Tropical Cyclone Preparedness and Response: Opportunities for Operations Research

by

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Abstract

This thesis explores how operations research methods can be applied in the emergency response community by looking at two recent tropical storm disasters; tropical cyclone Yemyin in Pakistan, June 2007 and super typhoon Durian in the Philippines, Nov 2006. The case studies are used to highlight three common problem areas; determining the scope of the disaster, agency coordination, and relief logistics. The thesis identifies some operational models and applicable research and suggests that these ideas should be formulated as emergency management decision making tools particularly for use in the developing world.

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The views expressed in this thesis are those of the author and do not reflect the official policy or position of the United States Coast Guard, Department of Homeland Security, or The U.S. Government.

Maurice D. Murphy, LT, USCG May 7th, 2008

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List of Abbreviations

CERF:	Central Emergency Response Fund
COE:	Center of Excellence
CRS:	Catholic Relief Services
DCC:	District Coordinating Council
DCO:	District coordinating officer (Pakistan)
DSS:	Decision support system
FAO:	United Nations Food and Agriculture Organization
FEMA:	United States Federal Emergency Management Agency
GIS:	Geographic Information System
IASC:	Inter-Agency Standing Committee (UN)
IFRCRCS:	International Federation of the Red Cross and Red Crescent Societies
INGO:	International non-governmental organization
IOM:	International Agency for Migration
JMA:	Japan Meteorological Agency
JTWC:	Joint Typhoon Warning Center
LDCC:	Local disaster coordinating council (Philippines)
LGO:	Local governmental organization
NDCC:	Philippine National Disaster Coordination Council
NDMA:	Pakistan National Disaster Management Authority
NFI:	Non-food item
NGO:	Non-governmental organization
NHC:	United Stated National Hurricane Center

OCHA: United Nations Office for the Coordination of Humanitarian Affairs

PAGASA: Philippine Atmospheric Geophysical and Astronomical Services Administration

PDMA: Provincial Disaster Management Authority (Pakistan)

PMD: Pakistan Meteorological Department

PNRC: Pakistan National Red Cross

PNRCRCS: Philippine National Red Cross and Red Crescent Societies

PSWS: Philippine public storm warning signal

RDCC: Regional disaster coordinating council (Philippines)

UN: United Nations

UNDP: United Nations Development Program

UNFPA: United Nations Population Fund

UNHCR: The office of the United Nations High Commissioner for Refugees

UNICEF: United Nations Children's Fund

UNRCO: Untied Nations Resident Coordinators Office

WASH: Water sanitation hygiene

WFP: World Food Program

WHO: World Health Organization

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1. Introduction

Recently many parts of the world have seen an increase in the number and severity of tropical cyclones that cause widespread destruction [8, 9]. While this could be part of a natural cyclical trend, many experts feel that human-induced global climate change will result in a continued increase in these disastrous events world wide (See Figure 1-1) [10]. As a result, the need for more efficient preparation for and response to these natural disasters is more important than ever before. While countries such as the United States and Australia, both prone to high numbers of yearly cyclone events, have relatively advanced warning, preparation, and response capabilities, many less developed nations do not enjoy such advantages. As a result, less developed countries bear the brunt of the disastrous consequences, and therefore also have the most to gain from continued research in this field [25].

This thesis looks to operations research methods to improve the efficiency and effectiveness of the relief process by studying two cases of tropical cyclone relief efforts: tropical cyclone Yemyin in Pakistan and super typhoon Durian in the Philippines. In examining the responses to these disasters, this thesis will focus on three aspects of each response that could have been made more efficient not only by tools and practices currently utilized but also by the proposed methodologies in the emergency management literature. These three aspects are the ability of emergency management authorities to estimate a storm's destructive force and the subsequent need for humanitarian relief, both before and after landfall, the coordination practices between responding agencies within the disaster region, and the logistical issues they face during their response efforts. In both case studies, the UN cluster approach was deployed several weeks after the storms struck. This thesis will concentrate on the emergency relief efforts that took place in each country before this more coordinated international approach was deployed.

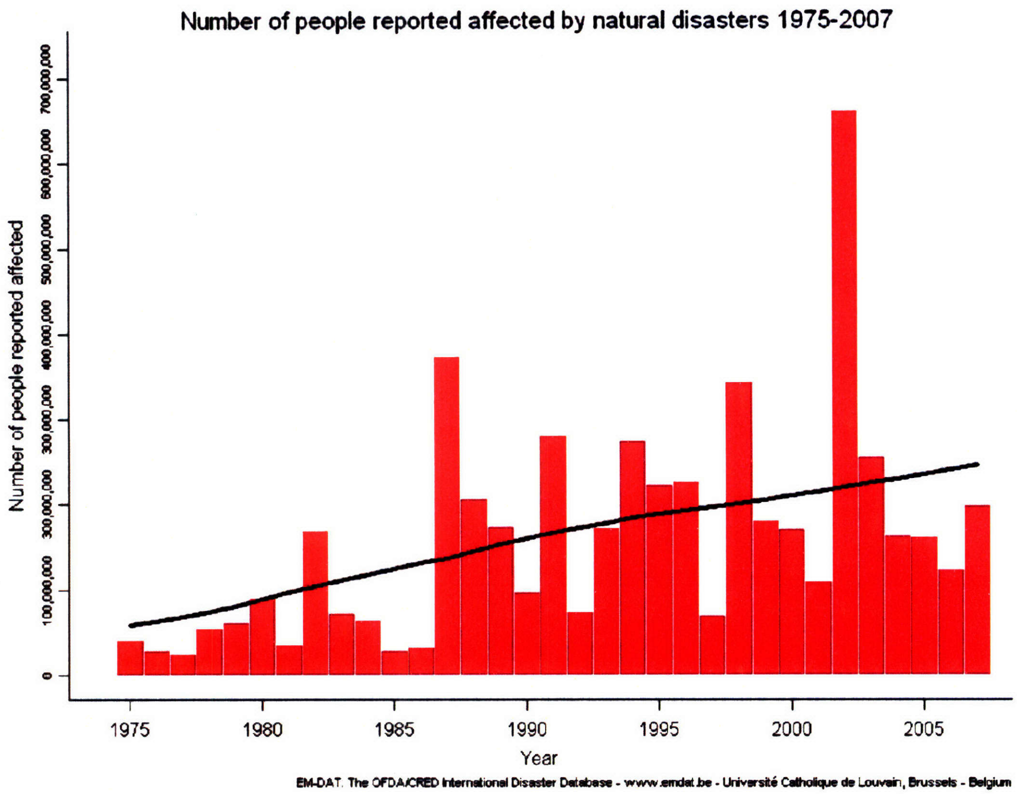

Figure 1-1 Number of People Affected Worldwide by Natural Disasters [67]

2. Literature Review

There is a growing population of literature addressing the humanitarian relief issues examined in this thesis. This section will review some of the applicable literature covering the three areas of concern identified in the introduction.

Much of the recent literature exploring the estimation of disaster damage and scope has called for further use of geographic information systems (GIS). Eveleigh argued that GIS systems can and should be developed to examine the damage sustained to the man-made infrastructural systems in a society [25]. Since GIS can be applied to a wide variety of emergency situations ranging from flooding, to hurricanes, terrorist attacks, and more, Johnson and others (Gunes, Cutter, and Goodchild) have called for GIS systems to be used much more widely in disaster response [36, 35, 14, 33]. Goodchild even argued that GIS technology is essential for an appropriate modern response to large disaster situations [33].

However, there have been relatively few efforts to quantify the accuracy with which emergency management agencies have been able to estimate the scope of natural disasters. One of the most successful implementation of a GIS system has been the HAZUS model in the United States. Thorough examinations into the accuracy of this system are still forthcoming, though one early study indicated that the model's accuracy depends on the scope of the target area [111]. Downton and Pielke argued that these estimates, and especially the cost of damage inflicted, have been historically inaccurate. They supported their claim with an instructive case study of flood losses in California [25]. Oxley has also outlined the difficulties relief agencies have faced in measuring humanitarian need following an emergency. He argued that supplied aid has not always been proportional to actual need and suggested that the relief community should develop a standard humanitarian need measurement capability to combat these discrepancies [70].

The inherent uncertainty of natural disasters, and specifically the behavior of tropical cyclones, has also been explored. Some have attempted to measure this uncertainty for use in better prediction models. Weber and others (Elsberry), for example, have proposed models to track hurricanes based on historical prediction errors [117, 22]. The NHC in fact has implemented a model based on similar arguments [93]. Even more interesting has been the argument by Lindell and Prater that not only are storms uncertain, but so too are the vulnerable populations that they affect [45].

Most encouraging, have been the calls by many to examine the uncertainty in disaster situations from an emergency manager's perspective. Wallace and others (Mansor, Ozdemar, and Larson) have called for these new technologies to be developed into deployable decision support systems for use in the humanitarian relief community [116, 50, 71, 42]. For example, Lindell and Cova have proposed models that assist emergency managers in making evacuation decisions [45, 12]. Lave and Apt argue that rather than focusing on statistics, successful decision support modeling systems will need to focus on providing vulnerable populations with applicable and clearly relevant information [43].

Coordination between relief agencies during disaster relief scenarios has also been a well examined issue. Malone argued that coordination is required to improve efficiency in any situation where many organizations operate in a common arena [49]. Others, including Van Wassenhove, McEntire, and Baber examined the complications of coordinating between agencies specifically in the disaster relief context [113, 51, 4]. Studies by Kahn and Rahman, Stephenson, and Kostoulas have identified the many the problems, including debilitating trust issues relief organizations face in humanitarian relief situations [38, 95, 39].

Whybark argued that there is relatively little literature addressing the logistical and supply chain challenges inherent in large disaster relief scenarios. He suggested that the relief community look to the medical field for good examples of emergency logistics planning [119]. Several recent papers have also discussed the problems facing relief agencies. Larson, Metzger, and Cahn have looked at several case studies and the special logistical considerations that must be handled on scene during a disaster event. These included pre-positioning of supplies, evacuation decisions, allocation of human resources, and communications issues [41]. Several others have proposed specific approaches to make difficult supply chain decisions, including making routing and inventory management more efficient. Van Wassenhove suggested that the relief community should learn from the successes seen in the private sector [113]. Ozdemar has proposed a network flow solution while Barbarosoglu has suggested a stochastic programming framework [71, 6]. Others have drawn attention to the fact that whatever models are developed will need to be robust enough so as to handle the inevitable disruptions to the supply logistics networks inflicted by natural disasters [42, 99].

3. Tropical Cyclone Yemyin

3.1. Overview

Tropical Cyclone Yemyin made landfall on the shores of Pakistan at 1100 am on Tuesday, June 26 2007 [15]. The storm slammed into the Balochistan and Sindh regions of Pakistan with torrential rains, winds over 130 kph, and a storm surge of nearly 25 feet [37] (see Figure 3-1). Yemyin affected an estimated 2.5 million people, in over 6400 villages, displaced 377,000, killed 420, and destroyed over 88,000 houses [120, 66]. Victims found refuge in 119 evacuation centers and in the over 90,000 tents issued by emergency relief agencies [66]. Over 400,000 patients were medically treated and 539,000 people benefited from water trucking and restored water schemes [77, 120]. The provinces of Balochistan and Sindh lost 68 percent and 31 percent of their crop areas respectively [92]. In addition, 30 temporary school shelters were erected while 50 schools were repaired [77]. Scores of national and international agencies, both public and private, contributed in the relief efforts which have combined for over 34.7 million US dollars in contributions [46]. The effects of the resulting disaster are still being felt nine months later in the Balochistan and Sindh regions of Pakistan.

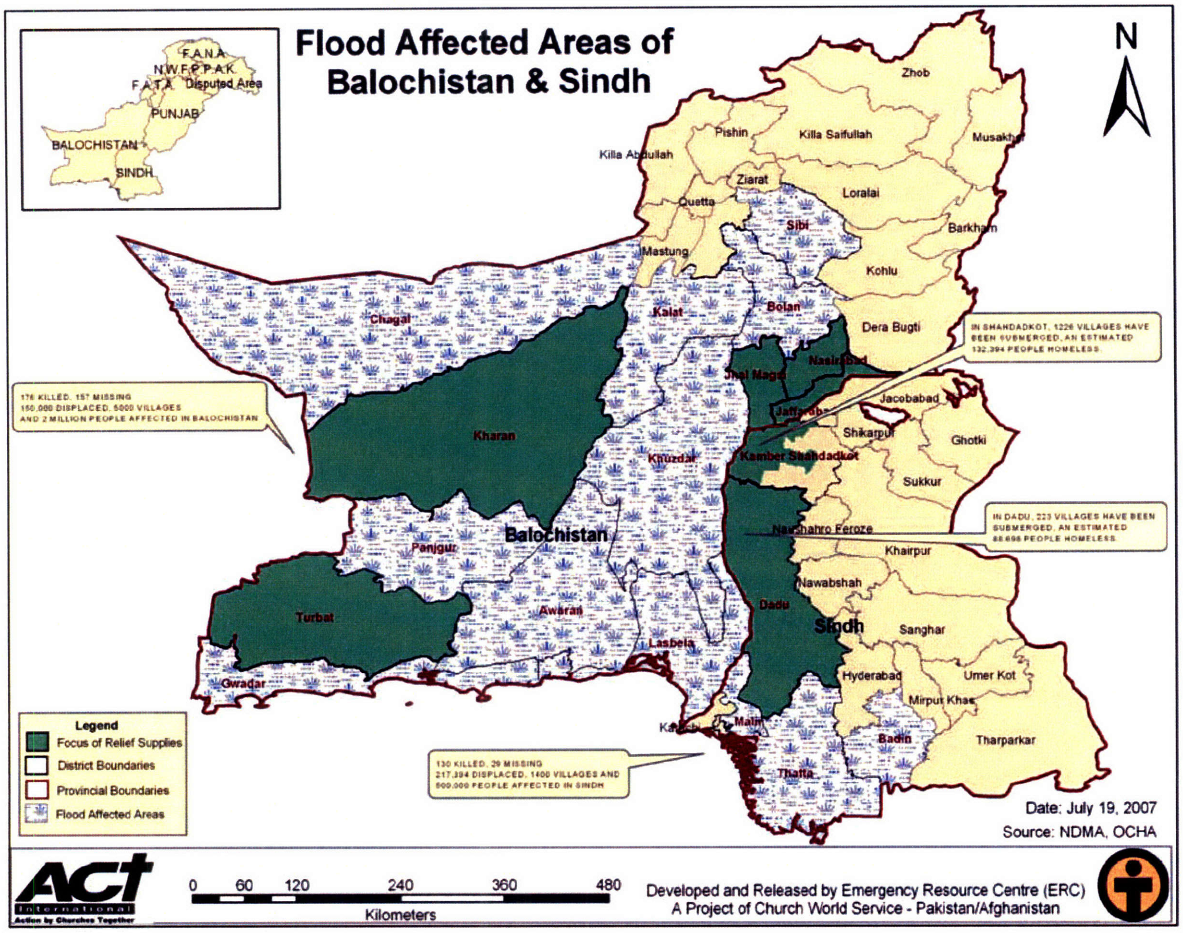

Figure 3-1 Pakistan's Flood Affected Regions [26]

3.1.1. Map of storm track

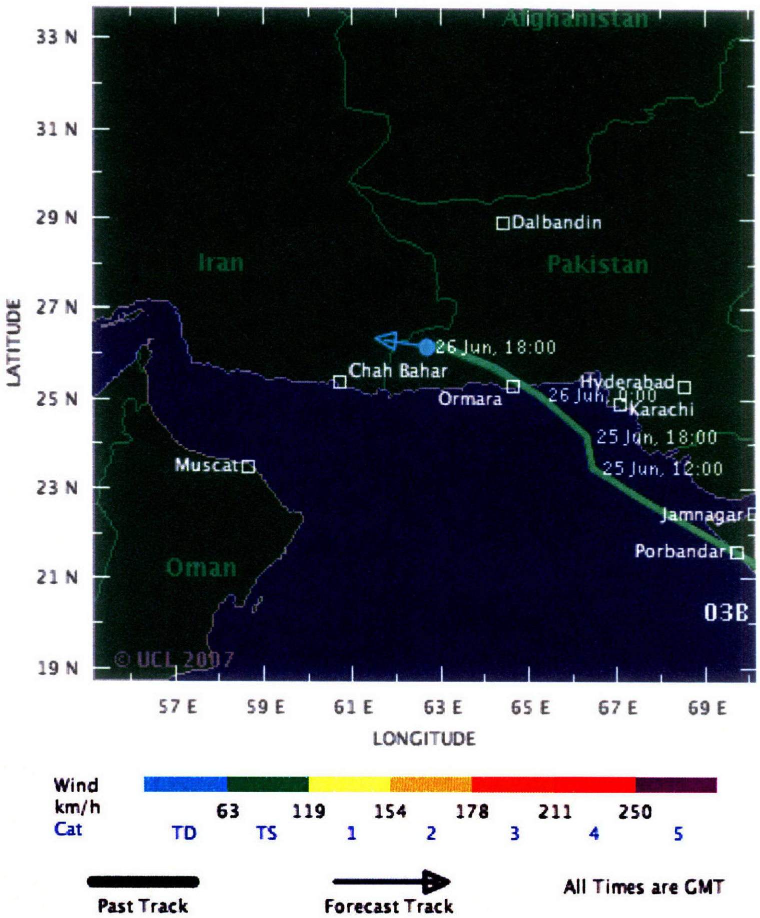

Figure 3-2 Yemyin storm track [108]

3.2. Timeline

Below is a timeline of important emergency relief events during this period.

22 June 2007

- 1300: First weather advisory from Pakistan Meteorological Department issued. Predicts widespread rains with scattered heavy to very heavy rainfall near Karachi, Sindh, and Balochistan. Notes hilly areas may experience flash floods [112].

23 June 2007

- NDMA informs Sindh and Balochistan Provincial Disaster Management Authorities to "stop fishing activities, warn communities to take precautionary measures, and undertake needs assessments based on worst case scenarios" [112].

25 June 2007

- Relief camps for 200 have been established in Gadap City [55].
- DCOs of affected cities have been given funds to mobilize relief efforts [55].
- PDMA Sindh told to plan response including relocation of low lying peoples [55].
- 1130: PDMA Balochistan advised to take preventative measures in flash flood prone regions [55].
- 1130: PMD advised to generate wider media coverage for warnings [55].
- 1130: Director general of emergency relief cell told to earmark 2000 tents and 20,000 blankets for Sindh and deliver when required from warehouse in Karachi [55].
- Sindh government has ordered evacuation of vulnerable coastal villages in Thatta and Badin districts [56].
- Army, Navy, and Karachi Port Trust placed on alert for relief operations [56].
- Rangers identified for relief efforts in Karachi [56].
- 1700: Pak Met Dept advised to consider advising regional offices to give max coverage over radio and TV in regional languages [56].
- 1700: Balochistan government advised to raise alert level and relocate vulnerable communities [56].
- 1800: Storm now a Tropical Cyclone. Expected storm surge along Sindh: 10 – 15 feet. Balochistan: 20 – 25 feet [112].

- 2000: Tropical Cyclone given number and name: 03B, Yemyin [112].
- 2350 : Weather advisory number 4 issued, noting that landfall is expected between Ormara and Gawadar on June 26 around noon. Areas of Ormara, Pasni, Gawadar, and Jiwani in Balochistan are likely to be the worst affected areas. Storm surge of 25-35 ft expected in Balochistan [112].
- NDMA/OCHA inform UNROC of impending cyclone and that situation is under control [120].

June 26, 2007

- 0300: Weather advisory number five is issued. Storm likely to intensify further and cross Balochistan coast in the evening of 26th June. Yemyin is likely to cause widespread destruction and coastal flooding along Balochistan. Evacuation from coastal towns of Balochistan is highly recommended [112].
- 0800: Weather advisory number six is issued, noting likely landfall before noon near Ormara (Balochistan) [112].
- Relief camps now set up along coastal communities close to Karachi [57].
- Reports of evacuations in coastal communities in districts Thatta and Badin [57].
- Army, Navy, and Port Authority on 2 hours alert [57].
- Health camps have been set up [57].
- Sindh government has released Rs 71 million for immediate relief [57].
- Population downstream of Mirani Dam has been evacuated [57].
- District governments urged to evacuate populations vulnerable to flash flooding [57].
- 1100: Yemyin makes landfall in Balochistan province with winds of up to 80 mph (130 kph) [15].

- 1400: Last weather advisory (number seven) issued: Coastal Balochistan expected to receive heavy rainfall, strong gusty winds during next 5 – 6 hours [112].
- 1800: Army, Navy, and Karachi Post Trust assisting with relief ops in Balochistan [57].
- Bridges and roads destroyed in nine districts of Balochistan. Telephone links down to most of affected region [16, 72, 58].
- Most of the 120,000 residents of Gwadar moved to higher ground [16].
- Thousands of people have been evacuated from low-lying areas near Karachi, in Sindh, and Balochistan [29, 78].
- Army has been asked to help evacuate people from coastal areas [29].

27 June 2007

- Khuda Bakhsh Baloch, the relief commissioner of badly-hit Balochistan province estimates 250,000 people homeless [72].
- Pakistani Prime Minister Shaukat Aziz orders the immediate airlift of supplies [72].
- Residents of Kechh, in Balochistan, have seen no sign of aid-bearing helicopters [72].
- In Sindh, more than 30 camps are operating, some people returning home [58].
- Vulnerable population in Kech and Hingol river systems evacuated [58].
- PM announces 200 million dollar relief package [58].
- NDMA reports regional damage in terms of severity: Turbat highest [59].
- Water levels still on rise, dams are near capacity [59].
- Airlifting of supplies commences [59].

29 June 2007

- Two relief camps established in Balochistan, three more scheduled in the next two days [1].

- UNICEF in Balochistan provided 740,000 water purification tablets, 33,600 blankets, 4,000 jerry cans, 12 tents and 50 MT of Unimix, two new emergency health kits, 10 water bladders, 10 water bladders, hygiene supplies and 12 bales of cloth for water filtration [73].

01 July 2007

- Relief commissioner Ali Gul Kurd estimates Hundreds of villages were inundated in at least 10 districts, affecting 1.5 million people, with 90 percent of crops, cattle, and houses destroyed in some areas, 200,000 people homeless [30].

02 July 2007

- Government of Pakistan has not yet requested international assistance [73].
- The IASC Country Team in Pakistan recommends using cluster approach [73].
- UNICEF, WHO, UNHCR, Pakistan Red Crescent Society, IOM, WFP, Plan International, Mercy Corps, Church World Service, and OCHA all have a presence in Pakistan [73].
- Save the Children UK and Church World Service are carrying out assessments [73].
- NDMA reports list of most needy districts [61].
- NDMA indicates that 250,000 people are homeless in Balochistan [61].
- Reports of dam and canal breaches with displaced populations [61].
- Twelve helicopters are being prepared for relief ops [61].
- Three damaged roads have been opened for traffic [61].
- Army troops deployed in vulnerable districts, Army engineers working on roads [61].
- Army medical support in all districts [61].
- NDMA reports that 100,000 displaced persons require shelter in Balochistan [61].

- NMDA reports there are 25,000 displaced people in Sindh [61].
- International humanitarian agencies assessment teams raise concern over threat of water-borne illness [7].
- CRS estimates that 5,000 families in the district of Thatta (in Sindh) are in need of vital emergency support [7].
- CRS identifies the most critical emergency relief items needed are shelter, clean water, food, hygiene kits, and medical supplies [7].
- The provincial relief commissioner in Balochistan estimates that 900,000 people may have been affected by the storms and flooding [27].

03 July 2007

- NDMA reports an urgent need for the deployment of health assessment and emergency treatment teams [74].
- OCHA lists provision of shelter and potable water as a priority [74].
- WHO and the federal Ministry of Health have activated the Health Emergency Preparedness and Response (HEPR) unit to facilitate emergency response [74].
- UNHCR is rushing 15 tons of emergency supplies to south-western Balochistan province [74].
- MERCY Malaysia plans to mobilizes its first five-member medical and assessment relief team into provinces of Balochistan and Sindh [74].
- A six person Pakistan Red Crescent medical team has joined the International Federation and National Society disaster management staff already on the ground in Turbat [74].
- NDMA re-emphasizes the critical districts are Turbat and Jhal Magsi; substantial population still stranded and homeless [62].

- NDMA estimates that Kharan may have suffered 50 percent loss of livelihoods [62].
- NDMA estimates homeless now at 150,000 (30,000 in Sindh) [62].
- Sixteen helicopters operating in Balochistan [62].
- Six highways now restored [62].
- Four highways still under repair [62].

04 July 2007

- Assessment by five international aid agencies – Oxfam, Save the Children, Concern, Church World Service, and Catholic Relief Services indicates a growing number of skin and stomach ailments among the victims in Balochistan [75].
- Five international aid agencies decided to deliver plastic sheets and bamboo poles for temporary shelter since tents are unsuitable in the extreme summer heat [75].
- Twenty six C-130 sorties have flown in Turbat [63].
- NDMA estimates affected part of districts: Turbat 70-80 percent, Jhal Magsi 60-70 percent, Jaffarabad 60 percent [63].
- Gwadar provincial government has started survey of post cyclone serviceability status of social support infrastructure, medical facilities in particular [63].
- Gwadar provincial government has arranged for 8 trucks of LPG [63].
- 3,000 tents released so far in Sindh, 5 relief camps set up [63].
- NDMA estimates there are 150,000 homeless people (50,000 in Sindh) [63].
- NDMA lists priority of relief goods: tents/shelter, food, water, medicine [63].

05 July 2007

- Cluster system is expected to be operational by the weekend. UNHCR chaired a meeting of the UN agencies working in Balochistan. The meeting was attended by UNHCR, UNICEF, WFP, UNFPA, FAO, WHO, and UNDP. Apart from sharing information on current relief activities, the modalities of the cluster approach at the Balochistan level were worked out [64].

- The Health Cluster has been activated in Islamabad and Karachi. Federal and Provincial Ministries of Health have established Health Emergency Operation Centers in Islamabad, Karachi and Quetta [76].
- NDMA notes shelter and water needed in Balochistan [64].
- NDMA estimates 25,000 people displaced in Sindh. Forty three camps have been set up by the provincial government [64].
- NDMA notes planning underway to facilitate relief from outside countries and agencies [64].

3.3. Stakeholders

The Pakistan National Disaster Management Authority was established in 2006 largely as a result of the disaster following the earthquake of October 08 2005. The NDMA is organized into a head office providing guidance and support to provincial, regional, district and municipal level authorities [54]. This relatively new organization was the primary response agency in the days following tropical cyclone Yemyin. In addition, over 20 other national and international agencies also took part in relief efforts during the first few days following the storms landfall. Many of these agencies possessed some level of organization and structure in the region before the storm hit. Since many of these groups were already working with the Pakistan government they were in a position to move quickly. These agencies included Mercy Corps, which possessed a large infrastructure with over 230 staff and 24 years of experience in the region [31]. Other agencies involved were Oxfam, Catholic Relief Services Pakistan Red Crescent Society, UNICEF, and Save the Children to name a few [118]. During the first few days after the storm, the NDMA, in conjunction with the Pakistan Army, Navy, and Karachi Port Trust, as well as many of these other agencies worked to provide relief support to the affected regions.

On July 5, 9 days after the storm hit, a United Nations cluster development team arrived in Pakistan to set up a cluster system response to the disaster [120]. The cluster system is a mobile, international emergency response vehicle employed by the UN Office for the Coordination of Humanitarian affairs (OCHA). It is designed to provide a robust coordination capability to disaster response. The first cluster meeting was not held until July 02, and the system was not operational until around July 5 [120].

This chapter will examine the response to tropical cyclone Yemyin during a 13 day period; from the first weather advisory until the OCHA cluster system became operational.

3.4. Pakistan's infrastructure

Pakistan, and in particular the Balochistan and Sindh regions along the coast, are quite susceptible to disaster. Specifically, the social structure and physical infrastructure of the affected regions left Pakistan predisposed to an elevated disaster. The following is an excerpt from the Pakistan National Disaster Risk Management Framework detailing this issue:

"A number of factors lay behind vulnerabilities of Pakistani society to hazards. These include poor construction practices, poor livestock and agricultural management, and fragile natural environment, weak early warning systems, lack of awareness and education and poverty. Poor communication infrastructure and lack of critical facilities aggravate vulnerabilities of communities. In mountainous regions the non-availability of safer land for construction, scattered settlement patterns and harsh climatic conditions further intensify vulnerabilities. The size and growth of human and animal population, environmental degradation resulting from poorly managed urban and industrial development processes, and climate change and variability are major dynamic pressures that increase vulnerabilities of Pakistani society" [54].

Pakistan had experienced and responded to flooding before. Prior to Yemyin there had been fourteen major floods in Pakistan since 1947. However, flooding from tropical cyclones was not a common occurrence. The NDMA's risk assessment prior to Yemyin noted that the frequency of cyclones along the Pakistani coast was low. During the period from 1971 to 2001, the region had only experienced fourteen recorded cyclones [54]. A lack of familiarity with the dangers of tropical cyclones, as opposed to the monsoon depressions they develop from, could have engendered an underestimation of the destructive powers of these storms.

3.5. Determining the extent of the disaster

On June 25, of as the damaging winds of Yemyin began affecting Pakistan, the NDMA informed the United Nations Resident Coordinators office (UNRCO) of the impeding storm and stated that the situation was under control [120]. Commensurate with this level of urgency, the first situation report released by the NDMA on the July 25 at 1130, called for a relief cell in the Karachi region to earmark a mere 2,000 tents and 20,000 blankets for release when required. In this situation report, the NDMA also advised the Balochistan PDMA to take preventative measures, but only in areas prone to flash flooding [55]. Despite this confidence, the Pakistan emergency response capabilities were overwhelmed by the enormity of the disaster. Warnings were insufficient, and damage assessments were either delayed, inaccurate, or both. By July 2, the Government of Pakistan had yet to request any outside assistance despite the overwhelming need for international aid [73, 120]. Contributing to the underestimation of the storm's damaging effects was the unfamiliarity with tropical cyclones in the region and the rapid buildup and formation of the storm itself. The initial actions of the NDMA in response to Yemyin not only revealed a lack of understanding of the immediacy of the need, but were also indicative of, as Dee Goluba of Mercy Corps explained, a "lack of understanding of the magnitude of the disaster" [31].

3.5.1. Warnings

Yemyin developed quickly, and morphed rapidly from a deep depression monsoon system over India on June 22 to Topical Cyclone landfall over Pakistan on June 26 [112]. The first weather advisory for tropical cyclone Yemyin was issued on June 22, four days before landfall. In this advisory, the Pakistan Meteorological Department noted only that the system was likely to bring "widespread rains with scattered heavy to very heavy rainfall" [112]. On the June 23, a second advisory added that the system may likely move towards Balochistan. This advisory also introduced the possibility of flash floods [112]. Later on June 23, a third advisory alerted the Sindh and Balochistan disaster authorities to "take precautionary measures", but did not give specific reasons why or on what scale. The tropical system known as storm 03B did not convert into tropical cyclone Yemyin until June 25. This development was reported at 1800. It was in this warning that an urgency to respond to the impending consequences was first conveyed in the weather service communications [112]. As a result, less than 20 hours before landfall, the Pakistan Meteorology Department first made note of possible storm surges (25 feet), coastal flooding, widespread destruction, and recommended evacuations [112]. Seemingly taken by surprise by this quickly developing storm, the NDMA recommended maximum television and radio coverage of the weather alerts on June 25 [55]. Despite these late attempts, the NDMA acknowledged that there were "weak early warning advisories to vulnerable communities particularly in remote regions" [57].

3.5.2. Assessments

During the weeks following Yemyin, many assessments were provided from a variety of sources including the NDMA, UN agencies, national and local authorities, and a handful of NGOs. Delayed by communication and transportation system damages, uncertainty of damage scope, and security concerns, vital assessments were not immediately available. On June 2, 6 days after landfall, many formal assessments were only just being completed by several agencies. Many others were still ongoing. Save the Children was carrying out assessments in Chagai in Balochistan, and the Church World Services in Gadap, Tattha, and Turbat [73]. These demand assessments would be the catalyst that helped determine the magnitude of the national and international relief response [120]. The NDMA continually acknowledged this fact in each situation report during the first week of the relief effort noting: "Both Federal and provincial governments will announce relief packages after initial assessments" [57, 58]. Unfortunately, these early damage and needs estimates in Pakistan lacked timeliness and accuracy.

3.5.2.1. Timeliness

After the storm passed, most relief agencies already present in the affected region conducted some form of rapid assessment. These brief surveys to determine the extent of damage and needed relief supplies are often done first-hand by small groups. Normally conducted in specific villages and cities, they provide an initial local baseline framework of need. Some agencies such as Mercy Corps already had organized and integrated response teams in the affected regions.

After the storm passed, Mercy Corps conducted such rapid assessments, sending four teams of three people each into the affected areas. Using a rapid survey tool during their walkthroughs, these assessment groups were able to provide photographs, interviews, and brief summaries on different needy locations. In this manner, relief agencies were able to start quantifying the magnitude of the emergency and the relief that was needed. Dee Goluba, of Mercy Corps Global Operations notes that the operators on the ground in Pakistan already had a good idea of the demographics of the area and therefore had a general idea of the numbers they were dealing with. In addition, emergency responders understood early on that food, shelter, WASH, and health supplies would be the primary relief items in need. However what they suspected on the ground still needed to be confirmed by their assessment capabilities before an official estimate was made [31].

One of the basic problems encountered by emergency response organizations in Pakistan was the remote nature of many of the affected regions [120]. This difficulty was then magnified after the storm hit on the afternoon of June 26 when communication lines were severed. In particular two major links were inoperable for several weeks [65]. As a result, relief efforts and assessments in particular were immediately hampered by a lack of information [31].

In addition, many roads were destroyed by the flooding waters the storm brought. The Coastal and Kurachi-Quetta highways would not be operational for more than a week after the storm [64]. "While the flood water has subsided, all major roads have been damaged and bridges have been washed out. With no traffic coming in, food is becoming scarce in some places," said the International Federation of the Red Cross and Red Crescent Society disaster management coordinator in Pakistan, Asar ul Haq [17]. Mr. ul Haq went on to say "the major problem is access and communications. Much of Balochistan is remote and sparsely populated. With roads out, telephone lines down and electricity off, finding out who is affected is as big a challenge as helping them" [17]. Parts of Turbat in Balochistan were still cut off over a week after the storm hit. July 2, six days after the storm, was the first day people were allowed to cross the river separating one region from the rest of Pakistan. Only then could a joint assessment team from Catholic Relief Services, Oxfam, Save the Children, Concern, and Church World Service reach the area to assess the damage and needed relief [27].

As a result, even the most rapid initial assessments from organizations in ideal positions to provide accurate needs estimates took at least three days to produce. Other assessments were not started for a full week following the storm. Due to the scarcity of initial damage information, eight days after the storm had made landfall, the NDMA and the Government of Pakistan were still struggling with the extent of the disaster. Still doubting the magnitude of relief aid that would be required in the country, and despite the urging of the UNRCO, the NDMA and Government of Pakistan hesitated to apply for relief aid from the UN central emergency response fund (CERF). As a result, the NDMA delayed the vital CERF damage and needs assessments from proceeding until July 9. This assessment would be eventually completed on July 12 and call for eighty eight million US dollars to "address the urgent humanitarian needs of the affected population" [120].

3.5.2.2. Effectiveness

Not only were assessments delayed, but when emergency officials started releasing damage estimates, their reports were confusing, inaccurate, and lacked the appropriate urgency. Days after landfall, NDMA officials could not come to any consensus on an appropriate level of response [120]. Even the initial situation reports published by the NDMA and OCHA failed to provide any information that indicated clear urgency [120]. One of the immediate consequences of this confusion manifested itself in the UN appeal process. A UN Flash Appeal for funds, usually delivered within the first week of a disaster, was delayed until July 19, almost three weeks after landfall. Among the primary reasons for this excessive delay was a lack of substantive information on the effects of the storm. As a result, the appeal did not coincide with the heightened media coverage that natural disasters will tend to generate at their outset. This disconnect results in a diminished sense of urgency among potential donors [120].

The NDMA and OCHA have been criticized for failing to give any indication of the scale of the relief needs or impact of the storm [120]. The initial NDMA situation reports from June 23 until July 2 give no clear measure of the magnitude of the disaster facing Pakistan. Not surprisingly, potential donors complained about a lack of strategic information being issued during the initial response [120]. Death toll data in both Sindh and Balochistan appear starting on the June 26, yet the reporting contained vast discrepancies between official and unofficial counts [59]. Not until July 2 did an NDMA situation report give the first concrete indication of the scale of the needed response. They noted in this report that there were an estimated 250,000 people left homeless and one million people affected in Balochistan province [61]. The following day, the NDMA reported a total countrywide estimate of 1.5 million people affected [62]. Not until July 5 did this number jump to two million [64]. A full nine days after the storm had passed, the NDMA, and therefore the world was still underestimating (at least in one measure) the scope of the disaster by 20 percent. (There were approximately 2.5 million people affected by tropical cyclone Yemyin.)

Media coverage of the disaster reflected and contributed to the confusion seen in the official situation reports. The Times of India quoted Ali Gul Kurd, the Deputy Relief

Commissioner for Balochistan, saying "We have sufficient supplies of food medicines, anti-(snake) venom kits and water purification tablets" [17] Yet at the same time other relief agencies were desperately calling for donations of these same items [102]. The relief commissioner of Balochistan province, Khuda Bakhsh Baloch, provided one of the earliest assessments of damage when he estimated that the storm left 250,000 people homeless in his province [72]. On July 2, the NDM confirmed this estimate of the situation in Balochistan noting that perhaps 250,000 people were homeless there. However, later that day, they revised this estimate to 100,000 people in Balochistan in addition to 25,000 in Sindh. This was again revised on July 4 to include 50,000 people in Sindh. On July 5 however, the Sindh estimate was again listed as 25,000 homeless. These estimates often were highly inaccurate (the total displaced population was around 250,000). [61, 63, 64, 66]. However, the imprecision (a 100 percent increase followed by a 50 percent reduction in shelter demand for instance) undoubtedly caused hesitation in relief effort coordination and planning [120].

In addition to confusing facts, damage and needs assessments came in many forms. With no standard assessment methodology in place, each agency or local organization provided information in different formats and structures. Asar ul Haq, the International Federation of Red Cross and Red Crescent Society disaster management coordinator in Pakistan, reached Turbat on June 28 and quickly made the assessment that "food is the number one priority at the moment" [27]. Still other assessments addressed a wide range of different needs and were unspecific in details. A CRS team noted on July 2 that an estimated 5,000 families in the district of Thatta in Sindh are in need of "vital support". They added that this number may be double for Balochistan. CRS also reported the need for other critical items such as, clean water, food, hygiene kits, and medical supplies [7]. Still other assessments integrated damage to infrastructure, including communication lines, roads, and social support infrastructure, and medical facilities. On July 4, the NDMA reported damage to certain districts as a percentage. The reports indicate that 70-80 percent of Turbat and 60-70 percent of Jhal Magsi were affected [63]. The NDMA also reported needed relief supplies in order of priority with no accompanying magnitude or location of the need [63]. The NDMA would also frequently identify districts they estimated to be the most damaged by the storm in descending order of priority [59].

It seems that each relief agency, both national and international, had its own damage reporting format. Some even had several formats. While some measured damage in terms of number of people affected, others reported numbers of families affected. While some agencies reported needed food in terms of how many families for how many weeks, others reported priority lists of specific food items. This lack of a centralized assessment procedure and reporting format contributed to the confusion and inefficiencies experienced in providing relief to the affected people in Pakistan [120].

3.6. Coordination

In order to provide the most efficient response, the over 20 different agencies providing relief in the affected region had to work together [49]. The NGOs tried to coordinate with local authorities (with whom some already had a relationship), medical facilities and other NGOs, as well as national and international agencies in the area. Often, in disaster situations NGOs try to send coordinators from other regions to provide expertise on the ground [31]. Dee Goluba explains that Mercy Corps tried to place these expert decision makers in the emergency area at the earliest opportunity to facilitate critical judgments. Local relief workers who knew each other and the region supported outside experts. As a result, they had a sense for not only their own, but also other local agencies' presence and capabilities [32]. Some attempted to coordinate efforts by sharing vehicles, freight, and communication lines. Often, several agencies would conduct joint assessments of common areas and conduct coordination meetings whenever needed, even in the middle of the night. They also relied heavily on each other for shared information. By doing so, they tried to prevent overlap and obvious gaps in relief coverage [31]. However, despite these efforts by many agencies on the ground, there still existed a debilitating lack of a "mature coordination framework" [120].

Even in light of the lessons learned during the Pakistan earthquake disaster in 2005, there was no prior coordination on how the different relief providers should work together [120]. Many of the NGOs, particularly in the Sindh province, reported that there was insufficient coordination between their agencies and the District governments [120]. There were also problems even among international relief agencies. The UNRCO reported that they did not receive full participation from the government agencies or the NGOs. A contributing factor may have been the tense relationship between the NDMA and the UN. A lack of shared and understood goals and objectives, responsibilities, and data gathering systems may have contributed to this strained relationship [120]. One result was that local NGO leaders felt their expertise was undervalued by the larger coordination entities [120]. As a result, decisions made at the regional coordinator level were not transparent to the local agencies. However, even more importantly, the decisions were not transparent to donors eager to understand where their money was being spent.

Information management strategies were also not in place [120]. Among relief agencies, in addition to laterally, information flow also needed to travel vertically, to various donors, UN, government, and NGO agencies. Agency assessments in particular needed to filter from cities and regions out to organizations such as OCHA who could disseminate them as part of their regular situation reports. This flow of information however was very slow and was not a high priority for decision makers on the ground [31].

The lack of coordination in Pakistan can also be attributed to the concerns by the government of Pakistan about the safety of non-national personnel. The NDMA required relief workers to obtain non-objection certificates before entering many of the affected areas. This proved to be a major hurdle for some international agencies. Equally as debilitating was the requirement that all offers of aid be coordinated through the NDMA in Islamabad [120].

All of these coordination issues led to complaints of inequitable relief coverage and gaps in relief service. These oversights, particularly in remote areas, can be attributed to the debilitating coordination and cooperation issues that hampered all responders on scene [120]. In short, poor coordination between relief agencies extended the suffering of the victims in Pakistan.

3.7. Logistics

Yemyin quickly overwhelmed the emergency supplies of the country. Price increases, delivery routing obstacles, and local supply shortages were a few of the logistical problems encountered. To react quickly, relief agencies needed to have a general idea of availability and pricing on the market for relief supplies at the outset of the response. Delivery times of locally procured supplies were understandably quicker and therefore were more desirable during the first few days. For instance, approximately 20 percent of the first round of distribution of relief supplies from Mercy Corps was from local sources [31]. Although agencies such as Mercy Corps preferred to buy locally, the magnitude of the demand for relief supplies required them to establish procurement hubs throughout the region. In order for agencies to ensure they were using their financial resources efficiently, they established accelerated competitive bidding processes saving money and reducing delivery times [31]. Due to the unpredictable condition of the roads in the affected regions, relief agencies also had to deal with disrupted supply routing. In anticipation of these issues, some agencies improvised on the fly and rented warehouses in strategic locations that were close to their area of influence, and were accessible from major cities [31].

While relief agencies saw some limited successes with their on the fly logistical decisions, the lack of an efficient solution to the historically difficult logistical problems hampered relief agencies on scene. These problems, such as of how to deal with a sudden and immense demand, relief supply price spikes, crippling infrastructural damages, and routing and warehousing decisions, were in most instances met with a reactive versus proactive approach.

4. Typhoon Durian

4.1. Overview

At 1030 am, on November 30 2006, Typhoon Durian, locally called Reming, made landfall in the province of Catanduanes, Philippines [68]. The storm brought winds of up to 195 kph and gusts up to 230 kph [68]. Durian exited into the South China Sea on December 1 after depositing 18 inches of rain over the Philippines [110]. Winds ravaged fourteen provinces, floodwaters inundated coastal regions, and the heavy rains prompted volcanic mudslides which completely buried the villages around the Mt Mayon volcano [68]. The storm claimed 1399 lives, injured more than 2000, damaged or destroyed over half a million homes, and caused over 1.3 million people to evacuate [68, 90]. In all, more than 3.5 million people were affected by the powerful storm [68]. A massive humanitarian response started from within but soon encompassed relief agencies from around the globe [47]. The storm caused nearly US $66 million in infrastructure and agricultural damage [23]. Since December 1 2006, over 16.5 million dollars in relief supplies and donations have been put toward the recovery efforts [47].

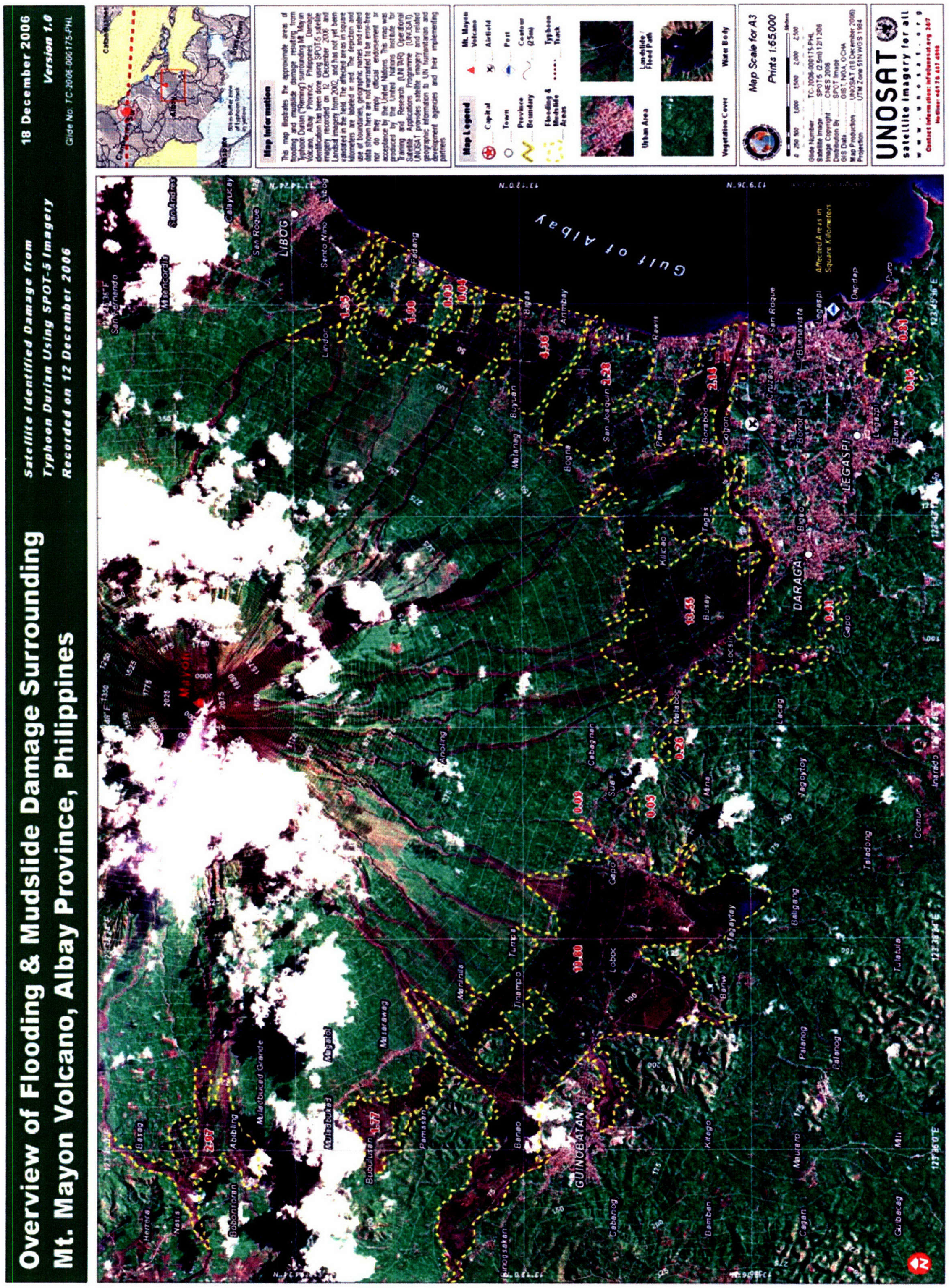

Figure 4-1 Mud floes Around Mt. Mayon [69]

4.1.1. Map of storm track

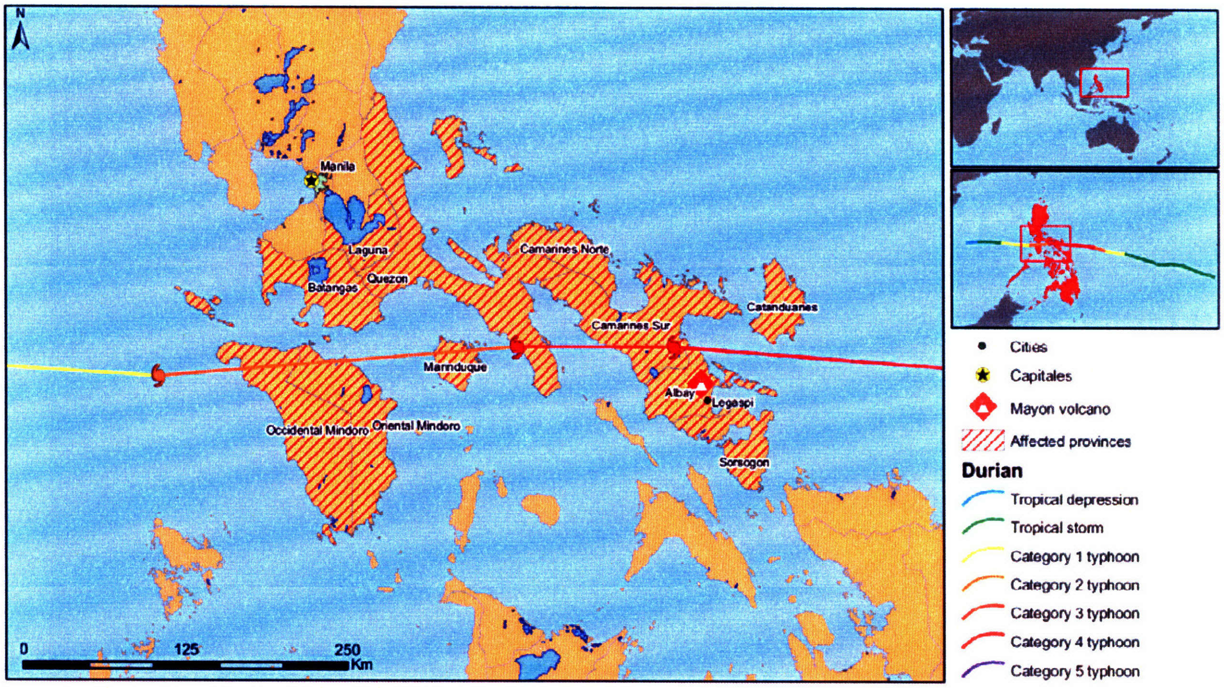

Figure 4-2 Durian storm track [84]

4.2. Timeline

The following is timeline of the events surrounding Typhoon Durian.

24 November 2006

- Tropical disturbance forms in western Pacific [110].

28 November 2006

- 1100: PAGASA issues Severe Weather Bulletin #1 [13].
- 1100: Tropical storm east of Vislays has entered Philippine area of responsibility. Storm now named Durian (locally called Reming) [13].
- 1100: No public storm warning signals have been raised [13].

- 1700: PAGASA issues Severe Weather Bulletin #2. Public storm warning signals have been raised in Luzon [13].

29 November 2006

- 0500: Severe Weather Bulletin #4 states that Durian has increased its threat to the Luzon area [13].
- 0500: NDCC activates its emergency operations center [2].
- 0800: Durian reaches super typhoon status [106].
- NDCC issues warnings to "all regional offices of the Office of the Civil Defense (OCD), Provincial Disaster Coordinating Council (PDCC), agencies like the Department of Health (DOH), Department of Social Welfare and Development (DSWD), and the Armed Forces of the Philippines." [2].
- 1700: PSWS Level 4 in Catanduanes. PSWS level 3 raised over Albay, Camarines provinces, and Polillio Island [96, 97].
- Officials ask coastal residents to move to higher ground, warning of flooding and landslides [96].
- Severe weather advisories sent to 12 provinces [96].
- NDCC advises government agencies and emergency operations centers to prepare for any eventuality [96].
- LDCCs directed to undertake monitoring and precautionary measures, alert emergency response units [68].
- Residents under PSWS 1,2,3,4 warned against possible flashfloods, landslides, and storm surges [68].

30 November 2006

- Department of Health activates regional operations centers and medical teams [85].
- Armed Forces of the Philippines pre-positions mobility assets in Catanduanes [85].
- Department of Social Welfare activates emergency management teams and quick action response teams [85].
- PSWS level 4 raised in Catanduanes, Albay, and Camarines provinces [85].
- PSWS level 3 raised in Sorsogon, Quezon, Marinduque, Mindoro, Batangas, Cabite, Laguna, and Manila city [85].
- Many other provinces are at PSWS level 2 [85].
- 1030: Durian makes landfall in Catanduanes. 190 kph winds, gusts up to 265 kph, and 18.35 inches of rain in the region. Floodwaters reach 10 feet in some areas [85, 68, 107].
- 1500-1800: Landslides bury 700 villages surrounding MT Mayon [109].
- Two major transmission lines damaged, Naga-Tayabas and Gumaca-Labo, resulting in the tripping off of ten (10) sub-transmission lines in Bicol region [82].
- First estimates of damage in most affected provinces expected on 02 December [83].

01 December 2006

- NDCC reports 198 confirmed dead, 260 missing, and 64 injured [85].
- NDCC reports 25,020 people were affected in 10 provinces [85].
- NDCC reports 1294 people, 246 vehicles, and 9 vessels are stranded [85].
- Red Cross indicates that over 140 people had been killed by storm and many areas are inaccessible [80, 5].
- Fernando Gonzales, governor of Albay, estimates half of his province's population of 1.2 million people were directly affected by the typhoon [11].

- Government Geologists plan to assess environmental damage and possibility of more mud floes on Mt. Mayon [85].
- NDCC assessment team will be fielded on December 2. Results expected to be known later that day [85].
- NDCC identifies priority actions: assessments, SAR and relief ops [85].
- NDCC lists needs: food, water, medical teams, social workers, medicines, body bags, blankets, tents and shelter items, rescue teams with dogs, helicopters [85].
- IFRC plans to mobilize a field assessment and coordination team [85].
- UN resident coordinators office in Philippines has been in contact with NDCC to offer UN support [85].
- UNICEF dispatches emergency health supplies for 10,000 for three months in Albay [107].
- Provincial disaster Coordinating Council of Camarine Sur says that in just 6 of 35 towns, 24,909 families needed housing in evacuation centers, 6356 houses destroyed, 15,678 partially damaged [107].
- Governor of Marinduque (island province) estimates that 40,000 families affected, 80 percent of population affected [107].
- Civil defense officials estimate that 90 percent of Bicol homes destroyed [107].
- 13,900 people evacuated in Bicol region [107].
- Public works department in Bicol estimates 1 billion pesos in damage to infrastructure ($20 billion) [107].
- Agriculture Secretary Arthur Yao estimates that farmers suffered 500 million pesos ($10 million) in losses [107, 53].

- Forty military rescuers flown to Mt. Mayon area by helicopter [107].
- National departments of Health and Social Welfare providing relief items [107].
- PNRC sends two assessment teams to Legazpi city, Daraga and Santo Domingo around Mt Mayon [107].
- East Asia emergency rice reserve allocates rice [107].
- Richard Gordon, senator and head of the Philippine Red Cross, estimates that 300 to 400 people could be dead [53].
- International Federation of Red Cross and Red Crescent Societies estimate that 25,000 people have been affected [53].
- No reports from Catanduanes. Assessment teams plan to fly to the island province on December 2 [81].
- World Vision Philippines is sending assessment teams to Legaspi City, where they think villages may have been buried in mud [81].

02 December 2006

- NDCC reports that 455,593 people have been affected by the typhoon [86].
- NDCC reports 29,790 have been evacuated (5,612 families) [86].
- 190 evacuation centers running [86].
- NDCC confirms 208 dead, 261 missing, 82 injured [86].
- PNRC reports that at least 388 people dead [86].
- OCHA reports that 25,545 properties destroyed, a further 80,532 damaged [86].
- Philippines government has not called for international assistance [86].
- Government agencies have provided initial relief assistance including, food medicine, shelter items, and body bags [86].

- NDCC assessments still ongoing [86].
- PNRC assessments teams in Sorsogon and Labay provinces and others in Camarines Sur and Quezon [86].
- IFRC mobilizing field assessment coordination team and 10 regional disaster response team members to support PNRC with distribution [86].

03 December 2006

- NDCC reports 309 dead, 298 missing, and 414 injured [87].
- NDCC reports 832,549 people affected in 86 municipalities over 12 provinces [87].
- 16710 people have sought refuge in 100 refugee centers [87].
- 28,119 houses destroyed, 91430 partially damaged [87].
- Red Cross Executive Assistant Gwendolyn Pang estimates the death toll could be in the thousands [105].
- The Red Cross estimates about 66, 616 people are now homeless [105].
- Damage estimated at approximately Php 34 billion ($634 million US dollars) (infrastructure and agricultural) [87].
- Interagency assessments still ongoing [87].
- Most main roads now cleared [87].
- Widespread power outages remain [87].
- Many areas still experiencing disruptions in water supply [87].
- PNRC reports that casualties and damages could increase when communication lines are restored [87].
- President Arroyo declares state of national calamity, commits $20 million US for recovery and relief [94].

- NDCC has facilitated 52 tons of food airlifted to affected areas [87].
- Philippine Navy providing support to island province of Mindoro [87].
- Netherlands, Japanese, and Canadian governments, as well as JICA and AusAid pledge funds and other relief assistance [87].
- Philippines government announces its readiness to accept offers of assistance [87].

04 December 2006

- COE reports 69,440 destroyed, 142,985 partially damaged houses [108].
- NDCC reports 1,146,001 million affected [108].
- COE reports Over 20,000 in 72 evacuation centers [108].
- NDCC estimates damage to property at 274 million pesos ($5.3 billion) [108].
- PNRC issues urgent appeal for over $7.3 million for food water, and medicine for 200,000 beneficiaries for next 9 months [108].
- NDCC reports that Agriculture damage over 250 million pesos ($4.9 million) [108].
- Help pledged from over 14 international government and agencies [108].

05 December 2006

- NDCC reports 526 dead, 740 missing, 1000 injured [88].
- NDCC reports 1,543,778 people affected in 13 provinces [88].
- 82,915 people have sought refuge in 29 different evacuation centers [88].
- 76,247 houses destroyed, 153,872 partially damaged [88].
- Damage estimates at Php 608 billion [88].
- President Arroyo visits the devastated area for the first time. She promises to consider spending up to $300 million [94].
- The first supplies of food and medicine arrive—12 tons from Indonesia [94].

- UN interagency assessment team deployed in Albay [88].
- 12 outside governments and agencies have pledged relief funds and supplies [88].

06 December 2006

- NDCC reports 1316 dead or missing from landslides [109].
- NDCC reports 1,662,467 affected [109].
- Over 80,000 evacuees in 273 evacuation centers [109].
- 79,337 homes destroyed. 166,954 partially damaged houses [109].
- Damage estimate at 1.27 bill pesos ($25.7 million), including Agricultural estimate 251 million pesos ($4.9) [109].
- National Irrigation Administration estimates that agricultural damage was 330 million pesos ($6.4) in Albay alone [109].
- National Transmission Corp estimates that power recovery will take until mid December [109].
- PNRC has provided food to 9,000 people [109].
- President Arroyo pledges R 3.6 bill ($74.8 million) for recovery and relief and Php 150 million for power grid repair [19].
- China and Korea pledge relief support [19].

08 December 2006

- Donors meeting held by UNICEF. Donors briefed on priority requirements and the coordination mechanism for effective donation and aid management [68].

09 December 2006

- NDCC reports 635 dead, 764 missing, 2143 injured [89].
- NDCC reports 2,560,374 affected in 13 provinces [89].

- 109,411 people have sought refuge in 475 evacuation centers [89].
- NDCC reports that 122,269 houses destroyed, 218747 partially damaged [89].
- Damage to medical facilities in some provinces is delaying delivery of medical services [89].
- Estimated damage at Php 3.3 billion (66.4 million US dollars) [89].
- 10 airlift sorties over the past 2 days have brought 150 tons of food, NFIs, medical teams, and equipment, and water purifying equipment to certain provinces [89].
- President Arroyo directs 200 vehicle convoy for 12 December to bring relief supplies to Bicol region [89].

4.3. Stakeholders

The Philippine National Disaster Coordinating council was created in 1978 and serves as the highest policy making body for disasters in the Philippines. Its purpose is to "strengthen the Philippine disaster control capability and to establish a community disaster preparedness program nationwide" [44]. The NDCC is composed of the heads of 18 government departments and agencies including: the Chief of Staff of the armed forces, who is the head of the council, the Executive Secretary and Administrator of the Office of Civil Defense, who is the Executive Officer of the Council, and the secretary of the National Red Cross [44].

This national framework supports regional, provincial, city/municipal, and barangay disaster coordinating councils throughout the country. These local councils consist of members of national government agencies operating at these levels as well as local officials. Each of these councils has elements in their operations centers that provide the following services: damage assessment and needs analysis, emergency management information, vulnerability risk reduction management, plans and operations, and resource management [44].

"At the national level, the NDCC serves as the President's adviser on disaster preparedness programs, disaster operations and rehabilitation efforts undertaken by the government and the private sector. It acts as the top coordinator of all disaster management and the highest allocator of resources in the country to support the efforts of the lower DCC level. In the discharge of its functions, the NDCC utilizes the facilities and services of the Office of Civil Defense as its operating arm" [44]. The NDCC is not allocated an operating budget. Instead it must rely on and operate through its member agencies and the resources contained within the local disaster coordinating councils.

The NDCC and the Philippine National Red Cross were the primary response agencies during the first week following Super Typhoon Durian. These larger entities were assisted by many local government organizations (LGO). In addition, many non-governmental national and international agencies also participated at varying levels of relief magnitude. These included Children International, Save the Children, Oxfam, Direct Relief, and World Vision Philippines [47]. Several UN relief organizations, specifically UNICEF, were also providing relief supplies and assessment efforts during the first few days following the storm. A fully engaged UN response was delayed until President Arroyo declared a state of national calamity on December 3, and formally called for international assistance. The UN Resident Coordinators office formally requested that the Cluster Approach be used for this disaster on December 5 [88]. Despite this request, the NDCC coordinated the international response until December 10 when the UN was asked to officially take over [89].

This chapter will examine aspects of the response to super typhoon Durian from the formation of the storm until significant international assistance and response mechanisms were employed approximately one week following landfall.

4.4. Philippine's infrastructure

The following is an excerpt from the Workshop on Financial Strategies Managing Economic Impact of Natural Disaster at the Macro-, Meso-, Micro-Level on 22-24 May 2006 at EDSA Shangrila Hotel. The workshop was provided by, among others, the National Disaster Coordinating Council.

"The Philippines is one of the most disaster-prone countries in the world. From 1900-1991, the Center for Research and Epidemiology of Disasters in Belgium recorded a total of 701 disaster incidents, or almost 8 disasters a year. From 1987 – 2000, the National Disaster Coordinating Council (NDCC) recorded 523 disasters, an average of 37 disasters annually. The European Commission Humanitarian Aid Office Disaster Risk Indicators ranked the Philippines the 11th most disaster prone among 115 counties.

The Philippines' predisposition to natural hazards is primarily a function of its geographical and physical characteristics. Located near the Western North Pacific Basin where 50% of the world's tropical cyclones are generated, 20 typhoons enter the country's area of responsibility in a year, of which 9 make a landfall. The world's second largest archipelago, it is composed of 7,100 islands with total land area of 30 Million hectares. Communities along its 36,289 kilometers coastline are prone to storm surges and sea level changes. Flooding especially in low-lying areas is common due to rains brought about by typhoons, monsoons, thunderstorms, and the inter-tropical convergence zone...The country's topography varies from high mountains, accounting for 60 % of land mass, plains and freshwater swamps. There are 220 volcanoes, of which 22 are active. Five earthquakes, mostly imperceptible occur daily. Heavy rains and earthquake can trigger landslides and debris flows.

Other than its geo-physical characteristics, the country's social, economic and political environment continues to be a significant factor in disaster frequency and loss. Poverty, environmental degradation, rapid expansion of urban areas, deficiencies in development and disaster management planning, patronage politics, government corruption and negligence, and poor enforcement of public safety and environmental legislations, have all contributed to recurring and chronic disaster situation. These as a whole have a great impact on the ability of individuals, households, communities and society to prepare for, cope with, and recover from disasters.

Environmental degradation and resource depletion have increased the country's vulnerability to natural hazards.... Deforestation has induced flood, soil erosion, landslides, and siltation in low-risk lowland areas. The destruction of mangroves and coral reefs has resulted in the decline of fisheries production and loss of natural protection of coastal communities from storm surges and beach erosion.

The poverty situation of many Filipinos severely restricts their capacity to cope with natural hazards, and recover from the damage and devastation of disasters. Poverty leads people to inhabit high-risk areas and engage in unsustainable and dangerous livelihoods" [98].

4.5. Determining the extent of the disaster

As can be expected during any major disaster, the Philippine emergency response capabilities were overwhelmed by typhoon Durian [41]. Richard Gordon, head of the Philippine

National Red Cross, stated on December 1 "There are a lot of conflicting reports but, looking at the trend, we could have about 300 to 400 people dead by tonight" [53]. Almost 1400 people lost their lives during the disaster [68]. Clearly, emergency officials were unaware of the magnitude of the disaster that was befalling the Philippines.

4.5.1. Warnings

The Philippines NDCC and the UN published a Lessons Learned Survey Report in the wake of typhoon Durian. The members contributing to this report cited several shortcomings in regards to the warnings provided to emergency managers and the public. One of their major concerns focused on the type of information that was delivered to the public as the storm apporached. In order for public notices and warnings to be effective, accurate information must be supplied to the public in an effective manner that produces results. According to the Philippines lessons learned survey report, this aspect of the Philippine response was deficient.

Typhoon Durian began its development on November 24 well east of the Philippines [110]. The Japan Meteorological Agency designated the storm a tropical depression on November 25 [110]. That same day the Joint Typhoon Warning Center also started issuing warnings as the depression moved westward toward the Philippines [110]. On November 26 the storm was upgraded to a tropical storm and named Durian [110]. Four days after its formation, on Novemmber 28, Durian entered the Phillipine area of responsibility and soon thereafter the JTWC and JMA upgraded the storm to a typhoon [110]. PAGASA, the Philippines atmospheric geophysical astronomical services administration issued its first severe weather warning pertaining to Durian on the 28th at 1100 am [13]. Within two days the powerful storm would come ashore in the province of Cantaduanes. At the time of this first warning, no public storm warning signals were displayed in any part of the Philippines. At 5 pm on the November 28, severe weather bulletin #2 was issued by PAGASA, now noting that Durian threatened the Luzon area [13]. At this time, PSWS #1 was raised in Cantandeuanes. As a result, less than 2 days before the storm residents of Cantanduanes, soon to be devestated by a massive typhoon, were being warned with an urgency that indicated "twigs and branches of small trees may be broken" and "some banana plants may be tilted or downed" [100]. These warnings were upgraded and eventually included PSWS #4 being raised in Cantanduanes by 5pm on the November 29 [13]. The warnings in fact were accurately deployed. PSWS #4 indicates that very strong winds and extensive damage will be incurred within 12 hours. PSWS #1 indicates that a storm is approaching and to be alert for upgraded warning signals [100]. However, the forecasts and warnings failed to convey in a timely manner the fact that a destructive and deadly storm was bearing down on the Philippines and preventive action was necessary. The Lessons Learning Report describes this fundamental shortmcoming as a lack of effective "risk communication" [91].

However, the report cites other examples of insuffcient warning mechanisms. Rainfall predictions for instance, especially for flood prone areas, needed to be accurate and were not. As a result, instead of having confidence in the predictions and taking preventative action, emergency response personnel were forced to monitor for flooding during the storm. They then reacted to this real-time information. They argue that this reactive instead of proactive approach may have directly led to disaster. Due to the marked volcanic nature of the region, mudslides are prevalent, especially in the Mt. Mayon volcano area. Although mudslides can reasonably be predicted given accurate rainfall forecasts, they were not during this disaster [91]. As a result, massive mudslides around Mt. Mayon accounted for a majority of the casualties.

Regardless of the extent of predictive detail, warning information must be disseminated properly. Although television, radio, and print media were all used to varying degrees in the days before Durian made landfall, not all people affected were able to be alerted to the impeding dangers. In fact in many areas, officials found the most useful tool for disseminating public warnings was the public address system of an ambulance [91].

However, even given accurate information, warnings must be presented in a way that produces results. Warnings must not only be disseminated properly, but they must also spur action. One of the most troubling aspects of the Durian response was the lack of action by the population who did get adequately warned. Often, warnings contained too much technical verbiage. Other problems stemmed from certain populations having credibility issues with the people providing the warnings. Still other advisories were said to be culturally insensitive [91].

Whether it was because the warning information was inaccurate, not delivered properly, or was somehow objectionable to the public receiving it, the result was tragically the same; although people were warned of the impending danger, many did not act in an appropriate manner to avoid harm [91].

4.5.2. Assessments

In their December 2 situation report, OCHA notes that "the scope of the [international] appeal will be determined after the NDCC has conducted damage and needs assessments" [85]. Logically, these vital assessments needed to be completed as quickly and accurately as possible; tragically they were not. Multitudes of assessments were conducted by local, national, and international agencies immediately following the passing of Durian. These included teams from the NDCC, PNRC, IFRC, UN, and various international NGOs. The information gathered in these assessments and disseminated from disaster response agencies often lacked specificity and were not delivered in a timely manner. Moreover, the assessment strategies employed by different entities lacked a coordinated focus.

4.5.2.1. Timeliness

On December 1, an OCHA situation report noted that "NDCC will field a national assessment team… on 02 December. Results of the assessment will be known later that same day, at which time the government will determine whether international assistance will be required" [85]. However, rapid damage assessments would be hampered by poor road conditions, severed communication lines and widespread power outages experienced throughout the affected region [91]. Initial damage and needs assessments were still ongoing on December 5th [88] and as late as December 10 the NDCC was still placing a high priority on understanding assessment results [89].

A UN Food and Agriculture Administration report described the NDCC expectations for rapid damage assessments in the following way, "an initial damage-and-needs assessment is conducted within six hours of the hazard's impact to determine what response was undertaken by the local disaster coordinating council, estimate requirements for follow-up response and serve as the basis for decision-making at higher levels and for future planning. Extent of damage is reported within 12 hours of the hazard impact" [101]. Clearly, many aspects of an appropriate local and international response hinge on the assessments of need after such a disaster. Although OCHA and the NDCC were expecting these rapid assessments to be complete within twelve hours, the reality is that these assessments took much more time than anticipated. In fact, the chairman of the PNRC was only able to give a vague assessment a full three days after landfall noting "apparently heavier loss of lives in Albay province" and "Catanduanes seems to have incurred heavier damage to property and infrastructure" [86].

Many regions were inaccessible and widespread power and telephone outages ravaged the areas hit by Durian. These conditions made it very difficult to determine the extent of damage in the hard hit regions. This was especially true of the smaller municipalities and the island provinces. Landlines, cell phone towers, radio antennas were all rendered incapacitated in the wake of Durian. With no phone or internet connectivity, there was no way of passing information within the emergency response centers hierarchy [91]. Although most of the main roads were cleared by December 3, most of the storm hit regions were left without power and communication outages for much longer [86]. Durian disrupted the vital transportation and communications networks that emergency responders were depending on.

Emergency responders were also hampered by a lack of information concerning the characteristics of the general populace. Those conducting assessments and surveys had no baseline data on the areas population and demographics. Instead of working from such a baseline, they were forced to create one. This deficiency also caused rapid assessments to take much longer than planned [91].

Assessments that were being completed were not shared with the emergency response community. Until the cluster system was employed several weeks after the storm, there were no formal means of sharing this vital information with other agencies. Assessment information aside, the assessment methodology itself may have been a contributing factor to a misunderstanding of the disaster. Due to the lack of centralized assessment procedures, each agency, and even each municipality, conducted assessments with their own various tools and procedures. Different formats, terminology, and information analysis led to conflicting and error prone reports [91].

4.5.2.2. Effectiveness

Accurate and timely assessments are the key to "getting the right package of assistance to the right people at the right time" [91]. Without critical knowledge such as local area population statistics, vulnerabilities, and specific needs, it is very difficult to provide victims the necessary relief supplies in an efficient manner. Given the trouble relief agencies encountered in conducting their assessments, it is not surprising that during the first days following the landfall of typhoon Durian, emergency management officials had a hard time gaining perspective on the magnitude of the disaster.

On December 1, the day following landfall, the NDCC reported to OCHA that 25,020 people were affected by the storm [85]. One day later, the number rose to 455, 593 [86]. By December 3, the NDCC and OCHA estimate was at 832,549 people affected [87]. This number was again doubled, two days later on December 5 to reflect an estimate of approximately 1.5 million people affected [88]. As a result, almost a week after storm, the best estimate was still underestimating the actual magnitude of the disaster by over 50 percent. (Actual number of people affected was approximately 3.5 million). The NDCC was not alone in their underestimation. The Pakistan national Red Cross independently issued a statement on December 1 that also placed the number of people affected around 25,000 [53].

The inability of disaster officials to forecast and gain an appreciation for the magnitude of the disaster had far reaching implications. Inevitably, such a massive disaster will overwhelm even the most adequately prepared disaster response agencies and government entities [41]. In these circumstances, outside help in the form of international aid relief will certainly be a large part of the recovery efforts. OCHA realized this as early as December 2 when it noted in a Situation report "a call for international early recovery assistance is likely to be made" [86]. The PNRC chairman himself echoed this notion in a statement he gave on December 2. "I am going to impress upon the President the significance of letting the world know about the destruction left behind by the super typhoon… and that we wholeheartedly welcome any assistance that can be given in this hour of great need" [34].

However, as we have seen, even the NDCC did not fully grasp the magnitude of the relief efforts that would be needed. Perhaps as a result of this general underestimation, President Arroyo did not declare a national state of calamity until December 3. Moreover, at this time she only pledged US $20 Million for recovery and relief. Just two days later on December 5, Arroyo visited the devastated area for the first time [94]. Perhaps starting to gain an insight into just how large the recovery would need to be, she pledged on December 6 US $74.8 Million for recovery and relief efforts [19].

From the start, the effects that typhoon Durian would have on the Philippines was thoroughly underestimated by the emergency management personnel at the national level. At the very least this underestimation led to an initially diminished perception of the relief efforts that would be needed both within the Philippines and worldwide. International response will be proportional to the perceived and reported magnitude of disaster [120]. Disaster officials took nearly six days to produce even marginally accurate magnitude estimates. Perhaps more importantly though, an opportunity was lost to convey to the world the magnitude of the devastation the country was experiencing. This diminished perception no doubt led to a delayed response by the international community.

4.6. Coordination

When many organizations work within the same disaster region, overlapping efforts and coverage gaps are two potential problems disaster managers will face. Although the relief coordinators on the ground work informally to reduce such overlaps and eliminate obvious gaps, these oversights will occur without a concentrated centralized effort to efficiently allocate relief resources [51]. A World Vision news story summarized the problem of coordination in the wake of Durian: "The challenge for World Vision Philippines is where to focus its relief efforts" [81]. The lessons learned report membership addressed this concern the following way. "External organizations like INGOs and NGOs from other parts of the country, upon hitting the ground, found it unclear as to which level to coordinate with – provincial, city or municipal. While it was later sorted out, there is a need to have a facility that will brief and provide information on the priority areas as the situation evolves and will direct humanitarian organizations to these areas with basic information on who to go to and the prevailing situation in the area" [91].

Another major problem for disaster managers was how to track and monitor donations. On December 10, eleven days following the storm, the NDCC formally requested the assistance of the UN to coordinate international donations of relief supplies [89]. The first eleven days however, proved to be an overwhelming logistical problem for relief agencies in the Philippines. Donations and relief supplies arrived from around the country, region, and globe. Some went to the government, others to local agencies, and some supplies were delivered directly to the victims themselves. With no centralized tracking system for this aid, it was impossible to know what kind and in what location relief was needed. As a result, relief supplies, search and rescue personnel, medical supplies, warehouses, and transportation assets, although available in many cases were not a known commodity to relief agencies and emergency responders [91].

4.7. Logistics

The ability of a region to respond to a disaster such as typhoon Durian relies heavily on the planning and preparedness of the emergency response. Durian exposed several major shortcomings in the infrastructure of the Philippine emergency response plan. Two of these problems were the transportation of relief supplies and the amount and location of emergency shelters.

By December 8, eight days after the storm, there had been a large local and international response to the disaster. Among the supplies pouring into the country were mattresses, bed sheets, tents, generators, cable cords, medicines, food supplies and countless other relief materials. The materials came from locations all over the world: including Japan, Singapore, and China to name a few. Much of it was housed at the National Resource Operations Center in Pasay City [21]. Despite this impressive response, the challenge of delivering these supplies was crippled by the disrupted transportation networks and the remote island nature of the affected regions. Even more challenging for relief workers was ensuring that the right type of supplies were delivered to the appropriate people in need. The varying social makeup of the affected regions required varying relief packages. While stockpiling policies had been instituted by government agencies, INGOs, UN agencies, and other international organizations before the storm, these supply sources were only suitable to provide the needed initial relief in the few communities where they were instituted [91].

Another shortcoming was the location and amount of appropriate housing for displaced persons. Over one million people were forced to evacuate their homes as a result of typhoon Durian. However, this process was not a smooth one. Many of the planned evacuation centers identified before the storm were unsuitable due to poor locations or disruptions in facilities. This facility location issue became a nationally recognized oversight when President Arroyo directed Vice President Noli De Castro to ensure existing shelters erected for the victims driven from their homes were safe from flooding and mudslides [19]. The safety of the evacuation shelters was not the only problem. Despite an assurance from the executive director of the NDCC, Retired Major Gen. Glenn Rabonza, that early warnings were sufficient to make fully operational all evacuation centers in the typhoons path, the sheer numbers of evacuation centers that would be needed overwhelmed the relief agencies [79]. Perhaps due to the safety and suitability concerns at many designated shelters, even the number of operational shelters seems to have been in doubt for several days following the storm passage. The day after the storm, December 1, the NDCC reported that only 229 evacuation centers were operational [85]. On December 4 the number of active shelters was reported as 72, and then rose to 450 on December 7 [21, 88]. Eventually, approximately 909 evacuation centers would be established in the region to accommodate the demand for shelter caused by Durian [68].

In the Philippines, we again see that logistical planning problems hampered the relief efforts. From the procurement and routing of emergency supplies in the face of infrastructural damage, to the location planning of the evacuation shelters, the Philippines experienced very difficult logistical problems in the wake of typhoon Durian. These problems undoubtedly led to the prolonged suffering of the victims in the Philippines.

5. Opportunities for Operations Research

5.1. Common problems

Common among the two cases we have examined are several recurring problems which delayed the appropriate aid being delivered to victims in a timely and efficient manner. This chapter will identify these common areas and discuss how operations research methods can be employed to work toward more efficient solutions.

In both cases, disaster management officials did not have an accurate grasp of the magnitude of the impending humanitarian disaster facing their country. Hampered by damage to infrastructure, specifically important transportation and communication networks, damage and needs estimates took days and even weeks to complete. In fact, the full extent of each storm's consequences was not fully realized until several weeks after they had made landfall. Due to this lack of accurate estimation and assessment capabilities both countries experienced delayed national and international responses to the suffering of their people. In addition, when initial assessments were completed, they failed to accurately characterize the magnitude of the required response or provide specific information concerning the needs of the victims.

Another problem facing emergency responders concerned the coordination of relief efforts. With myriad different national and international organizations operating in large disaster areas, gaps in service and overlapping efforts was a major concern. Relief agencies tended to work independently in areas close to their support structure where they determined there was the most need. Coordination, if at all, between agencies was informal and conducted in an ad-hoc manner. Not until the UN cluster approach was employed several weeks after each storm hit did any high level coordination of efforts take place between the many agencies working on the ground.

A third problem encountered both in Pakistan and the Philippines was one of logistics. Procurement of relief items and then the transportation of these supplies in the proper amounts to the appropriate people following both disasters proved to be extremely difficult. Questions such as how many and what supplies needed to be pre-positioned and where these supplies should be placed were vitally important logistic issues that relief agencies struggled to answer.

5.2. Determining the extent of the disaster

Accurate damage and needs assessments are crucial to an appropriate initial humanitarian response [120]. Relief agencies both public and private generate a proportionate level of response based on the predicted and estimated need in a disaster stricken region [120]. We have seen that initial damage and needs estimates generated after tropical cyclone Yemyin and typhoon Durian were hampered by the rapid onset of the storms, and a general misunderstanding of the magnitude of the humanitarian crisis. This type of error, and specifically a large underestimation such as those seen in these two countries, is not an uncommon phenomenon in the face of large disaster events [20]. The more information relief agencies can gather before an impeding disaster the better decisions they will make. The NDMA request for 2,000 tents the day before Yemyin struck illustrates how a lack of information can lead to a terrible underestimation (To date over 88,000 individual tents have been supplied to the region) [120]. Even a very general estimation with a 50 percent error would likely have prompted an earlier and more robust response in Pakistan. A baseline forecast of the magnitude of a disaster's reach might also prompt an earlier call for international assistance if one is needed. Not until Philippine president Arroyo visited cities devastated by Durian four days after the storm hit did she declare a state of national calamity, release significant recovery funds, or announce that the

Philippines was ready to accept international aid [94]. It is also logical to conclude that the consequences of an overestimation while not directly risking lives could be terribly damaging from a financial perspective.

Delays in the relief process will only heighten the peril experienced by storm victims. By waiting until after a disaster strikes to determine damage estimates and relief needs, relief agencies are foregoing days of possible response time. If information regarding the approximate scope of a humanitarian response was available to relief workers before a storm strikes, responders would gain not only the several days (and sometimes weeks) of extra time needed to estimate damage, but could start the relief process before possible logistically crippling infrastructural damage is inflicted.

5.2.1. Modeling

Given known social and infrastructural risk factors as well as the strength and location of a storm, operations research methods can produce models to asses the expected damage to a region or community. Feng and Hong for instance, have proposed a model to estimate specific flood damage resulting from storm surge [26]. Geographic Information Systems, in particular, have also been very successful in providing emergency responders with broadly applicable prediction models to estimate disaster consequences [35, 12]. One of these GIS systems is the HAZUS Hurricane model, launched in February 2004. This publicly available US model has proven to be fairly accurate when employed on a large scale [111]. Probabilistic models such as these, need to be developed for use in hazard prone areas throughout the world, and specifically in developing countries. While complex and expensive options are ideal, Feng and Hong show how relatively simple estimation procedures can provide significantly important results. The key concept of these models is to produce better decision making [50]. As a result, their applications should be specifically tailored for the decision making process emergency management officials and relief agencies will encounter when faced with an impeding storm. One such decision making tool has been proposed by Metzger. He uses hurricane track predictions to develop an evacuation decision model for emergency managers. Metzger's model weighs the costs of an unnecessary evacuation against the potential benefits gained by a timely and efficient evacuation of vulnerable populations [52].

However, even state of the art modeling tools have serious shortcomings. The HAZUS model, for instance "significantly underestimated economic losses for public and critical facilities" [111]. As a result, observed error rates for existing damage models would certainly preclude replacing rapid on-scene human generated assessments following a disaster. In fact, relief organizations have amassed a great deal of expertise for solving the intricate problems associated with disaster relief. The skilled on-scene personnel, able to react to a volatile situation, will never be replaced. Experienced responders on scene often can estimate with some accuracy the needs of their area of responsibility. The organizations on the ground in the Philippines and Pakistan were certainly staffed with skilled and experienced emergency response personnel, familiar with their specific regions and the threats they face. By seeing first hand the damage inflicted, these personnel surely recognized the general need for specific emergency supplies at the outset of both disasters [31]. However, these evaluations are hard to aggregate at an agency network level. As a result, quickly and accurately evaluating the extent of an unfolding disaster has proven to be very difficult [20, 70]. While unofficial estimates on a local level may be accurate, relief agencies often delay official damage estimates, and allocation of funding and supplies, until formal assessments have been completed. Therefore, having baseline estimates from reliable modeling sources to calibrate damage and relief need expectations before a storm even makes landfall would be an invaluable tool for responders.

5.2.2. Modeling inputs

The inputs to any damage prediction model would require knowledge of regional susceptibility in terms of geography, infrastructure (both public and private), and population characteristics. Using this information together with specific storm information in a probabilistic framework can give disaster managers vitally important information as to the expected extent of storm damage. This information in turn could lead to better emergency management decisions, saving money, reducing the suffering of victims, and possibly saving lives [36].

It is a fairly simple task to determine a region's geographic susceptibility to natural disasters. For instance, topographic particulars can be obtained from known resources such as elevation charts. Other obtainable information such as proximity to the coast, flood plains, drainage and flood protection measures, and land-slide prone areas all contribute to a region's geographic susceptibility.

Infrastructural susceptibility in a storm-prone region can also be a known commodity [43]. For instance, large and heavily traveled roadways and bridges can be studied to determine age, construction materials, condition, etc. In this manner one can assign fragility factors to specific infrastructural elements. A survey of such elements could be conducted to separate structures into building classes, or groupings of similar infrastructural elements with common characteristics. This same process can also determine the susceptibility of the average dwelling, public building, or even evacuation shelters. Public services such as water supplies, power grids, and communication networks can also be evaluated for their specific or expected susceptibility to disasters [114,115]. With an understanding of a region's infrastructural fragility, damage models can better predict the impact of a given storm on a population [25].

The specifics of a particular population would also be a major factor for any damage model to consider [45]. Population mobility, the ability of a population to relocate in order to avoid the storm's path, needs to be evaluated. Other considerations such as primary food and water sources and power supply would need to be analyzed to determine what impact a storm would have on these vital resources. For example, highly centralized and congested population centers would have vastly different susceptibilities than those of a less densely populated region [93].

5.2.3. Storm predictions

One of the most important factors for any damage model would be forecasted storm track and severity. However, equally important would be the evaluation of the forecast accuracy. Weather services worldwide have been successful in using complex models to improve the accuracy of storm location forecasts [22, 3]. However, these error rates are still significant. For instance, the 24 hour prediction of a hurricane's track in the Northern Indian Ocean is only accurate within 50 nm, 50 percent of the time [3]. Even small errors can be significantly important. A small deviation of a storm's predicted course could lead to vastly different damage estimates. Despite the relative success storm modeling has seen in regards to track forecasting, they have been less successful predicting storm severity in terms of storm surge, wind force, and rainfall amounts [22, 3]. Error rates would need to be analyzed to produce prediction probabilities given a forecasted storm track and severity. Any decision support system designed for emergency responders would certainly need these types of probability prediction models.

Recent advancements in this field have produced extremely relevant results. The United Stated National Hurricane Center (NHC) unveiled their wind probability graphic in 2006. This tool analyzes the predicted storm locations in context with historical track prediction errors to provide graphical probabilities of incursion [103]. This tool now gives emergency responders concrete data with which to make decisions. The graphic clearly indicates the probability that a given storm will produce damaging winds to a certain area of interest. (see Figure 5-1). From the emergency response vantage point, this easy to use probability analysis is a major advancement over the track probability cones previously offered [14]. This type of decision oriented tool is exactly the type of results operation research should be striving to attain [116]. This particular wind graphic tool would also be an ideal input into any emergency management decision support system.

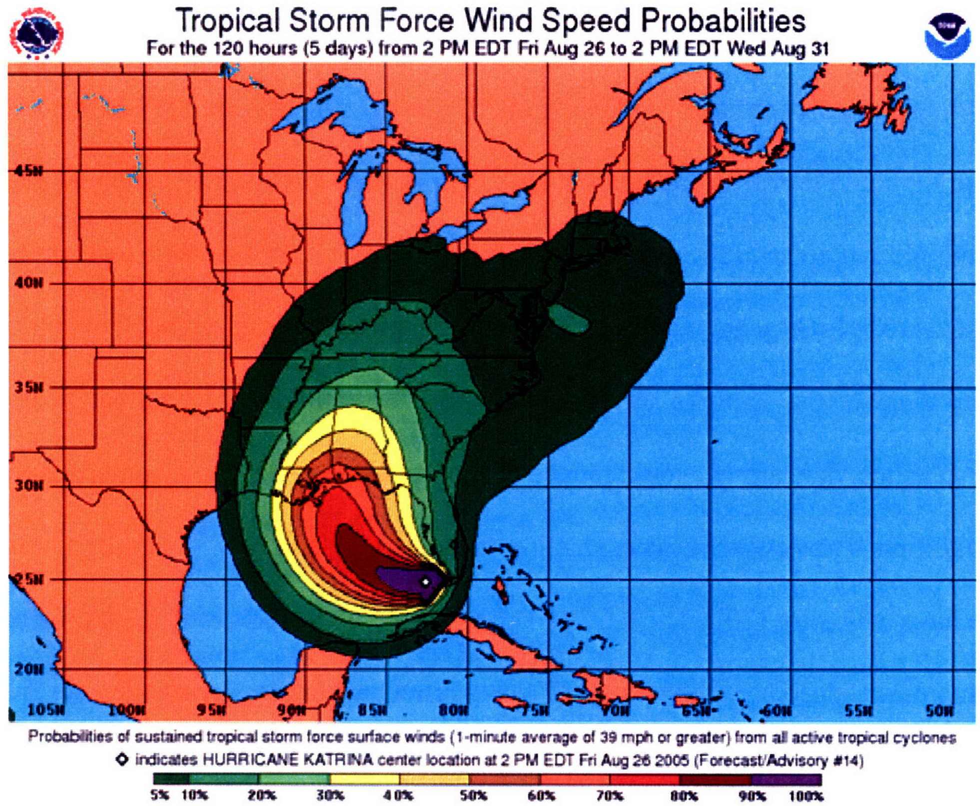

Figure 5-1 NHC Wind Probability Graphic [103]

5.2.4. Needs estimates

Responders are often left to interpret assessment findings on their own. Relief agencies would benefit from assessments or forecasts that are in more useful practical terms. As a result, almost as important as the damage forecasts, are models that would present this damage as specific relief supply needs. For example, the NDMA in Pakistan and the NDCC in the Philippines often gave damage estimates in percentages of the region affected, affected population, damaged houses, or evacuated people. The specific relief agencies were left to assess the actual amounts of relief supplies and aid needed. As a result, in the Philippines, often large bundles of generalized relief supplies were left in areas where many of the items were not needed [91]. In Pakistan, an estimate such as "50% of Turbat is affected" may be accurate, however, a needs estimate of "10,000 tents and 15,000 meals" would be much more practical information to a relief coordinator in the region. Damage estimates need to be filtered down in the appropriate relief terms. In Pakistan, it took over a week for five international aid agencies to realize that poles and plastic sheets provided a more appropriate shelter than tents in the extreme summer heat [75]. Emergency responders in the Philippines have urged the humanitarian relief community to develop a common assessment methodology and reporting format. Common reporting statistics, they argue, would reduce the confusion experienced by on-scene responders [91]. In addition, a pre-event needs estimation model would help set a standard reporting format that some have called for [70]. The amount and type of shelter, food, water, WASH, and medical supplies needed are the important facts to relief agencies trying to alleviate the suffering of storm victims. Translation of damage assessments into needed supplies would be an important aspect of any future damage estimate model.

5.2.5. Benefits of better estimates

In discussing the cooperation required to respond to such large scale disasters, Khan and Rahman stated "Disaster management is a nation-wide affair, involving each and every organization and citizen of the country. The government of any country cannot do it alone, because of resource constraints as well as the wide scope of the tasks involved. Therefore, a broad-based partnership involving all the stakeholders is a desirable and realistic approach to all stages of disaster management, namely, prevention, preparedness, response and recovery" [38]. This would also certainly be true for any effort to create a model that estimates the extent of storm effects, particularly in a developing nation [33]. Combining many elements into a damage prediction model would take significant efforts on the international, national, and local level.

However, the benefits of such a prediction tool would be immeasurable. Knowing which roads are susceptible to flooding would give responders time to lay out alternate routes, pre-stage supplies, or coordinate airlift and bridge repair capabilities in vulnerable regions. Local disaster coordinators would have strong evidence to convince local populations to take appropriate preparatory action. Storm warnings would have more persuasive arguments and evacuation orders would be more demanding. National disaster officials would have the leverage to urge political leaders to provide more aid in the form of monetary funds and manpower in a timely manner. Calls for international assistance, if required, could be made as the storm approaches as opposed to several days or weeks after the disaster strikes. In short, such a model would give a head start to local relief efforts and hasten the call for an appropriate level of relief assistance. At the very least, such a model would limit the suffering of storm victims and could possibly lead to saving more lives.

5.3. Coordination

Coordination between agencies during the initial responses to tropical cyclone Yemyin and typhoon Durian were handled locally at the ground level. While emergency response decision making expertise is often already located in a disaster stricken region, generally highly trained and experienced coordinators must be brought to the scene. While these local and industry experts are skilled coordinators, a framework for cooperation and coverage could provide baseline response coordination from which to work. Baber argued that a high level command structure is essential to optimize the response of the many agencies involved in an emergency response [4]. Organizations such as the NDMA, NDCC, and FEMA, connected to the various stakeholders, are in an ideal position to take on this planning role. Without such oversight, individual agencies or responders will not optimize the good of the overall relief effort, but rather their own area of responsibility [4, 49]. The UN cluster approach was adopted to carry out this very purpose. However, the cluster approach is designed, and was employed in both countries, after the initial response had been conducted. Therefore, the dilemma is how to provide this coordination during the early stages of a response without hampering the efforts of those on scene. Dee Goluba of Mercy Corps voiced this concern in the following manner: "Days lost on meetings and information flow is simply not ok during an acute, rapid onset emergency. While coordination and the larger picture may be under development somewhere else, nothing should hold up needed, humanitarian aid" [31].

Without prior planning, lack of coordination is quite common in disaster scenarios [51, 41]. As a result, there is a need to identify methods in which an initial response can take a more formally coordinated approach to relief efforts. As Mr. Goluba explains, this coordination cannot be done immediately after a disaster strikes [31]. Instead, priorities and responsibilities need to be allocated before the event. In order for this to happen, hazard prone regions would need to identify their existing emergency response resources and capabilities. Relief agencies, both public and private, would need to come together and share their own capability information including manpower, transportation capabilities, local expertise, stockpiled and planned access to relief supplies, and the physical location of their assets. With this information, the agencies involved could form a coordinated approach to the disaster events likely in their region. Regional partners would need to investigate the proper division of responsibilities among the different agencies likely to respond to a disaster event.

Operations research methods could greatly assist this process. Certainly a coordinated plan could be used to improve response times and distances traveled. An effective partitioning of the affected region could not only consider physical locations, but also the expertise of different organizations as well as their differing magnitudes of response capabilities. The divisions of responsibility among relief agencies might not only be geographical. An analysis might reveal that two agencies are needed to provide different types of relief efforts in the same area. This analysis would need to consider the probability of each type of disaster event and the likely amount of damage incurred to specific areas of the region. Divisions of responsibility could then be allocated based on any number of factors including geographical differences, area need, and agency expertise among others. This type of partitioning is not new to operations research [40].

The key idea of any coordination strategy would be to provide a framework. Instead of relying on ad-hoc agreements and the local knowledge of coordinators on the ground, a baseline understanding of cooperation and division of responsibilities would be in place from which to work from. With even a small amount of prior coordination, gaps in coverage and overlapping of efforts could be diminished, allowing for a more efficient regional response plan.

5.4. Logistics

In the face of uncertain transportation grids, pricing fluctuations, and varying demand, the logistical considerations for relief agencies during a disaster can be massive. In addition, during a large scale response, local supplies will be strained, placing their availability in question [24]. Since most humanitarian organizations rely on these local supply sources, it is not surprising that relief agencies in Pakistan and the Philippines encountered serious problems procuring and transporting needed relief supplies to victims.

Many of these logistical problems should be analyzed through an operations research lens even in lieu of specific circumstances to provide general principles for relief planning [41]. For instance, Lodree and Taskin describe a manufacturer or retail stochastic inventory control problem given a forecasted tropical storm landfall. By incorporating storm predictions with historical demand following such events, they propose a dynamic programming algorithm to model demand behavior during a destructive storm [48]. While their analysis focused on a manufacturer or retail sales in the United States, the same principles could be applied to relief agencies in a particular region. In this instance, the relief agency (the retailer) has both demand surges and supply constraints. Since most humanitarian agencies rely completely on local supplies, a large response will test its ability to meet these demand surges efficiently [24]. This type of demand and supply chain analysis should be extended to explore relief agency supply planning in the face of an impeding storm.

One possible solution is the strategic placement of warehouses and stockpiling of supplies [24]. Although operations research methods could also answer the critical questions of how much, what kind, and where relief supplies should be stockpiled based on the risk associated with these regions, there is very little literature on these inventory problems [119]. One promising exception, Whybark argues, is the medical field, which may be useful in providing vetted models for the vitally important task of managing disaster relief inventories [119]. Many of the donations sent to the Philippines were stocked in a single warehouse [21]. Multiple warehouses located strategically around the country may have expedited the transportation of aid to victims. Furthermore, with the possibility of fractured and damaged networks these methods become even more complex and important [41]. These ideas also need to be incorporated into locating evacuation centers, shelters, and emergency relief operation centers, for instance. A careful analysis would prevent evacuation centers being placed in flood prone areas and ensure enough space is allocated to meet the expected needs for beds even given disruptions to the network.

Transportation logistics models have also been described. Barbarosoglu and Ozdamar, for example, both provide stochastic and network flow models to plan for transportation logistics during disaster situations [6, 71]. These models would provide valuable planning and real time logistical efficiency for responding agencies. With a storm's probabilistic risk framework in place, relief agencies could also analyze their options of procurement sources and transportation options. A clear understanding of the probability of anticipated demand would lead to more optimal supply contracts and agreements and more robust transportation planning [99].

The challenges of handling logistical and supply chain problems in the face of an emergency response situation are numerous. While many models have been proposed, and some outlined in this thesis, we have yet to see many solutions to these particular problems in the context of a developing nation. However, it is exactly these emergency managers with challenges such as fewer resources, less flexibility in their procurement options, and limited delivery routes, who would benefit the most from efficient solutions to these complicated problems.

6. Conclusion

This thesis has looked at two tropical storm events and identified three areas where the field of operations research may provide exciting opportunities to improve the current effectiveness of humanitarian response. Accurate forecasts of damage and needed relief supplies would provide context for and give all responders a general understanding of the magnitude of a disaster. The sooner relief agencies understand the magnitude of what will be required of them, the sooner they can act to provide the needed relief. Early forecasts would enable more appropriate warnings for vulnerable populations and timely petitions for outside assistance. Baseline forecasts of need would also help fill in gaps in assessment capabilities such as those experienced in Pakistan and the Philippines due to limitations in communications and transportation functionality. In addition, responders trying to reach stranded regions would have specific ideas of what kind of relief need they will encounter when the region becomes accessible. Better coordination of the efforts of the many participating agencies would help to ensure those that need help are getting their needs met in the most efficient manner. Finally, with a scientific approach to disaster preparedness, relief agencies could efficiently prepare for and execute the complicated procurement, inventory planning, and transportation efforts required by such disruptive and demanding events.

Methods of operations research hold the promise of making substantial improvements to the effectiveness of emergency relief agencies world wide. These gains will be observed in better forecast accuracies, improved relief agency partnerships, and cost effective procurement contracts. However, most importantly, operations research methods can and should be used to directly alleviate the suffering of victims.

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