Telecom in Disasters

Jeff Hortobagyi
A member of the TELUS Team

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For questions about this presentation, contact cbco@telus.com

About TELUS

- TELUS is Canada's fastest-growing national telecommunications company
- $13.8 billion of annual revenue
- 13.2 million customer connections
  - 9 million wireless subscribers
  - 1.8 million internet subscribers
  - 1.3 million residential network access lines
  - 1.1 million TELUS TV customers
- TELUS provides a wide range of communications products and services, including wireless, data, Internet protocol (IP), voice, television, entertainment, video and business process outsourcing services, and is Canada's largest healthcare IT provider.
- Operations in more than 10 countries in North America, Asia, Central America, and Europe
- TELUS, our team members, and retirees have contributed over $525 million to charitable and not-for-profit organizations and volunteered more than 8.7 million hours of service to local communities since 2000

“If emergency service providers know what limits and risks telecommunications service providers have in…events, we can more effectively plan our own telecommunications processes.”

Fire Service

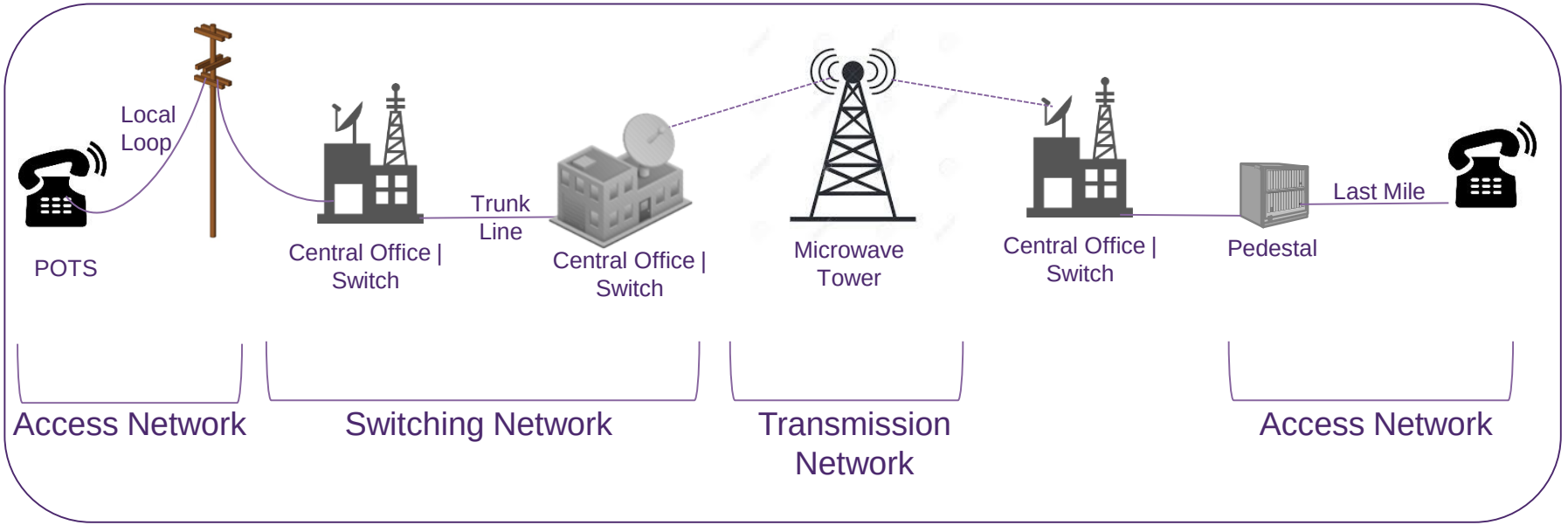
Post-2011 Christchurch, NZ, Earthquake

Agenda

1. How Telecommunications Works
2. Case Study: The 2011 Great East Japan Earthquake
3. Case Study: The 2011 Christchurch, NZ Earthquake
4. How People Communicated
5. Conclusions
6. Appendix: References

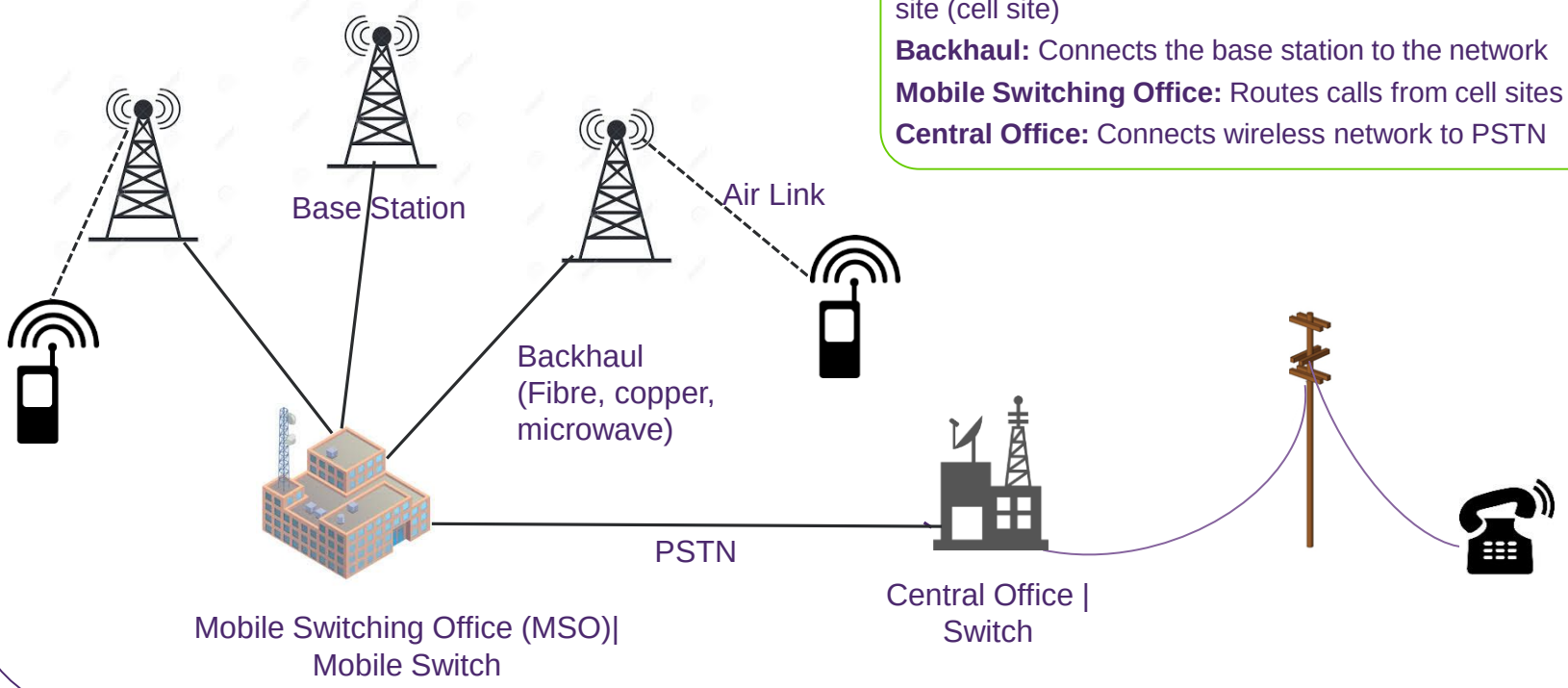
How Telecom Works

Public Switched Telephone Network



Public Switched Telephone Network (PSTN): A vast network of infrastructure and services supporting public telecommunications, consisting of copper and fibre optic cables, microwave transmission links, wireless access links, communications satellites, and submarine cables—all interconnected by switching centres—allowing any phones in the world to connect.

Wireless Network



Base Station: Radio part of a mobile radio transmission site (cell site)

Backhaul: Connects the base station to the network

Mobile Switching Office: Routes calls from cell sites

Central Office: Connects wireless network to PSTN

How Telecom Fails

1. Physical Destruction of Network Components

- Telecom has demonstrated resilience in major disasters
- Vulnerabilities still exist

2. Network Congestion

- Network congestion is typically an issue in the first 24-72 hours of a disaster
- Network congestion has improved as telecoms have increased capacity and developed sophisticated means to manage traffic

3. Interruption of Telecom Dependencies

- Power is the key dependency
- Access to sites for maintenance and repair is essential
- Cooling systems for central offices and data centres are important

The Future is Resilient

Landline

- Unlike the copper-based infrastructure, the new fibre network is a passive network that doesn't need a power supply, making it inherently more resilient to power outages
- Fibre is resistant to many environment factors, e.g. temperature fluctuations, flooding; on the other hand, wet copper cables can result in service degradation and outages

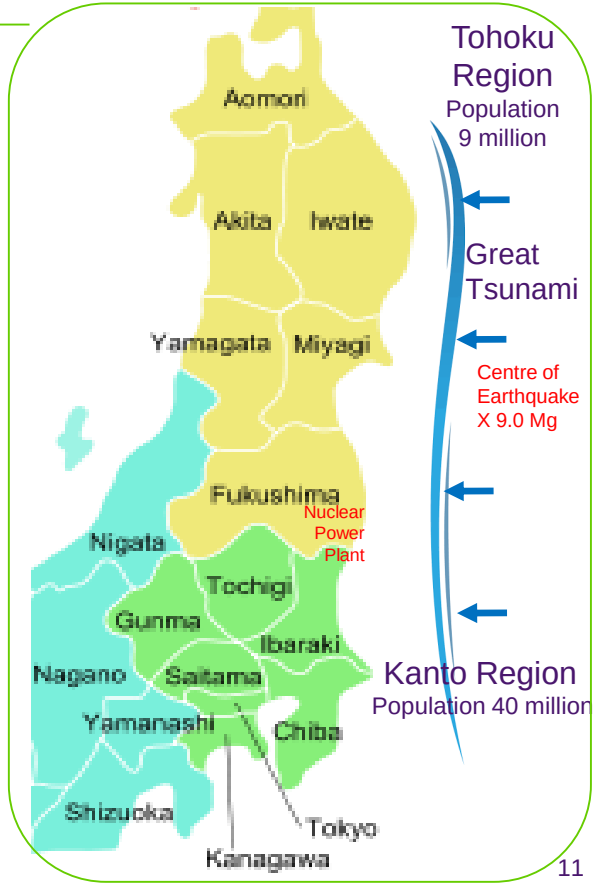
Wireless

- Overlapping coverage provides built-in resilience and will improve as telecoms continue to deploy and densify the site count
- 5G more effectively uses the layers within a network (macro, micro, in-building, pico sites) to provide overlapping coverage
- New technology developments will allow for load-shedding in power outages, extending the life of a site on batteries
- Telecom carrier agreement in progress to allow inter-network roaming in a disaster

Case Study: The 2011 Great East Japan Earthquake

Japan's Triple Disaster

- On 11 March 2011, a magnitude 9 earthquake hit the east coast of Japan
- 20 minutes later, 40 metre tsunami waves hit the shoreline and reaching 10 km inland
- A major nuclear power plant accident resulted
- It was Japan's greatest natural disaster
  - 19,000 lives lost
  - 470,000 evacuees
  - 370,000 houses destroyed or severely damaged
  - 8.4 million households lost power
  - US $210 billion in damage
- Nippon Telegraph & Telephone (NTT) East (landline) and NTT DOCOMO (wireless) are the largest carriers, followed by KDDI and Softbank Mobile



Threats to Telecom

Earthquake

- Caused minimal damage
- Liquefaction and landslides damaged underground services

Tsunami

- Serious damage from the unexpectedly high tsunami waves
- Outside plant destroyed, buildings flooded (severed transmission lines, building and equipment damage)

Power outages

- Unexpectedly long and widespread blackouts
- Most telecom outages due to power outages and the inability to deliver and refuel generators

Network congestion

- Network congestion had a limited impact after the first day
- Call restrictions put in place to protect the network and prioritize emergency calls

Infrastructure Damage

Exchange Offices

- Half of NTT exchange offices (990) disrupted; 385 incapacitated
- 55 exchanges offices directly damaged; 16 destroyed, 12 flooded

Transmission and Outside Plant

- 90 transmission routes severed
- 28,000 utility poles washed away or damaged
- 2,700 Kilometres of coastal aerial cables submerged or damaged

Most outages due to power failures

Greatest direct damage to telecom infrastructure caused by the tsunami

Wireless

- ~ 21% of mobile base stations out of service in Tohoku and Kanto
- One carrier in Tohoku reported 64% of mobile base stations out of service

Internet

- 1 of 3 submarine cables supporting the region damaged but the other two picked up the load
- No major Internet usage outages; local outages where physical damage occurred

Telecom Dependencies

Power Supply

- Widespread, prolonged power outages in Tohoku and Kanto
- Power outages caused estimated 80% of telecom disruptions
- Telecom outages higher on day 2 and 3 as batteries and generator fuel ran out

Supply Chain

- Limited fuel availability due to the destruction of oil storage facilities and damage to transportation routes

Access

- Road access issues hampered deployment of mobile equipment (generators, mobile base stations), fuel, and repair technicians

Fuel tankers and power supply vehicles used to secure power

Road damage, Hachinohe City

Network Congestion

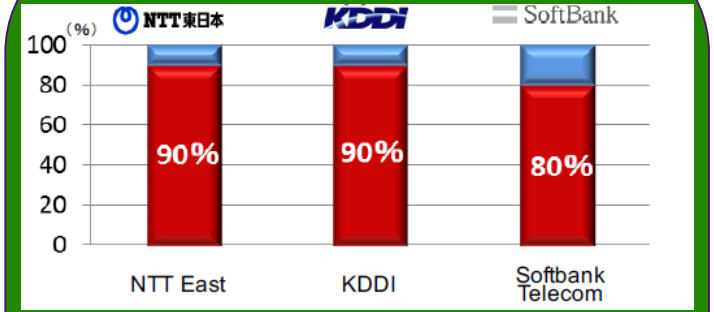
Congestion

- Congestion caused by the surge in call attempts
- Text messages more likely to get through as packet traffic was largely unrestricted, though often delayed

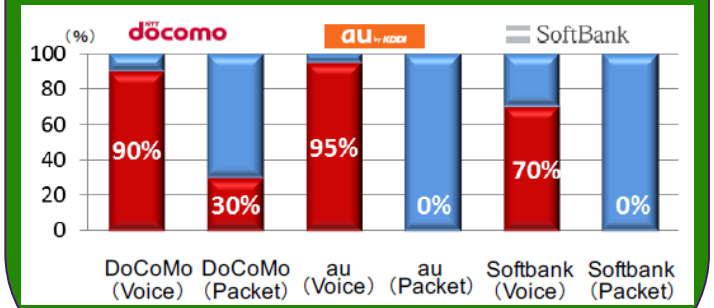
Call Restrictions

- Call restrictions implemented to protect the network and secure the capacity for emergency calls
- Landline restrictions removed after 1 day
- Wireless restrictions continued off and on for several days
- Limited restrictions on texting

Landline Call Restrictions



Wireless Call Restrictions



Service Impacts

Landline

- 1.9 million landline services impacted in Tohoku and Kanto (excluding last mile disruptions)
- An estimated 1/3 of landline services in Tohoku were disrupted at the peak of the incident

Wireless

- ~ 21% of mobile stations out of service in Tohoku and Kanto
- Areas of coastal Tohoku essentially had no wireless at the peak of the outages (Mar 13)
  - Iwate: 50% or normal coverage inland with no network coverage along the coast
  - Miyagi: No coverage along the coast. Almost no network coverage except for the city of Sendai
  - Fukushima: No coverage along the coast. Network coverage inland was 10% in the eastern half, 100% in the western half

Internet

- The internet held up very well among all the outages of landline and wireless networks
- It was able to cope with an estimated increase of about 200 times normal traffic

Community Isolation

- Some coastal communities isolated for days to weeks with no landline, wireless, or Internet

Network Management

- Heavy network traffic not a critical issue due to telecom initiatives:
  - Call restrictions to protect the network and support emergency calls
  - Restrictions lifted for landline the day after the earthquake; remained on and off for wireless for several days
  - Disaster Message Dial and Broadband Message Board that diverted calls seeking information about a person affected by the earthquake
- Traffic congestion mostly cleared up on the same day the earthquake struck

- Traffic increased by 8-9 times above normal; no impact to overall system performance
- Without network restrictions, estimated traffic would have been 60 times normal
- Network congestion in 1995 Kobe earthquake lasted 5 days

Power Restoration

Response

- Telecoms mobilized power supply vehicles, portable generators, and fuel tankers, and replaced damaged power equipment
- Fuel supply shortages resolved by procuring fuel on the market and cooperation with government

Recovery

- Power restoration played the most significant role in restoring telecom services
- By March 28, 95% of exchange offices and 90% of mobile base stations restored, primarily due to the restoration of the commercial power supply
- 18 exchange offices in Tohoku on generator 2+ months after earthquake

Power supply vehicles, fuel tankers, and emergency generators provide temporary power to telecom facilities.

Restoring Exchange Offices

Most exchanges were restored by restoring power, or repairing communications equipment, power equipment, or transmission lines. A number that were destroyed or inundated required more extensive repairs.

- Rerouted switching services to neighbouring undamaged offices
- Restored service at remote undamaged offices, initially for priority services
- Temporarily repaired damaged offices and installed new equipment and power supplies
- Replaced destroyed exchange offices with temporary container-like ones

The site where the Shichigahama Building stood

Rikuzen-takata building inundated by tsunami

95% of impacted exchanges restored by the end of March; most of the remaining 55 offices by early May

Restoring Transmission Lines

- 90 transmission lines disrupted, including extensive damage to lines under bridges and along railway tracks
- Restored by repairing severed cables, building bypass routes, and switching routes
- Re-routed submarine cable traffic to undamaged cables (no service impacts)
- Restoral wasn't a priority to areas where populations were evacuated

Building a By-Pass Route

The tsunami swept away parts of the Sanikura Railway, taking a transmission line with it.

NTT East erected 11 telephone poles alongside the railway and strung cables to restore the transmission line.

Restoring Wireless

Cell site destroyed by tsunami in Rikuzen-takata

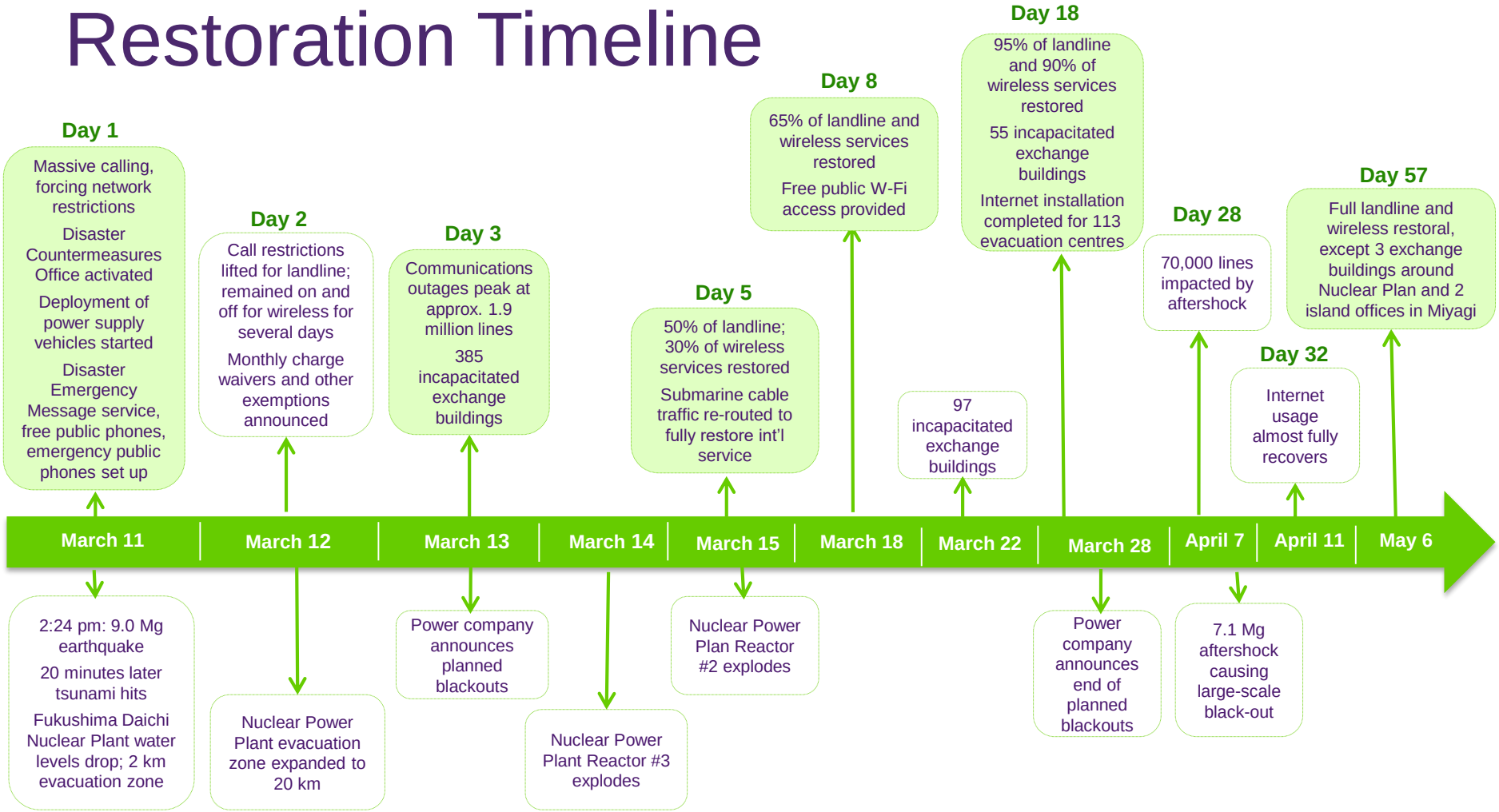
Cell on Wheels provides temporary coverage

Most sites restored through restoring power, replacing equipment, and repairing backhaul. Others required more extensive repair.

- Deployed Cellular on Wheels and micro-cells
- Expanded coverage of undamaged sites to neighbouring areas that lost coverage
- Assigned switching functions to other offices when the original was damaged
- Deployed temporary microwave sites and satellites links from sites that lost backhaul

90% of impacted mobile base stations restored by the end of March; most remaining sites by early May

Restoration Timeline



Restoration: The Community View

	City (Population)	Landline		Wireless		Internet	
		March 11	Restoration	March 11	Restoration	March 11	Restoration
Iwate	Miyako (54K)	OOS	20 days	Limited	-	OOS	15 days
	Rikuzentakata (20K)	OOS	Unknown	OOS	7 days	OOS	120 days
	Kamaishi (35K)	OOS	7 days	OOS	7 days	OOS	9 days
	Otsuchi (12K)	OOS	45 days	OOS	9 days	OOS	70 days
Miyagi	Sendai (1M)	In service	NA	Limited	3 days	OOS	2 days
	Ishinomaki (147K)	OOS	15 days	OOS	15 days	OOS	15 days
	Kesennuma (65K)	OOS	10 days	Limited	10 days	OOS	6 days
	Higashimatsu-shima (39K)	OOS	6 days	OOS	20 days	OOS	6 days
	Minamisan-riku (13K)	OOS	20 days	OOS	20 days	OOS	20 days
Fukushima	Iwaki (350K)	In Service	NA	In Service	NA	OOS	1 day
	Minamisoma (55K)	Limited	8 days	Limited	8 days	Limited	8 days
	Futaba (7K)	In service	NA	Limited	7 days	OOS	2 hours
	Namie (21K)	OOS	Unknown	OOS	Unknown	OOS	80 days

- Limited means service could be used with some restrictions, e.g. call throttled by telecoms, email and text effective
- Results based on survey of municipalities so may have some subjectivity.

- Significant recovery within a week, though there were lengthy outages, particularly in more remote areas
- The larger cities had greater telecom resilience and restoration
- Many smaller cities (ranging from 10K-65K people) were without any service for 6+ days
- Other cities had some service but full restoration was lengthy

Key Challenges

Temporary microwave repeater in town of Otsuchi

Destroyed street in the devastated city of Ishinomaki

Power

- Massive commercial power outages
- Fuel shortages
- Insufficient numbers of mobile generators to cover sites

Access to Sites

- Damaged roads delayed deployment of resources to maintain and repair sites
- Some areas were restricted

Scope

- The geographic range and massive scope of the impacts stretched human and material resources

Key Successes

Resilience

- Resilience of network design and operations
- The success of previous seismic mitigation

Response

- Ability to recover services rapidly and support communities
- Flexibility and creativity in developing recovery solutions

Communication

- Communication to communities and customers about recovery status and timelines

Case Study: The 2011 Christchurch, NZ Earthquake

About the Earthquake

- On 22 February 2011 at 12:51 pm, a magnitude 6.3 earthquake hit Christchurch, a city of 350,000
- The damage was severe because of the location and shallowness of the earthquake, liquefaction zones, and damage from the September 2010 earthquake
  - 182 lives lost; half in the collapse of the Canterbury Television Building
  - Estimated US $40 billion in damage
  - Major infrastructure damage in Central Business District (CDB) and eastern suburbs
  - Over 140,000 homes damaged (over 50% of area stock)
  - Airport closed and city centre evacuated
  - Power lost to >70% or Christchurch urban area and most of Christchurch was without water
  - Considerable flooding resulted from liquefaction
- A series of aftershocks caused collapse and damage to other buildings

Infrastructure Damage

Exchange Offices

- Network equipment in exchanges seismically braced, remained operational
- 2 exchange offices, including the central exchange, significantly damaged though operational

Transmission and Outside Plant

- Plastic and fibre cables and roadside cabinets generally undamaged, remained operational
- Underground cables—specifically, copper cables—affected by liquefaction
- Many telecom facilities in damaged buildings, e.g. cell sites, rooftop antennas, equipment
- Some microwave dishes misaligned

Wireless

- 2 sites destroyed, 4 with structural damage, ~20 failed due to power loss or transmission damage, many sites on battery
- ~25 sites in condemned buildings or relocated due to subsidence
- Masts at many sites developed leans due to liquefaction and land slumping

Telecom Dependencies

Power

- Power lost to >70% of urban area
- 75% of power restored within 3 days; 90% within 10 days, 4+ weeks for CDB, eastern suburbs
- Exchange buildings had generators; loss of power at cell sites and roadside cabinets

Access

- Road and bridge damage impeded access to sites, though roads generally stayed open
- Access restrictions, especially in the CDB, prevented maintenance of key sites
- Risk from damaged neighbouring buildings prevented safe access

Other

- Limited quantity of generators held locally by phone company and limited number for hire
- Water for exchange cooling systems, particularly the central exchange office, where they had to hook up to an on-site artisanal well

Network Congestion

Congestion

- Landline and mobile networks went into major congestion in the immediate aftermath, but returned to manageable call levels relatively quickly
- Texting was the most effective means of communications, though there were delays in delivery

Network Management

- Telecoms rationed available bandwidth (e.g. curtailed data) to protect voice and text communications
- Media release encouraged people to limit use of data and voice for emergency use only, and promoted text messaging as an option

Service Impacts

Landline

- Landline availability declined modestly due to power loss and limited transmission failures
- Some customer premise equipment failed due to power outages
- Network congestion in the immediate aftermath

Wireless

- Cellular performance temporarily declined in areas with commercial power outages as batteries at cell sites ran out
- Network congestion in the immediate aftermath

Telecommunications services generally performed well with limited loss of service due to infrastructure damage, telecom dependencies, or network congestion.

111 Service

- 111 calls increased 3X normal
- 111 calls exceeded capacity immediately following the earthquake and on some other occasions until the following day
- Excess emergency calls were diverted to non-emergency interconnect links

Response and Recovery

Core

- Prioritized assessment of key exchanges offices to minimize network interruptions
- Worked with authorities to maintain the central exchange, which served much of the area and was a transmission hub

Wireless

- Prioritized generator and fuel delivery for mobile network, heavily relied on for emergency response
- Engineered the network to ensure service
- Deployed Cellular on Wheels

Power and Site Access

- Prioritized deployment of mobile generators and fuel
- Worked with authorities to gain access to restricted areas

Service Continuity Priority

1. Core network
2. Wireless
3. Landline
4. Broadband

Key Challenges

Power Outages

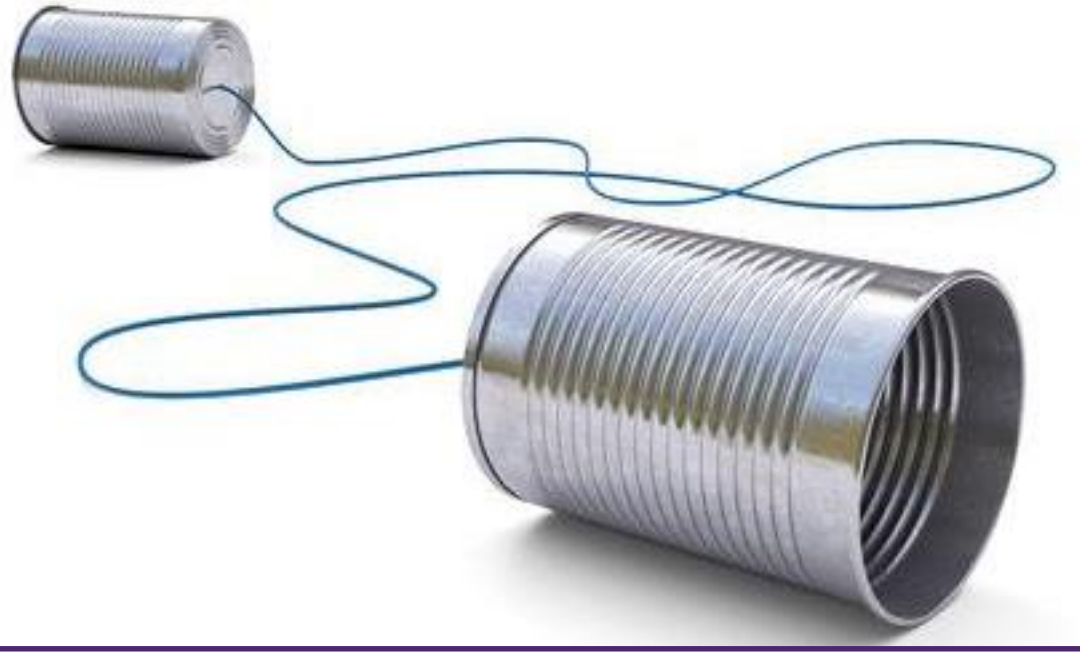
- Power outages were a major concern, particularly for cell sites and cabinets with limited power supply (battery and generators)
- Limited power restoration information in the early stages made it difficult to prioritize generator deployment; in later stages, the power company provided power restoration plans
- Limited quantity of generators held locally by phone company and service providers, and limited number for hire

Access to Sites

- Gaining access to restricted zones for maintenance of sites
- The state of roads and particularly bridges were an impediment to access for repairs, generators, fuel
- Safety issues maintaining sites in the fall zone of damaged buildings
- Coordination with authorities to disconnect telecom services building that were being demolished

Japan vs Christchurch

	Japan	Christchurch
Incident	9.0 Mg earthquake, tsunami, and nuclear meltdown impacting a large region and population	6.3 Mg shallow earthquake, impacting a moderate-sized region and population
Telecom infrastructure	Infrastructure held up well, though significant impacts in areas	Limited direct impacts to infrastructure
Telecom dependencies	• Power was greatest impact • Access was an issue for recovery • Limited quantities of generators and fuel	• Power was greatest impact • Access was an issue for recovery • Limited quantities of generators
Network congestion	Cleared up first day for landline; restrictions required for wireless for several days	Cleared up the first day
Service impacts	Held up relatively well though there were significant outages in many communities	Limited loss of service
Recovery	• Day 5: 50% landline, 30% wireless • Day 8: 65% landline and wireless • Day 18: 95% landline, 90% wireless • Day 57: Full recovery	Services mostly recovered the first week



How People Communicated

“Information and communication are a form of aid… Getting information to people may help them survive in times of crisis and help communities rebuild after immediate danger has passed.”

Connecting the Last Mile: The Role of Communications in the Great East Japan Earthquake

“When we went to the evacuation centres with the newspapers, big crowds gathered. People were so hungry for information, we could barely stick the paper on the wall.”

Editor, Hibi Shimbun Daily

Emergency Notification

What happened

- Early Warning System
  - Notification to mobile phones, public facilities, government offices, TV and radio programs
  - Initial tsunami warning underestimated height of waves
- Public Address System
  - Wireless public address systems along coastline to issues warnings
  - Worked well in many towns. In others, system damaged in earthquake or didn't have back-up power
- Word of Mouth
  - Local civil servants, fire brigades, and volunteers used loud speakers, fire bells, and sirens to warn residents in affected areas

Lessons learned

- Align warning systems with community evacuation procedures
  - Half the population evacuated by vehicle, many were stuck in traffic, some swept away by the tsunami
- Provide regional-specific notifications to address local issues
- Implement back-up power and redundancy for public address systems
- Use multiple channels to reach more people
- Educate the public on the limits of disaster management technology, e.g. tsunami forecasts

Confirm Safety / Locate the Missing

What happened

- Confirming safety
  - Voice calls, text messaging, and email were the first choice
  - Social media was used extensively
- Locating missing people
  - Google Person Finder
  - Software applications leveraging Facebook, Twitter, Mixi, etc. were developed to identify the missing
- Areas with limited communications
  - People visited evacuation centres to locate family and friends
  - Local radio stations read, and newspapers published, lists of the missing and the dead

Lessons learned

- Social media and digital companies have significant emergency response capabilities
- Create digital, standard format lists of people at evacuation centres that can be easily shared and searched, rather than paper lists

Relief and Recovery Information

What happened

- TV and radio provided disaster information
- Local radio and newspapers provided local information, e.g. shelter, food
- Municipal web sites provided information about relief supplies and restoration of services
- Volunteer web sites provided information about resources (ATMs, gas stations, grocery stores)
- Volunteer groups were creative in combining information of different types, e.g. crisis maps

Lessons learned

- Local, community-specific information related to people's everyday needs is essential
- Tweets (and retweets) and other means to identify the needs of people sometimes resulted in duplication of efforts
- Unclear to what extent the information posted by volunteers (e.g. crisis maps) was used by responders
- Lack of information-sharing systems and coordination mechanisms

Communication Channels Used

Channel	Normal	Day of	1 Week After	1 Month After
Radio	47%	68% (+21%)	75%	67%
Mobile	64%	38% (-26%)	55%	69%
TV	87%	33% (-54%)	71%	91%
Internet	81%	20% (-61%)	53%	79%
Landline	28%	8% (-20%)	26%	42%

- Radio was by far the most used channel for the first week, followed by mobile and TV
- Use of channels returned to the mean after a month, except radio which maintained high usage
- TV and computers not reliable in early stages, but were important sources where they worked

Digital and Social Media

- Internet-based information initiatives created a lifeline for those in areas with Internet connectivity and power
  - 1st hour: Twitter Japan created hash tags for specific information needs
  - 90 minutes: Google launched Person Finder and mobilized 5,000 volunteers to create over 600,000 personal records in 90 days
  - 1st day: Sinsai.info, Japan's version of an Ushahidi Crisis Map was built by a community of tech volunteers
  - 1st week: Following the Fukushima nuclear power plant meltdown, volunteers created a site to collect and share radiation measurements
- Municipal web sites were important sources of local information

- Social media and the Internet were found to be highly reliable and useful according to surveys
- For directly affected individuals and people in the affected areas, the strongest reasons for using social media were convenience and their mass dissemination capacity

Considerations

The Digital Divide

- "Individuals who had technology access were able to report their needs; those without access tended to be ignored or forgotten"
- Different populations access information differently
  - Social media was generally used by the younger generation
  - Radio was a key resource for the older generation
- Providing information to individuals without access to technology or technical literacy is a challenge

New media opportunities

- Digital and social media have created a large increase in information in disasters
- Lack of awareness by responders about valuable information created by volunteer technical and crisis-mapping communities resulted in missed opportunities to close information and response gaps
- Limited information-sharing systems and coordination mechanisms caused duplication and inefficiencies in response, particularly between responders and volunteer groups
- Opportunity to integrate this information into formal disaster management structures

Conclusions

Planning Factors

Planning factors are the consistently observed issues that can be anticipated to cause service impacts that all organizations should understand and prepare for.

Destruction of telecom infrastructure

- Earthquake caused minimal direct damage; core network in particular held up well
- Liquefaction caused damage due to flooding and subsidence In Japan, the tsunami caused the most physical damage

Network congestion

- Congestion was primarily an issue on day one
- Call restrictions put in place to support emergency calls and protect the network

Interruption of telecom dependencies

- Power outages were the main cause of telecom outages; power was the main dependency for recovery
- Limited quantities of generators available; fuel shortages in Japan
- Water for cooling exchange offices was an issue in Christchurch

Planning Factors

Access

- Access to sites required for damage assessments, maintenance, repair, and generator and fuel delivery
- Road and bridge damage impeded access, as did access restrictions and safety concerns
- Severely damaged buildings were destroyed without the opportunity to disconnect the telecom infrastructure, in some cases impacting service to emergency responders and others

Service disruptions

- Telecom performed relatively well and recovery was reasonably expediently restored
- Some areas, particularly along Japan's coast, had significant service impacts and a good number of smaller communities were isolated
- Recovery was mostly completed within a week for Christchurch; Japan achieved 65% recovery within a week and 90% within 3 weeks

Communication Takeaways

Information is a form of aid

- People need information: the safety and whereabouts or family and friend, information on relief and recovery, and just to know what is happening

Reaching People

- Multiple information channels and platforms including traditional media outlets, social media, public address systems, community mobilisers, broadsheets, brochures, word of mouth, etc. should be used, depending on context and audience

New media benefits and challenges

- Social and digital media, and private sector and volunteer technical communities, provide sources of information, communication, and coordination
- Some populations don’t have technology or technical literacy

The necessity of local information

- Local information is essential for response and recovery, and local radio and print play a key role in providing that

the future is friendly.

References

Telecom and Disasters

- Telecom 101: Fundamentals of Telecommunications, Eric C Cole, 2016
- Infrastructure: The Book of Everything for the Industrial Landscape, Brian Hayes, 2005
- Telecommunications Infrastructure in Disasters: Preparing Cities for Crisis Communications, Anthony M. Townsend and Mitchell L. Moss, Robert F. Wagner Graduate School of Public Service, New York University, April 2005
- Seismic Risk Evaluation: TELUS Outside Plant Assets British Columbia, MRP Engineering, LLD, September 2007
- Technical Report on Telecommunications and Disaster Mitigation, ITU-T Focus Group on Disaster Relief Systems, Network Resilience and Recovery, International Telecommunications Union, 2013
- Knowledge Note 3-2, Cluster 3: Emergency Response, Emergency Communication, The World Bank
- ITU-T Focus Group on Disaster Relief Systems, Network Resilience and Recovery, ITU-T Telecommunication Standardization Sector of ITU Version 1.0 (05/2014)

2011 Great East Japan Earthquake

- KDDI Initiatives after the Great East Japan Earthquake, KDDI Corporation, 16 March 2012
- Learning from Megadisasters, Lessons from the Great East Japan Earthquake, The World Bank, 2014
- Recovering from the Great East Japan Earthquake: NTT East's Endeavors, Nippon Telegraph and Telephone East Corporation, November 2011
- The Experiences and Lessons from the Great East Japan Earthquake, Ministry of Internal Affairs and Communications, January 28, 2016 https://www.itu.int/en/ITU-D/Emergency-Telecommunications/Documents/2016/GET/D2S3/D2S3-GET2016-Nakajima-MIC.pdf
- Great East Japan Earthquake and research and development for network resilience and recovery, NTT, 23 November 2012
- The Great East Japan Earthquake of March 11, 2011, Jonathan Zimmerman K6JGZ and William Coss KB6CNT Battalion 14 Auxiliary Communications Group Leaders
- Measures for Recovery from the Great East Japan Earthquake using NTT Docomo Technology, NTT Technical Journal Vol 13 No 4, 2012

2011 Great East Japan Earthquake

- Telecommunications Performance in the M=9.0 Off-Shore East Coast of Japan Earthquake and Tsunami, March 11, 2011, Proceedings of the International Symposium on Engineering Lessons Learned from the 2011 Great East Japan Earthquake, March 1-4, 2012, Tokyo, Japan
- Securing Communication Channels in Severe Disaster Situations – Lessons from a Japanese Earthquake, Mihoko Sakurai and Richard T Watson, Proceedings of the ISCRAM 2015 Conference
- Connecting the Last Mile: The role of Communications in the Great East Japan Earthquake, Lois Appleby, Internews Europe, 2013
- Maintaining Communications Capabilities during Major Natural Disasters and other Emergency Situations, Study Group on Maintaining Communications, December 2011
- People's Information Behaviors at East Japan Great Earthquake: A survey report - What worked and not worked, The Information Support pro bono Platform (iSPP), March 16, 2012

2011 Christchurch, NZ Earthquake

- When Online is Off: Public Communications Following the February 2011 Christchurch, NZ, Earthquake, Jeannette N. Sutton, Proceedings of the 9th International ISCRAM Conference, Vancouver, April 2012
- The Christchurch NZ Earthquake: Telecommunications Power Impact, Chorus, 15 April 2011
- Earthquake performance of telecommunications infrastructure in Christchurch 2010/2011, Colin Foster, ResearchGate, 2011
- The Christchurch NZ Earthquake: Telecommunications Power Impact, Chorus, 15 April 2011
- LifeLines: Lessons from Natural Hazards in Canterbury, Centre for Advanced Engineering, December 2012
- Telecoms Failure – Lessons learned form NZ, Japan, and Anytown, Oct 2014
- https://teara.govt.nz/en/historic-earthquakes/page-13
- https://www.theguardian.com/cities/2014/jan/27/christchurch-after-earthquake-rebuild-image-new-zealand
- Canterbury – Christchurch, New Zealand 2011 earthquake impacts on telecommunications, Peter Anderson, Telematics Research Lab, School of Communication, Simon Fraser University
- Emergency Telephone Call Services and the February 11 Christchurch Earthquake, A Review for the Ministry of Economic Development, Tony Fenwick, August 2011