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Disasters and the Information Technology Revolution

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This paper, the second in a series of state-of-the art reviews, examines the evolution and possible medium-term future of information technology (IT) in disaster management. Until the end of the 1970s, civilian application of IT to disaster management was confined to a few specialised departments of universities, large companies and government. Between the late 1970s and mid-1980s, microprocessor-based devices brought limited, though rapidly improving, computing capacity to a wider range of organisations and individuals. Operational applications included real-time emergency information, management decision support and programme and project planning. Extensive innovation occurred, though operational implementation was often long delayed or limited in scope. During the late 1980s, desktop systems became more powerful, more networked, more portable and generally more mature, with a range of practical emergency-related tools emerging. Computer communications emerged as a practical technology for linking emergency professionals on a global basis. From the early 1990s onwards, powerful and inter-connectable computer equipment has evolved to become an indispensable component of disaster operations worldwide. There are presently major changes under way in emergency-related global information access and networking — the implications of which have yet to be played out. The last part of the paper highlights a set of key technologies which seems likely to shape disaster planning, management and research over the next 10 years, and draws out some operational and organisational implications.

Introduction

The mid-1990s have seen increasingly ubiquitous application of information technology (IT) to emergency planning and management. The convergence of computers and communications, and the accelerating growth of global information networking is beginning to have a profound impact on the organisation of disaster mitigation, planning and response and on the underlying matrix of research and knowledge transfer.

In this paper we look back at some of the key stages in the evolution of IT applications for disaster management. We then go on to highlight some of the ways in which the future of disaster management might be shaped by the burgeoning growth of computer and communications technologies.

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The full history of IT applications in emergencies has yet to be written. Many of the efforts of individuals and operational teams still remain unpublished. This is particularly the case for defence applications of civil emergency planning, but the efforts of staff in many relief projects in developing countries also remain undocumented or otherwise unrecognised. Internationally, there appears to be a large but hidden pool of analysis, ingenuity and experience. This paper can only be a brief, partial and selective review, but it is our hope that it may eventually stimulate a more comprehensive and definitive analysis, and a greater level of interaction within this community of interest.

Where have we been?

For the purposes of this article, we can highlight four main phases of IT application:

- an early period up to the end of the 1970s;
- a phase of great improvements in accessibility combined with much experimentation during the first half of the 1980s;
- a period of maturing applications combined with growing communications innovation in the late 1980s; and
- the start of a major revolution in networking during the 1990s.

The 1970s

In the early years of the 1970s, few could have foreseen the extent of diffusion of computer equipment over the next 20 years. The range of applications was constrained by the equipment available, and limitations on access. The key feature of the period was 'time sharing': many users shared one large machine. Terminals were linked to mainframes and minicomputers, and these terminals were almost all text based. Graphics terminals were expensive and complex to use. Most of the applications focused on various types of calculations, scientific analysis or accounting. Specialised training was needed, with a learning time to operate core equipment of between one and five years.

Mainframe computers were used in a variety of ways in disaster management in the early 1970s (Friedman, 1975). The most common applications were operational research and mathematical simulations, mostly for defence-related civil emergency planning. Research programmes included modelling of traffic flows in urban evacuation, fire spread modelling, predictions of weapons effects, economic recovery modelling and some early Geographic Information Systems (GIS) pilot studies. One well-documented and long-lived simulation was the SPLASH model, and its successor SLOSH, for storm surge forecasting and mitigation planning (Griffith, 1986; Jelesnianski, 1972). An increasing amount of work was also done on operational command and control systems in the civil emergency planning sector. In the United States, much of the work was carried out by large commercial research groups or universities under government contract.

Computers were physically large, and terminals had little or no independent computing capacity. Desktop electronic statistical calculators started to appear more widely, and were used by an increasing number of field researchers for analysis in epidemiology and nutritional assessment in developing-country relief programmes.

The telex was increasingly replacing the telegraph for data transmission. A relatively small proportion of machines were interconnected, but a range of experiments were also begun in the civilian sector — particularly in banking to introduce electronic money transfers. The X25 communications protocol emerged during this period, and was to become the foundation for modern international networking over the next decade.

During the latter part of the 1970s, a gradual diffusion of computer technology occurred. Minicomputers, such as the DEC PDP-8 and PDP-11 started appearing at the departmental level, running statistical, modelling and accounting applications. Applications in emergency management were initially limited to relatively simple data management and real-time modelling in a few operations centres in Western countries (Sheffi et al., 1980; Strauch, 1980). Quickly, however, the introduction of machines under the direct control of researchers and operational managers presaged a radical revolution in technology which would become apparent over the following decade.

Between the late 1970s and the mid-1980s the new generation of microprocessors began substantially to change the cost structure of computing. Small, crude, but usable, desktop computers became cheap enough for relatively unfettered purchase by departmental budgets, as well as by many individuals. After an initial period of experimentation, the learning time needed to achieve useful results decreased substantially to a few weeks or months. The key outcome of this technological diffusion was a substantial change in power relationships. Mainframe functions became easily accessible to individuals, and data could be stored and processed locally After a short time, a range of new applications not even available on mainframe computers appeared on microcomputers. Basic but effective software tools for numerical analysis, database management and word processing became widely available, and rapidly became easier to use than their mainframe equivalents. Stored data became much more portable, with easy transfer on to cheap diskettes. Generally, there was much more flexibility and control by end users.

Initially, the impact of the new microprocessors on disaster planning and research was very limited. Most operational research and simulation studies continued to use mainframe and minicomputer equipment, which was also evolving in performance, and gradually becoming more accessible to staff of universities and larger organisations. Both the availability of cheap data storage, and the quality of graphic output improved significantly during this period, leading to increasingly sophisticated and large-scale simulations of disaster impact (McLean et al., 1983).

Use of computers in real-time emergency information management remained at an early stage. There were some innovative experiments; for example the EIS commerial operations package, conceived several years earlier, evolved into a fully fledged microcomputer system early in the decade. During the period, there were many attempts at operational implementation of many different software packages in the US and western Europe Some of these efforts are described in a seminal collection of papers assembled in 1986 (Marston, 1986). Other studies include those involving decision-support for emergency resource management (Belardo et al., 1984); attempts at expert systems development (Mick and Wallace, 1985); and work on GIS for risk projection (Everson, 1985; Scawthorn, 1984). Most of the early applications based on microcomputers were constrained by the cost of mass storage, and limitations of early databases such as dBaseII. Minicomputers were more powerful and also used in some operational applications, especially in the US, but required specialised skills and remained expensive.

By 1985, a range of practical applications in disaster management was also beginning to emerge for use in developing countries. Many of these applications were basically administrative. Field staff greatly appreciated the convenience and independence of document production, interactive calculation and simple interactive simulation. It was not unusual to encounter staff in even remote field offices using an IBM or Compaq PC to run spreadsheets for refugee food programming, project management, commodity tracking and accounting or beneficiary databases. Microcomputers also found a useful role in anthropometric studies and epidemiology (Bertrand et al., 1984). Mainframes were used, with increasing effectiveness, in a few projects such as the UNHCR Biodata system for refugees in Thailand, and in the ICRC tracing system.

A series of additional, relatively unnoticed innovations had an important impact on research support. The early and mid-1980s saw wider diffusion of on-line bibliographic information services. While costly, these proved a real boon to researchers. Unfortunately, however, specialist bibliographic support for disaster research remained one of the weaker areas, and little support was forthcoming for comprehensive information support.

Computer communications began to see more widespread application during the mid-1980s. In retrospect, this period can be seen as a defining stage in the evolution of global networked communications. The quiet growth of internetworking of academic and government mainframe computers in the US, using the Internet protocols was making e-mail and large-scale file transfers routine, but access was confined to a small minority of users. Low-speed modems became widely available for microcomputers, and a number of experimental bulletin boards emerged, providing files to download and rudimentary public e-mail.

Practical digital radio communications also developed during the early 1980s. Amateur radio groups in Canada, building on experimental work done at the University of Hawaii, worked on ways of effectively transmitting digital data by wireless signal. Experimental amateur packet radio began in Montreal in 1978, and was followed by additional experimental work by the Vancouver Amateur Digital Communication Group (VADCG). By the early 1980s groups in Canada and in Arizona were developing equipment which would be available to amateurs at very low cost. The various projects eventually resulted in the design of modems and control devices, and the selection of common communications protocols. Together, these allowed reliable transmission of digital information such as e-mail on inexpensive radio networks. By the mid-1980s thousands of amateur radio operators had set up a wireless equivalent of the Internet long before most people had even heard the term, with e-mail, bulletin boards and chains of repeater stations. Packet radio proved invaluable in many local emergencies, but the full potential was never used at the time by the international relief community.

One international group did make good use of the new wireless technology. The American NGO VITA became involved with the Radio Amateur Satellite Corporation (AMSAT) in a very innovative project to combine packet radio and low-orbiting satellites as a way of linking health and other development projects in isolated areas (Garriott, 1991).

The late 1980s

The second half of the 1980s was dominated by an accelerating trend towards departmental and workgroup computing. The growth of local area networks of microcomputers shifted the control of information resources in many large organisations away from the centralised management information service units and towards individual departments and operational units. At first, this mainly involved clusters of enhanced terminal equipment such as the IBM 3278 and 3279 character-mode terminals linked to SNA networks. But soon, the steadily increasing power of inexpensive desktop equipment led to a growing emphasis on visual displays and improved graphical presentation of data to the rapidly burgeoning population of new and inexperienced users. This was a period of extensive local networking of common retail microcomputer equipment, and locally shared data storage. It was also a period of confusion, high expenditure and low return on investment, as the quest for independence and departmental control often overran the capacity of the equipment and software involved.

A range of more sophisticated software became available including desktop publishing, presentation packages and sophisticated databases. A detailed review of development during this period is given by Drabek (1991). Departmental databases began to migrate to the desktop level. Learning times decreased concomitantly. A microcomputer could be operated reasonably competently after about a month.

Equipment also became more portable, more independent of power supplies and more rugged, with the emergence of flat screens and improved battery technology. By the early 1990s, a sophisticated laptop computer and a portable printer could be transported to an overseas emergency site in a briefcase, and set up in a few minutes or less.

At the same time, mainframe machines also improved dramatically in capacity with massively powerful equipment available for simulation and modelling. Applications for emergency management grew more sophisticated. A number of practical and effective applications were developed for mainframe computers and workstations. Among the most developed were plume and spill modelling and evacuation simulations for industrial hazard responses. These were enhanced by mapping output and graphics displays — the forerunner of more recent GIS applications.

Databases of hazardous materials became available, either directly accessible by modem, on disk for use on laptops or on CD-ROMs. There were several different packages mostly produced by national government research agencies. Among the most widely used was CAMEO, produced by the US National Oceanic and Atmospheric Agency. Fire service research centres were often innovative users of computers for fire modelling, toxic materials management and evacuation modelling.

Meteorological forecasting and hazardous weather prediction were significantly improved by the introduction of supercomputer-based models of atmospheric dynamics. Storm-surge forecasting and modelling also improved, with the introduction of successors to the SLOSH model. Other applications included simulations of damage to utility networks.

At the operating-centre level in developed countries there was increasingly ubiquitous access to a new generation of microcomputers, with greatly improved memory, good graphics displays and network connectivity. The development of packages for real-time operational management accelerated during this period.

Commercial packages such as EIS and SoftRisk combined resource and incident tracking databases with map displays for output, integrated e-mail and wireless communications, and were widely purchased in North America.

This period also saw the emergence of GIS as a credible technology in support of emergency management. Implementation was initially slow, constrained by the need for relatively expensive workstations, and limitations in software and data entry. But gradually, with the introduction of a new generation of microprocessors and software packages such as ARC-Info, MapInfo and Intergraph, it became possible to envisage a whole range of information systems for mitigation support, response management and recovery planning.

Applications of information technology in developing countries continued to trail, but microcomputers began to appear in the most unlikely places. The trends established earlier continued. Use by scientists and technical specialists continued to spread, with the introduction of new packages for anthropometric statistics, epidemiology and mapping. The Centers for Disease Control (CDC) in the US distributed two packages: the Epistat statistics software, and later the new graphics-based Epi-Info, for public health and nutrition professionals. Both found wide application.

Logistics applications were also popular. The PanAmerican Health Organization (PAHO) introduced SUMA: a database initially conceived for tracking medical and other supplies in sudden-impact emergencies This was successfully used in several large emergencies, and continues to be developed (de Ville de Goyet, 1993). Many software applications for relief commodity accounting and control were developed over this period. Examples include the UN World Food Programme headquarters' experimental Food Aid Information System, and the networked food accounting and scheduling packages used in the Thai border operation by UNDRO. Most applications were relatively unintegrated, but some efforts were made to build more information systems for strategic management of relief programmes. Examples include the early innovative dBase applications used at the Office for Emergency Operations in Africa (OEOA), and the RICSU programme in Sudan.

Probably the most decisive innovations occurred in communications technology. Between 1986 and 1990, a quiet revolution began in computer-based emergency information management and communications. Initially, the fax emerged as the dominant interim messaging technology: it was easy to use and reliable. Around the same time, several UN agencies quickly recognised the potential of the new X25-based e-mail services being introduced by large commercial communications providers. By 1987, both UNICEF and UNDRO had introduced extensive e-mail networks based on the Dialcom service. Both were initially relatively expensive to use, but they provided a potentially much more flexible and cheaper means of international communication. This was also the period when commercial e-mail services such as Dialcom and Compuserve emerged.

In the late 1980s, a new confluence of factors evolved, which was later to precipitate a revolution in communications. These factors included the emergence of international packet switching networks, which handled data much more effectively than the pre-existing voice networks; the movement of private research network owners towards commercialisation of their operations; and the widespread adoption of standard communications protocols, beginning with UUCP applications, BITNET and the TCP/IP Internet protocols. In fact, these protocols, and the telecommunications networks which used them, had been steadily evolving for almost 20 years, and were already in widespread use in scientific research, government and defence, but few in the international natural hazards community were even aware of their existence.

By the late 1980s, another set of innovations was well under way, but again was utilised fully by only a small minority of emergency professionals. Computerised bulletin boards had been growing in popularity among computer users for a wide range of purposes. Around this time, several bulletin boards designed specifically for emergency management professionals were established. They included the Emergency Preparedness Information Exchange (EPIX) in Vancouver and SALEMDUG the Hazardous Materials Information Exchange in the US. In 1989, a nationwide network of bulletin boards for emergency professionals (ADMIN) was established in Australia (Anderson, 1990).

For the small minority able to use them fully, the electronic mail services gave emergency managers and planners the ability to gain direct contact with scientists. The scientists in turn could communicate easily outside their own communities of interest. The use of electronic mail started to break down traditional barriers to information exchange, providing a new means of communication common and accessible to all. The new communications technologies also provided a means for remote access to computing resources, large-scale, inexpensive electronic file exchange, electronic conferencing and the dissemination of news (Anderson, 1992).

The present decade

Trends in the early 1990s initially looked like a continuation of the previous pattern. New microprocessors and cheap disk storage brought workstation power to the desktop. Improved software reduced the learning time for basic tasks to less than a week. Improved local and wide area networks allowed data sources to be dispersed among new groupings of users, and complex configurations of machines developed to integrate these groups. A new and rapidly growing focus on relationships between users emerged, to the point where some observers suggested that 'Information Technology' should be renamed 'Relationship Technology'. New forms of client and supplier linkages emerged, with growing emphasis on electronic data interchange for production scheduling and commercial transactions. The X25 networks, including public networks such as Dialcom and Compuserve made e-mail widely available, and added a range of other information products. E-mail using the TCP/IP Internet protocols found new constituencies.

The changes in connectivity and data access were by this stage having a profound impact on organisational structures in commercial organisations. This included the removal of middle layers of management, more out-sourcing of work and a general re-drawing of organisational boundaries. Emergency management and relief organisations were not immune to these changes, although the impact was generally much less intense and more delayed. In North America especially, there was an increase in part-time emergency management activity, with some planners spending much less time in offices, and increasingly looking outside their formal organisation for support. In many relief organisations, staff noticed a general speeding up of the pace of operations, a compression of the decision-cycle and a flattening of organisational structures. Emergency communications patterns showed early signs of future radical changes (Gant, 1996).

Some of the emergency management applications which emerged in the early 1990s made full use of the combination of high-powered and increasingly inexpensive equipment and the new level of connectivity. Perhaps the most sophisticated work concerned simulation and modelling, and real-time information management. A variety of tools were gradually developed. Reviews of the range of different packages are included in the series of TIEMES workshops which began during this period, and include virtual-reality simulation, cyclone-damage forecasting and real-time warning of earthquakes (Sullivan et al., 1995).

Emergency Operations Centre (EOC) design and incident management systems received a boost in emphasis. A comprehensive review of EOC design principles reflecting the technology of the period is given by Buddenberg (1995). Computer networks became common in most large EOCs in most developed countries. Groupware packages, such as Lotus Notes began to appear. New versions of the EIS and SoftRisk commercial packages were introduced.

The use of computers for decision support was still relatively rare in developing countries. None the less, a number of innovations occurred. Computer systems found wider use in planning and scheduling of relief and recovery operations. Both UNHCR and WFP introduced new commodity tracking software (the UNHCR Commodity Tracking System and the WFP Interfais software). Several private relief agencies designed their own commodity management packages. The use of epidemiological and nutritional data also improved further with the introduction of new analytic and communications software by the CDC. A few applications focused on community-level interactions (Benini, 1991).

New support tools for early warning developed, including software and systems developed for USAID (The Famine Early Warning System, or FEWS) and the FAO GIEWS system (Marsh, 1994) and the EC-funded RiskMap package developed by SCF-UK.

There was an extension of more sophisticated information management and decision support to developing country operations. Projects supported by UNDP in Vietnam (Mindel, 1995) and Fiji (Stephenson, 1995) established the boundaries for more comprehensive and integrated disaster management systems in countries without an extensive IT infrastructure. Work by PADIS in Addis Ababa, together with innovations in digital radio by several relief agencies, established a framework for extensive networking and information exchange in the African region.

There was a growth in interest in GIS during the early 1990s, with many experiments in mapping and data management for mitigation and preparedness. Notable examples included work on earthquake vulnerability in San Mateo, California, mitigation projects in Quito, Ecuador (Tucker, 1994) and work in Latin America and the Caribbean by the Organization of American States. The proceedings of various conferences and symposia of URISA contain useful coverage of GIS applications for mitigation (Alexander and Johnson, 1991). A number of examples of other GIS work on natural hazards were presented at a succession of conferences organised by ESRI, the makers the ARC-Info package, and are now available in electronic format (http://www.esri.com). GIS applications are covered in more detail in a recent review (Dash, 1997).

Various mitigation applications emerged, including at least one comprehensive commercial GIS for use by insurance companies assessing windstorm hazards (see for example, http://www.cartograph.com). The range of applications in mitigation for seismic hazards increased substantially around this time (Frost and Chameau, 1994; King and Kiremidjian, 1994; Wadge et al., 1993).

GIS technology also found new applications in recovery planning. For example, the Federal Emergency Management Agency (FEMA) used GIS successfully to underpin grant support for recovery after the Northridge earthquake, and after several other emergencies (US Federal Emergency Management Agency, 1995). However, data quality has proved to be a significant problem with all resource databases designed for emergencies. A disconcertingly large proportion of data were found to be unreliable in some operations. Reportedly, in one commercial database used extensively in the Northridge recovery operation, there was a 40 per cent error rate in locating and identifying hospitals alone. The cost of commercial datasets was also a constraint.

Remote sensing also started to show signs of wider application, usually in combination with GIS. Several large floods in the midwestern US and in Europe prompted programmes to monitor flood hazard vulnerability (see, for example, the work of the interdisciplinary Scientific Assessment and Strategy Team in the US). UK-supported applications were reviewed in a recent publication for the IDNDR (Wadge, 1994) Other examples of projects on remote sensing operations focusing on developing countries included a study by Smith Industries reviewing the data needs of the NGO community, encompassing those in complex emergencies (http://www.smithinst.ac.uk/smithsys/pressrel/aidmap.html), and a Norwegian study of satellite remote sensing for refugee operations (http://www.nrsc.no:8001/~einar/).

In the early part of the decade, emergency management professionals and researchers still worked in relatively narrow communities of interest and few were in a position to make use of the emerging new communications services. For a minority, bulletin boards provided a useful interim solution, evolving into networks such as FIDO Net, with a form of store and forwarding of e-mail. FIDO networks in particular still have a significant role in linking researchers and operational staff together, particularly in Africa and the Pacific region.

Technical and scientific information exchange was growing, supported in part by the invaluable Natural Hazards Center in Colorado, and by groups such as PAHO. But comprehensive information on emergency management and relief operations outside the US was still hard to collect on a sustained basis, and information on developing-country activities was particularly inaccessible. The importance of IT in underpinning information exchange was increasingly emphasised (Butler, 1991).

The situation changed radically between 1993 and 1994. In North America, Europe and parts of Asia, the innovation which precipitated a major change in information management was a software package, developed originally at the University of Minnesota, called Gopher. This provided a new level of organised information retrieval for computer terminal users accessing remote computers over networks. The key feature was that the links to information displayed by the software did not point exclusively to files on one machine. Instead, a menu could point to information on other computers anywhere on a global network. A user on one machine could browse right across a network for information, and collect full text material without needing to know about the minutiae of transfer commands. Quite suddenly, a research community with global interests found a tool capable of realising them.

Gopher software was complemented by improved software tools for simple file transfer and simpler e-mail tools. In a further innovation, new tools for indexing material on large networks of computers started to emerge, with names like Archie, Veronica and Wais.

By 1994 a number of computers with gopher software were archiving or linking large amounts of documentation on disaster management. They included several university machines, most notably the EPIX server at Simon Fraser University in Vancouver, Canada; government servers, such as USAID and the US Department of Agriculture, several Australian emergency planning departments; a few UN agencies, including the Department of Humanitarian Affairs (DHA); and a very few NGOs, most notably VITA in the US. Generally most UN agencies were late in applying this tool and many operational relief NGOs failed even to discover the phenomenon for several months.

By early 1994 computer conferencing was also becoming much more widespread, both on the Internet, on FIDO-NET and other bulletin-board networks. Several groups in Africa and the Pacific area developed extensive e-mail networks based on the FIDO system. The conflict in the Balkans also soon generated its own plethora of information sources. The use of e-mail list servers, which echoed messages to all participants, was a straightforward and effective means of reaching globally dispersed communities of interest. Situation reports from DHA were also delivered relatively early on using list servers. Gradually, the number of subscribers making use of specialised professional lists increased: including VOLCANO-L for the vulcanology community, EARTHQUAKE-L, several lists servicing disaster specialists in Latin America (including services provided by the La Red group, and a PAHO listserv); and a number of casualty management and emergency medical care lists. One of the longest running and most effective lists was Networks in Emergency Management (NETS), with several hundred subscribers.

During 1994 a further innovation sealed the conditions for an explosive take-off of networking and information exchange. Developed originally at CERN (the European centre for nuclear physics research near Geneva) it consisted of a new set of protocols for accessing and linking information on computers called HTTP. Like Gopher, the new approach allowed software on one machine to reference and make links to information contained on another, regardless of physical location. The new system became known as the Worldwide Web and was rapidly given a boost by several highly graphical and easily learned 'browser' software packages developed by US groups, which amalgamated the capabilities of 'point-and-click' file downloading, simple formatting of text material for display and image transfers. A few months later, audio and video capabilities started to emerge. The Web was a product of genius: simple, accessible and based on open standards and established Internet protocols. Supported by software distribution strategies based on making free browsers widely available, the Web generated an explosion of innovation and a fever of interconnectivity, with connections to the Internet doubling every few months.

The outcome is now abundantly clear to anyone with a Web connection. Most of the major institutions have either established their own server equipment for providing information formatted for browsers or have rented commercial facilities to do so. Much information that was previously circulated in printed form, such as newsletters, brochures, bulletins and sitreps, is now routinely posted on the Web for downloading to any connected site. An increasing number of institutions are now making full text reports and discussion papers available electronically. Several new electronic journals are now posting refereed papers on emergency management on specialised Web servers. Growing interest has developed in further improving the reliability and robustness of networks for emergency use (Anderson, 1996; Botterell, 1996).

In 1995, the Internet became a self-help network, and a primary means of disseminating information about the impact of the Kobe earthquake in Japan. The electronic networks provided access to maps, digitised photographs of damage and advice for contacting friends and relatives. A similar growth of interest and information exchange occurred after the Oklahoma City bombing.

Various international initiatives also emerged during the early flush of enthusiasm. Among the first was a NASA initiative called GEOWARN. In February 1996, a new initiative was endorsed by the G7 ministers at the Conference on the Information Society in Brussels. The project called for a new global emergency management information network (GEMINI) to be established to foster national emergency management systems and to link them into a global network.

The current position

After a period of rapid growth between 1994 and 1996, the static presentation of digital information has now reached a certain level of maturity. Recent innovations mainly concern the use of the Internet as a real-time communications tool, and the transmission of multimedia information Recent Internet software allows crude but usable voice and video transmissions, making it possible to set up global conferencing or training delivery for small groups at minimal cost. So-called 'Push' technology allows tailored information to be delivered directly to individual desktop machines and displayed immediately. For emergencies, this can include warnings, flash news, fast-changing data (such as river levels or seismic sensor output) or real-time video broadcasts triggered by events at particular sites.

Many of these newer multimedia technologies are currently constrained severely by the speed at which data can be sent to and from individual machines. But simpler conferencing using the Web appears to work well for many users. A recent electronic conference on disaster mitigation sponsored by the IDNDR Secretariat in Geneva attracted many contributions and much interest (http://quipu.net:1996).

The Web has also improved access to the literature on natural hazards and emergency management. A number of sites, most notably FEMA (http://www.fema.gov), EPIX (http://hoshi.cic.sfu.ca/epix) and the Natural Hazards Center in Colorado (http://www.colorado.edu/hazards/), contain large collections of digitised material. A growing amount is also available on a DHA site known as ReliefWeb (http://www.reliefweb.int). All these servers also provide links to collections at hundreds of other specialised sites. Considerable amounts of new material are appearing only in digital form. An electronic journal, the *Journal of Humanitarian Assistance* contains a comprehensive set of papers on complex emergencies and related issues (http://www-jha.sps.cam.ac.uk). Library access has also improved, with direct connections to the catalogues of individual research institutions, and many examples of bibliographies for downloading.

The earlier work of the amateur packet radio community has also been extended. Packet radio initially used a variant of the commercial X25 standard called AX.25. Later systems emerged using protocols based on the Internet standard (TCP/IP). Several hybrid protocols, such as PACTOR, are widely used by relief agencies. More complex software has also emerged, which handles e-mail routing between fast incoming telephone links and slower outgoing wireless links, raising the prospect of seamless e-mail links between various levels of headquarters and field-based units.

Packet-based wireless systems generally transmit data more slowly than most land-line transmissions: a few hundred written words per second at best. A number of projects are under way to address this. One, focusing specifically on emergency management applications, is being carried out at Simon Fraser University's Telematics Lab. The ultimate goal of this project is to develop low-cost, robust and field-deployable wireless emergency management information networks. It aims to establish an experimental virtual emergency operations centre where wireless information networks, interconnected to other fixed and mobile networks, allow managers to remain in the information loop, either until they can reach their Emergency Operational Centre destinations or as a substitute for physical presence at the EOC This project utilises a new 56Kbps TCP/IP-based amateur radio packet network, faster than most ordinary phone lines, which permits access to a variety of commonly used Internet applications that are customised for emergency management purposes.

Other important advances have helped establish the conditions for effective wireless use in emergencies An international effort, involving DHA, the International Telecommunications Union and a wide spectrum of UN and NGO relief agencies, has resulted in a new draft convention on the use of telecommunications in emergencies. A substantial co-ordinating and motivating contribution has come from the Working Group of Emergency Telecommunications (WGET). This group of UN and humanitarian relief representatives meets periodically to deal with regulatory and legal as well as operational and technical issues of emergency telecommunications. It works towards the implementation of ITU Resolutions concerning Telecommunications for Disaster Mitigation and Disaster Relief Operation and towards the efficient co-ordination of field telecommunications.

The critical importance of information networks in emergencies is beginning to be recognised widely A number of recent studies on the wider implications of network vulnerability have highlighted this issue (Quarantelli, 1996). So far, however, this issue has not been reflected in either the selection criteria for emergency planning staff, or in the design of many of the international training programmes for emergency managers.

Networked IT initiatives continue to emerge almost weekly, and by the time this article is available many will already have been superseded. We have singled out here, simply for illustration, two applications of IT which have had a notable operational impact over the past year. Both illustrate two key features: the capacity of the new technologies to reach large audiences, and their ability to engender a particular sense of community.

The first example is the use of Web pages to focus community responses during major emergencies in North America. The California Emergency Digital Information Service (EDIS) combines existing data access networks with digital radio and other data distribution systems to give authorised entities a direct computer link to the news media and other local, state and federal agencies during emergencies. EDIS and its archives can be accessed via links on the EPIX gopher server (gopher://hoshi.cic.sfu.ca:5555/11/epix/topics/emcom/edis) or directly by telnet (telnet://oes1.oes.ca.gov). EDIS has proved to be a valuable operational tool in earthquakes, fires, flooding and other local emergencies, allowing the convergence of expertise and information from government agencies, commercial groups and the general public. Similar approaches are now being used elsewhere. Recently, during flooding in North Dakota and Manitoba in April and May 1997, local, state, provincial and media-owned Web servers played a crucial role, not only in co-ordinating local community responses, but perhaps even more importantly in maintaining a sense of community among evacuated people dispersed throughout the region.

The second application, the DHA Integrated Regional Information Network (IRIN), based in Nairobi, was an invaluable information tool during the Great Lakes crisis. IRIN's formal output consisted of twice-daily, written briefings on regional events of concern to relief agencies, donors, governments and the media. The main distribution route is by e-mail or by downloading from a Web page (ReliefWeb and several other sites). In addition, the IRIN office acted as a focus for informal discussions, and a source of more-detailed background information for the staff of relief agencies in the region. A widely held view is that IRIN's local presence and its accurate, open and high-quality electronic coverage of events has increased the overall level of NGO and donor participation while at the same time, paradoxically, reducing rather than increasing the potential for conflict and disputes between organisations and individuals during a particularly difficult period.

Taking stock

As a community we have come a very long way in the last 20 years in the application of information technology. Some of the resources now available would have been inconceivable even 10 years ago. However, perhaps it is worth emphasising some things that have not happened during that period. Taken together, they suggest that while much lip-service is given to the importance of information in relief operations, the reality in some areas may be quite different.

First, we still know very little about how to measure the real impact of IT on emergency-related activity. There have been very few analyses, and no clear methodology appears to exist. We might, for example, reasonably expect to see a substantial improvement in operational co-ordination stemming from communications improvements. So far, however, this has proved very hard to assess. Even the concept of co-ordination remains rather ill defined. Similarly, we might expect to see a reduction in operational costs as a result of IT application. Little published work of this type is available, however. We might also expect to see a decrease in administrative and clerical personnel for any given level of operation. Again, information of that type is absent. Finally, we might expect to see improvements in early warning. Clearly while there is great interest in this topic, few measures of effectiveness have yet been developed.

Second, there seems to be a significant underuse of technology for *operational* knowledge recording. There is much academic material available, but the ubiquitous practical FAQ (frequently asked questions) found in many 'hands on' Internet sub-communities has not emerged for humanitarian relief. Few manuals are available in electronic form, and substantial digital libraries of good technical material for field use are not yet freely available on any transportable media. Lessons-learned databases exist, but there has been little support for making these more widely available.

Third, brokerage applications have been very slow to appear. The major UN humanitarian organisations and NGOs procure millions of dollars of equipment and materials every month, yet there is so far no general system-wide tool for linking purchasers and suppliers. Until recently, most NGOs in the UK, for example, hardly even exchanged the most basic information needed to challenge suppliers offering inflated prices

Fourth, library applications are still limited. While North American research material is well documented, access to other sources has only been marginally improved by IT. Huge amounts of material remain uncategorised and effectively unavailable The opportunity to produce a widely available digital collection of relevant research material, on CD-ROM and the networks, has been delayed for years. Furthermore, field technical support has also lagged in its use of IT. The technical means exist to permit virtual 'anchor desks' for logistics, medical and other technical support to the dozens of NGOs which have appeared in some recent operations. Yet very little interest has been shown in this.

Fifth, training has lagged significantly in its use of IT. While many other fields now have active CD-based training courses and Internet colleges (see, for example, the tools developed by the Knowledge Management Institute for the UK's Open University at http://kmi.open.ac.uk), applications in developing-country humanitarian relief in particular are very limited.

The future: where are we going?

In the rest of this paper, we very briefly analyse some of the trends in information technology which are likely to affect disaster planners and managers directly over the rest of the decade. There are, of course, real pitfalls in such forecasting. Particularly in a field like information technology, there is a real likelihood that some new innovation will overturn all predictions. But some trends appear to be quite strong, and certain developments are already fairly clear. We have attempted to select a set of key technologies which appear very likely to shape the way emergency planning and response is done over the next decade, and to draw out some of the possible operational applications. The applications are set out in Table 1. Eleven technologies are described briefly below.

Broadband networks including broadband Internet Broadband networks will increasingly form the telecommunication backbone, linking clusters of computers dispersed over wide areas. They will carry huge amounts of data — thousands of millions of characters a second — in contrast with the few thousand characters currently transmitted by basic modems over copper phone lines. Broadband linkages will become eventually become accessible at the terminal ends, and will also increase significantly in capacity.

Network commerce With appropriate security and payment mechanisms, much routine and emergency-related commerce may shift to electronic networks.

Intelligent network search agents Software can be 'trained' to seek out documents and other data stored on networked machines. See below.

Digital libraries A number of major projects are currently in progress worldwide to develop very large digital document collections (tens of millions of items), easily accessible via networks.