Disaster Management, Developing Country Communities & Climate Change: The Role of ICTs

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Executive Summary

Climate change presents two types of disaster threat in developing countries. One is the potentially devastating impacts on vulnerable communities of more frequent and more intense extreme weather events. This contributes to the second threat, the compounding of what are already complex development problems leading to a potential downward development spiral for the world's poor.

Effective disaster response demands rapid access to reliable and accurate data and the capacity to assess, analyse and integrate information from varied sources. ICTs can obviously help, and this paper focuses on the role of ICTs in reducing the impacts of acute climate-related events. The centrality of the community in effective disaster management is argued while acknowledging the important role of governments, donors, businesses, epistemic communities and NGOs. Some ICT applications in hydrometeorological disasters are described. That the majority of applications are funded externally raises concerns about further dependency and unsustainability but the paper argues there are grounds for optimism.

Development of new wireless technologies; convergence of telecommunications, computing, and multi-media; multi-stakeholder partnerships; and the use of FOSS by socially minded ICT-savvy professionals are enabling greater standardisation and interoperability, more data availability, greater reach at lower costs, and to some extent transparency and accountability of disaster resource allocation and delivery.

The paper closes with some recommendations on how the use of ICTs in community-centred disaster management may be enhanced. ICT systems should be developed that accommodate interoperation. Some of this, including a commitment to standardised disaster data collection, could be mandated on NGOs and other local agencies by those that fund them. ICT systems should be based around routinely-used rather than specialised applications. Further, we recommend integration rather than specialisation: with climate change becoming an integral part of disaster management systems rather than separately catered-for; and with generic information systems being created that encompass both disaster and development purposes. Finally the paper argues that we also need to clarify how ICTs can address barriers to interagency coordination and collaboration, and how the new technologies can help evaluate the effectiveness and financial performance of disaster response programmes.

1. Introduction

Information that reaches the public on disasters has tended to focus on disasters of large magnitude, involving tremendous loss of life, property and infrastructure. This has helped create a public perception that disasters are comparatively rare. The dissociation of disasters from the normal has had serious consequences, in particular the mindset that normal development decisions on settlement, construction, production, trade and commerce can proceed without considering the hazards that they may create or disaster vulnerabilities that they may exacerbate.[1,2]

The link between disasters and development began to be seriously examined from various perspectives in the 1990s. What the different perspectives share is a recognition that disaster impacts depend to a large extent on historical and current development activities.[3] This rethinking was partly triggered by social science research largely in industrialised countries, showing that the impacts of natural hazards could be lessened if early warning systems were in place, conditions imposed on settlement patterns, and industrial siting and building codes established and enforced.[4] It was also triggered by the observation that in developing countries disaster relief agencies were struggling with disasters that appeared larger, more frequent and more complex; that regardless of the resources mobilised, disaster relief provided at best a palliative, at worst dependency-creation; and that just as disasters eroded development gains, certain development directions contributed to an increase in disaster vulnerabilities and impact intensity.[5]

An estimated 92% of natural disaster-related deaths occur in countries within the low and medium development indexes[6,7]. The attendant economic loss as a percentage of GNP also far exceeds that in developed countries, albeit smaller in absolute figures.[8] For example, in 2007 the Asia Pacific region suffered slightly over a third (37%) of all natural disasters but over 90% of all reported victims and almost half of the economic damage.[9] These disproportionate impacts reflect the vulnerabilities arising from high population densities, inadequate infrastructure, environmental degradation and poverty in all its faces.[10] Disasters have become "teaching moments",[11] not only on the relationship between humans and the natural world but also on how individual and societal decisions and social relations can aggravate or mitigate the impacts.

Global climate change is expected to exacerbate these vulnerabilities, particularly among communities dependent on rain-fed agriculture or fisheries. Viewed as the

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[1] Lewis 1999.
[2] The introduction of environmental impact assessment in the U.S. in the late 1960s was a recognition of the need for change. The practice was not adopted in developing countries until the 1990s.
[3] Allen 2006; Berke et al. 1993; Drabek and Key 1976; Lewis op.cit.; Paton and Johnson 2001; Tobin 1999; Wisner et al. 2003.
[4] See for example Hewitt 1983; Quarantelli 1989.
[5] Christoplos et al. 2004; Hay 1986; Lewis op.cit.; Ross, Maxwell and Buchanan-Smith 1994; Siddiqui 2008; Sylvester 2004.
[6] IFRC 2009.
[7] The Human Development Index, established by UNDP, combines three dimensions: (a) *life expectancy* at birth, as an index of population health and longevity, (b) *knowledge and education,* as measured by the adult literacy rate (with two-thirds weighting) and the combined primary, secondary, and tertiary gross enrolment ratio (with one-third weighting) and (c) *standard of living,* as indicated by the natural logarithm of gross domestic product per capita at purchasing power parity. A HDI ratio of less than 0.5 is considered Low Development Index, a ratio of 0.5 to 0.8 is considered Medium Development Index (http://www.eoearth.org/article/Human_Development_Index).
[8] UN ISDR 2004.
[9] UN ESCAP 2008.
[10] See for example Lewis op.cit.; Quarantelli 1998.
[11] Laituri 2010: 6.

single most disruptive factor in economic development in the next 50 years,[12] global climate change will amplify and further complicate the development challenges that have vexed development policy makers, practitioners, researchers and thought leaders for the past half century.[13] The local level impacts of increased average global temperature remain uncertain but there is general agreement among climate scientists on what we might expect to see. The incidence and severity of extreme events – droughts, heat waves, hurricanes, cyclones and floods – is likely to increase and sea level will continue to rise. In regions where water plays a significant role in socio-economic welfare, water scarcity or excess will cause socio-economic and further ecological distress as those impacted by a succession of disasters resort to environmentally-compromising survival tactics.[14] The shift in rainfall patterns and climate zones will result in increased pressure on freshwater sources and on sensitive ecosystems such as coral reefs, tundra, and coastal wetlands; an attendant lowering of resistance to water-related diseases; an increase in the number of environmental refugees; and a heightening of social tensions and potential conflict.[15] The annual economic losses for developing countries are estimated to be in excess of 10% of GDP.[16]

Some argue that "climate change is already with us".[17] In 2010 global bleaching of coral reefs was reported from Thailand to Texas, only the second time that the phenomenon has been observed. Scientists have argued that corals, highly sensitive to excess heat, would serve as an early indicator of the ecological distress caused by the buildup of greenhouse gases.[18] Unpredicted and unexpected weather is becoming part of the reality in many climate-vulnerable communities. People are struggling to cope with weather patterns they no longer recognise.

IFRC reports on some observations from the ground: "I don't remember we had floods like this before. The water rose so quickly to four meters, reaching our second floor", a resident said of the floods that hit Jakarta, Indonesia in February 2007. In Kenya, the manager of the Kenya Red Cross society notes, "the weather is upside down … In the months that used to be rainy there may not be rain. The winters that used to be cold are no longer cold. When it rains it floods and that kills people. When it does not rain there is drought and that kills people too".[19] The eastern part of El Salvador has reportedly seen a decline in rainfall of up to 800 mm and consequent reduction of surface waters in the past 70 years. The dengue season, which normally appears in April, is starting to appear in March.[20]

The sudden and unexpected climate changes are challenging local traditional knowledge of the environment such as when to harvest, what to plant and when. In the Pacific island of Tonga, local people are noticing changes in the flowering and fruiting time of trees. Fishermen who depend on traditional knowledge about the seas lament that "it's cold when it should be warm and warm when it should be cold… things are all wrong… the fish are confused and not breeding when they would normally breed. It becomes

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[12] UNDP 2007a.
[13] A 2010 assessment of progress towards the Millennium Development Goals concludes that only two of the eight MDGs are likely to be achieved by 2015 (MacFarquhar 2010).
[14] Polsky &Cash, 2005.
[15] Coyle & Meier 2009; ECA Working Group 2009; UN ISDR 2004.
[16] Stern 2007.
[17] IFRC 2009: 98.
[18] Gillis 2010.
[19] IFRC 2010: 107.
[20] IFRC 2009.

difficult to know when is the right time to fish for different types of fish because they are no longer behaving as they used to".[21]

Climate change thus presents two types of disaster threats in developing countries. One is the potentially devastating impacts on vulnerable communities of more frequent and more intense extreme weather events. This contributes to the second threat, the compounding of what are already complex development problems, potentially leading to a downward development spiral for the world's poor. The IFRC reminds us, "Whether the changing climate with all its uncertainties, contributes to more disasters that affect more people, does not depend merely on what happens to the weather. Climate change and the accompanying risks will be superimposed on an unequal world, where vulnerability to disasters is directly linked to poverty".[22] Other trends further complicate the picture including population growth and weakening of governance structures. Addressing any one trend will not significantly change outcomes.[23] Climate change responses need to be integrated into a broader development strategy that addresses the root causes of vulnerability.

During disasters, information is as much a necessity as water, food and medicine. Information and communication technologies[24] (ICTs) are thus among the lifelines. The right kind of information communicated and used at the right time can save lives, livelihoods and resources.[25]

Responding effectively to disasters demands rapid access to reliable and accurate data and the capacity to assess, analyse and integrate information from varied sources (including *ad hoc*, before, during and after the disaster).[26] It requires speedy communication to the right parties to marshal resources (e.g., food, water, medical supplies); to mobilise, deploy and coordinate emergency personnel; and to coordinate response activities among agencies involved.[27] Communication and information sharing is critical.

The role of information and communication technologies in community and national adaptation strategies to the long-term impacts of climate change has been reviewed in several recent publications.[28] This paper focuses on the role of ICTs in minimising and managing the impacts from acute climate-related events, a topic that is to date under-examined.[29] Actual ICT applications in hydrometeorological disasters will be described and analysed in the context of developing countries.[30]

[21] IFRC 2009: 96.
[22] IFRC 2009: 102.
[23] Ibid.
[24] ICT (information and communications technology) is the umbrella term for the range of tools, applications, systems used to input, store, edit, retrieve, analyse, synthesise and process information and share data in all its forms. ICT encompasses: radio, television, broadband, satellite and cellular mobile phones, computer and network hardware and software, websites, portals, remote sensing, satellite systems and so on, as well as the various services and applications associated with them, such as data storage, analysis and integration, videoconferencing and distance learning (TechTarget 2004; UNESCAP 2008; IBRD 2010).
[25] Coyle & Meier 2009; Denning 2006; Gunawardene & Noronha 2007.
[26] Bunker & Smith 2009; IFRC 2009; Laituri op.cit.
[27] See for example Dawes et al. 2004; NRC 2007a; Törnqvist et al. 2009.
[28] See for example Apikul 2010; Kalas and Finlay 2009; Ospina & Heeks 2010a and 2010b; Wattegama op.cit.
[29] Essentially this paper is situated between Strand 2 and Strand 3, along the direction of Stream (a) in Ospina and Heeks' typology of the literature on ICTs, climate change and development. It elaborates on the role of ICT in "Coping with Short-Term/Disasters" indicated in the Overview Model (Ospina & Heeks 2010b). Note that, given that ICTs are changing at a rapid pace, and their use in disaster management and the necessary institutional arrangements, evolving, this paper can only be an indicative, not an exhaustive discussion of the subject.

The importance of a people-centred approach to disaster management is argued in Section 2 while acknowledging the important role of other actors. The applications of ICTs in disaster management in low- and middle-income countries described in Section 3 also showcase the critical role of these other actors in enabling communities to prepare for and cope with the impacts of extreme climate-related events. Section 4 presents some reflections on the use of ICTs in disaster management under the conditions of scarcity in developing countries. The paper closes with recommendations for ICT practitioners and researchers on how the use of ICTs in disaster management in developing countries may be made more effective.

2. The Community in Disaster Management

Disasters vary in scale, severity, and duration, but there is one constant: the impacts are inherently local. During the disaster "there are important decisions to make, some of which – often very crucial ones – belong essentially to the community."[31]

This is recognised in the Code of Conduct for the International Red Cross and Red Crescent Movements and NGOs in Disaster Relief, which calls on aid agencies to involve local people in their decision-making. The SPHERE Standards[32] stipulate that local participation in the assessment, development, implementation and monitoring of responses be maximised. Effective climate change responses will ultimately depend on community capacities to reduce their medium and long-term risks as well as the ability to cope with the impacts of acute climate-related events.

There are challenges.

Studies in Mozambique and Nepal on community risk perception suggest that the risks highlighted by disaster management authorities may not necessarily be those at the forefront of community concerns. Vulnerability is often defined by the community in socio-economic terms. Cholera, earthquakes, fire, and storms can rank lower than issues of governance and poverty.[33] Reports from Bangladesh, Nepal, India, and Peru abound with evidence that not everybody who receives an early warning heeds it. Individual response is conditioned by cultural norms, access to resources and personal assessment of what else is at risk e.g., property, 'face', life of family members.[34]

At-risk communities should therefore be involved in assessing the risk of different disasters. Risk information – particularly when gathered and assessed through sophisticated technologies must be expressed in terms and language meaningful to those at risk, and framed within their overall development aspirations and survival strategies.

Note also that no distinction is made in this paper between climate change-related disasters from climate-related disasters. From the point of view of the affected communities this distinction is largely irrelevant.

[30] This focus imposes some limitations on the discussion of each case study. Research done on ICT use in disaster management in low and middle income countries is simply not as rich as that done in developed countries, e.g., ICT use in the response to Hurricane Katrina, or the terrorist attack on the World Trade Centre (Dawes et al., 2004).

[31] Benini 1991: 4

[32] The SPHERE Project was launched by humanitarian agencies and the International Federation of Red Cross and Red Crescent Societies to define and uphold the standards by which the global community responds to the plight of people affected by disasters (http://www.sphereproject.org/content/view/91/58/lang,english/).

[33] Ibid.

[34] IFRC 2005 and 2009. A study by Bunker & Smith (2009) of community response to EWS in New South Wales Australia led to a similar conclusion, quoting a front-line responder that "to develop and deploy effective CW [community warning] systems is a long process of informing, educating, reinforcing and re-education of the public" (p.10).

This is precisely what the International Red Cross did in one of the earliest published uses of ICT in disaster management, during a prolonged drought in southern Sudan in 1990. Computer simulation was used in choosing the most acceptable food allocation strategy among those preferred by donors and humanitarian NGOs and local traditional practice. A portable computer with a spreadsheet program was used to simulate five scenarios with assumptions about food stocks, receipts, the number of needy households and the disbursement behaviour of local food suppliers. The outcomes were displayed graphically for the local relief committees, governments and international agencies. The local strategy was shown to be the least risky.[35] The use of ICT enabled the community to persuade donors and relief agencies to respect local knowledge.

Slow-onset disasters provide more opportunities for risk information to flow from the bottom up. At-risk communities can 'see' the creeping onset of drought through for example observing crop and livestock health and perhaps their children's health, or seeing changes in flowering or shedding of leaves of local trees[36, 37]. Community knowledge related to flooding can be systematically structured into GIS (Geographic Information Systems) compatible hazard databases. In Dagupan City Philippines, the Asian Disaster Preparedness Centre used participatory mapping to develop an end-to-end[38] flood early warning system including evacuation routes, emergency response and small-scale mitigation projects.[39]

2.1. Other Actors

Allen, working on community-based climate change adaptation in the Philippines, cautions against what she calls "extreme localism".[40] She argues that linkages reaching beyond a community's borders are equally important for effective community responses to disasters of any kind. This echoes an argument made a decade earlier by Berke and co-researchers that the timing and outcomes of disaster recovery and reconstruction depend not only on the tightness of the community's social network but also on the strength of its vertical integration with extra-community political, social and economic institutions.[41] There are other actors.

Prompt and adequate response from the local fire department, health professionals, police and the military reduce loss of life and property. National and local governments can facilitate disaster planning and management.[42] The mass media is important for communicating disaster alerts and keeping the public informed as the disaster unfolds, and monitoring disaster aid allocation and delivery.[43]

In developing countries disaster management increasingly involves many more actors: UN agencies, donors, regional organisations and non-governmental humanitarian relief agencies such as the Red Cross/Red Crescent Societies, Médecins Sans Frontières and

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[35] Benini op.cit.
[36] Pratt 2002.
[37] A good example is the community drought preparedness programme of World Vision, Practical Action and Oxfam GB in the Turkana and Taita Taveta districts of Kenya (Ng 2007).
[38] An early warning system is called end-to-end if it connects the technical (upstream) and societal (downstream) components of warning through identified institutions.
[39] Apikul op.cit.
[40] Allen 2006.
[41] Berke et al.1993.
[42] IBRD op.cit.; IFRC op.cit.; Laituri op.cit.; Wattegama op.cit.
[43] A good example is AlertNet, a humanitarian news network around a popular website. It has a network of 400 contributing humanitarian organisations and its weekly email digest is received by more than 26,000 readers. It delivers operation-critical information to relief charities worldwide, encouraging them to share information with one another, and raises public awareness of humanitarian emergencies. It reportedly attracts more than 10 million viewers a year.

many others. Businesses are generally among the first to provide material goods and technical assistance in the aftermath of a disaster, independently or in partnership with NGOs. The private sector is also involved in developing ICT products and services that enable continuity when telecommunication structure is damaged. Experts from research and teaching institutions are frequently called upon to provide specialised input in designing monitoring programmes, integrating data, and translating scientific and technical information into EW messages.[44]

3. Use of ICTs in Climate-Related Disaster Management

Fig 1 Disaster Management Cycle

There is no complete consensus on the different phases of disaster management,[45] but there is general agreement that the different activities are most-productively conceptualised as a cycle.[46] "The disaster cycle has the distinct merit of highlighting development responsibilities in relation to disasters, as well as the need for post-disaster rehabilitation as a link to development".[47]

For the purposes of this paper we will distinguish four stages: preparedness, response, recovery/rehabilitation and reconstruction.[48]

As shown in Figure 1 the different phases form a continuum and the reconstruction phase (frequently presented by other disaster researchers not as one phase but as three: disaster mitigation, disaster risk reduction and disaster prevention phases[49, 50, 51]) is effectively indistinguishable from development.

Disaster preparedness includes actions taken in advance of disasters such as establishing early warning systems and training front-line responders. *Disaster response* refers to actions taken in the immediate aftermath of a disaster, to save and protect life, property, and infrastructure. It encompasses dissemination of disaster alerts, and subsequent search, rescue and care of casualties and survivors.

When the physical impacts of the hazard event are over and search and rescue operations subside, short-term actions are necessary to re-establish essential physical and social systems: finding replacement homes for the displaced, restoring services and

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[44] Coyle & Meier op.cit; Hall 2007; IBRD op.cit.; IFRC op.cit.; Roeth 2009; Wattegama op.cit.
[45] It might be added that neither is there a common definition of what constitutes a disaster. For example there is no shared definition of what is drought (see for example IDRC 2005; Lewis 1999; Wisner et al. 2003).
[46] DFID n.d.; IFRC op.cit.; Wattegama op.cit.; Wisner et al. op.cit.
[47] DFID n.d.: 25.
[48] Most UN agency depictions of the disaster management cycle show six phases - "mitigation", " risk reduction", and "prevention" replace the "reconstruction" phase in Fig 1 (e.g., Wattegama 2007; UNDP 2007b). Other agencies show six phases but different from those of the UN (e.g., Weets 2006).
[49] See for example Apikul op.cit.; Lewis op.cit.; Wattegama op.cit.
[50] One vision is where development is drawn at the core of the cycle and disaster is imposed as an interruption (Wisner et al. op.cit.).
[51] Figure 1 is supportive of, but not identical with Lewis' "bicycle". Lewis (1999) pictures disaster management as a bicycle with the two wheels representing disaster and development as concurrent processes; he argues that development still occurs even while a disaster is unfolding.

re-establishing the local economy.[52] This is generally referred to as the *disaster recovery* phase. It presents opportunities to 'reshuffle the deck' since support for hazard mitigation is generally strongest immediately following a disaster. Unfortunately recovery decisions tend to be subject to intense and conflicting pressure from the affected communities and not infrequently from the donors, to rebuild as quickly as possible, with inadequate time and resources devoted to complex problem solving.[53] This is a critical phase. "It is the aftermath which will eventually become the context for the next disaster – of whatever kind".[54]

Disaster reconstruction is considered achieved when all pre-disaster services and structures, e.g., homes, hospitals, schools, water systems, roads, electric power are restored. This clearly takes years and reconstruction activities generally become indistinguishable from normal economic development projects. In developing countries, reconstruction often becomes dependent on overseas development assistance with all the benefits and the vulnerabilities this implies.[55, 56]

A disaster thus presents a particular context for ICT use. Data need to be acquired and analysed under severe time pressure. The data users are frequently without adequate training and working under difficult circumstances. Uncertainty and ambiguity are an inherent part of the environment. A disaster may have discrete origins but its effects propagate and interact in such a way that intensifies the complexity and uncertainties. Further complicating an already highly-dynamic situation is the fact that there are usually several actors involved, working on different aspects of the crisis, each one with its own decision structure, administrative culture and quite likely, operating different sets of technical equipment.[57] There are also volunteers who need coordination.[58] The information typically needed in disaster management is shown in Table 1.

[52] Wattegama op.cit..
[53] Berke et al. op.cit.
[54] Lewis op.cit., p xvi.
[55] Donors do not always deliver on commitments for reconstruction made during the height of a disaster. A good recent example is the earthquake in Haiti. More than US$1.35bn was committed but less than US$23m had been delivered three months later (MacFarquhar 2010b).
[56] The very few studies on reconstruction suggest that the key to successful redevelopment lies in a capacity for embracing error, learning with people, building new knowledge and institutional capacity through action (Paton &Johnston 2001).
[57] Bunker & Smith op.cit.; Buzna et al. 2007; Dawes et al. op.cit.; NRC 2007a; Quarantelli 1998; Törnqvist et al. 2009.
[58] Quarantelli 1989, 2003. During Katrina for example, the American Red Cross had to deal with over 250,000 volunteeers (Asplund et al. 2008).

Table 1: Disaster-Relevant Information Needs[59]

Information	Preparedness	Response	Recovery	Reconstruction
1. Contacts at local community, regional and national levels	X	X	X	X
2. Local disaster plans, procedures and policies	X	X		
3. City and housing plans	X	X		
4. Phone management data bases	X	X		
5. Emergency centres: where, who, what	X	X		
6. Telecom: infrastructure, laws, organisations	X	X	X	
7. Social, demographic and economic data	X	X	X	X
8. Safety and environmental standards and codes	X	X		
9. Cultural asset information: significance, age, construction material and condition	X	X		
10. Land use plans		X	X	X
11. Critical infrastructure inventories	X	X		
12. Building inventories	X	X		X
13. Property ownership records	X	X		X
14. Birth and medical records			X	X
15. Hazard maps: nature, site and real time changes	X	X		
16. Vulnerability data: who, where, how	X	X	X	X
17. Loss/damage data		X	X	X
18. Weather data: short and mid-term	X	X		
19. Available resources: what, how much, who	X	X	X	X
20. Formal key decision-making: who makes what decisions, when, how	X	X	X	X
21. Informal local authority structures in the family, in the community	X	X	X	X

[59] Various sources: e.g., Coyle & Childs op.cit.; Coyle & Meier op.cit.; Dawes et al. 2004; UNESCAP 2008; IBRD op.cit.; NRC 2007a and 2007b.

The specific communication and information processing requirements will vary with context, type of disaster, distance of disaster site, time relative to disaster onset, latency of disaster and available bandwidth. However, we can identify some requirements typical of developing countries, drawing on findings of several ICT for emergency (ICT4E) studies.

A 2007 study by the Disaster Resource Network examined the factors contributing to effective ICT use in emergencies.[60] Also in 2007 the US National Research Council's Committee on Using Information Technology to Enhance Disaster Management identified areas of ICT capabilities necessary for improving ICT use in disaster management.[61] The EU ICT Strategy for Disaster Mitigation lists five key elements.[62] In 2010 a post-Haiti earthquake meeting of 20 technology and development experts identified opportunities facing ICT use in disaster response.[63] The four sets of recommendations are summarised in Table 2.

Table 2: Recommendations for Enhancing ICT Effectiveness in Disaster Management

DRN Report 2007[64]	NRC Report 2007[65]	2010 Post-Haiti T&D[66]	EU Strategy 2006[67]
Adequate penetration of broadband internet	Enhanced infrastructure survivability and continuity of social functions	Public education about use of alternative communications channels during an emergency	Full availability of broadband communications and positioning systems
Inter-and intra-agency coordination	Improved situational awareness and a common operational picture	More collaboration around an integrated framework	Shared operational picture and situational awareness among first responders
Competence in data analysis, interpretation, integration, maintenance and repair of hardware	Greater organisational agility	Self sufficiency of organisations involved in ICT response on the ground	Continuous monitoring through ubiquitous sensor systems
Interoperability of different user devices, network equipment and communication systems	More robust, interoperable, and priority-sensitive communications	Appropriate balance between reliance on Internet/cloud and localised content/resources	Full geo-spatial data interoperability
Sustained advance preparedness	Better public engagement	Better ICT pre-planning	Effective EW alerts for all hazards, all media
Technical & operating standards & policies on flexible access to ICTs	Improved decision support & resource tracking & allocation	Hospitable policy environment	

[60] Coyle & Meier op.cit.; Kalas & Finlay op.cit.; UNESCAP op.cit.
[61] NRC 2007a.
[62] Weets 2006.
[63] Blantz op.cit.
[64] UNESCAP op.cit.
[65] NRC 2007a
[66] Blantz op.cit.
[67] Weets op.cit.

These studies can help structure our discussion of ICTs used in climate-related disaster management in low- and middle-income countries. We will not utilise all of these different recommendations but will instead draw from them developing country-specific needs. In developing countries, the need is for ICTs that enable (a) timely and effective communication of disaster alerts to the 'last mile'; (b) rapid reliable two-way communication in challenged environments; (c) creation of a common operational picture, and (d) transparency and accountability of resource allocation decisions. These will form the focus for the sections that follow.[68]

3.1 Timely and Effective Delivery of Early Warnings to the 'Last Mile'

'Last mile' is the term used "to express the sentiment that warnings and the means to respond to them often do not reach those who need it the most",[69] people who for reasons of age, gender, culture or poverty, are not reached by disaster preparedness. It is viewed as the weakest link in the communication chain and seen as the cause of many casualties.[70]

People-centred approaches to early warning systems (EWS) are predicated on the assumption that people can be capable, resilient and able to protect themselves given accurate, timely, consistent and actionable information from a trusted source.[71] Such approaches require that individuals and communities at risk, particularly those at the 'last mile', understand the threats to their lives and property, share this awareness with others, and are able to take action to avoid or reduce their exposure. The use of different technologies, preferably one-to-many, is viewed as the effective strategy to deliver early warnings. Any one or a combination of the following media has been used.

3.1.1 Radio and Television

Radio and television remain the traditional media used in disaster management, because they are relatively cheap, provide a reliable one-to-many communication medium and most importantly, do not require literacy. Radio in particular is the most accessible medium to the poor, especially women in their homes, or fishermen at sea, workers out in the fields. Television, while more powerful, is more expensive and therefore not as available.

It is not surprising then that radio is the principal medium for delivering early warnings in Chittagong, Bangladesh. A highly populated coastal district, Chittagong faces several types of hazards – earthquakes, cyclones, floods – but has EWS only for cyclone and storm surges. With a high level of illiteracy and low level of telephony, radio remains the most frequently used, most publicly accessible and most effective medium, although television is reportedly making inroads.[72]

In the poorest communities however, even battery-powered radio is a luxury. The Freeplay Lifeline radio was designed for precisely these conditions. Both wind-up and solar powered, it provides dependable access to AM, FM and shortwave frequencies; it can withstand dust, water and extreme temperatures. The Mozambique Red Cross

[68] Unless otherwise specified, most of the cases presented refer to uses in the preparedness and response phases.
[69] IFRC 2009: 43
[70] Gunawardene & Noronha 2007; Sriramesh et al. 2010.
[71] IFRC op.cit.; Wattegama op.cit.
[72] Ahmed 2007; Wattegama op.cit.

integrated the Freeplay Lifeline radio into its cyclone and flood early warning activities. A volunteer is charged with listening to the radio. When a warning is heard, the volunteer alerts village leaders and a pre-planned response is launched. This has been credited with the dramatic reduction in devastation from cyclones and floods. There were 700 casualties in the year 2000 flood, 30 in 2007 and none in 2008. This type of radio has also been used in hurricane preparedness in Haiti, and in RANET[73] projects in Niger, Kenya, and Uganda.[74]

Radio and television are however limited by the fact that they provide only one-way communication[75] and are generally turned off in the evenings.

3.1.2 Satellite Radio

Satellite radio receives its signal from a communication satellite[76] and therefore has a wider geographical range than terrestrial radio. It is very useful when transmission towers are damaged. A satellite radio, combined with fixed or mobile phones was shown to be the most effective and reliable of five ICT tools in eight combinations tested for transmitting early warning information from government agencies to 32 at-risk villages in Sri Lanka. This Addressable satellite Radios for Emergency Alerting (AREA) system is being combined with GPS to issue hazard alerts in text and audio formats directly to specific at-risk communities in Bangladesh, India, Indonesia and Thailand.[77]

But satellite usage is very costly for both service set up and the purchase of a satellite-enabled radio, and service can be interrupted by trees, buildings and some weather conditions.

3.1.3 Telephones (Fixed and Mobile)[78]

Telephones (fixed and mobile) are useful in disseminating one-to-one disaster warnings. In some countries 'telephone trees'[79] are used to speed up the diffusion of the warnings. The drawback is that they are a one-to-one communication medium, the lines can get congested before and during a disaster, and in many areas telephone access remains a luxury although many rural areas with low fixed telephone penetration are seeing increasing use of mobile telephony.[80]

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[73] RANET is an initiative using RAdio and InterNET for the communication of hydro-meteorological information for rural development.
[74] IFRC op.cit.
[75] Community radio has the advantage of providing two-way one-to-many communication, very important during disasters. However it has been difficult to find reported cases of successful use of interactive community radio for early warning, as it is not a common media channel in developing countries. But the effectiveness of interactive community radio in disaster response has been studied by AMARC (Association Mondiale de Radiodiffuseurs Communitaires) Indonesia, looking at use of community radio for public education on disaster prevention, food security and poverty reduction (Kalas & Finlay 2009). It is also being tested in Sri Lanka through a disaster warning system implemented by Sarvodaya, an NGO (Wattegama op.cit.).
[76] A satellite is essentially a radio-frequency repeater that is launched into orbit (circular or elliptical) around the earth. It transmits data (from the simplest digital data to the most complex television programmes) to and from the earth (with a latency period depending on how high their orbit is) via ground stations and hubs connected to the Internet backbone (http://www.widernet.org/projects/satellite/moreaboutstatellites.htm).
[77] Apikul op.cit.; Gunawardene & Noronha op.cit; Rangajarn & Rao 2007.
[78] The disadvantages of mobile phones will be discussed in Sec 3.2.
[79] In telephone trees individuals basically serve as nodes. These nodes receive the EW message from the centre, through whatever means and relay the message to a pre-assigned list of individuals by phone or whatever means available. This ensures timely delivery of EW and minimisation of duplication of effort (Wattegama 2007).
[80] Best 2003; Yonazi 2009.

Mobile phones were the main tool for implementing a community-based flood monitoring and early warning system in An Giang and Dong Thap provinces of Vietnam, established after the devastating August 2008 Mekong floods. Thirty-eight at-risk villages were provided with mobile phones, and villagers in seven villages trained to take wet season water level measurements twice a day. They report their water level readings, via text messages, to the Southern Region Hydro-Meteorological Centre in Ho Chi Minh City, the local agency responsible for flood forecasting. The information is entered into the Centre's computer and the calculated flood forecast fed back to the villagers who publicise the information on information boards at central locations. Any imminent flood threat is publicised via loudspeakers.[81]

Voice communication through mobile phones was similarly useful when Hurricane Ivan made landfall in Jamaica in 2004. Jamaican Red Cross volunteers and parish disaster committee members used cell phones to issue early warnings the day before, when the hurricane hit the neighbouring island of Grenada.[82]

Short message service (SMS), a feature available in most mobile phones is an additional tool for delivering one-to-many text-based disaster alerts. It is used in Wenling China where sensor detection of building integrity (in relation to cyclones) is part of the EWS. Evacuation alerts via SMS are sent to residents before a cyclone hits.[83] The use of SMS is limited by the fact that it is affected by traffic load, and can only be delivered to pre-registered numbers and literate users.

3.1.4. Cell Broadcasting

Cell broadcasting (CB[84]) is a one-to-many geographically focused text messaging service. It is already integrated in most existing network infrastructure so there is no additional cost from laying of cables, purchase of new software or new handsets. It uses a dedicated channel and therefore is not affected by traffic load nor does it add to main channel load. It is geo-scalable so one message can reach millions in a minute; it is geo-specific, so the broadcast can be targeted at specific at-risk areas thus avoiding widespread panic. Equally important, a single CB channel can broadcast the message in multiple languages.

However, the user must have a CB-compatible handset switched on to the appropriate channel. This makes CB vulnerable to oversight or malice of the network operator who may turn off the CB feature to avoid paying for the channel. This possibility could be reduced with appropriate government regulation, or agreement with the private sector.

Such a public-private sector arrangement has been set up in Bangladesh where UNDP is supporting the development of instant network alerts using SMS cell broadcasting. Agreements were reached with Grameenphone and state-owned Teletalk to send alert messages to their subscribers, with the alert automatically flashing across the mobile phone screen. The programme is being piloted in flood-prone Shiraganj and cyclone-prone Cox Bazaar. If successful it will be expanded to other high-risk areas.[85]

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[81] The system proved to be very labour intensive so support committees were set up in each village to share the responsibility of implementation and maintenance: monitoring, recording and reporting (MRC 2009; IFRC 2009).
[82] IFRC op.cit.
[83] UN ISDR 2008.
[84] Note, not citizen-band radio, also referred to as 'CB'.
[85] Coyle & Meier op.cit.

A bigger problem with CB is the lack of standardisation across networks so it cannot be used as a stand-alone public warning system. This was recognised in the Maldives, an island under serious threat from sea level rise. After the 2004 tsunami the government launched several parallel disaster management initiatives including: (a) use of cell broadcasting for delivering alerts; (b) use of bulk SMS[86] on a mobile network; and (c) priority calling and national roaming during disaster response.[87]

3.1.5 Satellite Remote Sensing and Other Technologies

Preparing for drought requires the collection and analysis of weather, rainfall, vegetation data to monitor changes over time, and modelling the impacts on cropping systems. This is best done with satellite remote sensing.

This was the tool used in the Famine Early Warning Systems Network (FEWS NET) developed with funding from USAID in 1986, originally to monitor food security from Mauritania to Ethiopia.[88] Sensors including AVHRR[89] and MODIS[90] monitor vegetation vigour and density. Meteosat [91] infrared data is combined with rain gauge reports and microwave satellite observation to estimate rainfall. Using GIS, all the satellite data are combined with regional analyses of grain stocks and prices, political conditions and input availability to create early warning for drought-related food shortages.[92]

In Addakdal, Andhra Pradesh in India, ICRISAT uses the satellite-plus-GIS combination slightly differently in its drought preparedness programme. Weather forecasts and crop prices are provided to the community regularly, establishing the programme's credibility. Using GIS, colour-coded local vulnerability maps are generated based on water budgets under different rainfall scenarios. The maps allow planners to establish drought mitigation strategies and more importantly, farmers to decide which crops to plant and whether or not to take up off-farm employment.[93]

This combination is also used for cyclone preparedness in the Bay of Bengal. Meteorological data collected by India's Kalpana-1 and INSAT-3A satellites are processed in cyclone warning centres which issue early warnings. Community emergency response plans are developed with GIS, allowing the visual display of critical disaster data specific to each location.[94] South Africa's Advanced Fire Information System combines satellite data with mobile phone technology. Developed by the Council for Scientific and Industrial Research both MODIS and Meteosat data are used to detect hotspots and alerts sent to 40 fire protection associations across the country automatically via e-mail and text messages. They form part of the weekly weather forecast on national TV. Anyone can sign up to receive alerts in their area. The system can be extended to flooding alerts.[95]

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[86] This means mass delivery of SMS messages to mobile terminals via the Internet by making a standard HTTP request, although other technical interfaces are also available (http://www.textalert.com/t3/default.asp).
[87] Udu-Gama 2009.
[88] Ruth & Ronkin 1991.
[89] AVHRR – Advanced Very High Resolution Radiometer – a space-borne sensor on the NOAA family of polar-orbiting platforms.
[90] MODIS – Moderate Resolution Imaging Spectroradiometer, is a key instrument in the TERRA (EOS – AM) and AQUA (EOS –PM) satellites.
[91] Meteosat is a second-generation weather satellite.
[92] A similar satellite-cum-GIS-based system is used in the Global Monitoring for Food Security initiative, funded by the European Space Agency to predict drought and famine to provide early warning in Sub-Saharan Africa.
[93] Ganaparam et al. n.d.
[94] Apikul op.cit.
[95] Frost 2009.

While clearly a powerful combination the use of satellite data with other technologies including GIS and mobile phones is not easily affordable in developing countries without their own space programmes, although more open access to shared satellite data is becoming more feasible (cf Sec 3.3).[96] There are also limits to what satellite technologies can detect compared to on-the-ground data gathering.

3.2. Rapid, Reliable Two-way Communication in Challenged Environments

The period immediately after a disaster strikes is considered the most difficult, fluid, and confused.[97] Both one-to-one and one-to-many, preferably two-way communication channels are needed. For front-line responders the biggest need is mostly for maps that can be updated in the course of the disaster event, to locate the most affected areas, high-risk areas, and relief distribution centres. For affected communities it is to communicate with the front-line responders, look for family and friends, and increasingly also connect with diaspora communities.[98] The biggest communication surge is said to be in the first 12 hours after the onset with the intensity of demand declining somewhat but remaining high for up to three days.[99]

Frequently however, large parts of the telecommunications infrastructure are destroyed or incapacitated for several days if not weeks; those that survive suffer overload. The complex interdependencies of technology systems (e.g., dependency of financial services, transportation, on ICT networks) make them vulnerable to failure from ignorance, human malice and technical malfunction. It also means the failure of one system can lead to failure of another. Communication and coordination under such uncertain conditions has benefited from technological development and the creativity of committed ICT professionals.[100]

3.2.1 Mobile Phones

The usefulness and the limitations of mobile phones in crisis situations were demonstrated during the 2008 floods in Bihar India. Widespread mobile phone subscribership and 24-hour connectivity allowed large-scale SMS-based evacuation and rescue operations. Survivors who were marooned used mobile phones to guide rescue teams to where they were, to tell district officials of their immediate needs, and local television and newspapers, their plight. The prolonged non-availability of electricity however meant that the mobile phones could not be recharged.[101]

3.2.2 Wireless Ad-hoc Mesh Networks with GPS

When infrastructure is compromised or damaged the common response currently is to deploy satellite communication equipment, cellular and wireless infrastructure and microwave links since they are immediately usable and scalable. Wireless technologies are particularly attractive because they function in difficult terrains and their deployment is relatively inexpensive.[102]

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[96] Wattegama op.cit.
[97] Asplund et al. 2008; Quarantelli 2003; NRC 2007a; Shklovski et al. 2008; Törnqvist et al. op.cit.
[98] IFRC 2009; Shklovski et al. op.cit..
[99] Coyle & Childs 2005.
[100] Asplund et al. op..cit.; Shklovski et al. op.cit.; Törnqvist et al. op.cit.
[101] Manocha 2009; Verclas 2008.
[102] Asplund et al. op.cit; Tornqvist et al. op.cit.

After Myanmar was hit by Cyclone Nargis in 2008, a local NGO, EGRESS, developed the *Dumbo-Sahana* Project in partnership with the Myanmar Computer Professionals Association to enhance the communication and coordination aspects of Myanmar's emergency response system. The Project provides training on setting up of *Dumbo* (Digital Ubiquitous Mobile Broadband), wireless ad-hoc mesh networks, GPS mapping, *Sahana* (cf Sec 3.4) and *OpenStreetMap*.[103] *Dumbo* is a set of network technologies that allows users to chat, transmit video and update their location. The wireless mesh networks[104] penetrate remote, isolated areas with sensors to monitor environmental conditions, e.g., temperature, wind direction and speed.[105] It is rapidly deployable, relatively inexpensive, reliable, resilient and effective in harsh environments.

3.2.3. Internet and e-Mail

The Internet is acknowledged to be one of the most reliable information infrastructures even under adverse physical conditions, and electronic mail, its most widely used application. This was a critical tool during the 1997 Cambodia floods. The floodwaters had washed up venomous snakes and people were being bitten. The local WHO field offices did not have the antiserum in stock nor the taxonomic information on Cambodian snakes. The field officers sent e-mails to members of the Global Health Disaster Network (GHDNet) who forwarded it to several mailing lists. Specialists and institutions in the region were identified resulting in a speedy sourcing of the antiserum.[106]

The utility of the Internet and email in disaster management is however limited by the low Internet penetration (2 to 5%) in developing countries and the fact that many of those with connection are not regular users.[107] The non-English content of the Internet also remains limited.

3.2.4. Radio

For the small island of Granada a simpler technology proved to be the most cost-effective tool in 2004 when Hurricane Ivan hit. Approximately 90 percent of the country's homes and nearly every major building in the capital city, including the emergency operations centre, suffered structural damage. Power lines and all communication links were down. A private company, Mobile & Marine Systems received a call for help from the Grenada Police Force. Within 24 hours, Mobile & Marine Systems had in place, portable repeaters, mobile radio base stations and portable handheld radios, which provided the emergency backbone for island-wide communications.[108]

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103 *Open Street Map* is a free editable world map. The maps are created by users with data from portable GPS devices, aerial photography, other free sources or simply from local knowledge (http://en.wikipedia.org/wiki/OpenStreetMap).

104 Wireless mesh network is effectively a router network without the cables between nodes. Signal strength is sustained by breaking long distances into a series of shorter hops. Nodes act as routers to transmit data from nearby nodes to peers that are too far away to reach in a single hop, resulting in a network that can span larger distances (http://en.wikipedia.org/wiki/Wireless_mesh_network).

105 Myanmar Egress 2008.

106 Sriramesh et al. op.cit.

107 Coyle & Meier op.cit.; Wattegama op.cit.

108 Radio has also been used to provide emotional support to survivors particularly those who lost family members. A weekly radio programme in Indonesia sponsored by UNDP after the 2004 Indian Ocean tsunami that reached 13,000 internal refugees was reportedly very effective in helping survivors cope with their loss by enabling them to talk to others on the tragedy. Some survivors phoned in for advice on how to deal with stress. A counsellor and psychologist were made available for that purpose (Apikul 2010).

3.3 Creating a Common Operational Picture

Voice communication is typically viewed as the immediate need prior to and after the onset of a disaster, but as noted above geospatial data are equally critical for assessing damage, planning relief operations and coordinating relief activities.

The different agencies involved are likely to operate different sets of technical equipment with different data units and standards. Coordination will thus require the extraction, processing and integration of information from multiple sources to create a common operational picture, the lack of which is considered a major barrier to intra- and inter-agency coordination.[109]

3.3.1. Geographic Information Systems (GIS)

Geographic information systems[110] are perhaps the most versatile of all ICT tools and useful in all disaster phases. The power and strength of GIS lie in their ability to integrate spatial with non-geographic data into one encompassing system, and graphically display spatial patterns, creating a common operational picture. GIS allow real time monitoring for emergency early warning as well as modelling of possibilities, e.g., "if we add a road to this community will it significantly reduce evacuation times?". During a disaster event GIS allow one to answer questions of location, e.g., "how many primary schools are within 1 km from this flood flash point?". For recovery and reconstruction the use of historical data with GIS allows one to answer trend questions, e.g., "how has population density changed in the last ten years? For vulnerabilities to decline what should the settlement pattern look like?".

3.3.2. GIS, Satellite Remote Sensing, GPS

The combination of remote sensing[111] with GIS introduces more planning information and enables more predictions to be made. The combination is frequently used for assessing and mapping of hazard and risk areas, vulnerable groups, planning of evacuation routes, location of emergency centres, as well as assessing post-disaster damage. When all these data are integrated and mapped into a common operational picture, responses can be better targeted, and priorities established.

The most crucial element of GIS, and thus also the most critical barrier to its effective use is the data. The data may not be in a usable format, or at the correct scale and aggregation. Additionally the use of GIS, satellite communication and remote sensing require high bandwidth, high-speed networks and highly skilled professionals, [112] generally scarce in most low-income countries. External assistance has been indispensable in most reviewed initiatives.

The International Telecommunication Union (ITU) with support from FedEx, IGO global communication, Inmarsat, Iridium, TerraStar Global, Thuraya and Vizada, deploys mobile satellite terminals and other equipment to help establish communication links for coordinating relief operations. The European Commission/Joint Research Centre's

[109] Bunker & Smith op.cit.; Buzna et al. op.cit.; Dawes et al. op.cit.; ECBP 2008; NRC 2007a; Quarantelli 1998; Törnqvist et al. op.cit.

[110] GIS refers to an organised collection of hardware and software for storing, indexing, retrieving, processing, spatially analysing and displaying spatially referenced data (Dash 1997).

[111] Remote sensing is an information gathering technique using sensors and other instruments aboard vehicles (for example satellites, aircraft, spacecraft) not in physical contact with and at distance from the object being observed.

[112] Dash op.cit.; Laituri op.cit.

Global Disaster Alert and Coordination System (GDACS) (cf Table 4) sends alerts in real time and provides tools – updatable reports, maps, online discussion forum – to help coordinate response. The platform has been used to detect floods in Vietnam and fires in Nigeria.[113]

The International Charter on Space and Major Disasters (ICSMD), established in 1999, provides a unified system of space data acquisition and delivery to disaster-affected communities when so requested by member agencies. It delivers high quality satellite imagery to front-line responders generally within 24 hours.[114] In early 2009, the Charter was activated by UNDP in response to floods in the north-central and north-eastern regions of Namibia which affected 17% of the country's population. Satellite imagery showed the extent of the flooding along the Chobe River in Capribi as well as the flood changes over time. This dictated a phased return of the evacuees; the common operational picture facilitating consensus among the different agencies.[115]

Non-profit ICT-expert organisations are likewise active in providing access to satellite data to low-income countries in disaster response. TSF (*TelecomSansFrontieres*) deploys its teams and telecom equipment from one of three regional bases. These reach disaster sites within 48 hours and provide communication to emergency personnel facilitating coordination of response efforts.[116]

3.4. Establishing Transparency and Accountability

A major disaster generally triggers an outpouring of technical and financial assistance from ordinary citizens around the world, usually channelled through donors and NGOs. The potential for waste, misappropriation and misuse of these resources is high.117 Lack of transparency and accountability can lead to irreversible loss of goodwill and generosity. Donors and the intended beneficiaries need to know what has been delivered where, to whom and when. Such a task is beyond the capacity of a single organisation. Self-organising, self-managed social networking tools with free and open source platforms have proven powerful in meeting this need.

Web 2.0 tools enable information sharing, collaboration and creation of user-generated content, in areas with broadband Internet connection. People serving as 'sensors', crowdsourcing information from mobile phone, email, RSS feeds, the web, and feeding

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[113] Coyle & Meier op.cit.

[114] Non-members may make the request through members (Lateiri 2010).

[115] The Charter was also successfully activated during the Senegal and Burkina Faso floods of September 2009. The United Nations Institute for Training and Research Operational Satellite Applications Programme (UNOSAT) offers developing countries free enhanced access to satellite imagery and GIS services for disaster preparedness, response and reconstruction. It offers both regional as well as focused maps, informed by experts. UNOSAT deploys to the field to understand the specific needs of users (cf Table 1).

[116] The equipment includes a satellite receiver and several Global System mobile phones with local SIM cards. TSF provides free phone calls to disaster-affected families; it also provides training in emergency telecommunications to information technology or logistics officers. Since 2006 TSF has offered satellite communication and a computer connected to a small data transmitter in 12 remote and isolated communities in Niger to implement an early warning system on food scarcity (Coyle & Meier 2009). MapAction is another NGO with a similar mission (Laituri 2010.; MapAction 2010).

[117] The chaos in the 2004 tsunami response included "Ten international field hospitals set up none of which worked at full capacity… 20 surgeons competing for one patient". The chaos was attributed to "too much money" with competition to "spend unprecedented budgets" (IFRC 2005: 4). Out of over 200 agencies in Aceh only 46 submitted reports to UN coordinators. A review of 34 Australian NGOs that fund-raised for the tsunami showed that only three indicated how much of the funds raised would be targeted at the tsunami and less than half indicated how the excess funds would be used. Two years after the tsunami more than one-third of the NGOs had not provided any report on the funds to the donors, although most still had unallocated funds (Abraham 2007). See also the article "Too much of a good thing" (The Economist 2010).

it to decision-makers, add immense value to search and rescue operations and impose transparency in aid allocation and delivery.[118]

In the Philippines during typhoons Ondoy and Pepang in 2009 a local web developer set up a site using Google Maps to give flood updates and locate people needing rescue. The local news networks embedded the map in their news sites and Google created a link to the website below the keyword search box for *Google Philippines*. Other volunteers joined to improve the capabilities and interface of the map facility. Within a short time the site became a central hub of information on the latest developments in the flood relief effort.[119]

Ushahidi (meaning "witness" in Kiswahili) combines SMS, Twitter and Google maps to crowdsource crisis information. It is a free, open source, decentralised platform developed by Kenyan bloggers in the aftermath of the 2008 Kenyan elections but is now used in other disasters. Location-specific information is communicated directly to subscribers. Ushahidi has developed Swift River as a rapid verification system for crowdsourced information by crosschecking tagged information from different sources.[120]

*Sahana (*meaning "relief" in Sinhalese) is a free and open source disaster management system developed by volunteers from the ICT community in Sri Lanka in response to the 2004 Indian Ocean Tsunami. *Sahana* architecture allows users to modify the system. It now has six modules (a) an online Bulletin Board for missing persons; (b) a Registry that keeps track of all relief organisations and civil society groups (c) a Registry that keeps track of all shelters: location, basic facilities, capacity; (d) a Central Online Repository that matches requests for aid and supplies with pledges of support; (e) a Volunteer Coordination System; and (f) an updatable Situation Awareness module. *Sahana* has been used in Indonesia, Pakistan, Philippines, China and Myanmar.[121]

The ICT tools described here can support the earlier-described task of providing an overall operational picture but they can also help establish transparency and accountability for resource allocation decisions. However safeguards are needed against misinformation and caution must be exercised on unlimited sharing of information.[122]

3.5. Strengths, Weaknesses and Emerging Trends

The ICT applications described in Sections 3.1 to 3.4 show the power of ICTs in enabling rapid, efficient and interactive communication during disasters. Fig 2 summarises the ICT tools used in response to specific information and communication needs at particular points in climate-related disasters.

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[118] Coyle & Meier op.cit.; IBRD op.cit.; Laituri op.cit.; NRC op.cit.
[119] Apikul op.cit.; Ubalde 2010.
[120] Coyle & Meier op.cit.
[121] Treadgold 2006
[122] Information on shelter locations for example can facilitate criminal activities (ECBP 2008; Wattegama op.cit.)

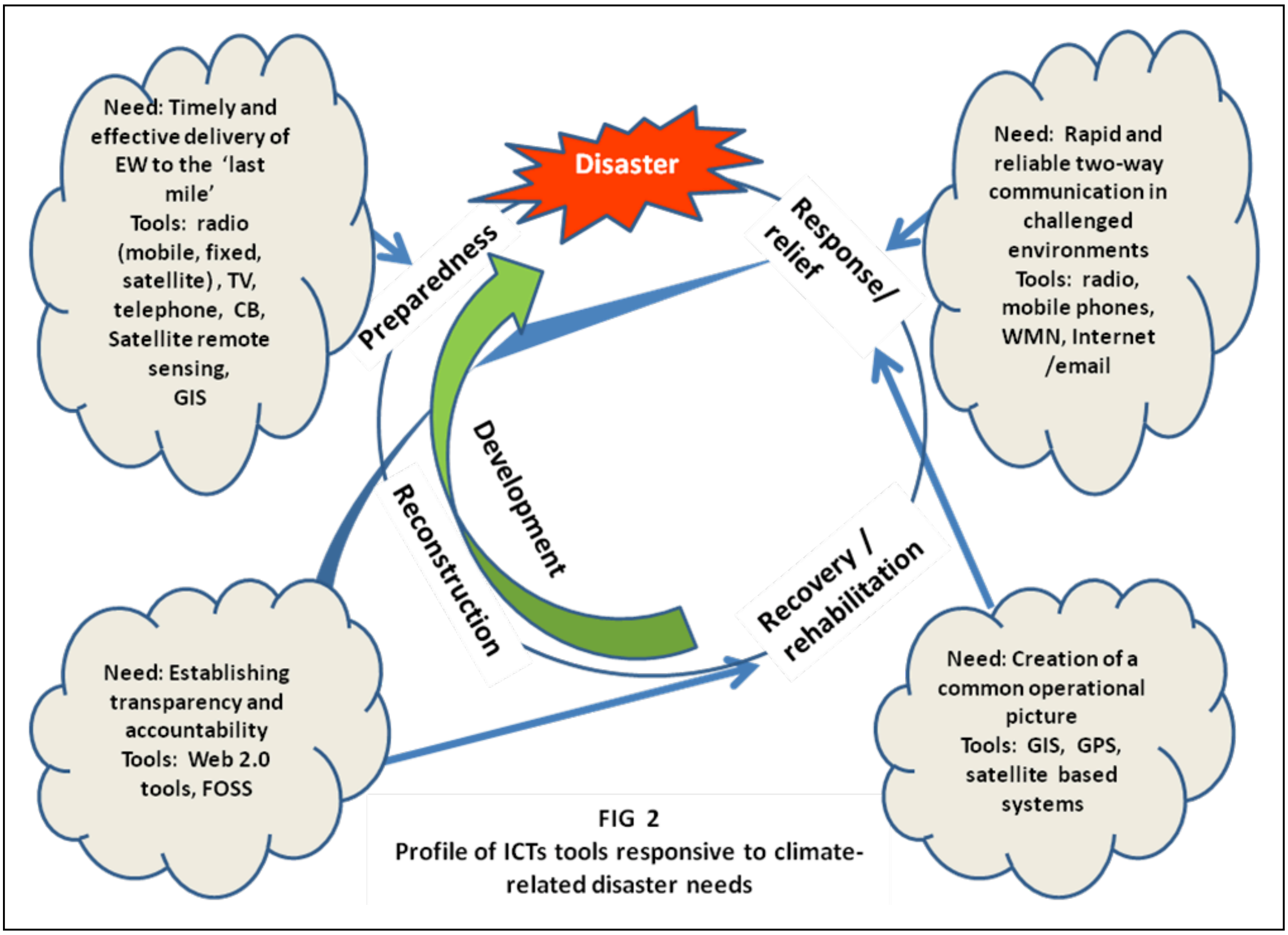

FIG 2
Profile of ICTs tools responsive to climate-related disaster needs

3.5.1. Advantages and Disadvantages

Each specific technology has its strengths but also its limitations. These are summarised in Table 3, drawing largely from the cases cited in the sections above.

Table 3: Comparison of Different ICTs for Disaster Management[123]

Channel	Advantages	Disadvantages
Radio and Television	Most accessible to low income households One-to-many Portable	Takes time to get the warnings Limited use at night
Community Radio	Excellent for rural poor and remote communities One-to-many Portable	Not widespread Obtaining a license can take time in some countries
Telephone (fixed)	Quick delivery	One-to-one Requires expensive infrastructure Vulnerable to congestion and delay
Telephone (mobile)	Relatively low cost Increasingly high penetration in rural areas	One-to-one Vulnerable to congestion and delay
SMS	Available on most mobile phones One-to-many Quick delivery	Vulnerable to congestion and delay Does not reach non-registered numbers Literacy required
Cell Broadcasting	One-to-many Not affected by nor adding to traffic Message can be differentiated by cells or sets of cells Geo-scalable Geo-specific targets Greater authenticity	Phone must be switched on and set to receive message Does not reach non-users Requires literacy No standardisation across networks to date
Internet/email	Fast and interactive Multiple sources can be checked for authenticity	Limited penetration in developing countries Limited local language content Subject to overload
GIS	Integrates spatial with social, economic and cultural data One-to-many Visual display of patterns	Require high bandwidth and high speed networks Utility depends on data Costly hardware and software Requires expertise – interpretation, integration
Satellite-based Systems	Large geographic range One-to-many Independent of terrestrial infrastructure Two-way, one-to-many communication Provides broadband connectivity Rapid deployment Reaches 'last mile'	Expensive, requires technical specialists Requires line of sight Data less accurate than ground-based systems (expanse over detail) Delays in propagation depending on satellite orbit
Web 2.0 Tools	Many-to-many and hence resilient Self-organising, self-managed	Requires Internet connectivity No security, open to false information Heterogeneity of wireless standards complicates inter-operability

[123] Various sources: Apikul op.cit.; Asplund et al. op.cit.; Coyle & Meier op.cit.; Dash op.cit.; IFRC 2009; Karanasios 2010; UNESCAP 2008; Wattegama op.cit.

3.5.2. Emerging Trends

Although the evidence base is relatively limited, it is already clear that ICTs will be increasingly used in climate change-related disaster management in developing countries. What, then will be the technical and organisational trends emerging from the development of new wireless technologies; from convergence of telecommunications, computing, and multi-media; from ICT-friendly policy revisions; and from lessons learned on previous disaster management initiatives? Some of these – including greater standardisation and interoperability, more data availability at lower costs and better inter-agency collaboration – are discussed below.

Standardisation

Several global initiatives are targeting this problem. GEOSS promotes the use of common technical standards so that geospatial data from thousands of different instruments can be combined to form a coherent dataset.[124] The International Charter on Space and Major Disasters (ICSMD), UNOSAT and EPIC have similar goals (cf Table 4). The Common Alert Protocol standardises early warning messages from different sensors and feeds them to different alerting technologies. This reduces inconsistencies and cost.[125]

Interoperability

There are strong market interests pushing for technological interoperability of ICT devices and networks. "There can be no mass market without seamless interoperability."[126] The use of free and open source software and open standards for data storage, communication and discovery is the favoured approach (cf Table 4).[127] Among public safety agencies this is reflected in the move towards partly or completely infrastructure-less ICT solutions such as those based on Tetra (Terrestrial Trunked Radio) standards[128] and mobile ad hoc network (MANET) communication platforms based on software defined radio (SDR).[129]

Increasing Data Availability at Lower Cost with New Technologies

Unmanned aerial vehicles (UAVs) or 'drones' are being adapted to monitor disaster impacts. UAV images are cheaper to produce and have higher resolution than satellite images because UAVs are not affected by cloud cover since they fly at low altitudes. Although still relatively costly, the decreasing size and increasing use of UAVs through

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[124] Coyle & Meier op.cit.

[125] CAP is an open, non-proprietary standard digital data interchange format that can be used to collect types of hazard warnings and reports at the local, regional and national levels, for feeding into a wide range of information and early warning systems. CAP essentially standardises the content of alerts and notifications across all hazards to different audiences. It provides a speedy, single authoritative and secure alert message. The CAP specification was approved by the Organisation of Structured Information Standards in April 2004 (Wattegama 2009).

[126] Graziano & Lűtteke 2006:11.

[127] Asplund et al. op.cit.; ECBP 2008; Graziano & Lűtteke op.cit.; NRC 2007a; Treadgold op.cit.

[128] Terrestrial Trunked Radio (TETRA) is a digital trunked mobile radio open standard developed by the European Telecommunications Standards Institute. Targeted primarily at the mobile radio needs of public safety groups, the interfaces, services and facilities are specified in sufficient detail to allow the development of fully interoperable infrastructure and radio terminal products. Encryption provides security of voice/data communication.

[129] SDR units can be programmed to interoperate with any legacy radio device (Törnqvist et al. 2009).

partnership arrangements between donors/NGOs and research institutions are expected to reduce cost.[130]

The use of wireless mesh networks may also become more affordable. In Feb 2010, ITU signed an agreement with Singapore-based SmartBridges Solutions to provide WiMAX and WiFi systems to strengthen ITU's on-the-ground disaster response capabilities. The equipment is sent to disaster sites to provide fast wireless phone and Internet connectivity when terrestrial networks are destroyed.[131]

Intra-and Inter-agency Coordination

Weak intra- and inter-agency coordination in disaster response is a significant problem in both developed and developing country contexts. Greater technological interoperability has not necessarily brought about the organisational behaviour change needed to achieve full interoperability. The problem is widely recognised as one of trust.[132] Most of those responding to a disaster will not likely have met face to face before but will nevertheless need to collaborate during and after the disaster, "often in a complex, chaotic or completely unplanned environment…"[133] Some researchers writing in the European disaster context, view ICTs as critical in facilitating collaboration among "hastily formed networks",[134] arguing that trust and efficient knowledge sharing can be achieved with collaborative technologies and appropriate social processes.[135] Others, focusing on international humanitarian agencies, stress that "many of the challenges of inter-organisational coordination cannot be solved by ICTs"[136] but that informal contacts, common language, professionalism, standardisation, and frequent external communication help.[137]

Global Covenants and Strategic Alliances

The ratification of the Tampere Convention[138] in 2005 has helped expedite the deployment, cross border movement, installation and operation of telecommunication services during disasters. There are also numerous partnership arrangements among government, industry and NGOs seeking to address the standardisation, interoperability, data availability, and cost issues related to the use of ICTs in disaster management. Table 4 lists a few of these.

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[130] Some examples include the World Food Programme, which has partnered with the University of Torino Italy and developed two UAV prototypes that would capture and map visual data early to plan and monitor the delivery of relief food aid. The European Commission's JRC, in collaboration with TerraPan Labs and University College London, has also developed a cheap and portable UAV prototype – the LOw cost Unmanned Imaging System (LOUIS). LOUIS can be assembled in less than three minutes and used by personnel with no previous UAV experience. In 2009 they integrated *OpenStreetMap*'s new Walking Papers with visual images from a UAV to produce a printable map that the user can annotate from the ground and then upload (Coyle & Meier 2009).

[131] http://www.smartbridges.com/company/news/59-press-release-sb-and-itu-for-haiti

[132] Asplund et al. op.cit.; Bunker & Smith op.cit; Dawes et al. op.cit.; ECBP op.cit.; UN ESCAP 2008.

[133] Törnqvist et al. 2009: 1.

[134] The term *hastily formed* networks (HFN) was coined by the US Naval Postgraduate School in 2004 and refers to "multiple organisations with no common authority that must cooperate and collaborate" with each other to fulfil a large, urgent mission (Denning 2006).

[135] See for example Asplund et al. op.cit.; Denning 2006; Shklovski et al. op.cit.; Tornqvist et al. op.cit.

[136] Maitland and Tapia 2006: 341. Also Suparamaniam & Dekker 2003.

[137] NRC (2007a) appears to have reached a similar conclusion.

[138] The Tampere Convention on the Provision of Telecommunication Resources for Disaster Mitigation and Relief Operations allows for tariff-free movement of telecommunications equipment and personnel across national borders, and into disaster affected areas, and waives licensing requirements for the use of needed frequencies (Coyle & Meier op.cit.; IBRD op.cit.; Wattegama op.cit.).

Table 4: ICT-Related Collaborative Initiatives[139]

Institution - Initiative	Purpose
EU – JRC Global Disaster Alert and Coordination System (GDACS)	Produces near real-time situation reports and tools to help disaster response coordination, such as media monitoring and map catalogues.
Innovative Support to Emergencies, Diseases and Disasters - RIFF[140]	Leverages open source technology to improve information flow, cross-sector collaboration and more efficient collective action.
UN Global Impact and Vulnerability Alert System (GIVAS)	Maximises use of new media and digital technologies for information collection to provide decision-makers with real time alerts and analysis of impacts on the poorest and most vulnerable populations.
UN Operational Satellite Applications Programme (UNOSAT)	Provides satellite images and analysis to relief and development NGOs with field contacts to provide context.
WFP – Emergency Preparedness Integration Centre (EPIC)	Creates a platform to integrate operational information from multiple sources for use by humanitarian agencies.
World Vision – Last Mile Mobile Solutions	Combines mobile technologies with improved humanitarian agency practices to "promote greater efficiencies and accountability in food aid programming and delivery at the last mile"[141].
NGOs/Bill &Melinda Gates Foundation/Microsoft Corp – Emergency Capacity Building Project	Develops ICT skills among frontline NGO staff. Its toolkit – *Building Trust in Diverse Teams* – integrates trust tools in learning projects, embedding them into existing preparedness, individual operation plans, training and induction plans.

[139] Coyle & Meier op.cit.; ECBP 2008.
[140] RIFF is a platform developed for monitoring public health threats which can be adapted to natural disasters. It combines satellite imaging, data analysis, and vulnerability assessment for early warning system. It was developed by an NGO, InsTEDD (Innovative Support to Emergency Diseases and Disasters) which is supported by the Google Foundation. RIFF includes automated feature extraction and integrates several capabilities, such as data gathering and aggregation module, data classification and tagging modules, a prediction and alert output and field confirmation and feedback modules. It allows the user to collect data from SMS, RSS feeds, email distribution lists, databases and online discussion fora and facilitates collaboration by allowing users to comment, tag and rank sets of related information. The application of this platform to other disasters is being explored (Lewis 2009).
[141] IFRC 2009: 22.

4. ICT Use, Disasters and Developing Countries: Some Reflections

ICT applications in developing country disaster management did not begin in earnest until the mid 1980s: at least a decade after their introduction in industrialised countries, and even then confined mainly to administrative purposes. A Virginia-based NGO, Volunteers in Technical Assistance, pioneered the use of low earth-orbiting satellites and Internet-based messaging services in its relief and development operations in Chad, Djibouti, and Pakistan in the late 1980s.[142] In the early 1990s software for decision support was introduced by UN agencies in their relief and refugee operations. By the mid-1990s, bulletin board networks were starting to be used by agencies in developing countries for disaster management-related discussions.[143]

Today there may be less overt sense of technological lag. As described Section 3, the uses of ICTs in disaster management in developing countries are as sophisticated as those in industrialised countries. Yet this has largely been enabled by external agencies, specifically, the UN agencies, donors, and international NGOs. Very few developing countries have the resources to install, operate and maintain the necessary ICT infrastructure, notwithstanding well-intentioned policy statements to this effect.[144] And in general, we need to recognise some of the ongoing issues surrounding use of ICTs for climate change-related disaster management in developing countries.

4.1. Institutional and Cultural Barriers

The barriers to greater ICT use in disaster management go beyond cost. Governments which have the resources may not implement ICT-friendly policies or may not invest in more resilient electricity and telecommunication systems that decentralise information generation and sharing, and democratise decision-making.[145] In many countries with moderate or high levels of ICT penetration, access to ICTs continues to be restricted by economic factors as well as government policies, illiteracy, and cultural barriers of gender, ethnicity, religion and caste.[146] All of these must be recognised and coped with in seeking to expand ICT disaster-related applications.

4.2. Data Standardisation and Quality Issues

The lack of standardisation in data collection in developing countries is acute. It is not uncommon for census, cadastral registries and other housing data within a country to be maintained using different media, standards, and definitions. They are frequently held by different institutions. Local laws, security protocols or inter-organisational rivalries may prohibit or complicate the sharing of certain types of data. Historical data and local maps are frequently not available in digital format and/or lacks proper meta data. Available data may be out of date, or collected using different methodologies.[147] The initiatives listed in Table 4, being all reactive, will ameliorate *some* of these problems in some *future* disaster events in *some* countries.

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[142] Gariott 1991; Ruth & Ronkin 1992.
[143] Stephenson & Anderson 1997.
[144] Best op.cit.; Statskontoret 2002; TeleCommons Development Group 2000; Yonazi 2009.
[145] Purbo n.d.; Wattegama op.cit.
[146] See for example Apikul op.cit.; Hazarika et al. 2010; Wattegama op.cit.
[147] Laituri op.cit.

4.3. ICT Capacity Deficits

Meteorological data, forecasts and analyses are often inaccessible or incomprehensible to those who need the information most because of lack of the necessary skills to interpret, process and integrate the data..[148,149] ICT skills development has been the goal of ICT for development projects which have proliferated in the last 15 years. Relatively few are deemed successful or sustainable.[150] Many reasons are cited for the failure but lack of local capacities, such as skills, is a repeating element.[151]

One proposal has been the linking of relief and development through ICTs. The argument is that ICTs introduced for relief can and should be retained in the area for continuing use in terms of information collection, analysis and sharing by local NGOs. The disaster ICT infrastructure may thus help leapfrog an area to a competitive telecommunications market structure.[152] A more interesting outcome from a capacity development perspective is that such a transition would reinforce the ICT skills learned and enhance local ICT capacities, though of course there is some elements of chicken-and-egg, in that successful application of the disaster/relief information systems would only be possible if a certain level of capacities are already present and/or transferable during usage.

Such capacities can often be quite basic. For example, it is interesting to note that all the ICT-in-developing country policy documents reviewed for this paper focus on cost as the major issue and market-friendly policy instruments as the solution to the digital divide.[153] There is no mention of illiteracy as a significant barrier to access, and basic education as a necessary policy response to this barrier. Yet the digital divide affecting ICT usage in disaster management is partly a literacy divide.

4.4. Grounds for Optimism

There are several grounds for optimism.

One is the compelling evidence from Cuba and Mozambique that reaching and therefore saving lives in the 'last mile' can be achieved by maximising "the use of readily available, low-cost low-tech solutions…".[154] Another is the evidence of socially minded ICT-savvy professionals from both sides of the development divide who are giving their skills and time to make ICTs a global public good – the Kenyan bloggers who developed *Ushahidi*, the Sri Lankan ICT professionals who developed *Sahana*, the professionals who developed *Dumbo*, the Filipino web developer and cyber enthusiasts who developed the hub during the 2009 floods, and the volunteers with TSF, MapAction, GISCorps and others. Additionally, the development of new wireless technologies, the convergence of voice, data, computing and modelling capabilities of services, networks, products and terminals are enabling the provision of user- and management-friendly information and communication services with a farther reach at a lower cost.

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[148] Coyle & Meier op.cit.
[149] Note that this is not unique to developing countries. Studies on the response to the attack on the World Trade Centre and Hurricane Katrina report exactly the same problem (Dawes et.al 2004; NRC 2007a).
[150] See for example Abbasi 2007; Maiye & McGrath 2010; Osama 2006; van Reijswoud 2009.
[151] See for example Heeks 2003; Maiye & McGrath op.cit.; Osama op.cit.
[152] Maitland et al. 2006.
[153] This specifically refers to: Best 2003; Statskontoret 2005; Telecom Dev Group 2004; van Riejswoud 2009; Yonazi 2007.
[154] IFRC 2009:28.

But the basis for hope rests not simply on a combination of bottom-up volunteering and exogenous technological change. It has also required coordinated efforts over many years by multiple national and international organisations.

For example, work on standardisation is progressing, facilitated by technology developers. Table 4 provided some details but another instance is *DesInventar*, a disaster management application first used in disaster preparedness in Latin America in 1994 to develop national-level disaster databases in 17 countries using up to 30 years of data from NGOs, universities, scientific organisations and government agencies. It ran up against the problem of data standardisation, but efforts to address the problem continued. Ten years later *DesInventar* was modified and applied successfully in developing India's Integrated Disaster Resource Network using data going back 30 years from governments and news media. *DesInventar* was further modified and adapted to South Africa's programme for Monitoring, Mapping and Analysis of Disaster Incidents, focusing on large urban 'non-drainage' floods, wildfires, extreme wind events, and highly frequent 'small' and 'medium' fires, effectively integrating socio-economic conditions and environmental risk factors.[155] *DesInventar* is now used to establish one of four international disaster databases, the others being EM-DAT, Nat Cat and Sigma.[156]

There also appears to be some progress on the problem of inter-agency cooperation and collaboration. As noted in Table 4, the impacts of coordination failure that surfaced during the 2004 Indian Ocean tsunami led to a grant to the Inter-Agency Working Group (IWG)[157] on Emergency Capacity Building (ECB) to find ways to address the problem.[158] Among the more than 20 work streams, the Building Trust in Diverse Teams Pilot Project focused on some of the softer, less well-recognised institutional and cultural barriers that can hamper effective ICT usage. Conclusions to date have been that, "Within the IWG, the substantially increased levels of trust, coordination, improved relationships, and willingness to share information and resources has been the ECB's most important outcome."[159]

Regional actions have also played their part. For instance, in the Asia Pacific there are initiatives aimed at establishing regional and subregional standby communications systems for disaster management purposes as well as arrangements for sharing information. These are enabling access at much reduced cost to countries with fewer resources and weaker infrastructure.[160]

Finally, national policies should not be forgotten. Governments may be criticised for the policy lag that continuous technological change often creates, but there is a flip-side of ongoing legislation. As one example, more and more countries are allowing the commercial utilisation of license-exempt radio frequencies and opening up markets for technology development.[161]

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[155] Apikul op.cit; Wattegama op.cit.
[156] EM-DAT – emergency disasters database, managed by the Brussels-based Centre for Research on the Epidemiology of Disasters. Nat Cat and Sigma are managed by Munich Re and Swiss Re, respectively.
[157] IWG was formed in 2003 by the emergency directors from 7 of the world's largest humanitarian assistance agencies – CARE Intl, Catholic Relief Services (CRS), Mercy Corps, OXFAM GB, Save the Children and World Vision
[158] Maitland & Tapia 2008.
[159] ECBP 2008: 21.
[160] Examples include the Sentinel Asia initiative aimed at integrating space information and the products and services of earth observation satellites.(UN ESCAP 2008).
[161] Best op.cit.

5. Strategic Recommendations

Large-scale, climate change-related disasters, regardless of the specific physical event involved, often result in similar scenarios: critical infrastructures destroyed or disabled for several days or weeks, and an influx of different organisations offering assistance. Generally more pronounced in developing countries, these scenarios pose tremendous challenges in communication, coordination and accountability, which have important consequences for the effectiveness of disaster response. They warrant strategic policy and programme responses.

5.1. Ensuring Continuity in Challenged Environments

Regulations should provide for priority access to communications for disaster responders, and priority repair of communication services to ensure continuity of ICT-enabled services and products. If the ICT infrastructure is in private hands such provisions should be included in licensing and concession contracts. Hardened data centres for archiving digital data and running of essential government services should be established. This is admittedly costly but has high development returns.

A forward looking government strategy would 'mainstream' wireless technologies more systematically, expediting the use of cheaper, energy-smart WSN in early warning systems, and the deployment of inexpensive ICT solutions when infrastructure is compromised.[162] Disaster conditions frequently demand extraordinary use of communication tools. ICT systems should be developed not with proprietary solutions but with diverse standard components and operational interfaces that accommodate interoperation. And when procuring ICT equipment, systems based more around routinely-used, familiar applications should be preferred over those requiring specialised training. Responding to disasters involves solving problems under high stress conditions. Skills used infrequently are often forgotten in such situations. Routine use builds confidence.[163]

5.2. Bringing about Inter-agency Coordination and Cooperation

Of the four acknowledged barriers to interoperability, only one is non technological – fragmented planning and poor coordination.[164] Interestingly, reviews of responses to several major disasters in the last fifteen years[165] share one conclusion, along the lines expressed by Denning: "the quality of the response depended not on response planning or on new equipment, but on the quality of the network that came together to provide relief".[166] Furthermore, the existence of a well established national disaster response plan does not appear to make a difference.[167]

Forming an executive committee on site, representing the different organisations, might be a non-threatening way to initiate coordination. Protocols for sharing information,

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[162] For example wireless sensor networks for monitoring environmental conditions in harsh environments (Karanasios 2010), or monitoring the integrity of buildings and bridges (Eisenberg 2011).

[163] NRC 2007a.

[164] The other three are: incompatible standards, aging equipment, limited and fragmented radio spectrum (NRC 2007a; UN ESCAP 2008; Wattegama 2007).

[165] See for example, Bunker & Smith op.cit.; Denning op.cit.; Maitland et al. op.cit.; Sjöberg et al 2006; Suparamaniam & Dekker op.cit.; Törnqvist et al. op.cit.

[166] Denning 2006: 15.

[167] The problem is best illustrated by the chaos that reportedly characterised the work of the two hundred or so NGOs that went into Aceh Indonesia in response to the 2004 tsunami. Indonesia has a well-established emergency response plan that did not prevent this (The Economist 2010; IFRC 2005).

equipment and resources and decision making would have to be agreed upon at the outset.[168] The experience in the 2001 Gujarat earthquake suggests that having ICT experts in the response teams hugely facilitates the coordination process.[169] Tools for labelling and filtering need to be developed so members can avoid being paralysed by information glut, and only access information relevant to their needs.

Donors could make standardised disaster data collection a condition for channelling funds through NGOs. A registry of participating NGOs could be put up in donor agency websites to inform potential donors.

For their part, national governments could make data sharing mandatory among public sector agencies for disaster management purposes.[170]

5.3. Maintaining Transparency and Accountability

Whether large or small, disaster response in developing countries often relies on external financing and assistance. ICTs have become very effective tools in raising funds for disaster assistance, but such financial assistance will only be continuously provided if donors – agencies, governments, individuals – are convinced that assistance was wisely used. Therefore the use of ICTs to create transparency and accountability of disaster response agencies should be more widely adopted. There are pioneer databases for this purpose, e.g., UNDP's DAD during the 2001 Gujarat earthquake[171, 172], Microsoft and Mercy Corps' FACTS (Food and Commodity Tracking System),[173] and *Sahana*.

5.4. Pursuing Combination, Not Specialisation

One continuous message from the case studies reviewed is the need to think broad rather than narrow. This applies to technology: almost all of the most valuable applications are those involving combinations of technologies. Sometimes, as in the Maldives EWS, these run in parallel. But often they run in combination within the same system – combining the Internet and mobile phones, combining satellites and GIS, and so on.

Very few, if any, of the ICT applications reviewed in this paper were climate change-specific. There is a strong argument to be made for combining disaster and development ICT uses into a single system – for example, generic weather information systems; generic 'human sensor' reporting systems, generic mapping systems. Not only is this more efficient, it also helps to embed disaster management systems into the routine functioning of communities.

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[168] This was proposed by Denning (2006) and something similar was reportedly adopted quite successfully by UNDP during the 2001 Gujarat earthquake (Maitland et al 2006).
[169] Maitland et al. op.cit.
[170] This was proposed by the National Research Council (2007a).
[171] Maitland et al. op.cit.
[172] UNDP's Development Assistance Database provides an interface that allows it to link to other accounting, financial and statistical systems (Synisys n.d.).
[173] The FACTS design team included the American Red Cross, Catholic Relief Services, Food Aid Management, Food for the Hungry International, Project CONCERN, and Save the Children. FACTS is already used in Bolivia, Guatemala, Indonesia and Kyrgyzstan operations of these NGOs (Sahu n.d.).

5.5. Areas for Future Research

More research is needed on the issue of using converged rather than specialised ICT systems. How great can the combination of systems be: just extending disaster management systems to incorporate climate-related events, or attempting the much broader task of integrating disaster and development systems? Technically, how could this type of convergence be made to work? Institutionally, what does it mean to seek to combine disaster and development applications? And institutionally how can the different actors that need to combine be brought together?

In addition, two of the problem areas discussed in this paper warrant more careful examination if we are to see significant improvements in the quality and efficiency in preparedness and response to climate-related disasters, as well as inform resource allocation decisions of developing country governments.

One is coordination and cooperation among hastily formed networks. Why is coordination and cooperation among response agencies immensely difficult? Are national NGOs better than international ones? Does organisational size make a difference? How about history of engagement in local development? Are development NGOs more amenable than humanitarian agencies to coordination? Are 'flat' organisations more willing to cooperate than hierarchical ones? Are decentralised or autonomous NGOs more cooperative than those with headquarters outside the country? Are field volunteers more willing than staff to cooperate with each other? Do donors care or are their reporting requirements partly responsible for the problem?

Examining these issues would entail interviews of key informants and review of reports and documents of government and non-governmental organisations that have been involved in major disasters in developing countries in the last five years.[174] This should be complemented by archival research (e.g., local newspapers), and interviews with local leaders in selected disaster sites.

The second area needing attention is performance evaluation and financial auditing of disaster preparedness and response programmes. Several million dollars are raised and spent in every major disaster but there is little public knowledge as to how the funds were spent, for what, who actually benefited, and how many.[175] How quickly were voice and data communication set up? How quickly was assistance delivered? Were the targets reached? Who were ignored or bypassed and why? How well did the group coordinate its activities with others? Did the organisation comply with relevant financial and legal requirements? Is the entity's internal financial control suitably designed and applied? Were their inefficiencies? What were the causes? What has been the contribution of ICT use on the quality of the outcomes?

The requirement for performance evaluation and financial audit could be embedded in the funding application process and budget allocated for the purpose. The evaluation and audit reports could become part of an organisation's file that would inform its next application for disaster relief funds.

Global climate change models predict more frequent and severe climate related disasters. It is in the interest of those committed to ameliorating disaster impacts on

[174] Longer than five years would probably pose difficulties of recollection among those involved.
[175] Labadie 2008.

the world's poor that the generous expressions of humanity and good citizenship that arise in the wake of disasters not be betrayed, and that public confidence in the integrity of humanitarian assistance systems be maintained.

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ANNEX 1. Glossary of Acronyms

AMARC	Association Mondiale de Radiodiffuseurs Communautaires
APCICT	Asian and Pacific Training Centre for Information and Communication Technology for Development
AREA	Addressable Radio for Emergency Alert
AVHRR	Advanced Very High Resolution Radiometer
CAP	Common Alert Protocol
FEWS NET	Famine Early Warning Systems Network
GEO	Group on Earth Observation
GIVAS	Global Impact and Vulnerability Alert System
IFRC	International Federation of the Red Cross /Red Crescent Societies
ICSMD	International Charter on Space and Major Disasters
InsTEDD	Innovative Support to Emergency Diseases and Disasters
ITU	International Telecommunication Union
OASIS	Organisation of Structured Information Standards
RAD	Remote Alarm Device
RANET	Radio and Internet Technology for Communication of Hydro-meteorological Information for Rural Development
TSF	TelecomSansFrontieres
UNESCAP	UN Economic and Social Commission for Asia-Pacific
UNOSAT	United Nations Institute for Training and Research Operational Satellite Applications Programme
WMO	World Meteorological Organisation