Special Report

◆◆◆

Effects of Natural Disasters on the Health Infrastructure: Lessons from a Medical Perspective[1]

JOSÉ LUIS ZEBALLOS[2]

Latin America and the Caribbean have not been spared their share of natural disasters. Almost every year catastrophic events cause deaths, injuries, and enormous economic damage. Besides "ordinary" floods that afflict most countries in the region nearly every year, in 1982–1983 the "El Niño" phenomenon produced a combination of flood and drought that directly affected over 3.7 million people in Bolivia, Ecuador, and Peru (*1*). In the second half of the 1980s, Chile, Costa Rica, Ecuador, Mexico, Panama, and Peru were all struck by earthquakes; the one in Mexico alone slew an estimated 10 000 people and destroyed thousands of buildings. When the Nevado del Ruiz volcano erupted in Colombia in 1985, the city of Armero was buried beneath a mudslide and 23 000 people were killed. Hurricanes Gilbert and Joan in 1988, and Hurricane Hugo in 1989, created swaths of major destruction in the Caribbean, Colombia, Nicaragua, and Mexico (*2*).

Overall, it is estimated that the major natural disasters of the last two decades in this region caused property losses affecting nearly 8 million people, some 500 000 injuries, and 150 000 deaths. These figures rely heavily on official sources. (It is quite difficult to obtain accurate information in sudden-onset disasters, because there are multiple information sources and no standardized information system.) The Economic Commission for Latin America and the Caribbean (ECLAC) estimates that during an average year, disasters in Latin America and the Caribbean cost 1.5 billion dollars and take 6 000 lives (*2*).

Table 1 lists major natural disasters that struck countries of the Region in the 1970–1990 period. It should be noted that slow-onset disasters, such as droughts and floods, are not included.

ECONOMIC IMPACT

In recent decades, ECLAC has carried out extensive research on the social and economic impacts of disasters. This has clearly demonstrated that disasters have negative repercussions on social and economic development in developing countries. Indeed, the monetary losses incurred by a major disaster often exceed the total annual gross income of the af-

[1]This contribution was also published in Spanish in the *Boletín de la Oficina Sanitaria Panamericana*, Vol. 115, No. 5, 1993.

[2]Adviser, Office of Emergency Preparedness and Disaster Relief, PAHO, Washington, D.C., U.S.A.

Table 1. Major disasters in Latin America and the Caribbean, 1970–1990.

Year	Country	Type of disaster	No. of deaths reported	Est. no. of people affected
1970	Peru	Earthquake	66 797	3 139 000
1972	Nicaragua	Earthquake	10 000	400 000
1976	Guatemala	Earthquake	23 000	1 200 000
1980	Haiti	Hurricane (Allen)	220	330 000
1982	Mexico	Volcanic eruption	3 000	60 000
1985	Mexico	Earthquake	10 000	60 000
1985	Colombia	Volcanic eruption	23 000	200 000
1986	El Salvador	Earthquake	1 100	500 000
1988	Jamaica	Hurricane (Gilbert)	45	500 000
1988	Mexico	Hurricane (Gilbert)	250	200 000
1988	Nicaragua	Hurricane (Joan)	116	185 000
1989	Montserrat, Dominica	Hurricane (Hugo)	56	220 000
1990	Peru	Earthquake	21	130 000

Source: PAHO/OFDA (USAID)/UNDRO.

fected country. Not surprisingly, such events can paralyze affected countries and foster widespread political and social turmoil.

In essence, disasters have three kinds of economic impacts:

- Direct impacts on the affected population's property.
- Indirect impacts caused by lost economic production and services.
- Secondary impacts that become apparent after the disaster—such as reduced national income, increased inflation, foreign trade problems, heightened financial expenses, a resulting fiscal deficit, decreased monetary reserves, etc. (2).

Table 2 shows the estimated economic losses caused by six major natural disasters. While such losses might not seem particularly devastating for developed countries with strong economies, they can have a serious and lasting impact on the weak and vulnerable economies of developing countries (2). For example:

- In Bolivia, Ecuador, and Peru, droughts and flooding associated with "El Niño" reduced internal per capita income by an estimated 10% and raised the retail prices of some foods by up to 50%.
- In Mexico, losses from the 1985 earthquake totaled only 2.7% of the Gross National Product (GNP); but financial expenditures for urgent re-

Table 2. Losses due to six natural disasters.

Disaster	Location	Year(s)	Total losses (US$ millions)
Earthquake	Mexico	1985	4 337
Earthquake	El Salvador	1986	937
Earthquake	Ecuador	1987	1 001
Volcanic eruption (Nevado del Ruiz)	Colombia	1985	224
Floods, drought ("El Niño")	Peru, Ecuador, Bolivia	1982–1983	3 970
Hurricane (Joan)	Nicaragua	1988	870

Source: PAHO/ECLAC.

construction and restoration of services strained the economy by increasing the demand for public funds at a time when Mexico was implementing a fiscal austerity policy.

- In El Salvador, the 1986 earthquake's social consequences included housing shortages, high unemployment (26–35%), and reduced public health facilities. (These and other economic side-effects were aggravated by ongoing guerrilla warfare.)
- Hurricane Joan, which wrought severe destruction along Nicaragua's Atlantic coast in 1988, damaged an already deteriorating economy during a difficult political period.

THE HEALTH INFRASTRUCTURE

In any major disaster-related emergency, the first priority is to save lives and provide immediate emergency care for the injured. Among the emergency medical services mobilized for these purposes, hospitals play a key role. Indeed, in countries with a standardized emergency response system (one where the concept of "emergency medical services" encompasses provision of emergency care through the coordination of independent subsystems involving paramedics, firemen, and rescue teams) hospitals constitute the major component of that system (3).

Hospitals and other health care facilities are densely occupied. They house patients, personnel, and visitors, and they operate 24 hours a day. Patients may be surrounded by special equipment or connected to life-support systems dependent on power supplies. According to project documents available from the Inter-American Development Bank (IDB), the estimated cost of one hospital bed in a specialized hospital varies from country to country, but the average runs from US$ 60 000 to US$ 80 000 and is greater for highly specialized facilities.[3] (In the United States, particularly California with its extensive experience in anti-earthquake engineering, the cost of one hospital bed can exceed US$ 110 000.) In sum, modern hospitals are highly complex facilities combining the functions of hotels, offices, laboratories, and warehouses (4).

These health care facilities are highly vulnerable to hurricanes and earthquakes. This has been amply demonstrated by past experience in Latin America and the Caribbean. For example, as Table 3 shows, just three disasters of the 1980s damaged 39 hospitals and destroyed some 11 332 hospital beds in El Salvador, Jamaica, and Mexico. Besides damage to these physical plants at critical times, the loss of human life (including the death of highly qualified local professionals with promising futures) needs to be considered.

At present the ability of many Latin American hospitals to survive earthquake disasters is uncertain. Many such hospitals are housed in old structures, some dating from Spanish colonial times; and while many others occupy contemporary buildings of appealing architectural design, lax application of antiseismic building codes makes their ability to resist earthquakes questionable.

PAHO has steadily promoted and supported organizational measures in Latin American and Caribbean countries that are directed at improving the health sector's ability to confront disasters. Within this context, the disaster preparedness of hospitals is treated as a cornerstone of the institutional response capability. With regard to this specific matter, it appears that countries of the Region are taking past experience to heart and are starting to seriously consider the need to protect

[3]Tomas Engler, Inter-American Development Bank, Washington, D.C. Personal communication.

the health infrastructure as part of the effort to organize an effective emergency response (*5*).

SELECTED CASES

The following summary of selected cases illustrates the effects caused by disasters to the health services:

The 1985 Mexico Earthquake

The epicenter of this 8.1 magnitude earthquake, occurring 19 September, was located off the Pacific coast of the state of Michoacán. The quake killed approximately 10 000 people; 30 000 of the injured received emergency medical care in the first days after the event.

This disaster destroyed or severely damaged 13 highly complex hospitals. As a consequence, a total of 4 387 hospital beds were lost (Table 4). Of the 10 000 people who died in the earthquake, 856 (over 8%) died while trapped inside two major hospitals (the Hospital Juárez and the Hospital General) in Mexico City (*6*) (Table 5).

Table 3. Numbers of hospitals and hospital beds damaged or destroyed by three major natural disasters.

Type of disaster	No. of hospitals damaged or destroyed	No. of beds lost
Earthquake, Mexico (Federal District, September 1985)	13	4 387
Earthquake, El Salvador (San Salvador, October 1986)	4	1 860
Hurricane Gilbert (Jamaica, September 1988)	23	5 085
Total	40	11 332

Source: PAHO/OFDA (USAID)/ECLAC.

Table 4. Operating hospitals and available beds in the Mexico City Metropolitan Area before and after the 1985 earthquake.

Resources	Health ministry	Social security	Government employees social security	Family development	Others	Private sector	Total
Hospital types II and III:							
Before	17	37	9	24	8	23	118
After	15	28	7	24	8	23	105
Lost	2	9	2	0	0	0	13
Available beds:							
Before	4 975	8 197	2 427	1 807	1 383	760	19 549
After	4 230	5 422	1 560	1 807	1 383	760	15 162
Lost	745	2 775	867	0	0	0	4 387

Source: Health Ministry of Mexico, Office of Epidemiology.

Table 5. Victims in two hospitals collapsed by the 1985 earthquake in Mexico.

	Collapsed hospitals			
	General		Juárez	
	No.	%	No.	%
Fatalities	295	62.6	561	75.8
Rescued	129	27.4	179	24.2
Missing	47	10.0	—	—
Total	471	100.0	740	100.0

Source: PAHO, *Crónicas de desastre: terremoto en México*, Washington, DC, 1987.

The 1986 El Salvador Earthquake

In October 1986 a moderate earthquake hit El Salvador, causing approximately 1 500 deaths and 10 000 injuries (*7*). The quake severely affected four hospitals and destroyed several health centers. The cost of urgently needed health facility repairs was initially estimated at US$ 98 520 000 (see Table 6).

The 1985 Chile Earthquake

A 7.8 magnitude earthquake struck heavily populated areas of Chile in March 1985, causing 180 deaths and some 2 500 injuries (*8*). The havoc wrought included structural damage to 22 of the 79 existing hospitals in the affected area. As a consequence, 3 271 hospital beds were lost, 73% of them in the Santiago Metropolitan Area (Table 7).

Hurricane Gilbert, Jamaica, 1988

Like earthquakes, hurricanes (affecting mainly the Caribbean) have caused severe damage to the health infrastructure. Specifically, there have been many occasions when hurricane-strength winds have ripped roofs off hospitals, caused heavy rains to flood the facilities, and wrought irreparable damage.

In 1988, Hurricane Gilbert did an estimated US$ 4 billion worth of damage to Jamaica. Only two of the country's 25 public hospitals escaped the hurricane's ravages with minimal damage. Two hospitals were completely destroyed and 11 others sustained severe damage (*9*).

Table 6. Projected health sector investment required for hospital reconstruction, repairs, and equipment in El Salvador following the October 1986 earthquake.

Items	Projected investment required (US$ thousands)
Reconstruction and equipment, general hospital	16 000
Reconstruction and equipment, children's hospital	15 000
Reconstruction and equipment, social security hospital	24 000
Reconstruction and equipment, 9 health care centers	26 600
Rehabilitation, maternity hospital	200
Rehabilitation, 7 health care centers	1 520
Rehabilitation and construction, both military hospitals	13 000
Rehabilitation, 9 private health care centers	2 000
Construction, pediatric hospital	200
Total	98 520

Source: ECLAC, 1986.

Table 7. Hospital beds lost as a result of the March 1985 Chilean earthquake.

Region	No. of existing hospitals	No. of beds	Beds lost	
			No.	% in region
Metropolitan Area (Santiago)	26	11 464	2 373	20.7
Region 5 (Viña del Mar, Valparaíso, San Antonio)	23	4 573	622	13.6
Region 6 (Rancagua)	15	1 413	212	15.0
Region 7 (Ralca, Meula)	15	2 286	64	2.8
Total	79	19 736	3 271	16.6

Source: Wyllie L, Durkin M, et al. (*8*).

RISK FACTORS IN EARTHQUAKES

Of the various types of sudden natural disasters, earthquakes are by far the most damaging to hospitals. Of course, each earthquake has its own characteristics relating to its epicenter, type of seismic waves, geologic nature of the soil through which the waves travel, etc. Nevertheless, studies have revealed certain common factors that tend to cause death and injuries and certain others that tend to prevent them. These factors include structural characteristics related to building failure, various factors related to human behavior, and certain characteristics of nonstructural equipment, furnishings, and other items inside buildings.

In recent years, scholars and planners have been paying special attention to identification of risk factors affecting hospitals in hopes of framing better recommendations and norms to govern the building and organization of hospitals in highly vulnerable zones.[4] A brief listing of relevant risk factors is shown in Table 8. These risk factors, particularly those related to the structural aspects of construction, were observed to influence patterns of destruction during a December 1988 earthquake in Armenia that killed some 25 000 people, affected 1 100 000, and destroyed or severely damaged 377 schools, 560 health facilities, and 324 community and cultural centers (*11*).

Damage on a similar scale occurred in June 1990, when an earthquake in Iran killed about 40 000 people, injured 60 000 others, left 500 000 homeless, and collapsed 60% to 90% of the buildings in affected zones (*12*).

To address these and like calamities, an international seminar was held in Lima, Peru, in 1989 on the planning, design, repair, and management of hospitals in earthquake-prone areas. The seminar, sponsored by PAHO, Peru's National University of Engineering, and the Peruvian-Japanese Center for Seismic Research (CISMID), brought together architects, engineers, and hospital administrators to study issues related to health facilities located in these areas. The seminar approved a core of technical recommendations and commitments directed at carrying out vulnerability analyses of hospital infrastructures, improving the design of new facilities, and establishing safety measures for existing hospitals with emphasis on those located in high-risk earthquake areas (*13*).

[4]One country that has been making a concerted dedication of financial resources to reinforce its hospital infrastructure, following several experiences with earthquakes in the 1980s, is Costa Rica. This effort, made despite a difficult economic situation confronting the nation, has given special priority to damage prevention activities in public hospitals (*13*).

Table 8. Risk factors associated with earthquake damage to hospital infrastructure.

Structural	Nonstructural	Behavioral
Design	Medical equipment	Public information
Quality of construction	Laboratory equipment	Motivation
Materials	Office equipment	Plans
Soil conditions	Cabinets, shelves	Educational programs
Seismic characteristics	Stoves, refrigerators, heaters	Health care staff training
Time of the event	X-ray machines	
Population density	Reactive materials	

RECOMMENDATIONS ON HOSPITAL PREPAREDNESS

As the foregoing suggests, hospital disaster preparedness constitutes an important component of PAHO's Office of Emergency Preparedness and Disaster Relief. Over the last 10 years, member countries have been encouraged to pursue activities directed toward this end, including the following:

- Classifying hospitals according to their risk factors and vulnerabilities.
- Developing internal and external hospital response plans and training personnel.
- Developing contingency plans and establishing safety measures for the professional and technical hospital staffs.
- Strengthening lifeline backup systems that help hospitals to function during emergency situations.

More broadly, a principal aim of the current International Decade for Natural Disaster Reduction (IDNDR) is to attract, motivate, and commit national health authorities and policy-makers around the world, thereby encouraging them to strengthen the health services directed at coping with disasters and to reduce the vulnerability of those services in the developing world.

Acknowledgment. The author is indebted to Ms. Alicia Pomé for secretarial support in preparation of the manuscript.

REFERENCES

1. Jovel JR. *Los efectos económicos y sociales de los desastres naturales en América Latina y el Caribe*. Santiago, Chile: ECLAC; May 1991:7–15. [Document presented at the First Regional UNDP/UNDRO Disaster Management Training Program in Bogotá, Colombia].
2. Pan American Health Organization. *Analysis of PAHO's Emergency Preparedness and Disaster Relief Program*. Washington, DC: PAHO; 15 March 1989:1–20. (Executive Committee document SPP12/7).
3. Peisert M, comp; Cross RE, Riggs LM, eds. *The hospital's role in emergency medical services systems*. Chicago: American Hospital Publishing; 1984:1–10.
4. Federal Emergency Management Agency. *Seismic considerations: health care facilities*. Washington, DC: FEMA; 1990:7–15. (Earthquake Hazard Reduction Series, 35).
5. Pan American Health Organization. Volume 1: *Health Conditions in the Americas*. Washington, DC: PAHO; 1990:202–205. (Scientific publication 524).
6. Zeballos JL. Health aspects of the Mexico earthquake. *Disasters (United Kingdom)*. 1986;10(2):141–149.
7. Comisión Económica para América Latina y el Caribe. *El terremoto de 1986 en San Salvador: daños, repercusiones y ayuda requerida, perfiles de proyectos*. New York: ECLAC; 1987:1–50.

8. Wyllie L, Durkin M, et al. The Chile earthquake of March 3, 1985: casualties and effects on the health care system. *Earthquake Spectra.* 1986;2(2):489–495.
9. Pan American Health Organization. *Hurricane Gilbert in Jamaica.* Washington, DC: PAHO; 1988:6. (Disaster report 5).
10. Cruz MF. *Comportamiento de hospitales en Costa Rica durante los sismos de 1990.* Bogotá: 1991:1–27. [Document presented at the Regional PNUD/UNDRO Workshop on Training for Disasters].
11. U.S. Agency for International Development, Office of Foreign Disaster Assistance. *Soviet Union: earthquake.* Arlington: USAID; 1989:24–25. (OFDA/AID Annual Report, FY 1989).
12. United Nations Disaster Relief Coordinator Office. Iran earthquake. *UNDRO news, July-August 1990.* 1990;(Sep):4.
13. Centro Peruano-Japonés de Investigaciones Sísmicas y Mitigación de Desastres, Universidad Nacional de Ingeniería. *Seminario International de Planeamiento, Diseño, Reparación y Administración de Hospitales en Zonas Sísmicas: conclusiones y recomendaciones.* Lima: CISMID/Univ Nacional de Ingeniería; 1989:1–9.

♦♦♦

Mitigation of Disasters in Health Facilities

Hospitals are especially critical to community survival in the event of a disaster, but because of their high level of occupancy and special equipment and supplies, they are particularly vulnerable to natural disasters. In the past 20 years, more than 100 health facilities in the Americas have been damaged by earthquakes, and one-fifth of the these structures either collapsed or had to be demolished.

Reducing the impact of sudden disasters through improved design, construction, and repair of hospitals is the subject of a new four-volume series entitled *Mitigation of Disasters in Health Facilities: Evaluation and Reduction of Physical and Functional Vulnerability,* published by PAHO's Office of Emergency Preparedness and Disaster Relief. The series is aimed at four different audiences. The first volume, "General Issues," provides an introduction to the topics of vulnerability and risk mitigation in health facilities. The second volume, "Administrative Issues," includes chapters on hospital emergency plans and training, topics of particular interest to health administrators. Volumes 3 and 4 ("Architectural Issues" and "Engineering Issues") were written for architects and engineers.

The series is available in Spanish and English. It may be obtained free of charge from the Office of Emergency Preparedness and Disaster Relief, Pan American Health Organization, 525 Twenty-third Street, N.W., Washington, D.C. 20037, U.S.A.; fax (202) 775-4578.

Source: World Health Organization. Press release WHO/78. Geneva, 12 October 1993.