry. Ash fall from subsequent eruptions in 1996 represented an additional economic threat to communities dependent upon winter sports. The 1995-1996 eruptions caused similar physical effects to the 1945 eruption but had considerably greater social and economic impacts.



Figure 2: Ruapehu erupting in 1995. No direct impacts were felt in Ohakune, but indirect economic impacts occurred to one of three sub-populations due to the closure of the ski area. Photo courtesy of I. Nairn, GNS.

The risk at Ruapehu has increased significantly over the past 50 years due to an increased population, higher visitor usage and a more technologically advanced infrastructure.

To gain an understanding of the social and economic impacts of these events a longitudinal survey was undertaken in the ski-resort town of Ohakune (Paton et al., 2001). Ohakune sits on the flanks of the volcano exposed to the 1995 and 1996 eruptions. The surveys were distributed in June prior to the commencement of the 1997 ski season, and again in September, during what proved to be a successful ski season.

The first sample was collected at a time when the community faced both economic and eruption threats. When the second sample was collected, because of a successful ski season, the economic threat had subsided but the eruption threat remained. There was a significant drop in psychological vulnerability between June and September, suggesting that respondents perceived economic and volcanic hazard threats differently, and attributed greater importance to the economic risk.

Despite the small community population, this study found three distinct sub-populations in terms of livelihood: tourism-reliant, agricultural, and retired/region-independent-income. Only those from the tourism-reliant group were economically affected. This study highlighted the need to accommodate community heterogeneity in the development of warning and response programs, and to construct messages around issues of personal importance (e.g., economic, livelihood) for members rather than providing information on the hazard process *per se*.

Quantifying and characterising social and economic impacts: Coromandel 2002 ‘weather bomb’ flooding

The 21 June 2002 ‘weather bomb’ developed from a mid-latitude depression that rapidly deepened as it approached the northern tip of New Zealand. Severe Weather Warnings for the storm were issued by MetService on 19 and 20 June, forecasting heavy rain and strong wind for the region (Walton et al., 2004). Anticipating the intensity of the storm, MetService issued media releases that deliberately used the term “weather bomb” to attempt to maximise public attention to the potential severity of the weather. Heavy rain and strong winds were widespread over much of the northern parts of New Zealand, with slips and flooding reported in Northland, Coromandel and the Waikato. An intense band of rain occurred at the rear of the main rain area, causing torrential rain to fall after the catchments were already saturated by earlier rainfall. Significant flooding was recorded in the Thames-Coromandel coastal area, but also occurred in other areas across the region. Return-period analysis by Environment Waikato suggests that the storm was a 1-in-100 year event.

The authors undertook a postal survey of businesses and households in the Thames-Coromandel district in September 2003 aimed at evaluating the direct and indirect costs and benefits of the event. Economic modelling of the regional economic effects was conducted to try and more-fully characterise indirect impacts. The survey also aimed to assess community impacts, and their understanding of the flood risk and warnings.

Assessment methodology

Intangible impacts reported by some respondents were subjective and by definition there was no clear way to quantify these, so they were not included within the economic modelling. Direct losses were captured by a survey of affected households/businesses, use of insurance data and modelling via flood depth-damage curves. Indirect losses were surveyed in terms of lost operating time for businesses, time spent cleaning up, lost staff time etc.

Indirect impact modelling by the New Zealand Institute of Economic Research (NZIER) utilised an input-output table with linkages between sectors of economy, and more sophisticated Computable General Equilibrium (CGE) modelling was conducted taking into account price impacts, supply constraints, lifeline breakages and welfare (real value of income) measures (Walton et al., 2004). The economic modelling raised the following issues: economic versus financial losses; the larger the region of interest selected, the more intra-regional transfers; selection of impact measure – ‘production’ vs GDP – hazards are potentially GDP enhancing; below the line transactions such as insurance claims and relief funding; and stocks vs flows – stocks are assets whereas flows are production – thus stock and flow losses are non-additive.

The study produced the following summary of financial and economic impacts:

Direct Costs:

\$8M	Insured loss
\$2.1M	Uninsured loss
<u>\$3.1M</u>	Response agency costs

TOTAL: \$13.2M

cf. Thames-Coromandel District Council industry output \$1031M, household consumption \$398M source: NZIER/GNS

Indirect Costs:

- Negligible business disruption costs
- Negligible flow-on impacts at a regional scale (modeled)
- \$0.5M Insurance excess payments

Regional modelled economic impacts were negligible but do not account for social impacts and

extreme individual losses. Quantification of social and other intangible costs and benefits were not attempted in the initial study as there was no clear way to account for them adequately in the economic model. The authors also found it is difficult to capture, let alone quantify, the full range of indirect and intangible losses (or benefits). This has been further explored following the February 2004 flooding in the lower North Island, where semi-structured interviews were found to be the only way of characterising the full range of social intangible impacts (Leonard et al., 2004; Saunders et al., (in press)). It became clear that the recurrent nature of natural hazard events (of the order of once every 10 years in these communities) means that we need longitudinal sampling, to gauge true medium to longer term impacts, and to consider cumulative impacts. The most striking cumulative impact in these communities is the cancellation of insurance.

To begin to characterize intangible impacts, follow-up meetings were held with the local councils and community groups involved. In this example the community is being asked to 'buy-in' to any mitigation measures and the regional council has supplied detailed engineering options and costings for the use of the community in cost-benefit considerations. However, at the community-group meetings, perception-driven emotions were a large social impact, possibly eclipsing numerical cost-benefit analysis in residents' risk-acceptance decisions. Central Government have now approved a multi-million-dollar relief package and further study is needed to follow the evolving process and impacts.

The difficulty of empowering informed risk-acceptance: Matata debris flows, May 2005

On 18 May, 2005, the small coastal Bay of Plenty community of Matata was impacted by debris flows from the steep catchments behind the town (McSaveney et al., 2005). Twenty-seven homes and eighty-seven more properties were damaged in an approximately 500-year-recurrence rain-fall event (Figure 3). Similar and larger debris flows have occurred in the area in the last 7000 years, and historical records indicate that four debris flows have probably occurred since 1860. At least one of them damaged buildings, which have since been removed.



Figure 3: Some of the debris flow damage at Matata in May, 2005. Damaged properties are in many cases no longer owned by those who initially made the risk-acceptance decision to build. They are now being asked to make another risk-acceptance decision (most likely, to relocate). Photo courtesy of the Whakatane Beacon.

Despite this history of debris flows, most current residents have no experience of such hazards in Matata. The risk-acceptance decisions on which the construction of their houses were made

occurred at a range of different times over the last century, each governed by different personal and community memories and experiences, and changing planning and regulatory frameworks. In many cases the decisions were most likely made by people who do not now own or occupy the dwellings.

In the wake of the 2005 debris-flow event, residents, the community and local government are attempting to make informed risk-acceptance decisions for the future of parts of the township. Two key issues exist here: the first is fully understanding the nature of (a) the hazard (there has been some debate over the nature of debris flows compared to the more-familiar hazard of flooding) and (b) the risk (probabilities based on historic and especially geological evidence can be difficult for non-experts to conceptualise and for experts to calculate robustly). The second is that no matter how well-informed the risk-acceptance decisions made are, the level of awareness of the premises and the fact that a decision was made at all will wane with time and turn-over of population. This is unfortunate, for in most cases the next hazard impact will occur after such awareness has substantially decreased, often to people uninvolved in the previous decision-making process.

Discussion: Improving our knowledge of disaster impacts – a tool for more-informed planning and preparedness

Two key issues can be discussed from the above case studies: (1) how to adequately measure and characterise hazard costs, benefits and impacts, and (2) how to use these to calculate risk and mitigate future impacts (ie. make maximally-informed risk-acceptance decisions, because these impact on people's livelihoods).

Measuring costs and benefits

Direct costs and benefits

Direct costs and benefits are theoretically the easiest to quantify. However, without full and accurate reporting of losses, increased business and impacts from every person and property involved, these will always be estimates. Making such estimates as accurate as possible is more difficult than it may seem at first attempt. Nationally-aggregated insured-loss figures are currently aggregated from estimates by individual companies of the value of claims received, soon after the event (Insurance Council, pers. comm., 2004). This has also been observed in the USA by Downton et al. (2005). These do not include uninsured losses, do not include the claims not paid-out, and do not include benefits, yet they are the values reported in the mass media while the event is still fresh in the collective mind of society, and usually stick as the values of loss remembered.

The authors have attempted to survey losses and benefits via postal questionnaires, after most insurance claims are reported to have been settled – usually 9-12 months after the event (Walton et al., 2004). No survey can expect 100% return, even if it could be made 'compulsory'. In the case of a voluntary postal survey 30-40% return can be considered a good return rate. Phone surveys are usually too brief to acquire all of the necessary data, and/or tend to have higher refusal rates. Face-to-face interview surveys may achieve higher return rates but cost makes these prohibitive.

In summary, estimation is the only feasible method, and we have found postal surveying up to a year (or more) after the event to be optimal. These can be extrapolated to the known numbers of impacted properties, and the wider population.

Indirect costs and benefits

Problems with the method used in the 'weather bomb' case study revolved around limitations of the CGE model. New Zealand needs enhanced economic modelling capability, to determine the resilience of the NZ economy to natural-hazard events. This work would mirror current research being undertaken in the USA and Europe. An improved model will provide the basis for assessing, in terms of practical measures (e.g. GDP, numbers employed, price levels), the indirect economic impact of natural-hazard events. GDP is often improved by a disaster, and some sectors gain jobs, while others lose jobs.

As well as quantifying the magnitude of loss, an enhanced CGE model could also determine the recovery path, and hence the recovery time of the economy following a natural-hazard event.

Intangible costs and benefits

Identifying, characterising and attempting to quantify intangible costs such as health impacts and social disruption, and any social benefits, have always presented a challenge to researchers. However, as has been observed in our flooding research, (the 'weather bomb', above, and February 2004 flooding, Leonard et al., 2004) and is now commonly postulated elsewhere (e.g. Lindell and Prater, 2003; Mileti, 1999), this is an area worth persisting with, as perceptions can outweigh tangible losses in the making of risk-acceptance decisions. One approach we have found that can at least give weight to intangibles in reporting event impacts is characterising social disruption through qualitative discussion of the results of interviews with effected people. However, by definition these are impossible to apply directly to numerical cost-benefit calculations.

Calculating Risk

In an attempt to provide a framework for assessing community exposure to future natural hazard risk, New Zealand's Foundation for Research, Science and Technology funded the Regional Riskscape model, channelled through Riskscape (NZ); a joint venture involving The Institute of Geological and Nuclear Sciences and The National Institute of Water and Atmospheric Research, with input from other hazard and impact researchers (King and Bell, (in prep)). The aim is to develop a multi-hazard computer based risk assessment tool for use within New Zealand communities. Initially incorporating our most common natural hazards (earthquake, flood, tsunami, volcano and wind storm), the programme will be structured so that additional hazard modules can be added. A major component is the preparation and maintenance of a suitable inventory database with attributes that can define various fragility classes. A statistical sampling technique has been developed to inspect a significant sample of the population, and to extrapolate this across the entire inventory within the area of interest. For Riskscape the minimum reporting entity will be the statistics NZ meshblock unit, with 32,500 units representing all of New Zealand, and with the numbers partially correlated to populations.

The desired output from any Riskscape hazard assessment is to include both direct economic loss, and an estimate of disruption and probable casualties. Indirect losses and overall regional economic impact modules will be added later in the program, and are contingent on the ability to model these, as discussed in this paper. Social disruption and community resilience and preparedness are expected to be very significant when assessing recovery and disruption. Representing such data in a tangible way is by definition erroneous. If the effects are truly intangible, qualitative characterisation may be the only way of considering them.

Mitigating impacts

The decrease in public awareness of tsunami risk in the period from 1960 to 2004, compounded by ever-increasing natural hazard risk (e.g., as a result of population, economic investment, and infrastructure development growth), highlights the need to institutionalise lessons from events into policies and procedures. Ongoing public-education activities should be linked to social policy, training, and community-engagement strategies for them to have lasting effect.

The Ruapehu study showed that risk perception is influenced by the relationship between hazard consequences and personal circumstances, rather than by the physical event *per se*. This conclusion has implications for risk communication. It suggests that message content should target the threat(s) perceived as important by the community (e.g., economic impacts). Additional work must be directed to developing the measurement models and instruments used to assess resilience in this paradigm. Resilience should be conceptualised and managed in ways that reflect the needs of the community at the time, rather than in a pre-determined manner. That is, risk communication programs must be tailored to the community.

Researchers, planners and emergency managers must acknowledge heterogeneity in commu-

nity characteristics and understandings, and develop resilience models that accommodate real and evolving relationships between hazard consequences and community, cultural, geographical and temporal factors. Focusing mitigation strategies and threat communication on actions designed to protect economic integrity or safeguard livestock, rather than uncontrollable threats such as ashfall, may help community adoption of mitigation measures and foster resilience, perceived control, and self-reliance (Paton et al., 2001).

The Ruapehu work highlighted that perceived risk and consequences vary even within small communities. This variation in perception led to criticism of assistance to those with indirect economic hardship by those without, when no physical or direct financial losses in any part of the community were received.

Making educated risk-acceptance decisions should be based on accurate event and cost estimates. However, even the best-informed risk-acceptance decisions are made at a point in time different to that at which the next hazard impact occurs – often to people not involved in the acceptance decision-making process.

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References

- Cutter, S L, 2001. "The changing nature of risks and hazards" In: S L Cutten (Editor), *American hazardscapes: the regionalization of hazards and disasters*. Joseph Henry Press, Washington, D.C..
- Downton, M.W., Miller, J.Z.B. and Pielke Jr., R.A., 2005. "Reanalysis of U.S. National Weather Service flood loss database", *Natural Hazards Review*, Vol. 6, No.1, pp 13-22.
- Johnston, D, Leonard, G, Bell, R, Stewart, C, Hickman, M, Thomson, J, Kerr, J and Glassey, P, 2003. "Tabulated Results of the 2003 National Coastal Community Survey", *Institute of Geological and Nuclear Sciences science report 2003/35*, Lower Hutt.
- Johnston, D, Leonard, G, Downes, G, Paton, D, Pettersson, R and Bell, R, (submitted). "Public response to tsunami warnings: Lessons from the warning of the 1960 Chile earthquake tsunami in New Zealand coastal communities", *Natural Hazards Review*
- Johnston, D M, Houghton, B F, Neall, V E, Ronan, K R and Paton, D, 2000. "Impacts of the 1945 and 1995-1996 Ruapehu eruptions, New Zealand: an example of increasing societal vulnerability", *Geological Society of America bulletin*, Vol. 112, No.5, pp.720-726.
- King, A B and Bell, R, (in prep). "Riskscape New Zealand - a multihazard loss modelling tool", *Earthquake Engineering in the 21st Century 2005 - proceedings*, Skopje, Masedonia.
- Leonard, G S, Kelman, I and Johnston, D M, 2004. "Residential impacts, perceptions and preparedness related to the Lower Hutt City February 2004 flooding: Preliminary results", *Institute of Geological and Nuclear Sciences science report 2004/38*, Lower Hutt.
- Lindell, M K and Prater, C S, 2003. "Assessing community impacts of natural disasters", *Natural Hazards Review*, Vol. 4, No.4, pp.176-185.
- McSaveney, M J, Beetham, R D and Leonard, G S, 2005. "The 18 May 2005 debris flow disaster at Matata: Causes and mitigation suggestions", *Institute of Geological and Nuclear Sciences Client Report 2005/71*, Lower Hutt.
- Mileti, D S, 1999. *Disasters by design: a reassessment of natural hazards in the United States*, Joseph Henry Press, Washington, D.C..

- Paton, D, Millar, M and Johnston, D M, 2001. "Community resilience to volcanic hazard consequences", *Natural hazards*, Vol. 24, pp.157-169.
- Saunders, W, Becker, J and Johnston, D, (in press). "Civil defence emergency management after the February 2004 Manawatu-Wanganui flood event: a focus on recovery", *Institute of Geological & Nuclear Sciences science report 2005/15*, Lower Hutt.
- Walton, M, Johnston, D, Leonard, G, Gray, W, Bell, R and Paton, D, 2004. *The Waikato Weather Bomb: Understanding the impact*, New Zealand Institute of Economic Research, Wellington.

