new media & society

London, Thousand Oaks, CA and New Delhi
Vol7(6):731–747 [DOI: 10.1177/1461444805058159]

POLICY COMMENTARY

Mobilizing information and communications technologies for effective disaster warning: lessons from the 2004 tsunami

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Abstract

The Indian Ocean tsunami of 26 December 2004 was one of the greatest natural disasters; it was also the first internet-mediated natural disaster. Despite the presumed ubiquity and power of advanced technologies including satellites and the internet, no advance warning was given to the affected coastal populations by their governments or others. This article examines the conditions for the supply of effective early warnings of disasters, drawing from the experience of both the 26 December 2004 tsunami and the false warnings issued after another great earthquake in the Sunda Trench on 28 March 2005. The potential of information and communication technologies for prompt communication of hazard detection and monitoring information and for effective dissemination of alert and warning messages is examined. The factors contributing to the absence of institutions necessary for the realization of that potential are explored.

Key words

Asia • disaster alerts • disaster warnings • governance • hazard detection and monitoring • Indian Ocean • information and communication technologies • Sri Lanka • tsunami

INTRODUCTION

On the morning of 26 December 2004, water came ashore from the clear blue sea. Within a few hours it killed over 280,931 people, caused around $4.45 billion in damage, and destroyed untold lives and livelihoods in 12 countries bordering the Indian Ocean. The total number of deaths worldwide caused by waves and tidal surges over the entire 20th century was less than 5 percent of the number of deaths caused that day (Centre for Research on the Epidemiology of Disasters, 2005).

The magnitude and significance of the 2004 tsunami appear to be equal to, if not greater than, the great Lisbon Earthquake and resultant tsunamis and fires of 1755 (around 100,000 deaths; Pararas-Carayannis, 1997) and the eruption of Krakatoa and the resultant tsunamis of 1883 (around 35,500 deaths; Pararas-Carayannis, 2003). The destruction of Lisbon transformed western thinking of the time and contributed to the displacement of religion from a central position in intellectual life (Neiman, 2004). Krakatoa was the first global disaster to be made known through a mode of electronic communication (undersea telegraphy) and had wide social and political impact (Winchester, 2003). It is too soon to assess the full significance of the 2004 Indian Ocean tsunami, but part of its significance is likely to be its manifestation as the first global internet-mediated natural disaster.[1] Interestingly, the telegraphic agencies carried the Krakatoa story a day late (Winchester, 2003), qualitatively little different from the greater than two-hour delays in reporting the destruction of Aceh by satellite and internet-equipped news organizations a century later. The ubiquity and power of information and communication technologies (ICTs) that many take for granted is not evidenced by their actual performance in the face of this catastrophe.

On the night of 28 March 2005, three months after the 2004 tsunami, another great earthquake measuring 8.7 on the Richter Scale occurred in the Sunda Trench near Nias Island, south-east of the epicenter of the earthquake of 26 December 2004. Millions of people along the coastlines of the Indian Ocean ran from their homes in the dark as a result. There was no destructive tsunami. Some people died either in the scramble to evacuate, or simply in shock (at least 10 in Sri Lanka), babies were born prematurely (at least five in Sri Lanka), and some looting occurred (Nuwansi, 2005). The evacuation illustrated the problem with tsunami warnings: 75 percent are false (Associated Press, 2005a), and false warnings are costly.

This article contains two sections. The first section describes the uses (or lack thereof) of ICTs in disaster warning, using the 2004 tsunami and the 2005 March false warning as case studies. It identifies the potential uses of ICTs for disaster preparedness and the policy actions necessary for those uses. The second section addresses the problems of market and government failure affecting the effective supply of warnings and alerts and pulls together general lessons from the case study.

ICTs IN DISASTER WARNING

The physical, the symbolic and linking of the two

Hazards occur in the physical world: if there are no humans in the vicinity of the occurrence of a hazard and if it is not observed by humans through sensing devices, the hazard will not only not become a disaster, it will not even be recognized as a hazard. Examples are a landslide under the ocean or in an uninhabited and remote part of a land mass such as Antarctica. In other words, the occurrence in the physical world will not be represented in the symbolic worlds within which human action originates.[2]

If there are humans in proximity to a hazard, it is possible that the physical effects of the hazard will themselves constitute the information (warning) about it. The advice that is given to the citizens of Hawaii about local tsunamis that may be created by proximate earthquakes exemplifies this: 'Your feet are your signal; if you feel an earthquake, head for high ground' (Samarajiva, 2005). Absent ICTs, this is how humans will learn of all hazards.

The function of an early warning system is that of conveying information about a hazard to the humans likely to be affected by it as far in advance of the physical effects as possible. That is, to represent the physical occurrence in the symbolic worlds within which human action originates as quickly as possible. What early warning systems that include electronic communication do is to link the physical and symbolic worlds before the physical manifestations of the hazard. The lead time gained by the linking through the warning (as opposed to the linking by the physical manifestations of the hazard) is what enables humans privy to information in the symbolic worlds to act in ways that reduce risk.

Hazards occupy a continuum in terms of the potential for issuing effective warnings. Droughts, a major hazard, can be forecast months in advance and in fact are described as 'creeping' disasters. Cyclones and similar weather systems that move over oceans are tracked for days by satellites, allowing plenty of time for the linking of the physical and symbolic worlds through ICTs. Tsunamis that travel great distances are described as 'teletsunamis' by the scientists who study them, in order to distinguish them from local tsunamis. The latter allow for little warning, striking land almost immediately after the occurrence of an undersea earthquake. Teletsunamis, which strike land hours later, allow for systematic warning. For example, the 2004 tsunami struck the east coast of Sri Lanka approximately 90 minutes after the occurrence of the earthquake and took more than seven hours to reach the east coast of Africa. Floods and weather systems that move over land, such as tornados, come next in the continuum. Landslides and mudslides tend to occupy the end of the continuum that allows for minimal warning. Hazard detection and monitoring technologies, which are continually evolving, determine the placement of hazards at different points in the continuum.

Electronic media including telecommunications and the internet are critical to the linking of the physical and symbolic worlds. So, for example, the occurrence of the earthquake in the Sunda Trench on 26 December 2004 was known on the other side of the world in Hawaii at the Pacific Tsunami Warning Center almost as it ended 500 seconds after 12.59am Universal Coordinated Time (UTC) and was communicated to warning centers across the Pacific by 1.10am UTC (National Oceanic and Atmospheric Administration [NOAA] timeline, nd). All this was made possible by the underlying infrastructure of fiber optic and copper cables, satellites and other telecom equipment. The occurrence of the earthquake was also known to the Geological Survey and Mines Bureau (GSMB) of Sri Lanka, because it housed a seismometer for the US Geological Survey (Lanka Business Online, 2005). The GSMB was not tasked to issue warnings and did not have the capacity to interpret the seismic data. This may have been the case in the other tsunami-affected countries as well. Therefore, the tsunami hazard was not represented in the symbolic worlds of the tourists in the Maldives and of Sri Lankan villagers in advance of the waves that caught them unawares.

The tsunami that was generated by the earthquake and the destruction of coastal Aceh and ensuing deaths of over 100,000 people was not mapped onto the symbolic worlds of the tsunami experts in Hawaii or anyone else for several more hours. No one heard Aceh's scream. That tragedy did not 'exist' as far as the rest of world was concerned until the first reports were made. The first recorded reports of some form of sea-based hazard were recorded at 2.57am hrs UTC or 3.20am UTC; according to the US National Oceanic and Atmospheric Administration (NOAA), the first news reports came in at 5.12am UTC (Lanka Business Online, 2005; NOAA timeline, nd).[3] It was only when the news reports from Sri Lanka were combined with the previously known earthquake data that the world's foremost tsunami scientists were able to conclude that a massive, destructive teletsunami was ripping its way across the Indian Ocean (Associated Press, 2005b).

Unless new information comes to light, it appears that information on the destruction in coastal Sri Lanka reached the media and the users of media prior to news of the decimation of Banda Aceh. Telephone calls from informants in Trincomalee, Kalmunai, Matara and Galle reached Agence France Presse and Lanka Business Online journalists who broke the story at 3.34am UTC in the form of an online news report (Lanka Business Online) and at 3.46am UTC in the form of a news agency dispatch (Agence France

Presse) (Lanka Business Online, 2005). The ceasefire agreement between the government and the Liberation Tigers of Tamil Eelam appears to have been an enabling factor in the communication among government and non-government actors in the east coast and Colombo, allowing for greater access to telecom facilities, which contrasted with the lack of information flowing out of civil war-afflicted Aceh.[4] But even in a civil war environment, information can flow through military channels. Why this did not happen in Aceh and the east coast of Sri Lanka is a mystery. It appears that the information reached naval and police headquarters in Colombo, but that the secretive culture and/or ineptitude of the recipients resulted in the information not being disseminated further.

Hazard detection and monitoring

Ideally, the existence and magnitude of hazards are identified by the interpretation of data from multiple sensing devices by skilled personnel, based on scientific and historical data and the use of models. The sensing devices necessary to identify the existence and magnitude of a tsunami hazard include seismometers, tide gauges and deep-sea tsunameters, possibly supplemented by ship-mounted accelerometers in the near future (Samarajiva, 2005). Unless sensing devices are equipped with telemetric capabilities, they are of little use other than for historical research, as were the tide gauges in various Indian Ocean ports on 26 December 2004. Hazard detection and monitoring systems straddle the line between communication technologies and hazard-specific detection and monitoring technologies.

Once detected, the hazard must be communicated to those who can interpret and convert it, where applicable, to an alert or a warning for broad dissemination. The further away from the vulnerable humans that the hazard detected by sensing equipment is, the more possible it is to convert the hazard information into an effective warning. The reduction of the risk rests on increasing the interval between the warning reaching the people who can take action to reduce the risk and the physical manifestations of the hazard reaching those humans. In the case of a proximate earthquake generating a local tsunami, the interval is very small, making futile sophisticated hazard detection equipment and disaster warning systems. In the case of teletsunamis, the interval can be quite long. The tsunami generated by the great Chilean earthquake in 1960 killed 61 people in Hilo, Hawaii, 14.8 hours after origination. Several hours later it killed over 100 people in Japan.

In the case of the 2004 tsunami, the hazard was not detected in time. The earthquake itself was detected in time, though its magnitude was not correctly estimated for a while. By 2.04am UTC, one hour and five minutes after the earthquake event began, the Pacific Tsunami Warning

Center in Hawaii issued a second, corrected bulletin upgrading the magnitude to 8.5 and indicating the possibility of 'a tsunami near the epicenter'. In tsunami warning terminology, this indicated a local tsunami that could affect Aceh, not necessarily a teletsunami that would kill people in far-away Tanzania. The bulletin reached all the participating centers, including those in Indonesia and Thailand, and was posted on the web. But no one capable of raising a warning in the Indian Ocean countries, including the media, was watching or paying attention at that moment.[5] It was only at 5.25am UTC, more than four hours after the event, that the magnitude of the earthquake was determined to be 8.9; the final magnitude of 9.3 was calculated only about a month later.

People themselves are additional sources of hazard information. For example, evidence of a tsunami hitting or not hitting Nias Island or the Sumatra shores was critically important in estimating the likelihood of a tsunami generated by the great Nias earthquake of 28 March 2005, in the absence of telemetry-equipped tide gauges and tsunameters in the region. For people to perform hazard-detection functions, they require access to telecommunications. Short numbers such as 112 or 911 are critical to this. Ideally, the public would be given one number to call regarding all emergencies, with the receiving entity (an advanced information technology-based, 24-hour call center) channeling the information to the appropriate agencies for evaluation. Additional modes such as SMS (short message service) and email should be made available. The centers receiving such communications must be properly dimensioned and staffed to handle peaks in calls likely to be generated by hazards. The very patterns of calls (increased volumes, areas of origin, etc.) can be a source of supplementary hazard detection information.

The generation of hazard information from people is hindered by the low connectivity that exists in developing Asia, especially in rural areas. For example, the paucity of telecommunications access in the east coast of Sri Lanka, where the tsunami made first contact, contributed to the lack of information that could have been used to generate a warning for those on the southern, northern and western coasts. The use of the dedicated communication systems of the Sri Lankan police and Navy camps, which are manned by trained personnel and are equipped to communicate hazard information and alerts countrywide, were not exploited on 26 December. Here, it appears that the fault lay not in the technology but in failures of the Police and Navy command structures.

In an ideal system, ordinary people as well as government entities such as police stations and private entities such as hotels would serve as a decentralized system of hazard detection. Along with data from sensing equipment, analysis of the flows of such information as well as its content could be used by an early warning center to generate effective early warnings.

Dissemination of alerts and warnings

It is rare for hazard detection information to yield an unambiguous warning. Mostly, the information is incomplete, yet conclusions must be drawn immediately. The failure to reach prompt conclusions regarding alerts and warning can have dire consequences. Wrong conclusions also lead to bad outcomes. An evacuation in Hawaii is estimated to cost as much as $68 million in lost productivity (Schwartz, 2004). The generation of authoritative disaster warnings requires the application of judgment by experts. Of course, an individual or a group of individuals can take action based on their own interpretations of hazard information.

Therefore, effective disaster preparedness requires the capacity to receive hazard detection and monitoring information and to convert that information into credible, accurate, unambiguous and timely alerts and warnings. The question of why none of the 12 countries affected by the 2004 tsunami (with the limited exceptions of Seychelles and Kenya, which had several hours' warning) exercised this capacity is discussed in the section on institutional constraints below.

Assuming that the capacity to receive hazard information and convert it into alerts and warnings exists, the next question is how those alerts and warnings will be disseminated to first responders, the media and the public. The electronic media industries play a crucial role in the dissemination of warnings. Because it is important to place this discussion in the context of developing country reality, Sri Lankan data will be referred to for illustrative purposes.

Excluding three districts affected by the war, according to 2004 survey data 74.9 percent of Sri Lankan households have electricity, 78.3 percent have a radio, 70.8 percent have a TV set and 24.5 percent have access to telecommunications in the home (Central Bank of Sri Lanka, 2005). During the largest natural disasters that Sri Lanka experienced prior to the 2004 tsunami, the two cyclones of 1978, effective use was made of radio despite the fact that electricity was available to less than 15 percent of households at that time. Less than 60 percent had radios, there was no television in the country and telephones per 100 of the population were less than one. Casualties from the cyclone that actually hit the east coast (the other was a near miss, veering off to hit the east coast of India) amounted to only 915 despite 250,000 families being displaced by the wind and massive tidal surges, a number not very different from that of 2004.

A key difference between 1978 and 2005 has been the proliferation of media outlets. The only electronic medium that was available in Sri Lanka in 1978 was radio broadcasting. The government monopolized it, operating a total of six channels in three languages, all of which received their news from a single newsroom.[6] The situation is more complex now, with a plethora of radio and TV channels available to viewers and listeners. Effective use of electronic broadcasting for disaster management purposes will require a significant amount of prior coordination and preparation, ranging from the establishment of reliable communication channels between the disaster warning center and broadcast stations, to the education of media personnel in proper emergency communication practices, to the clear demarcation of emergency broadcast responsibilities in broadcasting licenses.

It is rare that a hazard affects all citizens of a country simultaneously, unless it is a city state. For example, even with the tsunami, which was by far the largest disaster in Sri Lankan history, only those persons living or traversing a half-kilometer strip around the country required warnings. The tsunami devastated Aceh, on the northern tip of Sumatra, but had no effects on the rest of the Indonesian archipelago.

Communication of public warning is most effective when it is targeted to potentially affected populations. The BBC-based centralized model that rests on the retransmission of centrally produced content adopted in Sri Lanka is not conducive to the dissemination of this kind of targeted communication. The US model of local broadcasters that participate in national networks based on economic and programming requirements is more appropriate. Community or low-power broadcasting stations can be used for effective, targeted dissemination of disaster alerts and warnings.

Multiple, redundant means of communication are required for the dissemination of public warnings. This includes mobile operators who could make wider use of cell broadcasts to reach subsets of their customers, totaling over two million. Unlike cascade-type phone trees and SMS dissemination, cell broadcasts are not vulnerable to congestion and can be targeted to display messages only to phones connected to a particular base station or stations immediately and reliably (see www.cellbroadcastforum.org). Currently, this technology is not capable of alerting the intended recipient through a device such as a ringer, but it appears that this problem may be on the verge of a solution (Purasinghe, 2005).

In an environment of low telecom penetration, it is necessary to communicate alert and warning messages through intermediaries, for example, religious establishments that serve as community centers in most rural areas in Sri Lanka. The Sri Lanka concept paper, NEWS:SL, recommends creation of a virtual network capable of disseminating emergency messages to temples, mosques and churches. It is even possible for the bells and similar devices in these locations to be activated remotely through CAP (Common Alerting Protocol; see www.isoc.org/challenge/index.php). NEWS:SL also recommends the use of non-public and nationwide communication networks such as those operated by the public utilities in conjunction with Wireless Fidelity (WiFi)-based local access systems to activate sirens and otherwise disseminate public warnings. An addressable satellite-based radio system for dissemination of warnings that is currently being trialed (Brewin, 2005) appears to hold considerable promise, especially because of the low costs of its receivers: $130.

The use of public or private communication systems facilities for the purpose of disseminating public warnings carries the risk that the warnings may be inaccurate, tardy, ambiguous or otherwise faulty. The public systems would be protected under doctrines of state immunity. However, the status of private systems is less clear, at least in developing countries.[7]

EFFECTIVE WARNING PROVISION

Why did the millions who suffered and the hundreds of thousands who died on 26 December 2004 not receive one minute of official advance warning, despite the completion of the International Decade for Natural Disaster Reduction in 1999 (Secretary General of the UN, 1999), and numerous conferences, workshops and training courses in the affected countries?[8] Why did their symbolic worlds connect to the physical world in which the hazard occurred only when it was too late, through the waves that drowned them or dragged them out to sea? The answers to these questions are vital to the design of effective warning systems for the future.

With the singular exception of Thailand, the countries that were affected by the tsunami have shown little signs of a proactive approach to institutionalizing effective disaster warning systems beyond attendance at conferences and the utterance of platitudes. Two factors appear to be responsible for Thailand's exception: the recalling of Smith Thammasaroj from the enforced retirement to which he had been sent for demanding a tsunami warning system and the massive losses of tourists to the tsunami. The necessity of providing credible safety assurances to potential tourists, when combined with the passion and authority of a man recognized as being wrongfully punished for his foresight (Associated Press, 2005b), resulted in Thailand actually implementing a national warning system, including the conduct of high-profile evacuation drills.

Market failure

Disaster warning systems, including regional and local hazard detection and monitoring systems, are technological artifacts that require the expenditure of resources to build and maintain. They are public goods that satisfy the conditions of non-rivalry (consumption by one economic agent does not prevent consumption by another) and non-exclusion (a user cannot be excluded from consuming the good without significant effort), in abstract form. Given these characteristics and the associated 'free-rider' syndrome, pure public goods will not be supplied by the market. Goods with significant public goods characteristics will be undersupplied by the market.

A disaster warning system is constituted by a hazard detection and monitoring system and a warning and alert dissemination system. The former may be seen as a cluster of systems that fall into two main categories. Some are regional in scope, such as cyclone detection and tracking systems and tsunami detection systems. Others, such as systems for detecting dam breaches and floods, are local in scope. The warning and alert dissemination systems, ideally dealing with all hazards (Partnership for Public Warning, 2003), may be national or local in scope.

In the case of moving hazards such as cyclones and tsunamis, the warning is more effective the further away from the vulnerable population the hazard is detected. This requires hazard detection and monitoring systems that cover large geographical areas. If each country set up systems of this nature, wasteful duplication would result; if one country was to set up one and the others were to use it (given the moral issues involved, it would be difficult to bar others from access to the information), the additional users would be free riders. Therefore, the logical design is a regional system supported by all beneficiaries. Setting up a regional system with the participation of sovereign states is a difficult task with high transaction costs. The tugging and pulling between India and Thailand even in the immediate aftermath of the 2004 tsunami illustrates the problem (Wiseman, 2005).

Government failure

Problems of intergovernmental coordination may perhaps explain why there was no tsunami detection and monitoring system in place in 2004 despite previous calls by several experts (e.g., Associated Press, 2005b; Breen, 2005). The absence of national all-hazard or even single-hazard warning systems within the countries affected by the tsunami can be explained, although not justified. A public good that is not provided by the market is difficult to be provided by government, especially when multiple stakeholders are involved (driving up transaction costs), when the pay-off is not immediate and obvious, and especially when the pay-off is perceived as likely to occur outside the current electoral cycle.

Yet, other countries such as the US and Japan do have effective disaster early warning systems within their borders while belonging to effective regional networks for hazard detection such as the Pacific Tsunami Warning System, centered on the Pacific Tsunami Warning Center in Honolulu.[9] Why have they succeeded in protecting the lives of their citizens while the governments around the Indian Ocean failed?

Disaster warning is part of the core business of government, by any criterion. In economic terms, it is a public good akin to national defense and has tremendous impact on the economy. In political terms, it is a core element of the state, one that legitimates the existence of the state, a fact well understood by former US President Bill Clinton, whose administration earned a strong reputation in this area: 'Voters don't choose a President based on how he'll handle disasters, but if they're faced with one it quickly becomes the most important issue in their lives' (Clinton, 2004: 428).

Yet, the benefits of disaster warning do not mesh well with the calculus of politicians (Downs, 1957). The pay-offs are not assured within the electoral cycle: most probably the benefits of a warning system established by one politician will be enjoyed by future politicians. This factor is exacerbated in the pathological form of the state, described by Evans (1995) as the predatory state, which is found to a greater or lesser extent in the countries affected by the 2004 tsunami. Here, the driving force of state action is rent-seeking (partly to get re-elected, consonant with the Downs model, but partly by sheer venality). Dissemination of disaster warnings and alerts at the national or local levels offers little attraction for decision-makers driven by these considerations (hardware installations necessary for hazard detection and monitoring appear to be perceived differently as evidenced by the enthusiasm displayed by various politicians in the aftermath of the 2004 tsunami). By contrast, the emphasis on relief and recovery that is evident in relation to all disasters in all countries meshes well with political and venal logics. The benefits fit within the political cycle and opportunities abound for skimming aid flows.

The predatory tenor of many developing states also explains the phenomenon of 'install but do not maintain' that is so common with complex technical systems found in these countries. The opportunity for rent-seeking exists at the moment of procurement, therefore the installation happens. Maintaining the equipment in good working order delays the next procurement and is in fact contrary to the governing logic.

Empirical evidence?

Government performance may be situated in a continuum that extends from the failed states of Somalia and Liberia at one end and the efficient and non-corrupt Scandinavian states at the other. The location of specific governments on the continuum and the reasons for their location cannot be discussed in this article. For the present purposes, it would be suffice to say that the 12 countries affected by the 2004 tsunami do not belong to the top quartile of well-governed countries (Kaufman et al., 2005).

Kaufmann et al. (2005) did not address disaster preparedness directly, but their findings may shed some light on the contribution of good governance to effective disaster warning. It is reasonable to assume that the general category of government effectiveness would have a bearing on a government's provision of effective early disaster warnings. Table 1 shows that, except for Malaysia and the Maldives, the countries affected by the

• Table 1 Government effectiveness compared across tsunami-affected countries

Country	Dataset	Percentile rank (0–100)	SD	No. of surveys/polls
Bangladesh	2004	26.4	0.16	11
India	2004	55.8	0.15	12
Indonesia	2004	40.9	0.15	13
Kenya	2004	22.1	0.14	13
Malaysia	2004	81.3	0.15	12
Maldives	2004	66.8	0.29	4
Myanmar	2004	2.9	0.19	8
Seychelles	2004	44.2	0.26	5
Somalia	2004	0.0	0.25	5
Sri Lanka	2004	45.7	0.16	11
Tanzania	2004	40.4	0.14	13
Thailand	2004	65.4	0.15	12

Source: Kaufmann et al. (2005)

2004 tsunami fall into the bottom three quartiles. Maldives, Thailand and Sri Lanka, countries that suffered significant losses, rank surprisingly high. Even Malaysia, which ranks highest, failed to generate any effective warnings. Kenya, with one of the least effective governments, was one of two countries of the set to mount an effective warning and evacuation, losing only one life (Afrol News, 2005). The explanation lies primarily in the length of the interval between the news reports of the devastation in Sri Lanka, Thailand and India and the arrival of the tsunami on the Kenyan coast.

Control of corruption in the tsunami-affected countries, another possibly relevant criterion, yields a more somber picture in Table 2, with no affected

• Table 2 Control of corruption compared across tsunami-affected countries

Country	Dataset	Percentile rank (0–100)	SD	No. of surveys/polls
Bangladesh	2004	10.3	0.14	10
India	2004	47.3	0.12	13
Indonesia	2004	17.7	0.12	15
Kenya	2004	18.7	0.13	14
Malaysia	2004	64.5	0.12	14
Maldives	2004	60.6	0.24	3
Myanmar	2004	1.0	0.19	6
Seychelles	2004	57.6	0.24	4
Somalia	2004	0.5	0.30	3
Sri Lanka	2004	52.2	0.14	11
Tanzania	2004	36.0	0.13	12
Thailand	2004	49.3	0.12	12

Source: Kaufmann et al. (2005)

countries in the top quartile. Yet it too does not provide unambiguous support for the thesis that venal state structures are correlated to failure to provide effective warnings. A whole range of countries with widely different corruption scores failed to warn their citizens of the 2004 tsunami.

CONCLUSION

There is much that ICTs can contribute to the alleviation of human suffering caused by disasters. ICTs enable the linking of the physical world within which hazards occur and the symbolic worlds of the humans likely to be harmed by those hazards, so that they may take life-saving action. But effective linking of these worlds requires not only the use of ICTs, but also the existence of institutions that allow for the effective mobilization of their potential.

One clear lesson is that effective disaster warning requires greater access to ICTs in general as a necessary condition. In the absence of proper institutional structures, it is unlikely that a significant number of lives could have been saved; however, all the institutional structures in the world cannot help unless the basic instruments exist for linking the physical world in which hazards occur and the symbolic worlds where action originates. The seismometers and the observation satellites existed, but the lack of basic telecom infrastructure in the critical areas of first impact in Aceh, southern Thailand and eastern Sri Lanka did not allow for an early understanding of the hazard and for prompt dissemination of the warning. Much of developed country-based disaster research assumes the existence of this basic infrastructure (e.g. Kasperson et al., 2003). Developing country research has to begin from a different starting point and perspective.

The catastrophic outcome of the 2004 tsunami points primarily to the absence of institutional mechanisms for the provision of warnings to vulnerable populations including, but not limited to, mobilization of ICTs. The available evidence does not yet allow the drawing of firm conclusions on the contribution of poor governance to the failure to warn on 26 December 2004. There is likely to be little debate about better governance leading in general to more effective warnings, notwithstanding the recent tsunami warning fiasco in California (Marshall, 2005).

This is not to say that effective warning rests on the improvement of the entirety of governance processes; the strategy of building and reinforcing islands of good governance is also an option. Bangladesh, which once suffered some of the most catastrophic losses of human life due to natural disasters, has managed to reduce these losses radically, despite remaining one of the least well-governed countries in the world. Because of focused efforts to improve cyclone hazard detection and monitoring as well as dissemination of alerts and warnings in the coastal areas through effective public–private partnerships, Bangladesh is unlikely to suffer losses on the scale that it did in 1970 and 1991. As stated in one report:

> The cyclone of 1970 took the lives of 300,000 people but the cyclone of the same intensity of 1991 killed 138,000 people, and the cyclones of 1997 and 1998 resulted in only 127 and 6–7 deaths respectively. (Asian Disaster Reduction Center, 2005: chapter 3.3.2)

Another option that is being developed in Sri Lanka is the provision of hazard information and training on disaster response to villages organized into self-governing entities by a Sri Lankan social movement, Sarvodaya. Sarvodaya has an organizational presence in 15,000 Sri Lankan villages and has set itself the task of making disaster resilient the 226 Sarvodaya villages that were affected by the tsunami. It recognized the necessity of an effective disaster warning system if it were to achieve its objective of rebuilding communities, not simply houses.

Should the government get an effective national early warning system organized, the villages will be primed and ready to accept the warnings and respond effectively. Should the government fail to fulfill its duty, Sarvodaya plans to transmit the hazard information it receives from regional and international sources to the self-governing village societies, which will decide on the actions most appropriate for their circumstances, based among other things on the training that they have received.

In the same way that islands of good governance emerge in the course of events that pull economies out of the dysfunctional equilibria that they are stuck in (Samarajiva, 2001), it is possible to implement reforms that will create effective early warning systems. Possibly different from previous efforts to improve governance in specific industries, such as electricity or telecommunications, where the emphasis was still placed on carving out space for a well-functioning government agency within the general environment of poor governance, the present efforts may result in community-based solutions that will work, whether or not the government does.

Acknowledgements

The article draws extensively and primarily from sections written by the author in Samarajiva et al. (2005). The research and consultation leading to that document was supported by the International Development Research Centre of Canada, the Vanguard Foundation, the Institute of Policy Studies, the Eagle Insurance Company, the Ceylon Chamber of Commerce and many volunteers. The valuable contributions of co-authors and various participants in the consultation process are gratefully acknowledged. The editorial and graphics assistance of Ayesha Zainudeen and the useful comments of Leah Lievrouw, Divakar Goswami, Robin Mansell and participants at a colloquium at the University of California, San Diego, are gratefully acknowledged.

Notes

1 For an archive that recognizes the uniqueness of this event see: http://tsunami.archive.org/ (consulted 26 June 2005).

2 This is not to ask, with Bishop George Berkeley: 'If a tree falls in the forest and no one hears it, does it make a sound?' The hazard occurs, and may be discovered to have occurred, by human instruments at a later date. It simply does not become known to humans and does not affect them harmfully at the time of occurrence and therefore does not become a disaster.

3 The 3.20am UTC report in the Malaysian *Star Online* (http://thestar.com.my/) has been verified, although it is no longer available on the web. The author was unable to verify the claim by the *New York Times* that news reports carried the story as early as 2.57am UTC. The *Times* did not state its source or the name of the news channel.

4 For example, prior to January 2002 when the ceasefire agreement took effect, supply of mobile service was prohibited in the northern and eastern provinces of Sri Lanka; the two provinces had a combined total of 4 percent of the country's fixed phones in 2002. By 2004 it was estimated that there were over 200,000 mobile phones in operation in the two provinces, along with a significant, although not as dramatic, increase in landline connectivity.

5 Which raises the Berkeley question in its modern form as asked by Dyson (1994): 'Does a place in cyberspace exist if no one visits it?'

6 The author worked in the newsroom of the Sri Lanka Broadcasting Corporation at that time and participated in the issuance of warnings.

7 It is common in US legislation to insert a specific "Good Samaritan" clause to shield from liability a third party who takes certain specified actions in good faith. See for example: http://www.soumu.go.jp/joho_tsusin/policyreports/english/group/telecommunications/rules_report2_e.html (consulted 26 June 2005).

8 For example, Sri Lanka had sent 143 persons, mostly government officials, for training in various aspects of disaster preparedness at the Asian Disaster Preparedness Center in Bangkok between 1986 and 2004. The number of trained individuals is lower because of attendance at multiple courses (personal communication with Asian Disaster Preparedness Center).

9 The early warning system for hurricanes worked in the cases of Hurricanes Katrina and Rita, giving accurate warnings of the onset of the hurricanes, their strengths and direction days in advance. These warnings resulted in the issuance of mandatory evacuation orders. What did not work in the case of Katrina was the effective implementation of the evacuation order for those without reliable private transportation. The other failures in the case of Katrina were that the levees had not been strengthened for a Category 4 storm and that the early warning system for levee failure did not work. The tragic outcome of Hurricane Katrina points to many improvements that need to be made in disaster preparedness in the United States, but does not point to any flaws in the early warning systems for hurricanes.

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