Cyclone preparedness and response: an analysis of lessons identified using an adapted military planning framework

Peter Tatham Senior Lecturer, Department of International Business and Asian Studies, Griffith University, Australia, **Richard Oloruntoba** Lecturer, Newcastle Business School, Faculty of Business and Law, University of Newcastle, Australia, and **Karen Spens** Professor, Department Supply Chain Management and Corporate Geography, Hanken School of Economics, Finland

The United Kingdom uses the Defence Lines of Development (DLOD) framework to analyse and understand the key components and costs of a military capability. Rooted in the Resource Based View (RBV) of a firm, an adapted DLOD approach is employed to explore, analyse and discuss the preparedness, planning and response strategies of two markedly different countries (Australia and Bangladesh) when faced with a major cyclone event of a comparable size. Given the numerous similarities in the challenges facing military forces in a complex emergency and humanitarian agencies in a natural disaster, the paper demonstrates the applicability of the DLOD framework as an analysis and planning tool in the cyclone preparedness planning and response phases, and more broadly within the disaster management area. In addition, the paper highlights the benefit to disaster managers, policymakers and researchers of exploiting comparative cross-learning opportunities from disaster events, drawn from different sectors and countries.

Keywords: Australia, Bangladesh, cyclone, Defence Lines of Development (DLOD), disaster planning, disaster response, military logistics

Introduction

The frequency and severity of natural and man-made disasters is increasing. This is true both in terms of the number of individuals killed and injured and the scale of financial loss, including the cost of response and recovery (McEntire, 1999; EM-DAT, 2010). For example, it has been estimated that more than 220,000 people lost their lives in the Haitian earthquake of 2010 (EM-DAT, 2010), whereas some 69,000 people died and 374,000 were injured in the earthquake in Sichuan, China, in 2008 (Reliefweb, 2008). Meanwhile, although the death toll for Hurricane Katrina (2005) was relatively low at 1,833 (EM-DAT, 2005), it caused damage in excess of USD 100 billion (Dyson, 2006). It is likely that such significant human and

financial costs will mount as the world experiences further the effects of ongoing climate change and population growth (DuPont and Pearman, 2006). Consequently, it is clear that disaster managers, policymakers and researchers should make every effort to learn from the effectiveness of planning and response to each disaster, as well as from other sectors, through the adoption of a more systematic and scientific approach to cross-event and cross-national learning.

Problem statement

Although this need for improvements in disaster planning, response and management has been recognised (see, for example, Thomas and Fritz, 2005; Kovacs and Spens, 2007), there is relatively little academic research on the disaster response lessons that have been identified, and on country-level comparative disaster mitigation and preparedness strategies. That said, researchers have undertaken studies of the challenges of disaster preparedness, response logistics and relief network management, using empirical investigations to assess whether techniques and practices developed for commercial, routine and repetitive supply and distribution in stable and secure uninterrupted environments can be adapted to meet the challenges of the non-profit, disaster relief context (see, for example, McLachlin, Larson and Khan, 2009). Similarly, others have applied published commercial logistics and supply chain management concepts and techniques to the provision of disaster relief (see, for example Oloruntoba and Gray, 2006, 2009). In addition, research has been conducted to analyse and evaluate the optimal mixture of military, non-military and composite response models of disaster response and management (see, for example, Pettit and Beresford, 2005). In parallel, Kovács and Tatham (2009) have considered the application of military planning models and approaches to the field of disaster response, preparedness and planning.

Aim

This conceptual paper is designed to develop this latter strand of thinking by considering in greater detail the potential for the use of one such approach–Defence Lines of Development (DLOD)–that has proved effective when employed by the United Kingdom's armed forces in a military context. It demonstrates how the DLOD framework can be employed to analyse the disaster preparedness planning and response strategies of two countries (Australia and Bangladesh) while preparing for, and responding to, broadly similar natural disaster events: Cyclone Larry (2006) and Cyclone Sidr (2007). It is argued that utilisation of the DLOD framework will enhance the likelihood of achieving a more efficient, effective and integrated

preparation and response that takes into account the nature of the disaster and local cultural, political and social circumstances.

To satisfy this aim, the paper first provides an overview description of the DLOD framework and the rationale for its migration as an analysis and planning tool from the military to the disaster management field. Second, the paper operationalises the framework in the context of the preparedness and response strategies of Australia and Bangladesh. These two cases were selected because, on the one hand, Bangladesh and the northern part of Australia regularly face significant cyclical rapid-onset cyclones, and because, on the other hand, the two countries are clearly demographically, economically and geographically different in terms of population density and levels of development and economic output. Thus, if the framework can be shown to have theoretical benefit in such markedly different contexts, then the benefits of its broader applicability can be more easily demonstrated.

In doing so, examples are drawn from the preparation and response approaches adopted by the disaster management authorities in both countries. It will be appreciated that such activities reflect an appropriate intersection of specific 'project' activities related to each individual cyclone and the 'process' nature of ongoing disaster preparedness and planning, which will continue even when cyclones are not in season. This confluence of short- and long-term activities has enabled a more rigorous analysis of the applicability of the DLOD framework as a planning and analysis tool for designing and executing cyclone preparedness and response strategies. The paper concludes by reflecting on the advantages of using 'cross-over thinking' that facilitates the migration of appropriate frameworks and models from, in this case, the military environment to the area of disaster response and management.

The DLOD model and its potential utility in disaster management

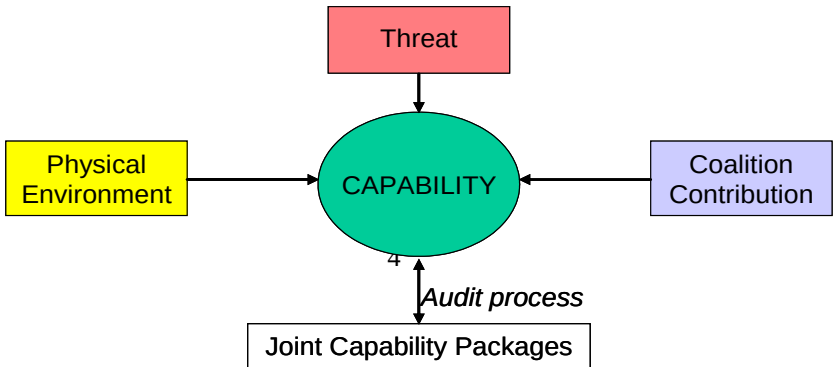
The DLOD model is a capability management framework that is used by the UK Ministry of Defence (MOD) to balance economy in meeting current operational needs with the sustainable use of current capabilities, and the development of future capabilities to fulfil the sometimes competing strategic and current operational objectives of an enterprise (MOD, 2011). It seeks to enable the relevant parts of the organisation to integrate, realign and apply the total enterprise ability or capacity to achieve strategic and operational goals. In addition, it helps the elements of the MOD to focus on the holistic management of the defined array of

interlinking functions and activities in its strategic and operational contexts. In short, it is a high-level approach to integrative management.

The DLOD framework has its genesis in the search by the UK armed forces for increased efficiency and effectiveness and holistic visibility of what is required to achieve a particular objective, operational or strategic, in the face of significant cost and time overruns. For example, the UK MOD was embarrassed in its procurement of both the Apache helicopter (NAO, 2002) and the Bowman Communications System (NAO, 2006) as the equipment-centric focus adopted by these projects led to considerable unplanned costs in areas such as infrastructure and training. Therefore, the MOD recognised the need to develop a more coherent and integrated approach to the management of such large projects—but, in doing so, it appreciated that the provision of various elements of the total capability often were to be found in specific silos within the organisation as a whole. However, given the difficulty of achieving cross-organisational and integrated oversight and the tendency to protect budgetary allocations, it was considered that some form of cross-cutting mechanism was needed to provide visibility of the total costs of a capability as well as an ability to analyse and pinpoint potential trade-offs. Thus, for instance, paying an additional sum to a manufacturer to achieve greater equipment reliability should lead to a reduction in the logistics and operating cost of maintaining the equipment through lower consumption of spare parts.

The result was called the ‘Capability Management Model’ (CMM), within which a capability is defined as ‘the continuing ability to generate an operational outcome or effect’ (MOD, 2011). The generic UK Defence CMM is illustrated in Figure 1. The upper part of the diagram shows that the desired military capability (that is, the operational outcome or effect) is determined by an assessment of three parameters: the enemy threat, the extent (if any) of the anticipated contribution from coalition partners, and the physical environment where military action might take place.

Figure 1 UK capability management model



Source: MOD, 2011.

This capability assessment is not required simply for a given point in time, rather it needs to be understood on a through-life basis. Clearly this adds a degree of complexity, yet, at the same time, it reflects the inter-related nature of a number of sub-capabilities. Hence, if, for example, the requirement is one of transporting soldiers and matériel across the battlefield, this may be achieved by a variety of existing and proposed vehicles of differing size and load capacity. As one of these vehicle fleets reaches the end of its operational life, a capability gap would open up that could then be filled by a new vehicle or by additional numbers of an existing vehicle.

The inclusion of the box labelled ‘joint capability packages’ in Figure 1 reflects yet another layer of complexity as some capabilities (or operational outcomes) can be met by a range of means. Thus, the destruction of an enemy position at a distance of 25 kilometres (15 miles) could be achieved by artillery, manned or unmanned aircraft, or even special forces that infiltrate enemy lines. The CMM model is designed to allow consideration of the costs and risks associated with each of these options. This occurs through the section at the bottom of the diagram in which the eight DLODs are positioned. As discussed above, the inclusion of these DLODs as sub-components of the overall military CMM reflects earlier planning errors in procurement, supply and sourcing which concentrated almost exclusively on the provision of a new class of equipment (such as the Apache helicopter) and ignored the associated costs of, for instance, training or infrastructure.

One of the key aspects of the framework is the recognition that a capability is delivered through the appropriate integration of all of the DLODs. Hence, all eight DLODs in the bottom part of Figure 1 contribute to the force elements that, in turn, contribute to the joint capability packages and, ultimately, to the (desired) capability. For example, if a decision is taken to procure a more technologically sophisticated piece of military equipment, then this will have a knock-on effect on the other seven DLODs as it may be necessary to recruit and train more highly skilled personnel for operating and maintenance duties at an attendant higher cost. Similarly, the infrastructure needed to maintain the equipment could well be more complex, as would post-procurement logistic support (that is, the volume, nature and cost of the future demand for spare parts and maintenance). In addition, there may be consequential effects on the doctrine (such as how the equipment is to be operated and integrated into other capabilities within a military formation). There may also be a need for a new military organisational structure to deliver the new capability, as well as the new information and communications. Consequently, any alteration to one of the DLODs is almost certain to have a concomitant effect on the remaining seven DLODs—the problem is, of course, that the magnitude and direction of such changes are unlikely to be uniform.

Rationale for the model

Borrowing and adapting theories from other fields is, according to Stock (1997), a beneficial and commonly used way to elevate rapidly a discipline's level of theoretical development. In the case of the CMM, the idea of managing a capability through its component DLODs has its roots in the Resource Based View (RBV) of a firm (Barney, 1991). Although, the RBV has been dominant in strategic management research over the past 20 years, to the best of our knowledge it has not been addressed formally in either the disaster management or disaster response and logistics literature—despite the fact that, in practice, it has formed an implicit element of this literature (see, for example, Grant, 1991; Oloruntoba and Gray, 2002, 2003; Helfat and Peteraf, 2003), and been explored more recently by Kovács and Tatham (2009).

Given the framework's efficacy within a military context, the question is whether it might form an appropriate basis for analysis and planning both specifically in cyclone preparedness and response, and more broadly in the context of disaster relief as a whole. To underpin this suggested inter-field transference of ideas, it is argued that there are clear parallels between the environment in which disaster relief and military (logistics) operations take place (see Table 1).

Table 1 A summary of the environment following a rapid onset disaster or a military operation

Issue	**Source**
Both disasters and military operations . . .	
. . . frequently (although not exclusively) fall into the category of 'uncertain future events', the location, severity and outcomes of which cannot be forecast accurately.	van Wassenhove, 2006
. . . are characterised by major disruption to the physical and transport infrastructure.	Pettit and Beresford, 2005; Banipal, 2006; Denning, 2006; van Wassenhove, 2006; Kovács and Tatham, 2009
. . . often are accompanied by a loss of some or all of the normal functions of state, such as law enforcement, local government and, potentially, elements of national government, as witnessed in the aftermath of Hurricane Katrina and the Haitian earthquake.	Derthick, 2007
. . . will see an influx of various actors, including indigenous and foreign non-governmental organisations (NGOs), and, in many cases, military personnel.	Couldrey and Morris, 2005; Telford and Cosgrave, 2007; Khan, 2008
. . . will almost certainly involve large numbers of injured and/or traumatised individuals, as well as an equally large number of homeless and/or displaced persons and families.	Kovács and Tatham, 2009
. . . are likely to see a heavy presence of the world's media—with associated interest by the general public and politicians in many countries.	IBLF, 2005; Kovács and Tatham, 2009
. . . will reflect a multiplicity of requirements of those affected (such as counselling, financial restoration, food/water, health, housing and rescue), and a multiplicity of service providers—thereby making the achievement of a united, coordinated, holistic response particularly challenging.	Oloruntoba, 2009a

Source: authors.

This parallel is illustrated further by drawing on the various activities in the different phases and models of disaster management and military planning, which have been described by authors with differences in approach and/or emphasis. Thus, Kovács and Spens (2007) proposed a phased approach comprising the short-term initial emergency relief response phase, which might include search-and-rescue efforts combined with the provision of medical aid, food and water, and the removal of those affected from ongoing danger. This is followed

by a second phase that sees continuing distribution of medical aid and the basic requirements for life in the medium term and builds on the systems implemented and activities undertaken in the initial phase. The third (and final) phase involves the re-establishment of more typical livelihood activities (that is, business, community, cultural and religious activities) in the affected area, with the goal of enabling relative self-sufficiency of the affected communities and businesses. Importantly, all three phases of this model are preceded by a preparedness and planning stage involving community risk analysis, hazard identification and mitigation, and allied community education and public awareness campaigns before a disaster strikes. A further important point is that these phases are not absolute as they almost always overlap.

Others have described disaster management as a process with several stages: the planning, mitigation, detection, response and recovery stages of disaster management (see, for example, Long, 1997; Cottrill, 2002; Safran, 2003), while Lee and Zbinden (2003) discussed the phases of preparedness, operations and post-operations. In short, different planning and operational activities may be distinguished: in the times before an event (the preparation phase, such as risk analysis); in the immediate aftermath (the disaster response phase, which will include the provision of emergency relief); and in the longer-term reconstruction/rebuilding phase. It is important to note that in this conceptualisation, the first two phases correspond to strategic planning to prepare for emergency projects and actual project planning when a disaster strikes (Kovács and Spens, 2007).

In the military context, such strategic planning activities are analogous to military requirements planning before combat, whereas actual project planning corresponds to the operational and tactical planning activities of the armed forces just before or during a combat mission. For example, planning activities in the strategic planning stage (military planning) may include capability planning, material requirements planning, equipment planning, transport planning, personnel planning and so on. The military must ensure, first, that its soldiers survive. Therefore, it plans any campaign in great detail, taking into account all relevant variables, then stockpiles whatever equipment or types of troops the commanders need to accomplish the mission (Pagonis, 1992; Davidson, 1999). This process may take several months, as seen in the first Gulf War (1990–91) when allied armies amassed in Kuwait before Operation Desert Storm. By contrast the Nazis suffered heavy losses during Operation Barbarossa (1941) while attacking the former Soviet cities of Leningrad and Stalingrad as they were unprepared for the Russian winter which resulted in troops freezing to

death because of poor uniforms. Thus, one seemingly insignificant detail resulted in failure and, arguably, changed the course of the Second World War. At the tactical, operational planning level, military planning might include consideration of how to get support items (such as fuel and spare parts) delivered to the commander in the field promptly (Payne, 1999; Smith, 1999; Dumond et al., 2001), and how to assemble, reconfigure and disperse soldiers and their equipment near the frontlines. Therefore, the overall success of a military mission is based on good planning in all respects.

In the disaster context, during the 'strategic planning' or disaster preparedness phase (which corresponds to strategic planning activities in the military before combat), disaster management authorities take an important step by analysing how best to support the communities that are particularly vulnerable to natural disasters and are at risk. For example, they identify hazards and plan how to respond to them. They may educate communities in what precautions to take and how to react when a disaster strikes. In addition, they may provide practical training in disaster response to community groups and institutions, early warning systems, and small-scale infrastructure works such as cyclone shelters, as well as conduct public information campaigns.

In the disaster relief phase (which corresponds to the tactical, operational plans of the military), authorities must quickly analyse, plan and develop a response to large-scale, unpredicted extreme disruptions to infrastructure and assist communities that have been affected by a natural disaster, resulting in a complete breakdown in everyday activities. Analysis could include the formal and informal needs assessment process and the damage assessment process to estimate the scale of the event—that is, how many people have been affected and what is required to bring succour to them. Needs analysis might include also reconnaissance of logistics infrastructure, the state of seaports/airports, and the site location of distribution points. The needs assessment has to be a first step in the response planning and response strategy formulation process before goods and services can be provided. This disaster information gathering, analysis and planning activity is performed in situations that are analogous to that usually associated with the conduct and impact of war operations. One can see, therefore, that both the short- and long-term planning processes conducted by military and disaster planning agencies are remarkably similar—albeit not necessarily sharing the same terminology.

A further justification for proposing the use of the DLOD framework is that, as amply demonstrated after the 2010 earthquake in Haiti, the sheer number of responding actors and uncertainties in the wake of a disaster increases the complexity in terms of coordination and many other 'unknowns'. Planning in such circumstances thus requires a broad, integrated and holistic view of all variables and parameters. In other words, in light of the huge variation and the diversity in the requirements of those affected by a disaster (such as education, financial grants, health care, non-food relief, psychological counselling, and security), the analysis and planning tool must be comprehensive, cross-cutting and robust. Not least, a 'whole-of-government response' will be required, as, in many cases, the response to the needs of those affected will be led by a different agency of government or by a different actor. Hence, there is a clear need for flexible, adaptable and broad-based plans—this is exactly what the DLOD model offers.

In summary, it is argued that many parallels exist in the underlying environment in which both humanitarian and military operations are planned and conducted, as evidenced by the similarities exposed in Table 1 and the subsequent discussion. Consequently, the CMM (and the associated DLOD framework), which was developed as a means of guiding the planning and execution of military operations, might usefully serve the same function in the context of planning, designing and executing preparedness for and the response to disasters such as cyclones. With this in mind, the following section extends the model to disaster management.

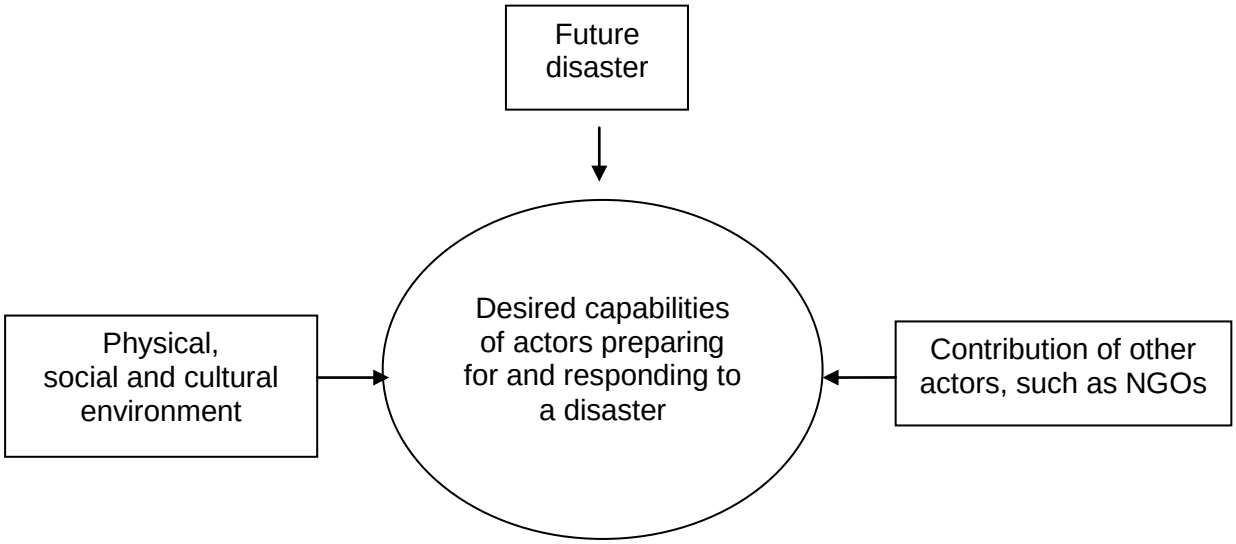
Extending the model to disaster management

In applying the CMM to a disaster preparedness planning and response context, it is necessary to contextualise the top half of the basic model, as shown in Figure 2. Given that the 'coalition contribution' in Figure 1 reflects the potential support from other armed forces, in the disaster relief scenario this element may be considered as the contribution of other countries or government departments, non-governmental organisations (NGOs) or United Nations (UN) agencies. Clearly, the implication of such an approach is recognition that if one particular NGO/UN agency has expertise in a certain area (such as water/sanitation), others should consider carefully whether further provision of this expertise is complementary or whether it represents unnecessary duplication.

By the same token, the 'threat' assessment in Figure 1 may be considered in a disaster relief context as being analogous to the potential for a specific type of disaster scenario occurring.

Once again, in line with the thinking behind the CMM, it is argued that the pooling of expertise between the affected government, local actors, NGOs and UN agencies would lead to the development of a more accurate and robust analysis and assessment of the threat to the population in a given country/region. Finally, the impact of the 'physical environment' (see Figure 1) on the capability required is equally applicable in the disaster relief context, although it is suggested that this can be broadened to reflect the need to take into account 'softer' aspects such as the cultural and social environment.

Figure 2 Adaptation of the UK military Capability Management Model to a disaster response context



Source: authors.

While the analysis and planning goal of Figure 1 is designed to identify and achieve the 'military capability' in the upper part of the diagram, Figure 2 adapts this capability management concept to the disaster analysis and planning context. Thus the goal of Figure 2 is to demonstrate how one might identify and achieve the required/desired capability of actors planning and preparing for, and responding to, a disaster. For example, it is suggested that disaster agencies and NGOs would all gain by cooperating in the planning, preparation and execution of their responses through the development of shared analyses, that is, the

equivalent of ‘joint capability packages’ in which one agency provides an element of the overall capability both for its own use and for use by other responding actors. However, given the controversial nature of such a collaborative approach to disaster relief, it is recognised that this will require considerably more trust-building among responding organisations, although the emerging UN Cluster Model clearly follows a similar line of thought.

Applying the model

Having explained and justified the proposed use of a modified version of the military CMM in the disaster field, this section operationalises the DLOD concept (that is, the bottom part of the framework) and demonstrates how it might be employed as a tool to support the achievement of a more efficient, effective and balanced response that reflects the nature of the particular disaster and local physical and social circumstances. This argument reflects the parallels between the two scenarios as previously discussed (see Table 1), as well as broader parallels, such as the challenge of achieving horizontal alignment and coordination, and an integrated output when faced with a vertical budgetary and hierarchical structure. In doing so, it is recognised that the socio-political issues faced in a public policy environment may be less easily defined when compared with those in a military context. However, the genesis of the DLOD model in the RBV of a firm supports its wider applicability. Indeed the RBV approach has been demonstrated in a broad range of contexts, including the public policy arena and where the social, cultural and behaviours aspects of the problem are pre-eminent.

To illustrate the utility of this migration of conceptual models, Cyclones Larry (2006) and Sidr (2007) have been selected. They were chosen because, on the one hand, they were similar in terms of their physical characteristics, yet, on the other hand, the affected countries have grossly different and contrasting social structures and economic situations. Therefore, if the model can be shown to be of value in these different circumstances then, by extension, it may have broader applicability and benefit.

The following subsections provide an overview of each country and the particular cyclone that struck it. The responses to the cyclones are then discussed using the DLOD framework. Rather than go through each of the DLODs in a relatively mechanistic way, a number of examples are set out that demonstrate the analytical approach. Conclusions are drawn from them.

Bangladesh

Bangladesh is a relatively poor developing country with a per capita gross domestic product (GDP) that results in it ranking 196 out of 229 countries in the world (CIA, 2008). It is particularly vulnerable to a broad range of disasters, including earthquakes, floods and tornadoes, as well as cyclones (Khan, 2008). It is a densely populated country that is located in the world's largest delta region (called, variously, the Bengal Delta, Ganges, Ganges-Brahmaputra or Sunderban) (Bowden, 2003). This stretches from the Hugli River in the west to the Meghna River in the east, and is approximately 350 kilometres (220 miles) across at the Bay of Bengal (Bowden, 2003). The delta region is composed of a labyrinth of water ways, swamps, lakes and flood plain sediments (*chars*), with a population of some 130–150 million people living in the region despite the risk of flooding caused by heavy monsoons rains, heavy runoff from the melting snows of the Himalayas, and tropical cyclones. At some 875 people per square kilometre (2,000 per square mile) this region is one of the top ten most densely-populated areas on earth (Bowden, 2003).

Cyclone Sidr

Cyclones of varying strength strike Bangladesh regularly, and there have been 14 serious cyclonic events in the past 25 years. Of these, three cyclones—Bhola (1970), Gorky (1991) and Sidr (2007)—have been particularly disastrous (Khan, 2008). For example, the loss of life following Cyclone Bhola in November 1970 was similar in scale to that following the Indian Ocean tsunami of December 2004, with somewhere between 250,000 and 400,000 deaths (Frank and Husain, 1971). However, although more powerful than Bhola, Cyclone Gorky, which struck the country in April 1991, killed far fewer people (around 140,000) (USGS, 1995). This lower death toll appears to reflect the preparatory efforts undertaken during the preceding 20 years, as well as the increasing effectiveness of post-disaster management processes.

Against this background of an improving national disaster preparedness and response management system, a similar magnitude cyclone (Sidr) struck in November 2007 and followed much the same track as its two major predecessors. The weather system began to develop on 9 November before being upgraded to a 'cyclone' on 12 November, a 'severe cyclone' later that day, and a 'very severe cyclone' early on 13 November. It reached its peak strength on the morning of 15 November before making landfall at around 18.30 local time across an area measuring some 1,000 kilometres (620 miles) in diameter.

The arrival of the cyclone was accompanied by heavy rainfall and a storm surge of between three and five metres (10–15 feet) although, fortunately, it struck at low tide otherwise the effects would have been greater still (GOB, 2008a). Consequently, although it had very similar characteristics to its two major predecessors, the estimated figure of 4,234 deaths (EM-DAT, 2008b) reflects a quite remarkable reduction of more than 85 per cent in the death toll over the preceding 37 years.

Australia

Australia is a country in the southern hemisphere that is composed of the mainland of the world's smallest continent, the island of Tasmania, and numerous other islands in the Indian and Pacific Oceans. ,In contrast to Bangladesh, Australia is a relatively prosperous and sparsely-populated country that is technologically advanced, industrialised and multicultural. Unlike Bangladesh, Australia scores highly on many comparative international indices of national performance, such as in the fields of health care, human development, life expectancy, public education and quality of life. Its population of some 22 million people is concentrated along the east and southeast coasts, and the country has an extremely diverse geography ranging from the snow-capped mountains of the Australian Alps and Tasmania to large deserts (covering some 40 per cent of the land mass) and tropical and temperate forests. Only the southeast and southwest corners have a temperate climate and moderately fertile soil; the northern part of the country has a tropical climate: part rainforest, part grassland, part desert.

Natural hazards and disaster risks include cyclones along the northern coast, severe thunderstorms, droughts and floods, and frequent bushfires, such as those that killed 173 people in 2009 (Victoria Police, 2009). Cyclones occur regularly in Australia, and include, most notably, the Koomana Tropical Cyclone of 1912, the Gold Coast Cyclone of 1954, and Cyclone Tracey of 1974. The worst ever cyclone-related disaster in Australia's history happened in March 1899, when more than 300 people were killed in what became known as the Bathurst Bay Hurricane.

Cyclone Larry

Although it was not accompanied by any fatalities, Cyclone Larry has been selected for comparison here as it occurred within 20 months of Cyclone Sidr, thus allowing a reflection

on ‘the state of the art’ in cyclone preparation and response in Australia and Bangladesh. In addition, and notwithstanding the zero death toll, it sparked Australia’s biggest relief, recovery and reconstruction effort (The State of Queensland, 2006).

Cyclone Larry began as a low-pressure system over the eastern Coral Sea and was registered by the Australian Bureau of Meteorology on 16 March 2006 (BOM, 2007). It developed into a tropical cyclone during the early hours of 18 March, and proceeded on a westerly course towards the Queensland coast before being upgraded to a severe Category 3 cyclone later that day. The cyclone made landfall on 20 March at 04:45 as a Category 5 severe tropical storm, with winds of more than 260 kilometres per hour (160 miles per hour) (ABC, 2006). The storm tore through Innisfail, a town of some 8,000 people located about 1,700 kilometres (1,050 miles) north of Brisbane, and then travelled almost 450 kilometres (280 miles) inland before being downgraded to a rain depression. Fortunately the high winds and associated rain were not accompanied by the anticipated tide and storm surges, and remarkably no lives were lost (ABC, 2006).

The area hit by Cyclone Larry is tropical, and subject to wet and humid weather (Turton, 2008). Annual precipitation generally is high and stable, and there is a cyclical cyclone season with heavy rainfall followed by short periods of low rainfall (BOM, 2007). It is the combination of heavy rainfall, storm and tide surges, floods and wind events that tends to cause particular difficulty in this economically important and relatively highly populated geographical area. Thus, although no lives were lost, the area between Babinda and Tully suffered extensive damage to infrastructure and crops, estimated at in excess of AUD 1 billion in total. To a lesser extent, damage occurred also in areas as far north as Cairns and as far south as Cardwell, as well as on the Atherton tablelands (BOM, 2007). Furthermore, more than 140,000 people lost their electricity supply, while the Government of Australia estimated that more than 25,000 people were directly affected by the cyclone (that is, lost or damaged homes and/or farms and personal property). Dozens of towns and villages that rely on business and income generated by tourism and the tropical fruit plantations (avocado, banana and sugar cane farms, for example) were wiped out, with attendant consequences for the regional economy (ABC, 2006). In addition, recent estimates indicate that the cyclone completely destroyed or damaged more than 16,000 houses as well as farms, hospitals, schools, water supply systems and basic sanitary infrastructure.

A DLOD analysis of Bangladeshi and Australian cyclone preparedness and mitigation

This section begins by highlighting a number of examples from the framework elements of doctrine, information, training, organisation and infrastructure because these provide key areas for learning. These particular examples were selected to demonstrate the integration of the DLODs, with examples taken from relevant literature and internet sources. Further work to verify the accuracy of these sources would be valuable, of course, although it is argued that the use of the DLOD framework itself is not compromised by the absence of such triangulation.

Defence Lines of Development–doctrine

Doctrine is defined as the 'fundamental principles by which military forces guide their actions in support of objectives' (MOD, 2008, p. iii) and it provides the UK armed forces with an overall framework of guidance for the conduct of operations. Importantly, the latest (2008) edition of the *British Defence Doctrine* specifically reflects recent operational experience through the incorporation of a section that underlines the importance of cross-government and inter-agency cooperation, the so-called comprehensive approach (MOD, 2008).

A similar overarching framework for the strategic guidance of disaster management activities (for instance, preparedness and risk analysis, planning, mitigation and response) has been developed in both Australia and Bangladesh. That said, Bangladesh's Comprehensive Disaster Management Programme (CDMP) has existed only since the turn of the twenty-first century, and been in place formally since 2006 (UNDP, 2008). More than simply a disaster management plan, the CMDP seeks to develop a holistic strategy for reducing the long-term vulnerability of the country to the effects of natural, environmental and human-induced hazards. Within this strategy, or 'doctrine', a key objective is to strengthen the capacity of the national disaster management system to reduce unacceptable risks, and to enhance response and recovery activities (UNDP, 2004). As a part of this 'doctrine', the CDMP addressed the integration of relevant national, international and non-governmental agencies into pre-disaster risk assessment, analysis and management activities, and it focuses more on the involvement of the population as a whole in disaster preparedness activities. In practice, Cyclone Sidr provided a valuable operational test of the CDMP and there is consensus (as seen in a diverse range of post-disaster analyses) that the CDMP provided a robust and high-level guidance model and document. That said, there was some criticism of poor coordination between local

and international relief NGOs, as well as between some government agencies (Tod et al., 2008).

In the case of Australia, a similar high-level plan or 'doctrine' exists in each of the country's eight states and territories; however, in relation to disaster planning and response, each state has a high degree of autonomy. In Queensland, where Cyclone Larry struck, the disaster management system is incorporated in the State Counter Disaster Plan (SCDP), which is an overarching 'doctrinal' framework developed for strategic guidance of disaster management activities. Similar to Bangladesh's CDMP, the SCDP aims to ensure the coordination of capabilities at all levels of government through a multi-tiered system of committees and coordination centres at the state, (disaster) district and local level (State Disaster Management Group, 2009).

The SCDP was activated 72 hours before the cyclone made landfall through the formal declaration of a state of emergency by the then Queensland state premier (BOM, 2007). This declaration had four key implications for the response:

1. State and federal disaster rescue funding was made immediately accessible, even before the cyclone made landfall—through the Commonwealth/State Natural Disaster Relief Arrangements (NDRA). The NDRA is designed to reduce the excessive financial burden associated with the provision of natural disaster relief and infrastructure restoration by the states, and it allows for prompt action in procuring and mobilising necessary resources such as relief goods and (military) personnel, and in moving them to disaster sites.
2. The Commonwealth Counter Disaster Task Force and the many Australian Commonwealth government agencies and their considerable financial, human and operational resources also were activated immediately to support state, territory and local measures to facilitate the short-, medium- and longer-term recovery of the communities affected by Cyclone Larry. This included the restoration of public assets (such as roads) and the movement of personnel from other cities and states to the disaster sites in Queensland before the cyclone made landfall.
3. It enabled the state premier to launch an appeal seeking private and corporate donor funding and assistance to meet relief and recovery requirements even before the cyclone made landfall.

4. It empowered the police to move those who would not leave their homes and harm's way and move to a safer place or to place them in some form of protective custody (ABC, 2006).

In terms of wider learning from Cyclones Sidr and Larry, it is clear that the general approach adopted by both governments with regard to the development and publication of the high-level doctrine and associated plans have been valuable in helping to ensure commonality of approach across each country, and in incorporating the contributions of myriad national and international agencies. Inevitably, the actual model adopted will reflect the governmental structures of the country, but it is clear too that, in the case of a poor and populous developing nation such as Bangladesh, translating high-level doctrine into effective action on the ground is a challenge—notwithstanding the relatively frequent natural disasters that beset it. In both cases, therefore, it is important to have a clear understanding across government and supporting agencies (such as NGOs) of the high-level approach to be adopted as well as the results of more detailed planning. It is also clear that action must be taken to ensure that the population as a whole understands the part that it must play in this overall response. For this reason, the information DLOD can be seen as particularly important.

Defence Lines of Development—Information

'Information' represents a broad range of collection, analysis and dissemination activities, such as early-warning communications and cyclone tracking via satellite. For example, indications of the serious nature of a cyclone are now, typically, available some 72 hours in advance of landfall. This is the result of improvements in aerial (satellite) surveillance and computer modelling, and it has had a major positive impact on mortality rates. Indeed, it is a far cry from the situation reported by Frank and Husain (1971) in which the estimates of the location and strength of Cyclone Bhola were based on a combination of reports from shipping, coastal-based radar systems and manned aircraft.

However, as demonstrated by Regnier (2008), the accuracy of the location and strength of the wind when making landfall is low (often no more than 10 per cent) at the 72-hour point—even in the United States where considerable research has been performed. This presents authorities in any country affected by such severe wind events with a key challenge: should they or should they not trigger a full-scale evacuation and accept the financial and social consequences, including 'warning fatigue' in the event of a false alarm? Such a decision will

be affected of course by the cost and timeline of such an evacuation. While no comparative figures for either Australia or Bangladesh have been identified, it is estimated that it costs USD 1 million per mile for an evacuation of the US coastline, whereas the cost of a false alarm is of the order of USD 1 billion per event (Regnier, 2008).

To be successful, early-warning systems must integrate successfully managerial, scientific, social and technological components across the whole communications system (King and Gourdie, 2007; Collins and Kapacu, 2008). As part of their response to this challenge, the Government of Bangladesh has developed a series of Disaster Management Information Centres at the national and district level (GOB, 2008b). These aim to provide an overview of the capabilities of various institutions (such as national and international relief NGOs), early-warning information products and dissemination media, collaborative tools, and a database of inventories of primary relief materials (such as drugs, food, shelter and water) (GOB, 2008b). However, key to the overall effectiveness of the response to Cyclone Sidr was Bangladesh's Cyclone Preparedness Programme (CPP), which includes a warning system based on a scale of 1 ('low') to 10 ('great danger'). Once the threat reached level 4, some 44,000 volunteers managed by the Bangladesh Red Crescent Society were activated. Working in small teams, they were able to get to the outlying areas typically using bicycles for transport, and loud hailers and flags to transmit their warning. As a result of these endeavours, around 40 per cent of the population living in the predicted path of the cyclone (some three million people) were evacuated in the 36 hours immediately preceding its landfall, and of these, some 1.5 million were accommodated in cyclone shelters (GOB, 2007). In addition, the CPP volunteers were able to employ to good effect many of their skills in basic rescue techniques, first aid, post-cyclone security, destruction damage assessment, and physical distribution of relief matériel (Khan, 2008).

However, as discussed below in the subsection on the DLOD of training and education, having a good plan that is understood by the government and associated agencies is one thing, but equally important is the need to ensure that the population as a whole is aware of the part that it must play. How, for example, should it respond to the warning signals? This has been achieved in part through dissemination of information to local community leaders, as well as by the creation of a number of rural knowledge centres. Although these aim primarily to provide access to computers, telephones and other office facilities, they are used also as a

mechanism to publicise actions to be taken in the event of a cyclone, by means of poster displays and explanations by staff (BNNRC, 2008).

Effective information (warning) dissemination is a complex issue that ultimately requires a degree of judgement, especially for an event that may occur only once in a generation. Nevertheless, learning from the experience of Cyclone Sidr, the Government of Bangladesh has proposed a more rigorous approach that includes: set times for the distribution of warning information, together with an assessment of the effectiveness of the existing system particularly in respect of the outlying islands (*chars*); improved information media (such as impact maps) that will help to overcome concerns that the current system is not understood by all of society; and linkage between outcomes and risks (GOB, 2008b).

As regards Australia, its meteorological system (utilising automatic weather stations (AWS) and images from MTSAT-1R satellite obtained courtesy of the Japan Meteorological Agency) also was able to provide a 72-hour warning of the arrival of Cyclone Larry. This was complemented by a system of standard emergency warning signals (SEWS) used in assisting the delivery of public warnings and messages concerning major emergency events. SEWS are an alert signal to be played on public media to draw listeners' attention to a subsequent emergency warning. Thus, in the case of Queensland, SEWS comprise a wailing siren that informs the population that an official announcement is about to be made on radio/television (BOM, 2007; State Disaster Management Group, 2009). Importantly, prior cyclone preparedness and awareness campaigns, as well as education of the communities, had ensured that the population as a whole had an understanding of what SEWS meant, and this was complemented by radio and television broadcasts that informed the population through hour-by-hour updates on the progress and intensity of the cyclone. The combination of these information dissemination strategies ensured a sufficiently high level of preparedness and awareness among the local populace to enable it to decide whether to bunker down or self-evacuate.

Disaster coordination centres were activated in Cairns and Townsville, while the state government also deployed emergency response teams from Brisbane, Melbourne and Sydney. Overall, the effectiveness of the Australian Bureau of Meteorology's warning service was highly rated in post-Larry community surveys (BOM, 2007). For example, even before the cyclone had made landfall, resources such as the Australian Defence Force (ADF) and other

emergency actors such as the ambulance, police and search-and-rescue service were on standby, ready to go. Likewise, the level of coordination and communication at the highest levels of government even before the cyclone struck contributed in no small measure to the effectiveness of the relief response and recovery effort (Cyclone Summit, 2006). Hence, in terms of preparedness processes, it would appear that Williams, Coles and Primavera (2007) are accurate in their assessment that specific disaster management plans were in place that met the specific requirements and specific demographics of the populace.

In summary, it can be seen that both the Government of Australia and the Government of Bangladesh adopted a similar strategy of employing high-technology information feeds such as satellite imagery and lower level methods of disseminating this information to the population in danger. Importantly, both countries made strenuous efforts to ensure that the implications of the warnings and the consequential actions required by the population were understood in advance of the disaster, although the specific modalities were tailored to the needs of the population in question. Thus, Bangladesh utilised low-tech CPP volunteers on bicycles and on foot, whereas Australia was able to use high-tech radio/television and internet as the dissemination medium. The key point, though, is that the nature of cyclones is such that, although they are classified as ‘rapid-onset’ events, there is now sufficient warning time to enable those who are likely to be affected to evacuate the area or to enter shelters. This has led both to a marked reduction in the loss of life and the concentration of the population in well-defined locations, which, in turn, eases post-disaster logistic issues such as the distribution of food, medicine and water.

From an academic perspective, however, there is a vast difference in what can be achieved during the timeline associated with the warning period for such cyclones when compared with, say, the extremely short equivalent for an earthquake, which is typically no more than tens of seconds (Wu and Kanmori, 2008). Although this latter period does have some benefit, such as enabling pre-programmed automatic responses, including, in the case of Japan, the slowing down of high-speed trains or the stopping of production lines (JMA, 2007), there is clearly only so much that can be achieved in such a brief period. As discussed by Tatham (2009), this raises the question as to whether the current model in which disasters are distinguished as ‘rapid-onset’ or ‘slow-onset’ (see, for example, van Wassenhove, 2006) is sufficient granularity, especially for the disaster response planner.

Defence Lines of Development–training and education/community preparedness

In the DLOD model, suitably tailored training and education is necessary for successful implementation of the doctrine. In the military context, as part of the procurement of a new weapons system, personnel must be trained to maintain and operate it in an appropriate manner. Extending this logic to the disaster context, training and education is closed linked to the effective operation of the system at all levels. Thus, for the overall doctrine to be effective, it must embrace meteorological specialists and forecasters, modellers, satellite technicians, bureaucrats and technocrats in disaster agencies, CPP volunteers on bicycles and on foot, and members of the public at large, as they all have to know what to do in order to play their part in the overall programme. Even more important is recognition that, if the doctrine is to change, as a result of improved technology, for example, then there is a concomitant cost associated with delivering the resultant re-training and re-education. This issue is more complicated in countries such as Bangladesh where the poorer, uneducated segments of society are most difficult to reach in a physical, informational/communicational, and educational sense (Khan, 2008). Ironically, it is these people who are most in danger—not least as frequently they inhabit the areas of land that are most at risk. Unsurprisingly, therefore, after each of the major cyclones, there have been calls for improved investment in education and in helping to raise the awareness of these people (Frank and Husain, 1971; Bern et al., 1993; GOB, 2008b).

The Government of Bangladesh has approached the issue of training and education from a number of dimensions:

1. At a higher level, through a proposal to establish a Disaster Management Institute to act as a focus for research and education within the field. Such a venture would mirror similar centres in India, Indonesia and Sri Lanka.
2. The provision of disaster management education within 61 focal points, including 28 government agencies, ministries and academic institutions, with the objective of mainstreaming the subject of disaster preparedness and early warning together with its broader links to climate change and sustainability.
3. A programme of training for more than 25,000 local disaster management committee members, who are, in turn, supporting more than 70 million members of the population, as well as activities to train the core trainers (Rector, 2008; UNOPS, 2008).

Given the higher levels of literacy and the relative ease of communication in Australia, the country has not had to expend the same level of effort on basic cyclone education programmes. Consequently, it has been possible to use resources to engage in the pre-identification and categorisation (segmentation) of key beneficiary groups, with subsequent tailored evacuation and disaster relief plans for categories such as the boating and fishing community, diabetics, farmers and plantation owners, older persons, pets, pregnant women, the sick/ill (embracing the supply of kidney dialysis machines for patients and insulin for diabetics), and tourists (such as Japanese tourists who speak relatively little English but visit north Queensland frequently) (Williams, Coles and Primavera, 2007).

Pre-identification and categorisation also was carried out in relation to the infrastructure restoration requirements, such as the repair of roads and schools and the restitution of communications, electricity, sanitation and water services. These were accorded priority in the sequencing of the emergency relief response as they had a great bearing on whether or not the relief was *perceived* to be effective and successful. For instance, if beneficiaries have been rescued and are safe, and have received food, medicine and water, but there is no electricity, no telephone or basic sanitation, the perception is that the relief has been a failure since these utilities have a direct bearing on the overall view of the effectiveness of the government assistance.[i]

In summary, the degree of education and training needed to achieve successful cyclone planning, preparation and post-disaster relief clearly has been appreciated by both countries. To a large extent, these initiatives have been shown to be successful in the tests that followed Cyclones Sidr and Larry. In particular, the Government of Bangladesh and its national and international partners have developed a comprehensive programme that aims to ensure that individuals have the knowledge to prepare for and respond to a major threat such as a cyclone, although it is clear that it will be necessary to maintain this emphasis on education and training for the foreseeable future. It is important to note too that Bangladesh is working to emulate the Australian model of pre-identification of particular vulnerable groups and, as discussed under the infrastructure DLOD subsection, is looking to improve the cyclone shelter arrangements to enable the separation of males and females—an important consideration in a strict Muslim country—and to provide facilities for disabled people and for livestock, which is of major economic importance to the population,

In parallel, and unsurprisingly due to the country's vulnerability, the Government of Bangladesh is actively pursuing the Hyogo Framework for Action 2005–2015 and, in this regard, is being supported by a number of agencies including the United Nations Office for Project Services (UNOPS), part of the United Nations Development Programme (UNDP), the UK charity Islamic Relief, and the European Union (EU). In an interim progress report (GOB, 2008c), the need to shift from disaster relief to disaster risk reduction is stressed, as is the need to 'roll out [a] recently simplified cyclone signal system and initiate a public awareness campaign on the use of disaster messages outlining likely cyclone impacts and a message on preparedness' (GOB, 2008c, p. 4). As part of this drive to achieve a better understanding of the implications of a cyclone and the associated preparedness activities, the Government of Bangladesh is concentrating specifically on the use of improved community alerting systems.

Defence Lines of Development—organisation, coordination and relationships

As in a military context, the structure of a country's disaster management organisation is critical to its effectiveness. This affects issues such as lines of authority and roles and reporting responsibilities, and any changes that are required to these as one migrates from the disaster preparation phase to the response and rehabilitation phases will have an impact on other key variables and components. For example, Kapucu (2008, p. 248) argues that 'successful participation in . . . pre-disaster, consensus-building planning processes can lead to strengthened organisational relationships and thus improve post-disaster action'. By the same token, he suggests that public officials must establish relationships before a disaster strikes to build the trust and rapport that is so vital for effective coordination in an emergency. The organisational structure that is adopted must take into account, therefore, many variables in an holistic fashion, including (horizontal) relationships with other agencies of state, national and international NGOs, the military and others with non-disaster related structures. Consequently, the model adopted by each country inevitably will be unique to that nation and its peculiarities. Nevertheless, the key is to develop an organisation that embraces all of the key stakeholders, including the population as a whole.

In the case of Cyclone Larry, there is a general consensus that the level of communication and coordination, partnering and trust prior to and following the event was unprecedented in the disaster response history of Australia. The teamwork and spirit of unity (across both individuals and organisations) contributed in no small measure to the effectiveness of the

relief response and recovery effort (McEntire, 2002; Stephenson, 2005; Oloruntoba, 2009b). There was a tripartite partnership of government and its agencies (such as the ADF, disaster response, infrastructure, police, public health and transport), the private sector (such as the banks, the construction industry, the insurance industry and the Qantas airline), and the charity and NGO sector (such as the Red Cross, the Rotary and Lions Clubs and the Salvation Army). At least in part, this three-way collaborative approach worked well because the partners were very familiar with each other, and had responded successfully to various disasters over the 12 years that the then government had been in power.

However, it would seem that, from the perspective of the public at large, Australian leaders 'made sense' of the crisis and were, in particular, able to recognise prior community vulnerabilities through specialist advice (Boin et al., 2007). By means of a team approach with clear inter-organisational collaboration and coordination, officials made key choices and decisions at crucial times about what to do and how to do it. For example, the Operation Larry Assist taskforce, composed of elements of the ADF (air force, army and navy), undertook day-to-day operational relief distribution for three weeks, whereas the Operation Recovery taskforce (composed of broader public, private and charitable agencies) undertook longer-term recovery, rehabilitation and rebuilding activities (such as cleaning up, extension of loans and grants, psycho-social counselling and restoration of livelihoods). These programmes were planned, designed and instituted as soon as it became clear that Cyclone Larry would strike somewhere along the coast of Queensland.

There is broad agreement that the pre- and post-Cyclone Larry organisational construct was highly effective, and it is to be hoped that it was not simply driven by the personalities of those involved—rather, that it represented an appropriate approach that integrated all of the relevant stakeholders (Grigg and King, 2006; Oloruntoba, 2009a). In this respect it was in stark contrast to the response of the US authorities after Hurricane Katrina in 2005, which was largely uncoordinated and suboptimal, as well as to the emerging stories of chaos and confusion following the earthquake in Haiti in 2010.

In the case of Bangladesh, given both the population size and the consequential difficulties in developing a robust and efficient organisational model, the current approach of using bicycle units, for example, to disseminate physically warning information in rural areas, appears to have been effective—although, inevitably, there is room for improvement.

Defence Lines of Development—infrastructure for disaster protection

In a military context, the DLOD of 'infrastructure' covers the support provided to a capability through the provision and operation of facilities such as airfields, dockyards and military garrisons. As indicated above, the demands made on such infrastructure must reflect all of the other DLODs, not just that related to equipment. Thus, for instance, is it acceptable from the standpoint of doctrine for such facilities to be contracted out, and if so, what is the impact on, say, the selection and training of military personnel? Increasingly, there is a particularly close relationship between the infrastructure DLOD and that of information as the former must accommodate the means of delivering the latter—that is, access to electronic media and the internet, inter alia.

The experience of major cyclones in 1970 and 1991 led the Government of Bangladesh to engage in a number of important physical infrastructure projects that resulted in the construction of some 300 cyclone shelters to accommodate 350,000 people (Bern et al., 1993; GOB, 2007). Following Cyclone Gorky (1991), the number of shelters was increased to 2,400 by 2006, although a recent survey identified a number of deficiencies (GOB, 2008a). For example, the total number of shelters is insufficient to hold all members of the evacuated population; more than 65 per cent of all shelters have no provision for the special needs of women; few have facilities for people with disabilities; and three-quarters of the shelters surveyed had no provision for the storage of water, four-fifths had no provision for the shelter of valuable livestock, and a large percentage had some kind of structural vulnerability. As a result, the Government of Bangladesh recommended a revision to the 2008 National Disaster Management Plan. Future versions must cater for gender needs and the safety of livestock, as well as protection against all hazards (GOB, 2008a). Nevertheless, the shelters served their purpose during Cyclone Sidr, although the above improvements clearly will be beneficial.

Of equal importance is the construction of more than 7,500 kilometres (4,700 miles) of embankments along riverbanks and across low-lying areas (Khan, 2008). These act as physical barriers to reduce the power of the tidal surge, as well as to protect the surrounding areas from its effects. In addition, they serve as a means of rapid transit between areas, allowing the population to escape or providing access to emergency services. Unfortunately, due to the shortage of suitable land, the embankments have been used, in some cases, for housing and their destruction by the Cyclone Sidr tidal surge was one of the major causes of

loss of life (GOB, 2008a). The problem of destruction of embankments has been reported consistently, and it is clear that, as with shelters, greater emphasis needs to be placed on ongoing maintenance (Miyan, 2005). However, the Government of Bangladesh appreciates this imperative and recognises the need for a further risk-based analysis of both the causes of failure of these embankments as well as integration of the potential hazards associated with climate change into a future (re-)building programme (GOB, 2008b).

Another element of the infrastructure preparedness and mitigation strategy has been the coastal afforestation programme that has been in place since the 1960s (GOB, 2008a; Khan, 2008). The area of the country that Cyclone Sidr struck initially consisted of the world's largest mangrove forest, and this had the key effect of reducing the intensity of the wind and tidal surge before they reached more populated areas. In stark contrast to the reports following the 2004 tsunami in which the clearing of mangrove forests was seen as one of the principal causes of significant loss of life in certain areas, the encouragement by the Government of Bangladesh of such natural defences through the Coastal Zone Policy (CZP) and associated Integrated Coastal Zone Management (ICZM) plan (Miyan, 2005) is to be applauded. However, the effects of Sidr resulted in major destruction of the forest area and it is necessary, therefore, to replant in affected areas given the clear effectiveness of the mangroves in reducing the ramifications of the cyclone.

In the case of Australia, the frequency with which cyclones impact on a particular geographic area, the relatively light population density, and the relatively good transport infrastructure have been construed generally to mean that the construction of fixed cyclone defences or shelters is an inappropriate policy except in the greater Darwin area in the Northern Territory (The State of Queensland, 2006), although there are still some public shelters. This difference in approach represents the classic trade-off that the DLOD approach to the delivery of an overall capability encourages. With regard to Bangladesh, the large population, difficulties in ensuring a timely warning, and poor road communications all militate against a policy of evacuation from the danger area and for the use of fixed infrastructure (such as cyclone shelters and embankments). Australia, by contrast, has elected to adopt an evacuation approach that not only reflects its better road infrastructure, but also the state's ability to ensure that those in danger receive adequate awareness, education and warning. In practice, therefore, the Governments of Australia and of the State of Queensland aim to evacuate all members of the population from high-risk areas if required, although this can present

significant challenges (such as the potential presence of large numbers of foreign tourists who may not be able to understand warnings in English). Furthermore, enforced evacuation only can be carried out by the Queensland police following a formal 'Declaration of a Disaster Situation', although it is acknowledged that some people will refuse to evacuate regardless of the threat (The State of Queensland, 2006).

Defence Lines of Development—personnel, equipment and logistics

While important DLODs in their own right, it is interesting to note that the areas of personnel, equipment and logistics have received relatively little attention in the disaster planning, response and management literature—although this is increasing following such logistically challenging disasters as the Indian Ocean tsunami (2004), the Pakistan earthquake (2005) and Cyclone Nargis in Myanmar (2008). This is particularly true of the logistic response to Cyclone Sidr; the literature contains only brief discussions of the difficulty of achieving access to the affected area due to devastated infrastructure, as well as calls for the stockpiling of appropriate commodities in, or near, cyclone shelters.

The government of the State of Queensland allows both self-evacuation to safer areas away from the target zone or to cyclone shelters, as well as for communities to remain in situ in cyclone-prepared houses. Unlike the case of Cyclone Sidr, therefore, the requirement to provide post-disaster logistics support was a key feature of the response to Cyclone Larry. The nature of the demands in the wake of a disaster challenges supply networks that are optimised to operate generally within relatively routine and fixed demand parameters. However, it was possible to achieve a degree of forecasting accuracy through the use of demographic data such as the distribution of children and women and the number and location of houses; importantly, such data was accessible locally and remotely. This was complemented by good visibility across the length and breadth of the supply network, permitting future capacity issues to be recognised and managed in a timely manner. This represents another example of the appropriate integration of DLODs—in this case by ensuring that the necessary information was available to support the logistics model that had been agreed within the framework of the state government's doctrinal model.

In addition, two ADF units were deployed as direct responders after Cyclone Larry. These organisations are both based in the affected area and are experienced in responding to disasters both at home and abroad. As such, the ADF was able to bring a broad range of

capabilities to bear, including the repair of vital communications, broadcasting and transport infrastructure, as well as the transport of heavy equipment by landing craft, and the provision of key assets such as helicopters and trucks. In addition, trained medical personnel were able to provide a broad range of support activities, including in the fields of environmental and psychological health.

The ADF-led disaster relief activities were complemented by funding and goods-in-kind that poured in from corporate organisations and private individuals, notwithstanding substantial government cash handouts to relief beneficiaries (ABC, 2006). The speed with which funds and goods-in-kind were released by private donors for emergency relief operations was crucial. For example, the national airline (Qantas) made several aeroplanes available and air-freighted relief goods and more than 6,000 hot meals at no charge from Sydney to Cairns and Townsville, the biggest cities in the disaster zone (ABC, 2006). The ability to buy or receive the right materials (funds and goods-in-kind) from key and strategic suppliers (including government and commercial sellers) at the right cost and speed at least in part defines how quickly an emergency relief chain can become operational, as well as underscoring the importance of building and maintaining strong relationships with critical suppliers (Håkansson and Persson, 2004). In this regard, the response to Cyclone Larry clearly provides a good indication of 'best practice' that, potentially, should be adopted more widely.

In summary, the discussion of the personnel, equipment and logistics DLODs has centred on the response to Cyclone Larry because of the availability of relevant literature and because of the nature of the model. Certainly the logistic response in particular appears to have been highly satisfactory, and in line with many academic and theoretical approaches (such as the substitution of information for inventory, the integration of all aspects of the logistic process, and the successful implementation of agreements that had been brokered prior to the disaster). However, it was only sustainable as an approach because of the extent to which it had been integrated into the remaining DLODs.

Conclusions and implications for research and practice

Disaster response organisations and their personnel frequently are caught in the trap of not having time to collect and analyse data that may be useful in preparing for future emergencies (Thomas, 2003). This paper provides practical insights to help disaster managers, logisticians and policymakers prepare more effectively for responding to future cyclones. As such, it is

believed to be a contribution to the generation of a ‘body of knowledge’ in the field, as exemplified by the mission of the Humanitarian Logistics Association: ‘To build a community of practice for advancing the humanitarian logistics profession by promoting cross organizational learning and collaboration’ (HLA, 2009). In doing so, it is suggested that this paper makes three key contributions to such a body of knowledge:

- The first is to underscore the merit in basing research, analysis and learning on an appropriate theoretical and knowledge framework. In this case the UK military CMM and its associated DLODs were justified and selected. The CMM clearly is rooted in the RBV of a firm and, therefore, can be more broadly compared to other cases that are similarly grounded. To demonstrate this point, this study has drawn examples from two relatively effective and successful, yet markedly different, cyclone planning and response scenarios, illustrating how their planning, preparedness, analytical and response activities closely fit into the DLOD framework of the CMM. Since these cases reveal good alignment with the model, this approach has the potential for wider application in disaster analysis, preparedness and response planning and execution.
- Second is its description of how Australia and Bangladesh have developed their disaster preparation and response models by utilising an appropriate mixture of the DLODs. For example, faced with the challenge of a highly-populated country with low levels of literacy, the Government of Bangladesh has emphasised the importance of the communications, training and infrastructure DLODs, and focussed on providing safe havens within the disaster risk zone. By contrast, the relatively good communication links—both physical (that is, transport) and electronic (such as radio and television—available to the Government of Australia has enabled an approach that is based on evacuation of people from areas at risk, but with a concomitant need to develop a sophisticated logistical response.

  In terms of managerial and policy implications, this paper advocates broader use of planning models and frameworks from outside the traditional disaster management area, and it specifically promotes the military CMM/DLOD model because of its demonstrated utility in an environment that reflects similar characteristics. In doing so, it provides a planning tool that cuts through the complex reality of actors and requirements and helps to provide the optimum balance of both capabilities and more detailed planning and responses. By adopting this approach, the

paper highlights an opportunity for cross-sectoral organisational learning, collaboration and knowledge transfer.

- Third, by using the DLOD approach, those engaged in planning for, and responding to, a disaster will be better able to conceptualise the need to balance the components of the required capability according to the particular demands of the hazard and the national environment. The DLOD approach also helps to avoid concentrating on one particular element of the capability; instead it supports an approach that takes into account the implications for all elements.

In terms of further research, disaster response organisations and their personnel often do not have time to collect and analyse data that may be useful for their learning and for preparing for future emergencies as they quickly move on to the next disaster. Hence, this paper has initiated action in this area of research and suggests that the framework be tested on other disaster cases and types—both of a similar nature, such as Hurricane Katrina, as well as those of a different nature, such as a comparison of preparation for and the response to earthquakes in materially different countries such as Haiti, Pakistan or the US. Another valuable endeavour is to look for further examples where crossover thinking between the area of disaster relief and the military (or vice versa) may prove beneficial.

Correspondence

Peter Tatham, Senior Lecturer, Department of International Business and Asian Studies, Griffithi University, Gold Coast Campus, QLD 4222, Australia. Telephone: +61 (0) 7 555 28490; fax: +61 (0) 7 555 29206; e-mail: p.tatham@griffith.edu.au

References

ABC (Australian Broadcasting Corporation) (2006) ‘State of emergency declared in cyclone ravaged area’. http://www.abc.net.au/news/newsitems/200603/s1597062.htm (accessed on 2 June 2006).

Banipal, K. (2006) ‘Strategic approach to disaster management: lessons learned from Hurricane Katrina’. *Disaster Prevention and Management.* 15(2). p. 487.

Barney, J.B. (1991) ‘Firm resources and sustained competitive advantage’. *Journal of Management.* 17(1). pp. 99–120.

Bern, C. et al. (1993) ‘Risk factors for mortality in the Bangladesh cyclone of 1991’. *Bulletin of the World Health Organization.* 71(1). pp. 73–78.

BNNRC (Bangladesh NGOs Network for Radio and Communication) (2008) 'Rural knowledge centres (RKC)'. http://www.bnnrc.net/index.php?module=pagemaster&PAGE_user_op=view_page&PAGE_id=37&MMN_position=29:29 (accessed on 10 December 2008).

Boin, A., P. Hart, E. Stern and B. Sundelius (2007) 'The politics of crisis management: public leadership under pressure'. *Public Administration.* 85(2). pp. 541–568.

BOM (Bureau of Meteorology) (2007) 'Severe tropical cyclone Larry'. http://www.bom.gov.au/weather/qld/cyclone/tc_larry/ (accessed on 26 January 2010).

Bowden, R. (2003) *A River Journey, the Ganges.* Hodder Wayland, London.

CIA (Central Intelligence Agency) (2008) 'The World Factbook'. http://www.cia.gov/library/publications/the-world-factbook/rankorder/2004rank.html (accessed on 26 November 2008).

Collins, M.L. and N. Kapacu (2008) 'Early warning systems and disaster preparedness and response in local government'. *Disaster Prevention and Management.* 17(5). pp. 587–600.

Couldrey, M. and T. Morris (2005) 'UN assesses tsunami response'. *Forced Migration Review.* July. p. 6.

Cottrill, K. (2002) 'Preparing for the worst'. *Traffic World.* 266(40). p. 15.

Cyclone Summit (2006) 'Living with Cyclones – Queensland'. 7–8 December. Cairns, Australia.

Davidson, S.A (1999) 'Where is the battle-line for supply contractors?'. Air Command and Staff College, Air University, Maxwell Air Force Base, Montgomery, AL.

Denning, P.J. (2006) 'Hastily formed networks'. *Communications of the ACM.* 49(44). p. 16.

Derthick, M. (2007) 'Where federalism didn't fail'. *Public Administration Review.* Supplement to vol. 67. pp. 36–47.

Dumond, J. et al. (2001) *Velocity Management: The Business Paradigm that has Transformed U.S. Army Logistics.* Rand Corporation, Santa Monica, CA.

DuPont, A. and G. Pearman (2006) *Heating up the Planet: Climate Change and Security.* Lowy Institute for International Policy, Double Bay, New South Wales.

Dyson, M.E. (2006) *Come Hell or High Water: Hurricane Katrina and the Color of Disaster.* Perseus Books Group, New York, NY.

EM-DAT (The International Disaster Database) (2005) 'Database'. http://www.emdat.be/search-details-disaster-list (accessed on 25 January 2010).

EM-DAT (2008a) ‘Database’. http://www.emdat.be/ExplanatoryNotes/explanotes.html (accessed on 25 November 2008).

EM-DAT (2008b) *Annual Disaster Statistical Review 2007.* http://reliefweb.int/node/23680 (accessed on 29 May 2011).

EM-DAT (2010) *Annual Disaster Statistical Review 2010.* http://www.cred.be/sites/default/files/ADSR_2010.pdf (accessed on 28 May 2011).

Frank, N.L. and S.A. Husain (1971) ‘The deadliest tropical cyclone in history?’. *Bulletin of the American Meteorological Society.* 52(6). pp. 438–444.

GOB (Government of Bangladesh) (2007) *Emergency Response and Action Plans – Interim Report.* http://www.cdmp.org.bd/cdmp_old/reports/Revised-Sidr-Report-Final.pdf (accessed on 29 May 2011).

GOB (2008a) *Cyclone Sidr in Bangladesh: Damage, Loss and Needs Assessment for Disaster Recovery and Reconstruction.* http://gfdrr.org/docs/AssessmentReport_Cyclone%20Sidr_Bangladesh_2008.pdf (accessed on 10 December 2008).

GOB (2008b) *Super Cyclone Sidr 2007: Impacts and Strategies for Interventions.* http://www.cdmp.org.bd/cdmp_old/reports/Draft-Sidr-Report.pdf (accessed on 29 May 2011).

GOB (2008c) *Bangladesh: Interim National Progress Report on the Implementation of the Hyogo Framework for Action.* Report of the Secretary, Disaster Management Bureau, Ministry of Food and Disaster Management. http://www.preventionweb.net/files/7485_Bangladesh.pdf (accessed on 30 November 2009).

Grant, R.M. (1991) ‘The resource-based theory of competitive advantage: implications for strategy formulation’. *California Management Review.* 33(3). pp. 114–l35.

Grigg, T. and D. King (2006) *Disasters: Vulnerability, Mitigation and Planning. Secondary Data Project: Factors Affecting Preparedness for Cyclone Larry.* http://www.jcu.edu.au/cds/public/groups/everyone/documents/technical_report/jcutst_056209.pdf (accessed on 2 October 2009).

Håkkansson, H. and G. Persson (2004) ‘Supply chain management: the logic of supply chains and networks’. *International Journal of Logistics Management.* 15(1). pp. 11–30.

Helfat, C.E. and M.A. Peteraf (2003) ‘The dynamic resource-based view: capability lifecycles’. *Strategic Management Journal.* 24(10). pp. 997–1010.

HLA (Humanitarian Logistics Association) (2009) ‘Mission’. http://www.humanitarianlogistics.org/about-hla/what-is-hla/mission (accessed on 25 May 2009).

IBLF (International Business Leaders Forum) (2005) *Best Intentions, Complex Realities: Business and Lessons from the Tsunami.* http://www.dec.org.uk/download/14/BestIntentions.pdf (accessed on 26 November 2008).

JMA (Japanese Meteorological Agency) (2007) ‘Earthquake early warnings’. http://www.jma.go.jp/jma/en/Activities/eew.html (accessed on 10 March 2009).

Kapucu, N. (2008) ‘Collaborative emergency management: better community organising, better public preparedness and response’. *Disasters.* 32(2). pp. 239–262.

Khan, M.S.A. (2008) ‘Disaster preparedness for sustainable development in Bangladesh’. *Disaster Prevention and Management.* 17(5). pp. 662–671.

King, D. and D. Gourdie (2007) *Cyclone Larry March 2006: Post Disaster Residents Survey.* Centre for Disaster Studies, James Cook University, Townsville, Queensland. http://www.jcu.edu.au/cds/public/groups/everyone/documents/technical_report/jcutst_056193.pdf (accessed on 29May 2011).

Kovács, G. and K.M. Spens (2007) ‘Humanitarian logistics in disaster relief operations’. *International Journal of Physical Distribution and Logistics Management.* 36(2). pp. 99–114.

Kovács, G. and P.H. Tatham (2009) ‘Responding to disruptions in the supply network – from dormant to action’. *Journal of Business Logistics.* 30(2). pp. 215–229.

Lee, H.W. and M. Zbinden (2003) ‘Marrying logistics and technology for effective relief’. *Forced Migration Review.* 18. pp. 34–35.

Long, D. (1997) ‘Logistics for disaster relief: engineering on the run’. *IIE Solutions.* 29(6). pp. 26–29.

McEntire, D.A. (1999) ‘Issues in disaster relief: progress, perpetual problems and prospective solutions’. *Disaster Prevention and Management.* 8(5). pp. 351–361.

McEntire, D.A. (2002) ‘Coordinating multi-organisational responses to disaster: lessons from the March 28, 2000 Forth Worth tornado’. *Disaster Prevention and Management.* 11(5). pp. 369–379.

McLachlin, R., P.D. Larson and A. Khan (2009) ‘Not-for-profit supply chains in interrupted environments: the case of a faith-based humanitarian relief organization’. *Management Research News.* 32(11). pp. 1050–1064.

Miyan, M.A. (2005) *Cyclone Disaster Mitigation in Bangladesh.* http://www.fao.org/forestry/11285-03611be0ad43d80eefb3de4a8ee2e1fd0.pdf (accessed on 29 May 2011).

MOD (Ministry of Defence) (2008) *British Defence Doctrine: Joint Doctrine Publication 0-01.* Third edition. August. http://www.mod.uk/NR/rdonlyres/CE5E85F2-DEEB-4694-B8DE-4148A4AEDF91/0/20100114jdp0_01_bddUDCDCIMAPPS.pdf (accessed on 29 May 2011).

MOD (2011) 'What is Through Life Capability Management?' http://www.aof.mod.uk/aofcontent/tactical/tlcm/content/intro/capabilitymanagement_whatis.htm (accessed on 28 May 2011).

NAO (National Audit Office) (2002) *Building an Air Manoeuvre Capability: The Introduction of the Apache Helicopter.* Report by the Comptroller and Auditor General. HC 1246 2001–2002. http://www.nao.org.uk/publications/0102/the_introduction_of_the_apache.aspx (accessed on 11 February 2009).

NAO (2006) *Delivering Digital Tactical Communications through the Bowman CIP Programme.* Report by the Comptroller and Auditor General. HC 1050 2005–2006. http://www.nao.org.uk/publications/0506/ministry_of_defence_deliverin.aspx (accessed on 22 May 2009).

Oloruntoba, R. (2009a) 'On similarities between relief and supply chains'. In A. Potter, and M. Naim (eds.) *Proceedings of the Logistics Research Network Fourteenth Annual Conference.* Cardiff, Wales, 9–11 September. p. 42.

Oloruntoba, R. (2009b) 'An analysis of the Cyclone Larry emergency relief chain: some key success factors'. *International Journal of Production Economics.* Special issue. 126(1). pp. 85–101.

Oloruntoba, R. and R. Gray (2002) 'Logistics for humanitarian aid: a survey of aid organisations'. In J. Griffiths, F. Hewitt and P. Ireland (eds) *Proceedings of the Logistics Research Network Seventh Annual Conference.* Technology Innovation Centre, Birmingham, United Kingdom, 4–6 September. pp. 217–222.

Oloruntoba, R. and R. Gray (2003) *Humanitarian Aid Organisations and Logistics.* Institute of Logistics and Transport, Corby.

Oloruntoba, R. and R. Gray (2006) 'Humanitarian aid: an agile supply chain?' *Supply Chain Management: An International Journal.* 11(2). pp. 115–120.

Oloruntoba, R. and R. Gray (2009) ‘Customer service in emergency relief chains’. *International Journal of Physical Distribution and Logistics Management.* 39(6). pp. 486–505.

Pagonis, W.G. (1992) *Moving Mountains: Lessons in Leadership and Logistics from the Gulf War.* Harvard Business School Press, Boston, MA.

Payne, D. (1999) ‘Distribution-based logistics’. *Army Logistician.* PB 700-99-1. 31(1). January–February.

Pettit, S.J. and A.K.C. Beresford (2005) ‘Emergency relief logistics: an evaluation of military, non-military and composite response models’. *International Journal of Logistics: Research and Applications.* 8(4). pp. 313–331.

Queensland Government (2006) *Design Guidelines for Queensland Public Cyclone Shelters.* http://www.works.qld.gov.au/downloads/tdd/guideline_public_shelter.pdf (accessed on 30 May 2011).

Rector, I. (2008) ‘Cyclone Sidr Lessons Learnt Workshop’. *Challenging Times – A Newsletter of the [Bangladesh] Comprehensive Disaster Management Programme.* 2 (August).

Regnier, E. (2008) ‘Public evacuation decisions and hurricane track uncertainty’. *Management Science.* 54(1). pp. 16–28.

Reliefweb (2008) ‘More than 4.8 million homeless in Sichuan quake: official’. 16 May. http://www.reliefweb.int/rw/RWB.NSF/db900SID/PANA-7EPG6V?OpenDocument. (accessed on 7 July 2008).

Reliefweb (2010) ‘Haiti: earthquake situation report no. 12’. 24 January. http://www.reliefweb.int/rw/rwb.nsf/db900SID/MYAI-8225AV?OpenDocument&rc=2&emid=EQ-2010-000009-HTI (accessed on 26 January 2010).

Safran, P. (2003) *A Strategic Approach for Disaster and Emergency Assistance.* Contribution to the fifth Asian Disaster Reduction Center International Meeting and the second United Nations International Strategy for Disaster Reduction Asian Meeting, Kobe, Japan, 15–17 January. http://www.adb.org/Documents/Policies/Disaster_Emergency/disaster_emergency.pdf (accessed on 26 January 2010).

Smith, L. (1999) ‘Commercial logistics best practices for the revolution in military logistics’. *Army Logistician.* PB 700-99-1. 31(1). January–February.

State Disaster Management Group (Queensland Government) (2009) ‘About us’. http://www.disaster.qld.gov.au/about/ (accessed on 6 May 2009).

Stephenson, M. (2005) ‘Making humanitarian relief networks more effective: operational coordination, trust and sense making’. *Disasters.* 29(4). pp. 337−350.

Stock, J.R. (1997) ‘Applying theories from other disciplines to logistics’, *International Journal of Physical Distribution & Logistics Management.* 27(9–10). pp. 515–539.

Tatham, P.H. (2009) ‘The logistic implications of rapid and not-so-rapid onset disasters’. In P.H. Tatham (ed.) *Proceedings of the Second Cardiff/Cranfield International Humanitarian Logistic Symposium,* Faringdon, United Kingdom, 24–26 April.

Telford, J. and J. Cosgrave, J. (2007) ‘The international humanitarian system and the 2004 Indian Ocean earthquake and tsunamis’. *Disasters.* 31(1). p. 14.

The State of Queensland (Department of Emergency Services) (2006) *Operational Planning Guidelines for Local Disaster Management Groups.* http://www.disaster.qld.gov.au/publications/pdf/Operational%20Planning%20Guidelines%20for%20Local%20Disaster%20Management%20Groups.pdf (accessed on 15 June 2007).

Thomas, A. (2003) *Humanitarian Logistics: Enabling Disaster Response.* Fritz Institute, San Francisco, CA. http://www.fritzinstitute.org/PDFs/WhitePaper/EnablingDisasterResponse.pdf (accessed on 29 May 2011).

Thomas, A. and L. Fritz (2005) *From Logistics to Supply Chain Management: The Path Forward in the Humanitarian Sector.* Fritz Institute, San Francisco, CA. http://www.fritzinstitute.org/PDFs/WhitePaper/FromLogisticsto.pdf (accessed on 5 December 2008).

Tod, I., S.M. Nurul Alam, N. Wahra, T. Hoque and R. Begum (2008) *Independent Evaluation of CARE-B’s Cyclone Sidr Response Programme.* http://www.google.com.au/url?sa=t&source=web&cd=1&ved=0CBwQFjAA&url=http%3A%2F%2Fwww.careinternational.org.uk%2Fresearch-centre%2Femergency-response%2F31-independent-evaluation-of-care-bangladeshs-cyclone-sidr-response-programme%2Fdownload&rct=j&q=Independent%20Evaluation%20of%20CARE-B%E2%80%99s%20Cyclone%20Sidr%20Response%20Programme.%20&ei=zI3hTYbhO4PCvgO3w6D2Bg&usg=AFQjCNFhiPwDbCL0-H_EMFKHivKPP1huuw&cad=rja (accessed on 19 May 2011).

Turton, S. (2008) ‘Ecological impacts of tropical cyclones on Australian terrestrial ecosystems: insights from Cyclones Larry and Monica’. *Australian Ecology.* 33(4). pp. 365–584.

UNDP (United Nations Development Programme) (2004) *Bangladesh: Support for Disaster Management.* http://www.undp.org/cpr/disred/documents/publications/corporatereport/asia/bangladesh.pdf (accessed on 8 December 2008).

UNDP (2008) *Bangladesh.* http://www.undp.org.bd/library/publications/UNDP%20Bangladesh%202008.pdf (accessed on 8 December 2008).

UNOPS (United Nations Office for Project Services) (2008) ‘Disaster management in Bangladesh’. http://www.unops.org/english/whatwedo/unopsinaction/pages/comprehensivedisastermanagementprogramme.aspx (accessed on 29 May 2011).

USGS (United States Geological Survey) (1995) ‘Significant earthquakes of the World 1995’. http://earthquake.usgs.gov/eqcenter/eqarchives/significant/sig_1995.php (accessed on 11 February 2009).

van Wassenhove, L.N. (2006) ‘Humanitarian aid logistics: supply chain management in high gear’. *Journal of the Operational Research Society.* 57 (May). pp. 475–489.

Victoria Police (2009) ‘Victoria Police bushfire update’. 30 March. http://www.police.vic.gov.au/content.asp?Document_ID=19190 (accessed on 23 May 2009).

Williams, M.J., R. Coles and J.H. Primavera (2007) ‘A lesson from Cyclone Larry: an untold story of the success of good coastal planning’. *Estuarine Coastal and Shelf Science.* 71(3–4). pp. 364–367.

Wu, Y-M. and H. Kanamori (2008) ‘Development of an earthquake early warning systems using real-time strong motion signals’. *Sensors.* 8. pp. 1–9. http://www.mdpi.com/1424-8220/8/1/1/pdf (accessed on 29 May 2011).

[i] Interviews and discussions with senior managers at Emergency Management Queensland, 2007.