

The Resilience of ICT Infrastructure and Its Role during Disasters

This study has been prepared for ESCAP by LIRNEasia (Rohan Samarajiva and Shazna Zuhyle).

The generous funding support provided by the Ministry of Science, ICT, and Future Planning, Republic of Korea, is gratefully acknowledged.

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¹ The authors wish to thank Roshanthi Lucas Gunaratne for her research contributions and Mark Prutsalis, President / CEO of Sahana Foundation, for his insights on Sahana disaster relief implementation.

Acronyms

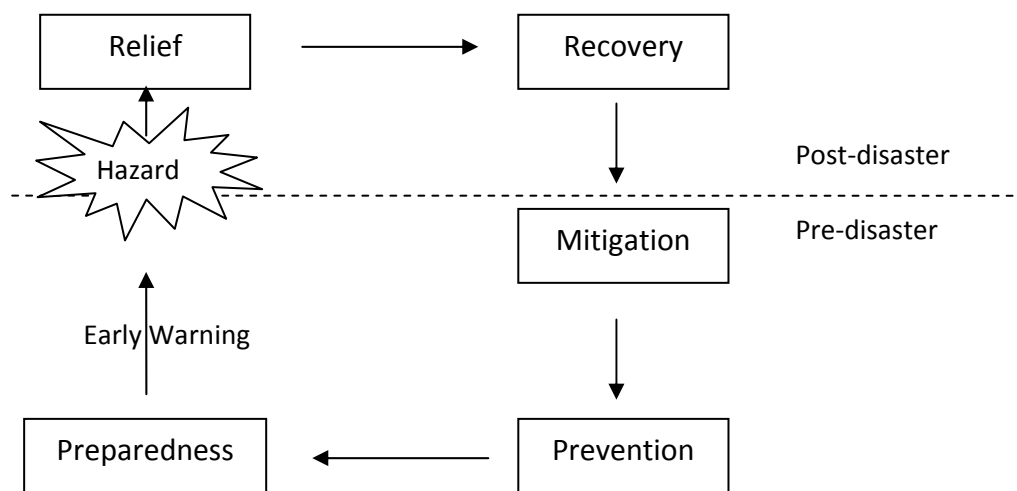
ASEAN	Association of Southeast Asian Nations
BTS	Base transceiver station
CBC	Cell Broadcast Centre
DMC	Disaster Management Centre
FCC	Federal Communications Commission
GIS	Geographical information systems
GPS	Global Positioning System
GSMA	Global System for Mobile Communications (GSM) Association
HF	High frequency
ICT	Information and communication technology
IEPS	International Emergency Preference Scheme
IT	Information technology
ITU	International Telecommunication Union
MNO	Mobile network operator
PCRAFI	Pacific Catastrophe Risk Assessment and Financing Initiative
PIC	Pacific Island Country
SEA-ME-WE	South-East Asia – Middle East – Western Europe
SMS	Short message service
TETRA	Terrestrial Trunked Radio
VHF	Very high frequency

1 Introduction

It is customary in the disaster risk-reduction field to place various actions in the context of the “disaster cycle” shown in Figure 1. Of these phases, mitigation, prevention, and preparedness are pre-disaster activities that constitute actions to be taken to limit the impact of a natural disaster. Post-disaster activities, particularly relief and recovery, include the processes of damage assessment, relocation, and repair of damaged infrastructure.

There is no doubt that natural disasters and humanitarian crises cause disorder and panic. There are many instances in which communication services are not considered a priority when there is lack of access to basic needs, such as food, clean water, and shelter, among others. However, it is often access to accurate information that calms the societal turbulence, and in order for information to be communicated, the underlying network must function. Similarly, in order to communicate accurate information, the supporting soft infrastructure (e.g., institutions and policies) must exist.

Figure 1: Disaster cycle



Information and communication technology (ICT) infrastructure plays different roles in different phases of the cycle. Generally, “during disaster” connotes the period beginning with the hazard making contact with humans (thus becoming a disaster) and up to the start or mid-point of the recovery phase. Services provided over ICT infrastructure can play perhaps their most decisive role in the early warning of natural disasters (see Annex), and there is much research documenting its role;² the emphasis in this report, however, is not placed on this phase, which is prior to the disaster. Further, the emphasis is on ICT infrastructure, primarily telecommunication networks and the facilities needed to keep them operational.

A disaster disrupts all activities in that region. Recovery from disaster requires the restoration of routine ways of doing things and of decreasing uncertainty. Relief is the immediate response to the disruption. Both require control and coordination.

² Rohan Samarajiva and Nuwan Waidyanatha, “Two complementary mobile technologies for disaster warning”, *Info*, vol. 11, No. 2 (2009), pp. 58-65; Rohan Samarajiva, “Mobilizing information and communications technologies for effective disaster warning: Lessons from the 2004 tsunami”, *New Media and Society*, vol. 7, No. 6 (2005), pp. 731-47; J.C. Villagran de Leon, J. Bogardi, S. Dannenmann, and R. Basher, “Early warning systems in the context of disaster risk reduction”, *Entwicklung & Landlicher Raum*, vol. 2 (February 2006), pp. 23-25. Available from <http://www.ehs.unu.edu/file/get/10735.pdf>.

Information and communication technology, usually understood as electronically mediated communication, storage, and manipulation, allows for the necessary actions related to relief and recovery to be done in ways that are qualitatively superior to the alternatives:

- **Documentation of needs and resources.** The enhanced information processing and visualization capabilities of modern computing hardware and software can, by themselves, enable better documentation of the needs that have to be met, ranging from registries of the missing and injured, to medicines and food for the affected, to housing and infrastructure damage assessments. When combined with geographical information systems (GIS), these capabilities are further enhanced. If the information processing capabilities are coupled with communication technologies to enable both superior field data collection (faster and with fewer errors) and effective dissemination to those who can address the needs, the performance is even greater. If databases are organized and populated prior to the incident, especially in terms of resources such as earth-moving equipment, locations of food stocks, and skills, the efficacy is greater.
- **Spatial coordination.** ICTs allow for synchronous and asynchronous communication across space, enabling greater coordination of spatially separated actors. This is especially important when a disaster has a geographically wide scope (a tsunami or a cyclone versus a localized landslide) and when physical transportation systems may have been degraded or even destroyed in the disaster. Even with localized disasters, ICT enables the coordination of assistance from unaffected areas.
- **Publication.** ICT can also give a voice to the affected people, especially in terms of empowering them in their interactions with the relevant authorities, be they governmental or non-governmental bodies.
- **Facilitation of payments.** This particular function has not thus far been implemented in a disaster situation because payment through mobile telephones is a relatively new phenomenon. However, it has potential, owing to the fact that the payment functions of mobiles have become relatively ubiquitous in several countries.

2 What ICT can be used for

2.1 Documentation of needs and resources³

Systems that document needs and resources rest primarily on information technology (IT) and may, in extreme conditions, function even in the absence of the communication infrastructure. For example, a computerized database system could work even with no remote data entry capabilities, with data gathered in the field being entered onsite, as long as the location of the equipment is not affected by the disaster and some form of electricity supply is in place. There is, in fact, no need for the databases to be physically located in the disaster-affected area at all. These types of databases should ideally be located in “the cloud”, or at least backed up in the cloud.

A premier open source software suite for post-disaster response is Sahana, developed by volunteers mobilized in Colombo by the Lanka Software Foundation in the aftermath of the 2004 Indian Ocean tsunami, further developed by a network of disaster and software professionals, and spun off as a separate non-profit

³ Thorough detail on data collection and standardization efforts of the United Nations and humanitarian organizations is provided in B. McDonald and P. Gordon, “United Nations’ efforts to strengthen information management for disaster preparedness and response”, in *Data against Natural Disasters*, Samia Amin and Markus Goldstein, eds. (Washington, DC: World Bank, 2008). Available from <https://openknowledge.worldbank.org/bitstream/handle/10986/6511/449830PUB0Box3181OFFICIAL0USE0ONLY1.pdf?sequence=1>.

organization.⁴ Such software can be deployed after disasters quite quickly but there are advantages to prior deployment and population of certain databases (e.g., with disaster relief supply locations), along with training of personnel who will work with it in disaster situations.

Box 1: The Sahana Disaster Management System⁵

The overwhelming relief efforts in Sri Lanka following the tsunami, carried out by multilateral organizations and individual volunteers, confirmed that, without a disaster management system, the coordination of these efforts would be near impossible. Based on free and open source software (FOSS), the web-based tool addresses problems that arise post-disaster, such as locating missing people, managing humanitarian aid, organizing volunteers, and surveying temporary camps, among others. Coordination between government entities, civil society, aid organizations, and survivors is a core function of Sahana. One of the main barriers to its adoption in Sri Lanka was caused by the lack of a proper institutional framework. The multiple changes in the government-led disaster management effort meant that there was no proper transfer of data.

With aid from Sweden, the scope of the system was enhanced for use in large-scale disasters; a particularly helpful feature was the ability to rally global support. The 2005 earthquake in Pakistan was its first international deployment, and the most recent was in New York City and New Jersey during Hurricane Sandy in 2012.

Since 2007, the Office of Emergency Management of the City of New York has been managing the all-hazards sheltering plan through its customized version of Sahana known as SEMS (Sahana Emergency Management System). This system consists of two components: one used for the management of staff assignments at shelters, and the other for staff and family registration at shelters. Having this system in place enabled New York City to better manage its responses to Hurricane Irene (2011) and more recently Hurricane Sandy (2012). Additionally, and in response to Hurricane Sandy, community-based organizations (e.g., Occupy Sandy) deployed another customized version of Sahana that was capable of integrating with existing systems and adapting processes. The adaptable nature of the system enabled rapid customization, so it could be configured to the specific needs of disaster response operations for Hurricane Sandy. The initial design supported the collection and aggregation of requests for material assistance and volunteers from the neighbourhoods hardest hit by Hurricane Sandy. This allowed organizations, relief drop-off workers, and volunteers to prioritize the drop-off and dispatch of resources to areas that were most in need. The option of conducting daily inventories to provide visibility and transparency was also available, thereby allowing for more efficient and effective distribution of aid. This latest deployment is now being institutionalized by the community groups, with the aim of everything being in place before the next disaster occurs.

The registries (e.g., injured and missing persons) require data inputs, and updated reports must also be disseminated appropriately. Ideally, these actions can take place over a communication network, through e-mail, short message service (SMS), Google Talk, and the like. However, most disaster management software packages are designed to be usable under harsh conditions, where, for example, information can be moved around in universal serial bus (USB) drives.

A good disaster management software package will include mapping and visualization features that can leverage the potential not only of GIS and the Global Positioning System (GPS), but even of location-aware smart phones. They also tend to be equipped with polling capabilities, in which, for example, the package can be programmed to poll field coordinators via SMS, e-mail or other means at specified intervals and collate the responses automatically.

⁴ See the home page of the Sahana Foundation at <http://sahanafoundation.org/>. See also M.A.L.R. Perera, "Ex ante preparedness for disaster management: Sahana in Sri Lanka", in *Data against Natural Disasters*, Samia Amin and Markus Goldstein, eds. (Washington, DC: World Bank, 2008).

⁵ See the Sahana Foundation products at <http://sahanafoundation.org/products/>.

These packages can also be used to alert first responders through cell broadcasting on non-public channels, through SMS, or by other means and then to keep track of their requirements as the disaster response moves from warning, to rescue, to relief.

2.2 Spatial coordination

Disasters disrupt normality. Physical transportation links break. People become displaced. Routes by which supplies of necessities are taken to users become disrupted.

First responders need to find other first responders.⁶ The authorities need to find all sorts of people and things and move them from one place to another. People need to find their loved ones. They need to grieve. They need reach those who can help them restore normalcy to their lives.

All this requires spatial coordination. When buildings have collapsed and roads have buckled, spatial coordination is difficult. Even in normal times, electronic communication, which is increasingly to people instead of places (i.e., via mobile devices), is the primary mode by which spatial coordination is managed. During and immediately after a disaster, the need for spatial coordination is even greater, but the physical infrastructure works less effectively. Hence, a greater burden shifts to the ICT infrastructure.

But ICT infrastructure is located in physical space: it is powered by energy sources; it is operated by people. All these elements are susceptible to the effects of disaster. The cables can break; the towers can topple; the power sources (and the backups) can fail; the people who operate the systems may die, be injured, or be unable to get to their stations. Depending on the technological platform, ICT infrastructure is vulnerable in varying degrees to damage and disruption from the physical causes described above.

The destruction of a country's ICT infrastructure by a natural disaster is exemplified by the Mexico City earthquake of 1985, which caused a collapse of the central communication facility of the Ministry of Communication and Transportation, cutting off most of the communication with the world. This catalysed the formulation of the Tampere Convention on the Provision of Telecommunication Resources for Disaster Mitigation and Relief Operations (see Box 2).

To the extent that ICT networks can be kept functioning in the midst of a disaster, spatial coordination can be done not only by emergency first responders (who are the most important in such situations) but also by public and private entities responsible for restoring services and by members of the public.

Prior to liberalization, communication services were supplied by integrated monopolies, in most cases owned by the government. This allowed for certain advantages, particularly the ability to absorb additional costs for public-service objectives (such as redundancy beyond what market dynamics would support, and even cross-subsidies for emergency first responder services) and creating a single point of contact. However, the monopoly structure also had significant disadvantages. Decision-making procedures were diffused and accountability weak. And if the network went down, there was no alternative.

Box 2: The Tampere Convention⁷

The Tampere Convention was negotiated in 1998 and came into force in 2005, shortly after the 2004 Indian Ocean tsunami. It simplifies the import and rapid deployment of telecommunication equipment in the event of an emergency. This treaty defines aspects of the provision of telecommunication equipment and human resources, the procedure for requests for assistance, and the termination of assistance, among other facets. It makes specific reference to the reduction of regulatory barriers,

⁶ Darrell M. West and Elizabeth Valentini, "How mobile devices are transforming disaster relief and public safety", 16 July 2013. Available from <http://www.brookings.edu/research/papers/2013/07/16-mobile-technology-disaster-relief-west>.

⁷ International Telecommunication Union, "Tampere Convention", 1998. Available from http://www.itu.int/ITU-D/emergencytelecoms/Tampere_convention.pdf.

including, but not limited to, recognition of foreign type-approval of telecom equipment and/or operating licenses.⁸ As such, it requires all states to maintain an inventory of telecommunication resources (equipment and personnel) available in the event of disaster relief. Signatories of the treaty are also required to develop action plans with detailed information on emergency deployments. It also recognizes that within its territory, a state has the right to direct, control, and coordinate assistance.

Forty-six countries have ratified the treaty to date, with the most recent being Luxembourg in June 2012. It does not appear that it has been invoked in any disaster up to now. It appears that the state-to-state request and offer procedures embodied in the Convention may be of limited relevance in the new liberalized markets, in contrast to the government-owned or sanctioned monopoly markets that existed when the Convention was conceptualized.

Sri Lanka played an important role in negotiating the Convention and became a signatory in 1999. Studies were conducted and an inventory was prepared. Yet it played no role when the country experienced its greatest natural disaster in the form of the 2004 Indian Ocean tsunami. For one thing, the communication networks did not suffer widespread destruction, unlike in the 1985 Mexico City earthquake, which shaped the formative discussion on the Tampere Convention. In Mexico City, the central communication facility of the Ministry of Communication and Transportation collapsed, cutting off most communication with the world. In the case of the tsunami, damage occurred only in limited coastal areas and none of the core facilities were affected. Therefore, there was little need for bringing in containerized exchanges as was done in Mexico City.

The Convention sought to ease the bringing in of communication equipment, but still left it to national authorities to decide the form of the relaxation. There was a need for point-to-point wireless communication that could have been operated by amateur radio enthusiasts, and equipment was donated to Sri Lanka for their use. However, security concerns from the ongoing civil war resulted in the equipment not being cleared from the port. Whether or not the Tampere Convention was invoked, it is unlikely that the equipment would have been cleared. Yet it must be noted that the telecommunication infrastructure, comprising the nationwide networks of three fixed operators, four mobile operators and one trunked-radio operator, was fully operational within 2-3 days of the disaster, with the needed repairs and replacements in coastal areas being completed.

The Tampere Convention sought to address the problem of almost complete destruction of the telecommunications infrastructure in a city or a larger area. It appears that the only natural hazard that is likely to yield such an outcome is an earthquake by itself or combined with a tsunami, as was seen in Lisbon in 1755, in Aceh, Indonesia in 2004, and most recently with the Great Tohoku Earthquake in eastern Japan in 2012. It appears that governments are wary about invoking the Tampere Convention even in these circumstances. In the case of Indonesia and Japan, it may have been because there were plenty of resources within the unaffected parts. There may be value in raising the awareness of the Tampere Convention among decision makers, especially in small countries located in earthquake zones or tsunami paths. But the possibility that multiple networks operating independently of one another are inherently more robust and disaster-resilient than the old monopoly networks that shaped the thinking behind the Tampere Convention cannot be ruled out.

In liberalized environments, multiple suppliers and technologies exist. Even long-held assumptions, such as the technical and economic infeasibility of building multiple undersea cable stations, have had to be abandoned in the new competitive environment.⁹ The most important benefit of competitive markets is the inherent redundancy created by the existence of multiple, competing networks. So even if one were to fail, it is unlikely that all networks in a specific locality would fail at the same time. Solutions such as permitting the customers of one operator to roam on the networks of competitors for the duration of “a state of

⁸ International Telecommunication Union, “Tampere Convention – Article 9(3)”, 1998. Available from http://www.itu.int/ITU-D/emergencytelecoms/Tampere_convention.pdf.

⁹ Office of the Communications Authority, Hong Kong, China, “Landing of submarine cables in Hong Kong”, 1 August 2013. Available from http://www.ofca.gov.hk/en/industry_focus/telecommunications/facility_based/infrastructures/submarine_cables/index.html.

exception” resulting from a disaster are available only in competitive markets. Local roaming has been tested and is ready for implementation in the event of a disaster by the two mobile network operators (MNOs) in the Maldives (see Box 3). Additionally, crews travelling across post-disaster terrain to repair one network can coordinate their activities using mobile phones from another functioning network. Where multiple undersea cable and satellite paths controlled by different companies exist, various kinds of formal and informal swap and barter arrangements can be made to ensure redundancy and business continuity.

Under government ownership, governments for the most part “self-insure” with respect to the kinds of catastrophic losses caused by disasters. Following liberalization, the question of who will compensate the owners of damaged infrastructure and to what extent has come to the fore. If government continues to act as an informal insurer of last resort, it has been argued that the wrong incentives will be created, whereby private owners will not take prudent measures to safeguard their assets from disaster risk. On the other hand, mandating compulsory insurance would mean passing on significant additional costs to end-users of services, especially in regulated industries. Regulatory agencies will have to achieve a reasonable balance between these two outcomes.¹⁰ One possible solution is to create risk pooling systems, with adequate diversification strategies, that rest on the fact that a hazard cannot affect at the same time all the forms of infrastructure in a group of countries. A starting point is the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI), a regional programme that seeks to provide disaster risk modelling and assessment tools to member countries (only five have joined, so far). PCRAFI also seeks to engage in a dialogue with the Pacific Island Countries (PICs) on integrated financial solutions for the reduction of their financial vulnerability to natural disasters and to climate change. It is not a regional risk-pooling system as such, but may be developed into one.

Programmes that foster disaster risk management, such as PCRAFI, can be used to ease the burden by providing immediate liquidity to governments.¹¹ It can also provide expertise on financing strategies and disaster risk management and foster regional collaboration. PCRAFI is a joint initiative between the Secretariat of the Pacific Community (SPC/SOPAC), the World Bank, and the Asian Development Bank (ADB), with financial support from the Government of Japan and the Global Facility for Disaster Reduction and Recovery (GFDRR), established in partnership with the World Bank and the United Nations.¹²

With technical inputs from GNS Science, Geo Science Australia, and AIR Worldwide, PCRAFI provides a host of tools for studying historic disasters and their losses, country-specific catastrophe risk models, including country risk profiles and the Pacific Risk Information System, the largest collection of geospatial information for the Pacific Islands.¹³ Additionally, there are other applications that provide, for instance, finance ministries with advisory services and help develop a national disaster risk financial strategy, among others. In January 2013 the Pacific Catastrophe Risk Insurance Pilot was launched with the aim of providing the five participating countries (Marshall Islands, Samoa, Solomon Islands, Tonga, and Vanuatu) with immediate funding in the aftermath of a severe natural disaster.¹⁴

¹⁰ Leena Srivastava and Rohan Samarajiva, “Regulatory design for disaster preparedness and recovery by infrastructure providers: South Asian experience”, in *Critical Infrastructures: State of the Art in Research and Application*, W.A.H. Thissen and P.M. Herder, eds. (Boston: Kluwer Academic Publishers, 2003). Available from <http://unpan1.un.org/intradoc/groups/public/documents/APCITY/UNPAN022463.pdf>.

¹¹ J.D. Cummins and O. Mahul, *Catastrophe Risk Financing in Developing Countries – Principles for Public Intervention* (Washington, DC: World Bank, 2009). Available from <http://siteresources.worldbank.org/FINANCIALSECTOR/Resources/CATRISKbook.pdf>.

¹² World Bank, “Pacific Disaster Risk Financing and Insurance Program”, 2013. Available from <http://go.worldbank.org/HVA5HLS4U0>.

¹³ Pacific Catastrophe Risk Assessment and Financing Initiative, “Pacific Catastrophe Risk Assessment Financing Initiative – Progress Brief”, 2012. Available from <http://ict.sopac.org/pcrafi/PCRAFIBrief.pdf>.

¹⁴ Pacific Catastrophe Risk Assessment and Financing Initiative, “Pacific Catastrophe Risk Insurance Pilot”, January 2013. Available from http://siteresources.worldbank.org/EXTDISASTER/Resources/8308420-1361321776050/Pacific-Catastrophe-Risk-Insurance-Pilot_4pager_12Feb13.pdf.

Given the vulnerability of PICs to natural disasters, risk pooling mechanisms enable them to insure and purchase catastrophe coverage at a significantly lower cost than what individual government reserves or independent insurance covers would cost. When a disaster occurs, emergency funds are often derived from other development projects that are likely to create new debt.¹⁵ Therefore, in certain cases, risk pooling strategies are desirable. This is subject, however, to severe scrutiny of a country's profile, cost estimates of prior damages caused by natural disasters, catastrophe risk models, and information about many other variables. In order for catastrophe insurance to be feasible on both the supply and demand sides, the pricing of the insurance products needs to be transparent and there needs to be a critical business volume. In the case of the pilot project, the five participating countries have a less volatile disaster risk portfolio, making it attractive to insurance companies and less expensive for the participating countries.

In recent times, telecommunication infrastructure sharing in various forms has been promoted at government and inter-government levels¹⁶ and has been adopted by industry. The pressures to reduce costs and address the increasing difficulties of obtaining access to tower sites and spectrum have made operators amenable to infrastructure sharing. In some cases, companies spun off their towers to specialized tower operators.¹⁷ Increased vulnerability of ICT infrastructure has been an unintended consequence. Now, if a shared tower is destroyed, multiple networks are affected. However, a disaster can also prompt infrastructure sharing, as was the case in Sri Lanka, where recovery efforts included the relocation of cell sites and the sharing of towers with other operators.¹⁸

Different components of networks and different technologies have different advantages/disadvantages in relation to reliability. These components, as well as the general problem of congestion, which affects all types of infrastructure, are discussed in the subsections below.

2.2.1 Satellite systems

The least vulnerable, at least to earthly disasters, are satellite-based communication systems. Unless the master earth station is itself affected by the disaster, these systems are immune to the effects of cyclones, floods, tsunamis, and the like. They are, however, vulnerable to space-borne hazards such as meteorites, space debris, and solar flares. But these hazards do not simultaneously affect co-located populations and therefore have very different repercussions. Satellite-based communication systems are hence ideally suited to serve as backup systems to ground-based systems. Because of problems of high latency in all but a few satellite communication systems and capacity constraints relative to fibre optic cables, they tend to be secondary systems, except in special circumstances such as small island countries and sparsely populated remote regions (e.g., Maldives; see section 3.1). But even in these special locations, the access network is ground-based, so its reliability is subject to the factors discussed below. Though the costs are relatively high, satellite-based personal communication systems are among the most reliable, especially for emergency first responders, since they are completely independent of ground-based segments, other than the master antenna.

2.2.2 Access networks

Wireless systems, such as cellular mobile systems, terrestrial trunked radio (TETRA) systems, and even VHF/HF-based systems, may be considered somewhat more vulnerable because of their dependence on

¹⁵ J.D. Cummins and O. Mahul, *Catastrophe Risk Financing in Developing Countries – Principles for Public Intervention* (Washington, DC: World Bank, 2009). Available from <http://siteresources.worldbank.org/FINANCIALSECTOR/Resources/CATRISKbook.pdf>.

¹⁶ ITU Global Symposium on Regulation, "Best practice guidelines on innovative infrastructure strategies to promote affordable access for all", 2008. Available from http://www.itu.int/ITU-D/treg/Events/Seminars/GSR/GSR08/PDF/GSRguidelines08_E.pdf.

¹⁷ One example is Indus Towers. See <http://industowers.com/>.

¹⁸ Dialog Telekom Limited, "Disaster Recovery and Business Continuity – Post 26/12", 2009. Available from [http://www.itu.int/ITU-D/asp/Events/EmergencyTelecomWorkshops/SriLanka_Workshop/Presentation/9\)%20Dialog%20Telekom.pdf](http://www.itu.int/ITU-D/asp/Events/EmergencyTelecomWorkshops/SriLanka_Workshop/Presentation/9)%20Dialog%20Telekom.pdf).

towers and power from the electrical grid, which means that the vulnerability of the grid also affects these systems. Greater amounts of backup power can address the latter vulnerability, though the experience of Hurricane Sandy in 2012 suggests the limitations of even eight hours of backup battery power.¹⁹

The remaining concern, then, is the vulnerabilities of the towers, which can be toppled, flooded, or otherwise damaged. The solutions are selecting robust locations and building adequate redundancy into the network so that communication can continue even if some towers fail. The specialized networks may use higher power levels and frequencies that cover greater distances and so may rely on a less dense network of towers, but they too are vulnerable. As a broadcast technology, high-frequency (HF) transmission is accessible by anyone who is tuned in to the frequency, albeit the trade-off is significantly lower bandwidth, sufficient for transmitting text. A more pertinent characteristic to consider is signal propagation; the atmosphere alters the propagation of signals in general, and HF signals are more prone to react to these propagation characteristics, but the effect can be overcome by using equipment that will automatically tune in to the best available channel. Regional collaboration on standardizing the use of HF frequencies is imperative in order for its optimal use as a mode of emergency communication.

Other access networks are composed of “wireguides”, such as fibre, coaxial cable, or twisted pair copper. Buried wireguides can be damaged by floodwaters and earthquakes. Aerial cables are susceptible to wind damage. The poles that carry the wires can collapse. Japan, after the earthquake of 1995 and the earthquake and tsunami of 2011, experienced significant damage to aerial cables in comparison with buried cables (see section 3.4). As a result, a recommendation made by experts in Japan was to promote the use of ducts and to encourage the use of buried cables.²⁰

2.2.3 Backhaul networks

Both wireless and wireguided public networks depend on domestic and international backhaul networks for effective functioning. The relatively small amounts of traffic generated by individual users become aggregated into large streams of data in backhaul networks. Whereas damage to network links (wireless or wireguided) will affect localities, damage to a backhaul link will have much broader effects, affecting not only the areas directly affected by the disaster but larger regions and, in the case of international links, entire countries.

Backhaul links may be fibre optic or coaxial cables, or satellite or microwave links. The cables may run undersea, be buried underground, or in some cases be pole-mounted. Undersea cables are especially vulnerable to damage in shallow waters as they come to shore. Cable stations and satellite earth stations are considered critical parts of the infrastructure. Cable stations tend to be built like bunkers, evidence that their builders wish to safeguard them from danger. Satellite earth stations are vulnerable to wind and water damage but again, tend to be built in secure locations to high standards. However, there are limitations, especially on small islands where such locations may be few. Microwave links are vulnerable because of the antenna towers, which tend to be in high locations.

It is not possible to make these critical infrastructure elements completely secure, though it is important to strive for high levels of robustness in design and operation. Therefore, network design has to incorporate redundancy. For example, the design may allow power to be drawn from more than one electrical substation. Battery backup is common, though generators may also be placed in the location, along with adequate supplies of fuel.

¹⁹ Brian X. Chen, “FCC seeks ways to keep phones alive in a storm”, *New York Times Bits*, 5 February 2013. Available from <http://bits.blogs.nytimes.com/2013/02/05/f-c-c-revisits-communications-failures-after-hurricane-sandy/?src=recg>.

²⁰ Hideo Tomioka, “Maintaining communications capabilities during major natural disasters and other emergency situations”, Ministry of Internal Affairs and Communications, 16 March 2012. Available from http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/presentation/pdf/Telecommunications_Policy_Division_MIC.pdf.

In addition, the potentially vulnerable element itself can be made less critical by the use of ring architecture, whereby a single break can be worked around, albeit at a degraded network speed. Multiple breaks, however, can result in network failure. Therefore, ring architecture is not ideal when network availability is critical. It is now becoming more common to shift to even more robust mesh architectures, in which multiple, simultaneous breaks can be worked around. In a mesh network topology, all nodes are connected to every other node, thereby increasing redundancy and cost, the latter being its main disadvantage. With cost and complexity in mind, hybrid ring-mesh architectures may prove a more viable option.

As the debate between the Federal Communications Commission (FCC) and the United States mobile operators in the aftermath of Hurricane Katrina demonstrated,²¹ redundancy has costs. In a competitive environment, it is not always clear what customers are willing to pay in order to receive the highest levels of reliability. Corporate customers place a money value on the level of reliability they want by paying for service level agreements (SLAs) that charge a premium for the highest levels of reliability (e.g., “five nines”, or 99.999). Non-corporate customers, on the other hand, tend to make their purchase decisions on the basis of price and factors other than reliability under extreme conditions, yet when the extreme conditions do occur they expect the networks to function. Therefore, striking the right balance between adequate levels of redundancy and efficiency continues to be an issue that regulators will have to grapple with.

Quantifying the premiums that different categories of corporate customers may be willing to pay for increased reliability is not an easy matter. The premiums change from country to country and with different classes of customers, and in any case the specialized service suppliers who provide these kinds of services negotiate the contracts away from the public eye.

Simply having fibre in the ground or under the sea is not enough in itself. Terabit Consulting has shown that, despite considerable investments that have resulted in the building out of undersea and terrestrial cable throughout South-East Asia, most international backhaul traffic transits via the international bandwidth hubs in Singapore and Hong Kong, China. The collection of bilateral links does not add up to a coherent and seamless regional network that can support regional integration initiatives, such as the plan to make the Association of Southeast Asian Nations (ASEAN) a single market by 2015, let alone provide low-cost, redundant international backhaul capacity to any but the most advanced of the region’s economies.²² Terabit’s recommendations for a pan-Asian terrestrial optical fibre network addresses these larger concerns and, if implemented, would result in lower-cost and more resilient international connectivity. Understanding the difficulties of developing the necessary multi-state consensus, Terabit also assesses the state of bilateral connectivity among ASEAN member country pairs and makes recommendations for where they can be supplemented with additional cables. These interim measures should also result in incremental improvements in reliability.

2.2.4 Congestion

Even if the physical elements such as towers and wires survive the disaster, the networks may fail because of congestion. The end result, in the short term, is no different from failure caused by physical damage. The best way to understand failure caused by congestion is through analogy with traffic on roads. If all the vehicles in a country are put on the roads all at the same time, it is unlikely that any will be able to move. Roads are simply not dimensioned to accommodate such an unusual spike in traffic. It is not impossible to build roads wide enough for such a volume of traffic, but costs would be horrendously high and wasteful, since multiple lanes would be unused most of the time. In the same way, it is inefficient to dimension communication networks to handle the levels of peak traffic levels experienced at the onset of a disaster.

²¹ Dan Jones, “Sandy: The case for better cell site backup?” 2 November 2012. Available from <http://www.lightreading.com/fourth-generation-4g-wireless/sandy-the-case-for-better-cell-site-backup/240143534>.

²² Terabit Consulting, “An in-depth study on the broadband infrastructure in the ASEAN-9 region”, version 2.2, report prepared for UNESCAP and Korea Communication Commission, 2013.

Sudden spikes of traffic in circuit-switched networks can cause the networks to crash, though it is possible to restore the network relatively quickly. In packet-switched networks, the result is degraded performance. Where store-and-forward capabilities exist, such as with SMS, the message will still be delivered, but hours late.²³

The consequences of congestion for first responders are extremely serious. Therefore, it is customary to give them forms of connectivity that are immune to congestion. For example, first responders may be provided with subscriptions to TETRA networks, which are not interconnected with public networks and are designed to accommodate the expected volume of peak-hour calling by the smaller number of first responders. As a result, however, these networks are more costly per user. The handsets also tend to be more expensive and bulkier than normal mobile handsets. Public networks are likely to be highly unreliable for critical first-responder communications, especially in the early hours of a disaster. However, certain features, such as the cell broadcasting function (which is immune to congestion because it is a one-to-many communication system that reaches all handsets within range of a base station), may be used to supplement first-responder communication through dedicated private networks. Cell broadcasting has over 60,000 virtual channels. Therefore, certain designated and not publicly available virtual channels can be used to alert first responders to immediately initiate use of their TETRA units, for example.²⁴

If there is no physical damage to network elements, the problems caused by congestion will gradually subside as the general users modify their communication behaviour. Regulators cannot insist on networks being built to eliminate congestion altogether, though it is possible to develop standards for redundancy levels and recovery procedures, in consultation with service providers who are best-informed on the subject and have to implement the rules in difficult circumstances.²⁵

2.3 Publication

The ubiquity of mobile connectivity, the ability of mobile networks and handsets to work even after conventional power supplies have been disrupted, and their increasing use to disseminate user-generated information make it necessary to discuss publication. Conventional media such as newspapers are likely to be affected by transport system disruptions. Conventional television may not be fully viewable, either because the transmitting or retransmitting facilities have been knocked out, or because television sets are not available, or power supplies to homes have been disrupted. Radio broadcasting is more robust, but surveys of users at the bottom of the pyramid have shown that it is declining vis-à-vis television and phones.²⁶

One may ask why it is necessary to discuss publication in post-disaster situations. A very practical reason is that it is a means of holding accountable the government and non-governmental entities that are engaging in relief and recovery activities. While communications from the beneficiaries traditionally took the form of petitions and protests, these functions are made possible now with social media, which are monitored by media personnel and possibly even by those with authority over persons administering relief and recovery in the field.²⁷

²³ Congestion and how it can be dealt with are discussed in detail in Rohan Samarajiva and Nuwan Waidyanatha, "Two complementary mobile technologies for disaster warning", *Info*, vol. 11, No. 2 (2009), pp. 58-65.

²⁴ Natasha Udu-gama, "Mobile cell broadcasting for commercial use and public warning in the Maldives", May 2009. Available from http://lirneasia.net/wp-content/uploads/2009/07/CB_Maldives_FINAL_2009_041.pdf.

²⁵ P.S. Anderson and G. Gow, "A general framework for mitigation-oriented planning assessments of mobile telecommunications lifelines", *Natural Hazards*, vol. 28 (2004), pp. 305-318.

²⁶ LIRNEasia, "Teleuse at the bottom of the pyramid: Data booklet", 2008. Available from <http://lirneasia.net/wp-content/uploads/2008/04/Teleuse-at-BOP-Data-Booklet-LIRNEasia.pdf>.

²⁷ LIRNEasia, "Webhamuva Final Report", September 2006. Available from <http://www.lirneasia.net/wp-content/uploads/2006/10/Webhamuva%20Final%20Report.pdf>.

No special reliability problems affect publications beyond those discussed above in terms of the resilience of the networks. The need for publication arises a few days after the disaster and the relief and recovery efforts are underway, so it may be expected that some of the most serious problems with infrastructure would have been resolved by then.

2.4 Facilitation of payments

During the relief phase, resources flow into the disaster-affected area. At the beginning, they take the form of actual goods. As time passes and recovery begins, the mix changes in favour of money. In fact, disaster professionals advocate the practice of discontinuing the importation of supplies and reengaging local sources by giving disaster survivors the wherewithal to purchase necessities so that economic revival can begin.²⁸

It is not a simple matter for government to disburse money to citizens while minimizing the risk of fraud. In conditions where people are still living in temporary accommodation, keeping cash is likely to be a problem. The increasing presence of mobile money and payment mechanisms may be able to provide solutions to both problems.²⁹ It is not difficult to establish a unique relationship between a citizen and a “mobile wallet” associated with a specific phone number. Once the money is in the mobile wallet, all that is required are local vendors who will accept mobile payments and a few cash-out locations to disburse cash to those who might require small quantities of old-fashioned money.

The government may have difficulty if the mobile payment system is limited to one company and not all beneficiaries are subscribed to that company. It may be necessary to make at least temporary arrangements within the disaster-affected area for some kinds of interconnection, perhaps even based on proxy numbers, to be made possible in the payment space.

The robustness of the system comprises two parts. The robustness of the underlying mobile network has been discussed above. The security of the payment system is the second part. This is an issue that must be addressed, but not necessarily in the context of post-disaster relief and recovery actions.

3 Country examples and good practices

This section looks at selected examples of disaster occurrences, the effects on existing ICT infrastructure, and steps taken to rebuild resilient networks.

3.1 The 2004 tsunami in the Maldives³⁰

After the tsunami in 2004, the operators and the Communication Authority of Maldives took some key steps to safeguard their communication networks in the event of another natural disaster. As a disaster mitigation step, the two mobile network operators (MNOs), Dhiraagu and Wataniya, have changed their network topologies from a series type to a ring, with the aim of increasing resilience.³¹ In addition, two very small

²⁸ Disaster Management Training Programme, “Disaster economics”, 2nd ed., 1994, United Nations Development Programme and Department of Humanitarian Affairs. Available from http://www.pacificdisaster.net/pdnadmin/data/original/dmtp_17_disaster_economics_8.pdf.

²⁹ Matt Daggett, “Mobile money in Haiti: A new support for disaster relief and development programs”, 9 March 2011. Available from http://www.ssireview.org/blog/entry/mobile_money_in_haiti_a_new_support_for_disaster_relief_and_development_pro/.

³⁰ Information received by the Deputy Director of the Communication Authority of Maldives.

³¹ Although failure in one node can cause problems for the entire network, this can be overcome, unlike in the series topology, by terminating connectivity to the affected node and sending data both clockwise and anticlockwise.

aperture terminals (VSATs) have been installed for emergency communications in strategic locations (Vilimalé and South Gan), which were selected based on geographic dispersion of the two islands and population density. Other measures taken include the interconnection of the country's two submarine cables (one owned by the incumbent Dhiraagu and the other a consortium that includes Wataniya and Focus Infocom, an Internet service provider). This measure will reduce the risk of completely losing connectivity with the international community. National roaming and priority calling that will be activated with the official announcement of a disaster are other initiatives taken by the operators in Maldives.

Box 3: Local roaming during disasters

After Hurricane Sandy hit the east coast of the United States in 2012, around 20 per cent of the base stations went down due to electricity problems.³² To ensure that customers received the best service during the disaster, AT&T and T-Mobile allowed local roaming on each other's networks in the affected areas. Implementation of this service was not complicated, as both networks used similar technologies.

Telecom regulators from different countries are also in the process of introducing emergency roaming. For example, in the United Kingdom, calls to 999 and 112 emergency numbers can be made via any network, if the person's network is unavailable and an alternative provider has coverage.³³

3.2 The 2004 tsunami in Sri Lanka

Following the tsunami of 2004, perhaps the worst natural disaster ever to affect Sri Lanka, Dialog Telekom (now Dialog Axiata PLC) reported the extent of the damage and the disaster recovery mechanisms they undertook. The primary damage to the network was caused by water entering the power systems and cabins housed alongside the base transceiver stations (BTSs). In some cases, the cabins that housed the BTS equipment were washed away, and in other cases the towers were damaged by the impact of the waves that hit the shores. Although there was a disconnection of the power supply from the main grid, the backup batteries were equipped to sustain the power supply. It took 72 hours to restore 66 per cent of the damaged stations, and complete restoration took four days. This was achieved by relocating cell sites, replacing generators, and sharing infrastructure. The badly damaged transport routes were the main obstacle to sending the engineering teams required for the restoration work and the fuel required for the generators.³⁴

The following factors contributed to the quick turn-around time:

- The availability of backup power supplies that could last 10 hours. Given the limited geographical area of the island, this was deemed sufficient;
- Use of flexible technology that allowed for the redirection of calls;
- Pre-designed guidelines for emergency team deployment;
- Cooperation among network operators.

The network of the incumbent fixed-line operator Sri Lanka Telecom (SLT) also suffered heavy damage on the east coast and in a few cities in the south and north coasts of the Island. Two per cent of the SLT network went down, with around 59,000 lines disconnected.³⁵ Around 33 per cent of these damaged lines

³² Edward Wyatt and Brian X. Chen, "F.C.C. details storm-related cellphone problems", *New York Times*, 31 October 2012. Available from [http://www.nytimes.com/2012/11/01/technology/fcc-details-cellphone-problems.html?nl=todaysheadlines&emc=edit_th_20121101#h\[\]](http://www.nytimes.com/2012/11/01/technology/fcc-details-cellphone-problems.html?nl=todaysheadlines&emc=edit_th_20121101#h[]).

³³ Ofcom, "Connecting citizens", 2009. Available from <http://consumers.ofcom.org.uk/2009/10/connecting-citizens/>.

³⁴ Dialog Telekom Limited, "Disaster recovery and business continuity – Post 26/12", 2009. Available from [http://www.itu.int/ITU-D/asp/Events/EmergencyTelecomWorkshops/SriLanka_Workshop/Presentation/9\)%20Dialog%20Telekom.pdf](http://www.itu.int/ITU-D/asp/Events/EmergencyTelecomWorkshops/SriLanka_Workshop/Presentation/9)%20Dialog%20Telekom.pdf).

³⁵ Sri Lanka Telecom, "Annual Report", 2004. Available from http://www.slt.lk/sites/default/files/reports-html/annual/2004/html_version/ceo/message.htm.

were reconnected within two weeks following the tsunami. SLT used microwave links to connect its affected base stations to the network.³⁶

Immediately following the devastation of the tsunami, SLT restored connectivity to all essential services, such as police and hospitals, and set up the Disaster Management Centre (DMC). They also provided satellite communication facilities and wireless phones to relief agencies. Two days after the disaster hit, they had arrangements for telephone facilities on a free-of-charge basis for the public to convey urgent messages. SLT also widened the scope of the SLT operator-assisted services (101) to provide connectivity to relief centres, hospitals, police, and the like.³⁷

3.3 The 2010 earthquake in Haiti

The 7.0-magnitude earthquake severely disrupted access to services through Haiti's new and only undersea cable that carried voice and data traffic. The base station in Port-au-Prince, the link between the undersea cable and the communication network, was destroyed; as a result, Bahamas Telecommunications Co., the operators of the undersea cable, was unable to contact their on-site Haitian partners for two days.³⁸ The resulting information vacuum impeded relief and recovery operations.

Information was deemed critical by the disaster-affected communities in Haiti during the aftermath of the earthquake and the outbreak of cholera that followed a few months later.³⁹ While there were many forms of broadcasting information that were used via radio, television and web-based solutions (see Box 4), the two MNOs, Digicel and Voila, had trouble getting equipment and workforce into the country to repair the damaged infrastructure, as mobile networks were not considered a humanitarian priority.

Box 4: Noula – Web-based system for mapping local needs and sources of assistance, Haiti⁴⁰

The Noula project (Kreyol for “We are here”) is a web-based system developed immediately after the earthquake in Haiti in 2010. They developed a web-based map, charting needs and places where help was available. This map could be accessed by the public online, where real-time help could be posted. A Kreyol-speaking call centre was also set up where people could call with their needs and questions. The Noula call centre had received 25,000 calls within six months after it was set up.

This experience with Noula has also given some insight into the types of issues that people face after a disaster. For example, in the months following the earthquake, the call centre received a high volume of calls from survivors who had left Port-au-Prince but wanted to know how they could claim aid in their new location.

Even after the infrastructure restoration, the sheer volume of calls was too much for the network to bear. Both operators, inundated with requests to share their services and subscriber bases with non-governmental organizations, soon had to rescind their help because of the spamming that followed. As a result, services

³⁶ Lanka Business Online, “SLT estimates network damage due to tsunamis at LKR 750 million but says it will continue to expand aggressively”, 2 January 2005. Available from <http://www.lankabusinessonline.com/news/slt-estimates-network-damage-due-to-tsunamis-at-rs.-750-million-but-says-it-will-continue-to-expand-aggressively/25612406>.

³⁷ Sri Lanka Telecom, “Annual Report”, 2004. Available from http://www.slt.lk/sites/default/files/reports-html/annual/2004/html_version/ceo/message.htm.

³⁸ Christopher Rhoads, “Quake sets back Haiti's efforts to improve telecommunications”, *Wall Street Journal*, 15 January 2010. Available from <http://online.wsj.com/article/SB10001424052748703657604575005453223257096.html>.

³⁹ Imogen Wall, *Best Practice and Lessons Learned in Communication with Disaster Affected Communities: Haiti 2010* (Infoasaid, BBC World Service Trust, and Internews, 2010). Available from http://infoasaid.org/sites/infoasaid.org/files/iaa_haiti_2010_0.pdf.

⁴⁰ Imogen Wall, “Citizen initiatives in Haiti”, *Forced Migration Review*, FMR 38, October 2011. Available from <http://www.fmreview.org/technology/wall.html>.

were kept closed except to organizations they considered responsible and those that were linked to government entities.⁴¹

Box 5: Consequences of sending out mass SMS

Digicel reported situations in which their call centres were bombarded with follow-up questions after the sending of mass text messages. This led to poor customer service and network congestion. The solution implemented was to put up recorded messages for people who could not get through to a call centre agent. It was also noted that there were many attempts to call back the number the SMS was sent from.

3.4 The 2011 earthquake in eastern Japan

The eastern Japan earthquake and the tsunami that followed had a great impact on Japan's ICT infrastructure, with a considerable amount of equipment destroyed, from cables and switches of the fixed networks to BTSs of the mobile networks. Batteries and generator fuel were exhausted, because the congestion on both fixed and mobile networks continued for days. A total of 1.9 million lines were damaged in the fixed network and 29,000 BTSs stopped working (Figures 2 and 3). Each carrier was eventually able to restore its respective networks, apart from the areas surrounding the Fukushima nuclear power plant.⁴² The aftershock that occurred approximately three weeks after the main earthquake further contributed to the damage, with 68,000 fixed lines and 4,100 BTSs being affected.

According to sample data, the tsunami-affected areas (Noda and Kuji Building in Iwate Prefecture, and Shiogama, Iwanuma, Miyagi Ishinomaki, and Natori in Miyagi Prefecture) recorded an aerial cable damage rate 26 times higher than the damage to buried cables. The Great Hanshin-Awaji Earthquake of 1995 also demonstrated the same trend, albeit with less of an impact, with an aerial cable damage rate eight times that of the buried cable. Therefore, a mechanism to strengthen the resilience of telecommunication infrastructure is to promote the use of ducts to bury cables, rather than fostering the use of aerial cables.⁴³

⁴¹ Imogen Wall, "Citizen initiatives in Haiti", *Forced Migration Review*, FMR 38, October 2011. Available from <http://www.fmreview.org/technology/wall.html>.

⁴² Hiroyasu Hayashi, "ICT strategy for recovery of Japan", 12th Asia-Pacific Telecommunity Policy and Regulatory Forum, May 2012. Available from http://www.apr.int/sites/default/files/2012/05/INP-13_ICT_Strategy_for_Recovery_of_Japan_PRF_Japan_rev.pdf.

⁴³ Hideo Tomioka, "Maintaining communications capabilities during major natural disasters and other emergency situations", Ministry of Internal Affairs and Communications, 16 March 2012. Available from http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/presentation/pdf/Telecommunications_Policy_Division_MIC.pdf.

Figure 2: Number of damaged fixed lines

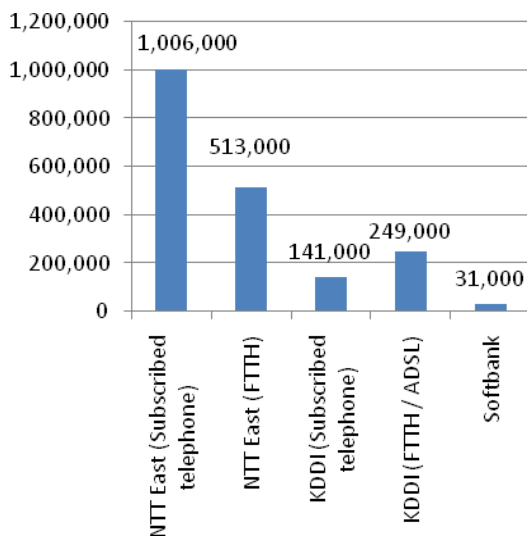
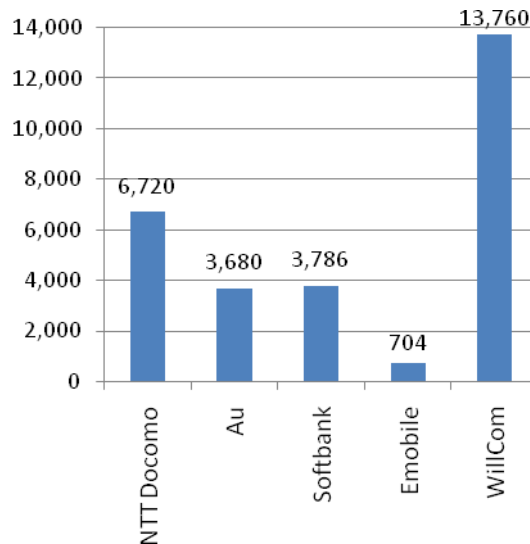


Figure 3: Number of damaged base transceiver stations



With the aim of strengthening the resilience of the communication infrastructure, the Information Communication Council proposed technical standards after analysing the causes of service interruption following the catastrophe:⁴⁴

- Increased capacity of battery and fuel for facilities that cover government buildings;
- Identify important BTSs and provide backup circuits to those facilities;
- Identify important switching facilities of the core network and ensure that they are geographically well-distributed;
- Adhere to restriction control guidelines to manage network traffic and congestion.

The use of multi-layered means of wireless and wired communication also highlighted, for example, the use of satellite phones and medium-frequency radio as alternative means of communication.

NTT DoCoMo has researched and developed technologies to counter the effects of a disaster:

- The development of a telescopic joint and duct sleeve that can expand and contract to offset the tension along the axes of the conduits;
- The construction of gravel drains around manholes to equalize the effects of ground liquidizing (and therefore the potential surfacing of equipment);
- The development of flexible technologies, such as a flexible building access conduit, a flexible excavation cable tunnel, and a flexible shield shaft connection, to protect communication cables from ground motion at level 2 on the Richter scale (seismic support);⁴⁵
- The use of a voice message delivery service that has the ability to avoid network congestion due to voice calls. Other carriers are planning on starting the same service, which would enable operators to deliver messages between each other. Approximately 1,900 BTSs (covering about 65 per cent of the population of Japan) are being equipped with an electricity generator and/or 24-hour-life batteries as mechanisms to secure the telecommunication needs of the local government;⁴⁶

⁴⁴ Hiroyasu Hayashi, "ICT strategy for recovery of Japan", 12th Asia-Pacific Telecommunity Policy and Regulatory Forum, May 2012. Available from http://www.apr.int/sites/default/files/2012/05/INP-13_ICT_Strategy_for_Recovery_of_Japan_PRJ_Japan_rev.pdf.

⁴⁵ Hideaki Kimura, "Japan: What forces did the infrastructure have to face, and how did it stand up to the disaster? Lessons learned", July/August 2011. Available from <http://www.itu.int/net/itunews/issues/2011/06/36.aspx>.

⁴⁶ Hiroyasu Hayashi, "ICT strategy for recovery of Japan", 12th Asia-Pacific Telecommunity Policy and Regulatory Forum, May 2012. Available from http://www.apr.int/sites/default/files/2012/05/INP-13_ICT_Strategy_for_Recovery_of_Japan_PRJ_Japan_rev.pdf.

- The development of a service for smart phones that would enable a voice message to be converted to a data file, and carry it on the less congested packet network;⁴⁷
- During emergency situations, maximum resources would be directed to basic communication services needed for rescue operations and confirming the safety of others, while the priority of servicing other bandwidth-intensive video services would be reduced.⁴⁸

The “Japan Revival Strategy” (a cabinet decision made on 24 December 2011) states that disaster-resistant ICT infrastructure and local “cloud” services should be introduced to promote safety and computerization, as well as achieving operational efficiency in the local government and the medical and education fields.

3.5 The 2011 earthquake in Christchurch, New Zealand⁴⁹

After the 2011 earthquake in New Zealand, the telecommunication network was not as badly affected as the networks in the Japan and Haiti cases. All core networks continued to operate during and after the main earthquake and in the aftermath as a result of the seismic bracing that had been fitted. MNOs too had a reasonable level of connectivity, with only a few cell sites damaged. The main threat faced by the MNOs was the shortage of power due to severe blackouts of the main grid, but the backup power systems continued to work as designed. The seismic support that was provided when planning the network paid off, as none of the equipment suffered any damage. Although the roadside cabinets and cell sites continued to operate, a decision was made to let the broadband cabinets fail, since customers in the area did not have power.

As would be expected in the aftermath of any emergency situation, both public switched telephone networks (PSTN) and mobile networks faced the issue of call-overloading. However, the network throttle was observed only during the immediate aftermath and at the height of panic.

New Zealand has been the victim of earthquakes before, and it is evident that its past experiences have informed implementation of more resilient systems. The mobile network was considered the prime mode of communication. Therefore, many sites were provisioned so that they could be connected to portable engine alternators with ease. Immediate restoration efforts included locating suitably sized engine alternators necessary for keeping the sites operational and for refuelling sites on a regular basis. The extensive congestion caused by vehicle traffic, however, made access to the sites difficult.

Box 6: Public Protection and Disaster Relief initiative

The Public Protection and Disaster Relief (PPDR) initiative, in New Zealand, is a national programme to maintain and improve public trust in the Radio, Communication and Emergency Call Service (111) systems.

The main areas of focus of this initiative are the following:

- Technical Interoperability: Led by the New Zealand police, this initiative aims to develop and implement government-wide technical interoperability standards for narrow-band voice and data radio communications used for public protection and disaster relief;
- Spectrum Allocation Plan: Led by the Ministry of Economics and Development, this initiative allocates suitable spectrum for emergency service use and for providing long-term spectrum licensing to PPDR agencies;

⁴⁷ GSM Association, “Dealing with disasters”, June 2012. Available from http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2012/06/Dealing-with-Disasters_Final.pdf.

⁴⁸ Hideo Tomioka, “Maintaining communications capabilities during major natural disasters and other emergency situations”, Ministry of Internal Affairs and Communication, 16 March 2012. Available from http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/presentation/pdf/Telecommunications_Policy_Division_MIC.pdf.

⁴⁹ Chorus, “Earthquake performance of telecoms infrastructure in Christchurch”, 2011. Available from <http://static.squarespace.com/static/5006875e24ac21f35d8de8d2/t/51622c85e4b058e82d89e12b/1365388421987/AELG%20-%20Foster%20Telecommunications%20-%20AELG%20Seminar%202011.pdf>.

- Radio Communication Strategy: Led by the New Zealand police, this initiative aims to develop a strategy to enhance the integration, performance, and reliability of PPDR radio communications;
- Emergency Call Service: Led by the New Zealand police, this initiative aims to develop emergency call service regulations under the Telecommunications Act 2001, to ensure that the requirements of emergency service providers are appropriately addressed.

3.6 The importance of redundancy in Bangladesh

Bangladesh connected to the SEA-ME-WE-4 undersea cable in 2006, directly connecting it to 15 countries in Western Europe, South-East Asia, and the Middle East. Up to that time, it was the largest country without access to an undersea cable. From 2006 to 2012, it did not have any form of terrestrial redundancy, having to rely on SEA-ME-WE-4 even to communicate with India, the country that almost completely surrounds it.

In the years following the SEA-ME-WE-4 activation, national Internet outages affected Bangladesh regularly. For example, in August 2007, Bangladesh was cut off from the rest of the world after the Chittagong-Cox's Bazaar fibre optic submarine cable was cut.⁵⁰ A few days after it was reconnected, the cable went down again and was only back after 10 hours, during which time Internet services were disrupted, forcing local providers to fall back on slow and expensive satellite services or to simply wait for reconnection. This situation is exacerbated by the absence of ring architecture in the link from Dhaka to Cox's Bazaar. Bangladesh is now connected by several terrestrial cables to India as of 2012.

The Bay of Bengal Gateway (BBG) cable, for which construction has begun, with completion expected in 2014, provides a good example of efforts to increase reliability by working around choke points. The BBG cable will be terrestrial across peninsular Malaysia; the undersea component begins in Penang, well away from the Malacca Straits choke point. It connects to Chennai, Colombo, and Mumbai and lands in Oman. From Oman it becomes, again, a terrestrial system, avoiding the Suez-Somalia choke point.⁵¹ From the United Arab Emirates, it connects to Europe through the recently commissioned Europe-Persia Express Gateway (EPEG), a terrestrial cable system.⁵² There is little doubt that this 100-gigabit-per-second cable, when commissioned, will result in a step-change in the availability, cost, and redundancy of international backhaul capacity in the region.

4 Efforts by international development organizations during disasters

Considering the importance of telecommunications networks during and in the immediate aftermath of disasters, the International Telecommunication Union (ITU), the United Nations, and other international development organizations have implemented disaster relief programmes.

ITU's emergency telecommunication deployments are part of its Framework for Cooperation in Emergencies (more commonly known as IFCE). IFCE provides telecommunication services for disaster mitigation, as well as resource mobilization immediately after a disaster to ensure continuity of communications. For example, immediately after the earthquake in Haiti in 2010, ITU deployed satellite mobile telecommunications

⁵⁰ BDNews24.com, "BTTB's submarine cable connectivity back after 10 hours", 28 August 2007. Available from <http://ns.bdnews24.com/details.php?id=73190&cid=8>.

⁵¹ Moneylife, "Global telcos extend network connectivity with 'Bay of Bengal Gateway' system", 30 April 2013. Available from <http://www.moneylife.in/article/global-telcos-extend-network-connectivity-with-bay-of-bengal-gateway-system/32473.html>.

⁵² Europe-Persia Express Gateway, "About the project," 2011. Available from <http://www.epegcable.com/#page-about-the-project>.

equipment to re-establish basic communication links. ITU also set up a Qualcomm Deployable Base Station (QDBS), a complete cellular system designed to enable wireless communications.⁵³

When the devastating tsunami hit Japan in 2011, Télécoms sans Frontières, a non-governmental organization based in France, deployed a team to Japan to assess the telecommunication needs of the local population and emergency personnel. They also provided portable satellite communication equipment to aid workers who needed to coordinate logistics and rescue efforts.⁵⁴ ITU deployed a hybrid of satellite devices equipped with GPS capabilities to facilitate search and rescue operations. To address the power disruptions, the equipment included solar panels and it was possible to charge them with car batteries.

ITU has also defined a number of standards and recommendations to be followed in times of disaster. One such standard is the International Emergency Preference Scheme (IEPS), which ensures that calls made by those involved in directing and coordinating relief operations get preferential treatment on public networks. IEPS is also operational for Internet protocol networks, cable networks, and next-generation networks. Standards for emergency alert delivery have also been defined.⁵⁵

ITU recommends that it is vital to ensure that women are also engaged in the disaster response programme, because in many communities, women often are the primary communicators and primary care givers, and are more likely to heed warnings and plan for them. It is imperative, therefore, that governments and disaster relief agencies involve women in their disaster preparedness programmes.⁵⁶

Another standard defined by ITU is a standardized, language-independent way to identify next of kin (or other emergency contact) in a mobile handset's directory, in case of an emergency. Usually the directory of the injured person's mobile handset is used to find the next of kin, but without a standard method, it can be difficult for rescue workers to identify who to call. A new clause in ITU Recommendation E.123 proposes storing emergency contact numbers in the form "0nx", where "n" is a digit from 1 through 9 (whom to call first, second and so on) and "x" is any meaningful descriptive character string in any language or script (e.g., "Anna" or "Spouse"). In the handset's directory this would be displayed as "01Anna" or "01Spouse", enabling easy identification by the emergency services.⁵⁷

5 Policy recommendations

For government entities

1. Information and communication are critical to the effective management of disaster relief and recovery and always play a role in those activities. If this awareness is translated into practical systems and procedures that are put in place prior to the disaster, the results will be superior.
2. All public and private entities with disaster management responsibilities should deploy appropriate disaster management software packages prior to the occurrence of a disaster, including prior entry of

⁵³ International Telecommunication Union, "Emergency telecommunications", 14 February 2013. Available from <http://www.itu.int/ITU-D/emergencytelecoms/>.

⁵⁴ United Nations Foundation, "Emergency relief communications for disaster relief deployments archive", 2012. Available from <http://www.unfoundation.org/what-we-do/legacy-of-impact/technology/disaster-relief-deployments/>.

⁵⁵ International Telecommunication Union, "Handbook on emergency telecommunications – Appendices", October 2003. Available from http://www.itu.int/ITU-D/emergencytelecoms/doc/handbook/pdf/Emergency_Telecom-e_appendices.pdf.

⁵⁶ International Telecommunication Union, "Handbook on disaster communications – Emergency telecommunications: Engendering prevention and response", 2001. Available from <http://www.itu.int/ITU-D/gender/documents/emertelegenderfinal.pdf>.

⁵⁷ International Telecommunication Union, "ITU standard allows emergency rescue workers to identify a victim's next of kin", 20 May 2008. Available from <http://www.itu.int/ITU-T/newslog/ITU+Standard+Allows+Emergency+Rescue+Workers+To+Identify+A+Victims+Nextofkin.aspx>.

resource and other relevant records, and ensure that personnel are trained, e.g., the Sahana deployment by New York City (see Box 1).

3. Attention should be paid to data collection from the field, and where possible the mobile devices that are to be used in post-disaster data collection and communication should be placed in the hands of field personnel prior to a disaster. Ideally, simulations and drills should be conducted at regular intervals.
4. Periodic consultations should be conducted with telecom operators to assess the resilience of their networks to the highest-probability disasters (e.g., cyclones would be at the top of the list in some countries, earthquakes in others).
5. Incentives for resilient telecommunication infrastructure should be created through the prescription of building standards, redundancy requirements, and insurance, and by prescribing sectoral standard operating procedures for effective response during disasters and emergencies.
6. Telecommunication service providers should be mandated to maintain approved contingency plans for post-disaster recovery and to update them periodically. The plans should include 100 per cent redundancy and backups for critical databases and systems.
7. Regulators should factor in redundancy and resilience when promoting telecommunication infrastructure sharing. Specifically, rules regarding critical infrastructure and essential facilities, such as undersea cable stations, should be formulated, taking into account the need to reduce disaster risk.
8. Governments, especially in small island countries, where the most suitable sites will be few, should earmark sites that are least vulnerable to disasters and ensure that they are made available to ICT infrastructure operators.
9. Governments and regulators should encourage private sector suppliers to diversify locations of critical infrastructure and deploy multiple technologies, for example, by ensuring that satellite connectivity is maintained even after fibre connectivity comes to a country. Reliance on undersea cables should be balanced by terrestrial cables where possible, and vice versa. Diversity of cable routes should also be a policy objective.
10. Governments should consider encouraging terrestrial cable systems that run alongside the Asian Highway and the Trans-Asian Railway Network.
11. Governments should develop criteria for declaring a “state of exception”, within which ICT sector rules of exception, such as expedited customs processing of communication equipment and domestic roaming, will come into effect. It is important that the conditions under which the state of exception ends also be specified.
12. Disaster managers in every country should have access to phones that can directly communicate through satellite systems.
13. Performance and reliability metrics should be developed for different segments of networks. Operators should be mandated to report performance indicators to the regulator so that evidence on the resilience of systems can be compiled. The regulator should ensure that the data are accurate through periodic audits and make the data available to stakeholders and the public.
14. Emergency first responders should be provided with private, robust communication systems that are not fully interconnected to public networks. Availability of spectrum for such public-security systems should be ensured.
15. Governments should consider using the potential of cell broadcasting over public mobile networks for supplementary first-responder communications and for post-disaster communication to citizens in specific localities.
16. Governments may consider public education campaigns to educate citizens on responsible use of public communication networks in the immediate aftermath of disasters; protocols for load-shedding based on prioritized number blocks may also be considered.
17. Governments should encourage social media platforms that will allow disaster-affected citizens to communicate their concerns to authorities.
18. As part of relief and recovery, governments should utilize mobile payment systems to transfer funds to disaster-affected citizens.

For operators

1. Operators should adopt mesh topologies for their networks to the extent possible, with ring topologies as the minimum, in order to reduce risks of network failure.
2. Operators should be required to report the extent of aerial cables they deploy, especially in critical backhaul segments, and should be encouraged to bury cables as much as possible.
3. Special attention should be paid to developing redundant solutions for power supplies to critical ICT infrastructure. The most appropriate solutions will differ by country.
4. All mobile operators should be encouraged to develop interoperable mobile payment systems; where this is not feasible, interoperability may be mandated during states of exception.
5. A model should be created that will enable the re-purposing of existing call centres (customer contact centres) that have sufficient capacity and resources and are well-equipped to service the communication needs post disaster. This task, however, is heavily dependent on accurate information that needs to come from government (or trusted) bodies to service the masses.

For ESCAP

1. Promote the concept of a pan-Asian, terrestrial, optical fibre network among member states, since it is the best solution to improving international backhaul, including the lowering of costs and enhancing of reliability. Ideally, the terrestrial network will utilize existing Asian Highway, Trans-Asian Railway, and electrical grid rights of way.
2. In the interim, promote the integration of existing and new bilateral terrestrial and undersea cable segments into regional networks.
3. Raise awareness among government decision makers of the possibilities of requesting help through the Tampere Convention, especially in small island nations and countries that are vulnerable to earthquakes and tsunamis.
4. Assess the use of priority numbers within countries in Asia and the Pacific and the standardization of emergency numbers.
5. Contribute to the standardization of channel allocations in cell broadcasting, which has been widely considered but not implemented. Given its importance and usefulness in post-catastrophe situations, actively engaging in setting standards for cell broadcasting regionally or internationally is important.
6. Assess countries' vulnerability to natural hazards and then determine the feasibility of creating or extending the current catastrophe risk management initiatives (PCRAFI or similar) to include a subregion or more countries.
7. Assist in implementing disaster management software similar to that of the Sahana implementation in New York (see Box 1) with long-term recovery organizations.
8. Disaster response responsibility is shifting to community-based organizations (a local empowerment/self-help model), rather than the more traditional government-led (top-down/charity) model of disaster relief. Therefore, it is recommended to design and promote new initiatives that look to build relevant capacity with local organizations.

Annex: Early Warning Systems

Implementation of an effective disaster warning system is a critical component of any national disaster management strategy in order to minimize casualties. This was made clear after the devastation caused by major disasters such as the Indian Ocean tsunami of 2004 and the earthquake and tsunami experienced by Japan in 2011. Owing to the ubiquity of the mobile phone, many public early warning systems are implemented with public warnings sent through mobile phones. According to the Global System for Mobile Communications Association (GSMA),⁵⁸ one of the most effective public warning systems is implemented through cell broadcasting. Two such examples are given below.

Disaster and Emergency Warning Network, Sri Lanka

The Disaster and Emergency Warning Network (DEWN), Sri Lanka's first early warning alert system, was launched in 2009 by the Disaster Management Centre, Dialog Axiata PLC (the country's largest mobile operator), and other partners. It was the result of research and development work undertaken by Dialog Axiata PLC, the Dialog – University of Moratuwa Mobile Communication Research Laboratory, and Microimage, on minimizing the destruction of disasters similar to the tsunami of 2004.

Because the country is nearing over 95 per cent mobile subscriptions,⁵⁹ DEWN uses GSM communication technologies in order to transmit alerts. The Emergency Operation Centre of the Disaster Management Centre of Sri Lanka has been given authority to alert the country through the DEWN system. When information (usually from multiple sources, including the Pacific Tsunami Warning Centre, Met Office, and others) is received by the DMC, it is verified and then customized SMSs are sent first to the emergency personnel on their individual phones. Public alerts are sent only after confirmation of the disaster in order to avoid false alarms. Messages can be sent either via SMS for direct alerts or by cell broadcast for mass alerts, which would still work even if the network was congested. Though the service uses Dialog Telekom's Cell Broadcast function, warnings can also be delivered to other local providers. These messages are also sent to DEWN alarm devices, which have been specially developed to be fixed in public locations, such as temples, churches, schools, and the like, and which contain a loud siren and flashing lamp along with a LCD screen, on which the message will be given in three languages.⁶⁰

Earthquake and Tsunami Warning System, Japan

Due to the prevalence of earthquakes and tsunamis, the Earthquake and Tsunami Warning System (ETWS) has been implemented in partnership with NTT DoCoMo as a method of warning the public about impending disasters. The Japan Meteorological Agency or other authorized local government organizations provide disaster and evacuation information to NTT DoCoMo's Cell Broadcast Centre. Then the message is broadcast (in Japanese) to base stations in relevant areas and appears on compatible handsets as a pop-up screen accompanied by a warning tone. ETWS shortens the message delivery time by sending two messages to the public. The first contains the minimum information needed to alert citizens and is sent using the paging

⁵⁸ GSM Association, "Mobile network public warning systems and the rise of the cell broadcast", January 2013. Available from <http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2013/01/Mobile-Network-Public-Warning-Systems-and-the-Rise-of-Cell-Broadcast.pdf>.

⁵⁹ International Telecommunication Union, "ICTeye", 2013. Available from <http://www.itu.int/net4/itu-d/icteye/>.

⁶⁰ Dialog Axiata, "Disaster and Emergency Warning Network (DEWN)", 2009. Available from <http://www.dialog.lk/about/responsibility/outreach-cr/dewn/>.

channel, which enables the message to be delivered within four seconds. The secondary notification is sent by cell broadcast about 20 seconds later, with full disaster information.⁶¹

⁶¹ GSM Association, "Mobile network public warning systems and the rise of the cell broadcast", January 2013. Available from <http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2013/01/Mobile-Network-Public-Warning-Systems-and-the-Rise-of-Cell-Broadcast.pdf>.