It is almost always the case that, when struck by large-scale natural disasters, hospital services are interrupted temporarily or permanently, mainly due to damage to their infrastructure. The operational loss of these facilities can mean the partial or complete loss of significant capital investments. Far more importantly, such catastrophic events often leave a severe and lasting scar on the welfare and the socioeconomic development of the population and the country.

In recent years, various PAHO/WHO member states have managed to reduce the vulnerability of their hospitals; several of them went on to withstand successfully the effects of subsequent disasters. Even countries with limited financial resources can serve their populations well by providing them with hospitals and other health facilities that are resistant to earthquakes, hurricanes, and other natural hazards.

This handbook, produced in conjunction with the PAHO/WHO Collaborating Center for Disaster Mitigation in Health Facilities at the University of Chile, puts forward three potential levels of protection from adverse events, or performance objectives: life safety, investment protection, and functional protection

PAHO/WHO recommends that essential areas and components of hospitals be built in keeping with the third and most demanding performance objective, and that any new health facility be built entirely so as to meet, at least, the first level of protection, namely life safety.

International experience has shown that applying this philosophy to the construction of a new hospital, even when meeting the third performance objective, only adds about 4 percent to the total cost of the project. This is the maximum amount that hospital authorities, project designers, builders and financial agents must weigh against the social, political and economic costs arising from the interruption or total loss of vital services at the very time that they are needed the most. By contrast, applying innovative approaches when designing and selecting the site of a new facility can improve its safety and efficiency without significantly increasing overall costs.

This handbook seeks to spread far this new vision of the conception and construction of public health infrastructure. It is to be hoped that health-sector managers, professionals, and technical consultants entrusted with managing, designing, building, and inspecting new health facilities may benefit from its reading and discussion.

This publication can be consulted on the Internet at:

www.paho.org/disasters

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PROVENTION

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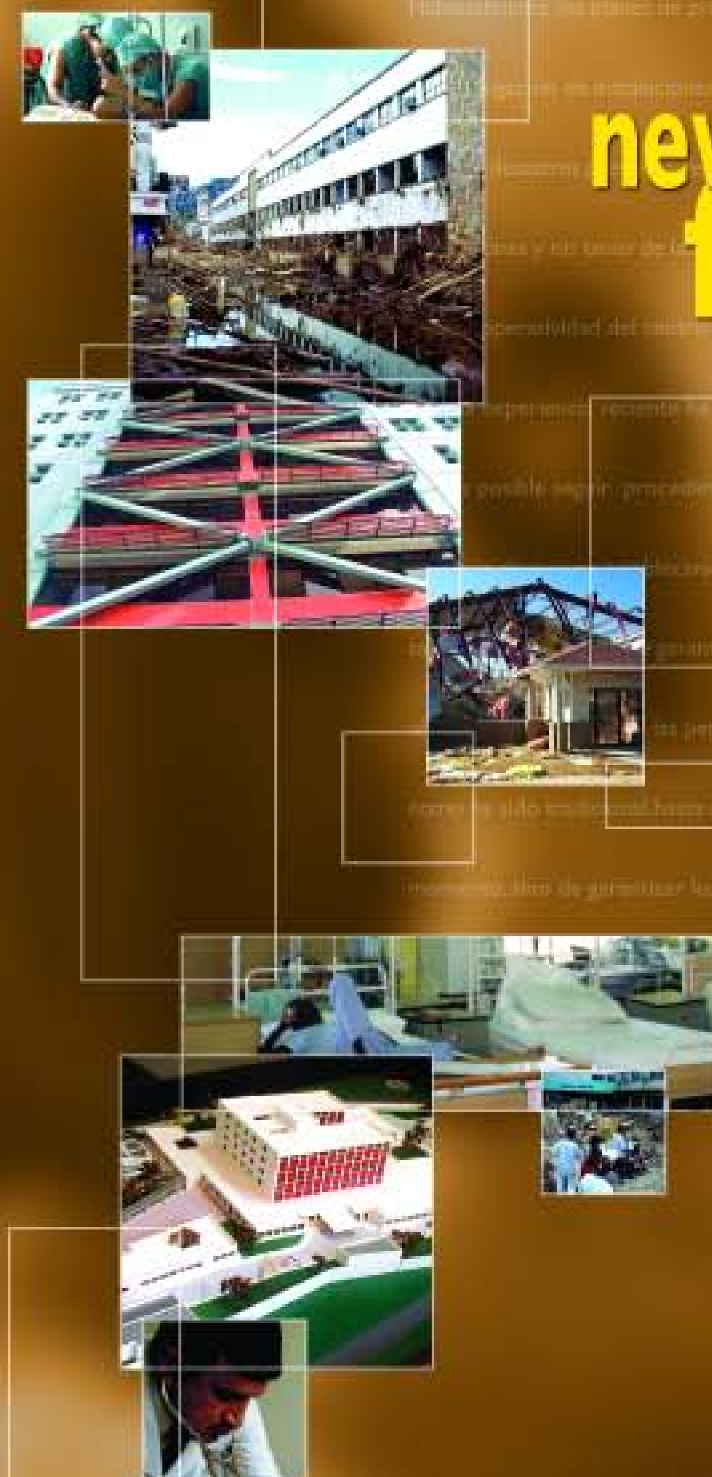

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PROVENTION

Guidelines for Vulnerability Reduction in the Design of New Health Facilities

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University of Chile

Pan American Health Organization
Regional Office of the
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A great number of professionals and experts in disaster mitigation have participated in the preparation and revision of this publication. It was revised and validated at the International Meeting *Hospitals in Disasters—Handle with Care*, celebrated in El Salvador, in July 2003. The new version produced was submitted to the technical criteria of the Disaster Mitigation Advisory Group (DiMAG) created by PAHO/WHO.

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Photos: PAHO/WHO
Page 5 photo of scale model courtesy of architect Micaela Baroni.

Contents

Preface

Keeping hospitals in operation consumes nearly two thirds of total public health spending in Latin American and the Caribbean. Hospitals are an investment of major social significance, and funding for their construction often comes from international loans.

It is almost always the case that, when struck by large-scale natural disasters, hospital services are interrupted temporarily or permanently, mainly due to damage to their infrastructure. The operational loss of these facilities can mean the partial or complete loss of significant capital investments. Far more importantly, such catastrophic events often leave a severe and lasting scar on the welfare and the socioeconomic development of the population and the country.

In recent years, various PAHO/WHO member states have managed to reduce the vulnerability of their hospitals; several of them went on to withstand successfully the effects of subsequent disasters. Even countries with limited financial resources can serve their populations well by providing them with hospitals and other health facilities that are resistant to earthquakes, hurricanes, and other natural hazards.

For this to happen, however, a change of strategy must take place—one that ensures that new, remodeled or extended facilities enjoy greater safety from adverse natural events.

This handbook, produced in conjunction with the PAHO/WHO Collaborating Center for Disaster Mitigation in Health Facilities at the University of Chile, puts forward three potential levels of protection from adverse events, or performance objectives:

a) *Life safety* – ensuring that the building will not collapse before evacuation can take place, and that any injuries that occur will not put the life of patients and staff at risk.

b) *Investment protection* – significantly reducing structural and non-structural damage, even though the facilities may be rendered temporarily non-operational.

c) *Functional protection* – guaranteeing that the facilities will continue to operate and serve the community with a minimum of disruption.

PAHO/WHO recommends that essential areas and components of hospitals be built in keeping with the third and most demanding performance objective, and that any new health facility be built entirely so as to meet, at least, the first level of protection, namely life safety.

International experience has shown that applying this philosophy to the construction of a new hospital, even when meeting the third performance objective, only adds about 4 percent to the total cost of the project. This is the maximum amount that hospital authorities, project designers, builders and financial agents must weigh against the social, political and economic costs arising from the interruption or total loss of vital services at the very time that they are needed the most. By contrast, applying innovative approaches when designing and selecting the site of a new facility can improve its safety and efficiency without significantly increasing overall costs.

This handbook seeks to spread far this new vision of the conception and construction of public health infrastructure. It is to be hoped that health-sector managers, professionals, and technical consultants entrusted with managing, designing, building, and inspecting new health facilities may benefit from its reading and discussion.

Mirta Roses
Director
Pan American Health Organization,
PAHO/WHO

Introduction

The experience of several countries shows that it is possible to employ a methodology for the design and construction of new health facilities that is capable not only of ensuring the safety of human lives, as has been the case until now, but of guaranteeing the safety of the investment in the facility and its continued operation as well. Depending on the characteristics of the health network and the economic resources available, it is possible to build health facilities that enjoy a high level of functional and investment protection. While it may not be expected that such facilities will remain intact and fully functional during and immediately following any emergency, it is reasonable to expect them to recover in a short time, and at a reasonable cost. Finally, if resources are limited or natural or technical conditions do not allow it, health facilities can still be built that, confronted with severe natural phenomena, will suffer moderate or even considerable damage without imperiling the lives of their occupants.

In order to meet different protection objectives, it is necessary to establish new design and construction criteria—and engage in quality assurance from start to finish. Experience shows that the financial cost of applying these measures represents less than 4 percent of the total construction cost, and in some cases is practically zero, since it only implies choosing a different location or changing the underlying design philosophy. In any case, the amount is marginal when compared to the economic costs of retrofitting or rehabilitating a structure damaged by a natural disaster—not to mention the social, political, and economic impact of the temporary or permanent loss of a health facility.

The traditional stages in the project development cycle for the construction of new health facilities are outlined below.

Phase 1: Preinvestment

Stage I. Identification of the need for a new health facility. At this stage, consideration is made of variables such as the characteristics of the existing health care network, current development policies, the rate of utilization of existing services, expected demand, epidemiological and demographic profiles, health policies, and geographical characteristics of the area. Directly associated with Stage I is the search for financing for the development of the new facility.

Stage II. Assessment of options to meet this need. At this stage the various options for meeting the need for a new health facility are identified, assessed, and compared. The definitive location of the facility is an essential variable in this process.

Stage III. Medical/architectural program and preliminary plans. In this stage the services and spaces desired are defined and preliminary plans are drafted in order to determine the functional relations and basic characteristics of the new infrastructure.

Phase 2: Investment

Stage IV. Project design. In this stage the project plans, specifications, budget, and tender documents are drawn up.

Stage V. Construction. At this stage, the new infrastructure is built.

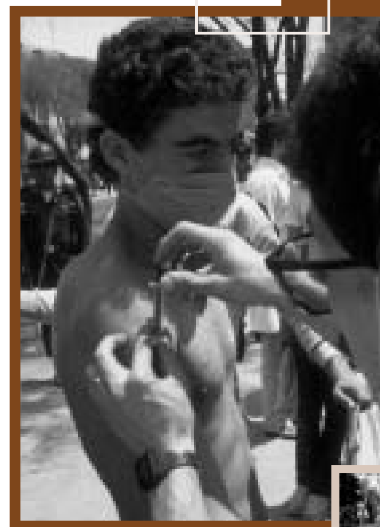
Phase 3: Operations

Stage VI. Operations and maintenance. While this stage is not part of the development of the new infrastructure, it is indispensable to define in advance how the facility will operate and remain functional.

The chief purpose of this handbook is to assist health sector administrators and professionals whose mission is the management, design, construction, and inspection of new hospitals, laboratories, and blood banks, with a view to protecting the infrastructure and operation of these facilities. With this in mind, improved criteria for the various project development stages will be described in the pages that follow, and the procedures for selecting the performance objective will be specified. We will also discuss how to assess the various siting, design, and construction options, as well as how to select the professional teams that will be involved in the project. While this handbook is not a design or building code, relevant basic concepts will be presented, and reference will be made to specific documents listing the appropriate technical recommendations needed to meet the performance objectives desired.

In preparing this handbook, only some natural hazards have been taken into account: seismic events, hurricanes and strong winds, landslides, floods, and volcanic eruptions. Other phenomena—such as drought, fire, or man-made hazards—have been excluded. It is important to acknowledge that different natural phenomena present different challenges to the development of a project. In the case of floods or volcanic activity, generally the only technically and financially feasible option is to select a site that offers the desired level of safety. If landslides, mudslides, or floods are the prevailing hazards, it is often possible to modify the variables that control the phenomenon—for instance, by planting trees, or building ditches and other water-diversion structures. When it comes to seismic events, hurricanes and strong winds,in addition to choosing the site correctly, it is necessary to design the structures so that they are resistant to such phenomena. In the specific case of earthquakes, it is necessary to provide safety to the entire infrastructure, both internal and external. In the case of strong winds, protection efforts should focus mainly on exposed external components.

In extreme situations, the only solution is to distribute the risk by building not one facility but several, distributed spatially, that can perform the desired health care functions. Locations in different sites should improve the odds of effective protection, since even if some of them are affected, functional damage will not be total. Being aware of these differences and options should facilitate appropriate and cost-effective risk management.




HOSPITAL
SAN MARCOS

Chapter 1

Natural Disasters and Health Facilities

1. Introduction

Major natural disasters in the last two decades have affected at least 800 million people worldwide, causing thousands of deaths, as well as economic losses of more than 50 billion dollars.[1] Growing population density in several regions of the planet—and the consequent settlement of high-risk areas—are likely to make matters worse. In Latin America and the Caribbean, hundreds of health installations were severely damaged by the action of natural phenomena. Earthquakes, floods, landslides, hurricanes, among others, caused severe damage not only to the infrastructure, but also the loss of human lives and the interruption of the operation of health facilities, whose function is imperative, even more so during critical times.

Tables 1.1 through *1.3* show some of the effects of adverse natural phenomena on health infrastructure.

Adverse natural phenomena affect health systems' operations both directly and indirectly.[2]

- Σ Direct effects include:
  - Damaged health care facilities;
  - Damaged infrastructure accross the locality (including the destruction of access roads), leading to the breakdown of public services that are indispensable to health facility operations.
- Indirect effects include:
  - An unexpected number of deaths, injuries, or disease outbreaks in the affected community, exceeding the capacity of the local healthcare network to provide treatment;
  - Spontaneous or organized migrations away from the affected area towards other areas where health system capacity may be overwhelmed by the new arrivals;

1 Noji, E. *The Public Health Consequences of Disasters*, Oxford University Press, 1997.
2 Adapted from E. Noji, *The Public Health Consequences of Disasters*, Oxford University Press, 1997.

- Increases in the potential risk of a critical outbreak of communicable diseases, and an increase in the risk for psychological diseases among the affected population;
- Food shortages leading to malnutrition and weakened resistance to various diseases.

Table 1.1 Effects of hurricanes on health systems

Location and event	Year	Nature of the phenomenon	Overall effects
Jamaica, Hurricane Gilbert	1988	Category 5	Twenty-four hospitals and health centers damaged or destroyed; 5,085 patient beds lost.
Costa Rica and Nicaragua, Hurricane Joan	1988	Category 4	Four hospitals and health centers damaged or destroyed.
Dominican Republic, Hurricane Georges	1998	Category 3	Eighty-seven hospitals and health centers damaged or destroyed.
Saint Kitts and Nevis, Hurricane Georges	1998	Category 3	Joseph N. France Hospital in Saint Kitts suffered severe damage; 170 beds lost.
Honduras, Hurricane Mitch	1998	Category 5	Seventy-eight hospitals and health centers damaged or destroyed. Honduras' national health network severely affected and rendered inoperative just as over 100,000 people needed medical attention.
Nicaragua, Hurricane Mitch	1998	Category 5	One-hundred eight hospitals and health centers damaged or destroyed.

Sources: Based on *Natural Disasters: Protecting the Public Health*, Scientific Publication No. 575, Pan American Health Organization, 2000; *Health in the Americas*, 2002 Edition, Volume I, Pan American Health Organization, 2002.

Table 1.2 Effects of floods on health systems

Location	Date	Nature of the phenomenon	Overall effects
Pacific and Andean Region of South America	1997-1998	Floods associated with the El Niño phenomenon	The floods stressed the health system's ability to combat acute respiratory infections, acute diarrheal diseases, vector-borne diseases (malaria, classic dengue, hemorrhagic dengue, yellow fever, encephalitis, Chagas' disease, etc.), water- and food-borne diseases (cholera, salmonellosis, typhoid fever, viral hepatitis, multiple intestinal parasitism, etc.) and skin diseases (scabies, bacterial infections and mycoses, etc.).
Ecuador	1997-1998	Floods associated with the El Niño phenomenon	Thirty-four hospitals, 13 health centers and 45 secondary health centers affected, either in their infrastructure, installations or equipment. Chone Hospital, not yet inaugurated at the time of the flooding, suffered severe losses in medical equipment, furnishings, supplies and drugs.
Peru	1997-1998	Floods associated with the El Niño phenomenon	Fifteen hospitals, 192 health centers and 348 health posts affected.
Bolivia	2002	Hail and heavy rains	Fifty-seven dead. Fuctional and structural collapse of the Policonsultorio de la Caja Nacional.
Argentina	2003	Flooding due to rivers overflowing	Severe damage to Dr. Alassia's Children's Hospital and the Vera Candiotti Rehabilitation Hospital, as well as to 14 health centers of the 49 that serve Health Area V in Argentina.

Sources: *Crónicas de Desastres Nº 8: Fenómeno El Niño 1997-1998*, Pan American Health Organization, 2000;
Health in the Americas, 2002 Edition, Volume I, Pan American Health Organization, 2002.
Las Lecciones de El Niño, Ecuador, Corporación Andina de Fomento, 2000.
Las Lecciones de El Niño, Perú, Corporación Andina de Fomento, 2000
PAHO/WHO Bolivia website. www.ps.org.bo, 2 February 2004
Evaluación del impacto de las inundaciones y el desbordamiento del río Salada en la provincia de Santa Fe, República de Argentina en 2003, Report of ECLAC, LC/BUEL/L.185, June, 2003.

Table 1.3 Effects of earthquakes on health facilities

Location	Date	Magnitude	Overall effects
San Fernando, California	1971	6.4	Three hospitals suffered severe damage and were unable to operate normally when they were most needed. Most of the disaster-related deaths and injuries occurred in the two hospitals that collapsed. Olive View Hospital, one of the most severely affected, had to be demolished and rebuilt. Since this was done in the traditional fashion, however, the new Olive View Hospital facilities suffered severe nonstructural damage in the earthquake of 1994, disrupting functions.
Managua, Nicaragua	1972	7.2	The General Hospital was severely damaged. It had to be evacuated and, subsequently, demolished.
Guatemala City, Guatemala	1976	7.5	Several hospitals required evacuation.
Popayán, Colombia	1983	5.5	Damage and interruption of services at the San José University Hospital.
Chile	1985	7.8	Seventy nine hospitals and health centers damaged or destroyed; 3,271 beds lost.
Mendoza, Argentina	1985	6.2	Over 10 percent of the hospital beds in the city were lost. Of the 10 facilities affected, one had to be evacuated; two were subsequently demolished.
Mexico City, Mexico	1985	8.1	Structural collapse of five hospital facilities and major damage to another 22. At least 11 facilities had to be evacuated. Direct losses estimated at US$640 million. The hospitals that suffered the most damage were the National Medical Center of the Mexican Social Security Institute (IMSS), the General Hospital, and Benito Juárez Hospital. Between the patient beds destroyed and those taken out of service due to evacuation, the seismic event caused a sudden deficit of 5,829 beds. At the General Hospital, 295 died; at the Juárez Hospital, 561 died. Among the casualties were patients, doctors, nurses, administrative staff, visitors, and newborns.
San Salvador, El Salvador	1986	5.4	Over 11 hospital facilities affected; 10 had to be evacuated and one was condemned; 2,000 beds were lost. Total damage was estimated at US$97 million.
Tena, Ecuador	1995	6.2	Velasco Ibarra Hospital (120 beds) suffered moderate nonstructural damage—cracking on several walls, breaking of glass windows, collapse of false ceilings, elevator system failure, and damage to water and oxygen pipes—forcing evacuation of the facilities.

Continued →

Table 1.3 Effects of earthquakes on health facilities (continued)

Location	Date	Magnitude	Efectos generales
Aiquile, Bolivia	1998	6.8	Carmen López Hospital severely damaged.
Armenia, Colombia	1999	5.8	Sixty-one health facilities damaged.
El Salvador	2001	7.6	The earthquake caused 1,917 hospital beds (39.1 percent of the country's total capacity) to be put out of service. Severely damaged San Rafael Hospital continued to provide some services outdoors, on the hospital grounds. Rosales Hospital lost its capacity to provide surgical services as a result of damage to several key wings. San Juan de Dios (San Miguel) and San Pedro (Usulután) Hospitals were severely damaged and provided partial services out of doors. The Oncology Hospital had to be completely evacuated.
Peru	2001	6.9	Seven hospitals, 80 health centers and 150 health posts were affected in the Departments of Arequipa, Moquegua, Tacna and Ayacucho

Sources: Based on *Principles for Natural Disaster Mitigation in Health Facilities*, Pan American Health Organization, 2000.
Natural Disasters: Protecting the Public Health, Scientific Publication No. 575, Pan American Health Organization, 2000.
Health in the Americas, 2002 Edition, Volume I, Pan American Health Organization, 2002.
"Daños observados en los hospitales de la red de salud asistencial de El Salvador en el terremoto del 13 of Enero of 2001, Informe preliminar," Boroschek and Retamales, 2001.
Regional Health Directorates of Arequipa, Moquegua, Tacna and Ayacucho, Peru (July 17, 2001.

Table 1.4 lists the most common effects of the natural hazards considered in this handbook.

Table 1.4 Effects of various natural hazards

Effect	Earth-quakes	Strong winds	Tsunamis and flash floods	Slow-onset flooding	Landslides	Volcanoes and lahar activity
Loss of lives	High	Low	High	Low	High	High
Severe injuries requiring complex treatment	High	Moderate	Low	Low	Low	Low
Major risk of communicable diseases	Potential risk following all significant events (the likelihood increases with crowding and the degradation of sanitary conditions).					
Damage to health facilities	Severe (structural and equipment)	Severe	Severe but localized	Severe (equipment only)	Severe but localized	Severe (structural and equipment)
Damage to water supply systems	Severe	Leve	Severe	Leve	Severe but localized	Severe (structural and equipment)
Food scarcity	Infrequent (generally caused by economic or logistical factors)		Common	Common	Infrequent	Infrequent
Major population movement	Infrequent (common in severely affected urban areas)		Common (generally limited)			

Source: *Vigilancia epidemiológica sanitaria en situaciones de desastre, guías para el nivel local*, Organización Panamericana de la Salud, 2002.

The interruption of a health facility's operations after a disaster may be short-term (hours or days), or long-term (months and years). It all depends on the magnitude of the event and its effects on the health sector. The magnitude of an event cannot be controlled; its consequences, however, can be.

When planning a future health facility, the effects of these phenomena can be controlled if site selection is guided by sound information and criteria, and the design, construction, and maintenance can withstand local hazards. In the south of Chile, for instance, the main hospital for the city of Concepción managed to continue operating in spite of being near the epicenter of the country's most devastating earthquake of the twentieth century, which took place on 21 and 22 May 1960.

Failures are more widely publicized than successes, but the Concepción case is by no means unique. Another example worth noting is the different behavior of two neighboring hospitals hit by the Northridge, California earthquake of 1994. The first, USC Medical Center Hospital, had been designed with a base-isolation seismic-protection system. Not only did the buildings suffer no structural damage, but none of the equipment or key contents were damaged in the earthquake, and the facility remained in operation throughout the crisis and beyond. The adjacent facility had been designed and built according to traditional standards. Damage to it was so severe it could not continue to operate, and was eventually demolished.

2. Economic aspects

Reports by the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) state unequivocally that natural disasters are a significant obstacle to the economic and social development of countries in the Americas. While adverse natural phenomena do not discriminate between industrialized and developing countries, their consequences can be very different. In 1998, for instance, 95 percent of the deaths associated with natural disasters took place in developing countries. Adverse natural phenomena are far more likely to devastate the population's standard of living and their development prospects. By contrast, natural phenomena generally affect only marginally the economy and population of developed countries.[3] (See *Table 1.5*)

The effects of a natural disaster are amplified in the health sector, for three reasons. First, it is one of the sectors that tends to suffer important economic losses in such situations, given the significant investments required. Second, its recovery also implies large outlays, difficult to procure at a time when the rest of the country is also trying to recover. Finally, it needs to quickly recover its capacity, not only to continue meeting the normal demand for its services, but also to care for the population directly affected by the event.

3 ECLAC/IDB, *A Matter of Development: How to Reduce Vulnerability in the Face of Natural Disasters*, 2000.

Table 1.5 Effect of natural disasters on national economies

Location	Eventt	Date	Effect on the economy
Managua	Earthquake	1972	Decline of 15 percent in GDP and 46 percent in Managua's industrial and productive activity.
México	Earthquake	1985	GDP fell by 2.7 percent
Nicaragua	Hurricane Joan	1988	GDP suffered 2 percent reduction; 17 percent decline in the agricultural sector.
Ecuador	Floods caused by the El Niño phenomenon	1997-1998	GDP growth 1.2 percent lower than expected in 1998.
Dominican Republic	Hurricane Georges	1998	GDP reduction of 1 percent compared to annual forecast.
Nicaragua	Hurricane Mitch	1998	GDP growth of 4 percent, 1.1 points lower than forecast for that year.
Honduras	Hurricane Mitch	1998	Fall in GDP of 7.5 percent.
El Salvador	Earthquakes	2001	The damages that resulted represent 12 percent of the country's GDP the previous year

Source: ECLAC/IDB, *A Matter of Development: How to Reduce Vulnerability in the Face of Natural Disasters*, prepared for the "Confronting Natural Disasters: A Matter of Development" Seminar, 2000.

3. Mitigating vulnerability to disasters in health facilities

In recent years, following the disasters caused by Hurricane Mitch and the El Salvador earthquakes, several countries, among them Argentina, Bolivia, Chile, Colombia, Costa Rica, Honduras and Peru, and international institutions such as PAHO/WHO, ECLAC, the Inter-American Development Bank (IDB) and the World Bank, have begun to raise awareness on the need to promote strategies for mitigating vulnerability and managing the risks facing health systems in the region. Considerable progress has been made in the field of disaster education in medicine and nursing faculties, and in schools of architecture and engineering. The lessons learned reveal that most losses in health infrastructure are due to location in vulnerable areas, inadequate design, or the lack of proper maintenance. While most efforts in the 1990s focused on assessing and reducing the vulnerability of existing health facilities, in recent years there has been an increase in investment in new facilities based on solid criteria for protecting infrastructure and operations. In Chile, for instance, it has been mandatory since 1999 for project consultancy groups to include specialists in hospital vulnerability. They are responsible for ensuring that protection criteria are incorporated in the design and construction of new health infrastructure.

The Pan American Health Organization (PAHO), through its Public Health in the Americas initiative, has defined a set of Essential Public Health Functions (EPHF). Aimed at the health authorities of the region at all levels—central, intermediate, and local—they set the foundation for evaluating the current healthcare situation, improving public health practices, and strengthening the leadership of health authorities.

Among the essential functions agreed upon in June 2000, during the 126th session of PAHO's Executive Committee, is reducing the impact of emergencies and disasters on health, which is to be achieved through the following actions:[4]

- Planning and executing public health policies and activities on prevention, mitigation, preparedness, response, and early rehabilitation;
- Providing an integrated focus addressing the causes and consequences of all possible emergencies or disasters that can affect a country;
- Encouraging the participation of the entire health system, as well as the broadest possible intersectoral and inter-institutional cooperation, in reducing the impact of emergencies and disasters; and
- Promoting intersectoral and international cooperation in finding solutions to the health problems caused by emergencies and disasters.

4 World Health Organization (WHO), *Public Health in the Americas: New Concepts, Performance Analysis and Bases for Action*, Scientific and Technical Publication Nº 589, 2002.

Chapter 2

Definition of the Security Level

1. Introduction

The effects of a disaster on a health facility are not restricted to the panic that may ensue among the staff and patients—or even the partial or total physical damage the facility may suffer. Consequences may also include the partial or total loss of the operational capacity of the facility and, therefore, its ability to meet the demand for healthcare when it is most needed by the affected community. Technical and financial restrictions often faced by the health sector in many countries in the Americas aggravate matters by delaying recovery and rehabilitation of such facilities. Even 10 or more years after a disaster occurs, it is not uncommon to see the effects of that disaster in health centers.

Technological advances and changes in design philosophy and quality assurance techniques for the construction and maintenance of health infrastructure now make it possible to limit the damage caused by disasters, even to set different levels of protection for the infrastructure and operations. However, it is not always possible to achieve the protection levels one might desire, owing to a variety of factors. Natural or technical barriers may exist, as, for example, in the case of a small island where there is significant volcanic activity and the community needs a health center. Health sector funding in the public sector is another example. The need to expand the system in order to meet national health targets may clash with the need to guarantee the safety of the facilities. Finally, there are social and political restrictions, such as when the development and location of facilities are chosen to satisfy community expectations.

Even though funding may be limited, and other circumstances may impose technical barriers to the fulfillment of performance objectives, a detailed assessment is still required in order to ensure the optimal utilization of available resources. And the starting point should be a clear assessment of the existing health services network—its operational characteristics, geographical distribution, the degree to which it meets health policies and targets, the epidemiological and demographic profile of the population served, and the natural hazards that threaten it. The effective functional capacity of all existing health facilities must be taken into account, considering as fully as possible all factual information on the natural or man-made hazards they face and their current level of vulnerability.

Once the actual characteristics of the health services network and the hazards to which it is exposed have been identified, and the need to build a new health facility in a specific location has been established, it is still necessary to define the role that the new facility will play, both in normal times and during emergencies of various kinds and intensities. Based on all this information, the level of overall functional performance must be set for the contemplated health facility. Is it meant to continue providing its vital services as smoothly as possible even as the emergency is unfolding? Less ambitiously, is the structure to withstand the disaster in such a way that recovery and rehabilitation can take place after a reasonably brief interruption of services? The level of overall performance is a function of the level of protection selected for each of the services provided. All this will have a bearing on the characteristics of the site, the specifics of the infrastructure to be built, and the basic services it can realistically be expected to provide based on different scenarios as shown in the following chart:

Definition of Protection Services

Define Facility's Performance Objective
(as a function of the desired resonse within the health system and based on different hazard scenarios)

↓

Define Performance Objective for Medical Services and Support Services and Systems

↓

Define Protection Levels for the Various Services' Structural, Nonstructural, and Operational Components

In practical terms, three broad performance objectives can be listed: functional protection, investment protection, and life safety.

Functional protection	Investment protection is implicit in this objective, which in addition calls for the development of systems that can remain operational during a disaster or recover their functional capacity in a relatively short time.

Investment protection	The protection of all, or at the very least the key components of, the health facility's infrastructure and equipment, even if the facility itself cannot continue to function. Based on this criterion, it is possible to design and build infrastructure that can resume operations within a reasonable time at a cost that can be met by the client institution.

Life safety	The minimum requirement for any infrastructure, and the criterion most commonly used in the design and construction of health facilities.

The approach hereby proposed, which focuses on setting performance objectives for each of the services to be provided by the facility, given the various hazards present in the region and their likely intensity, calls for two potential intensity levels to be considered when designing a facility: the traditional design level for each hazard, and a maximum credible scenario, which would call for exceptional protection measures. Basing the protection strategy on the latter scenario is the most desirable approach.

In the case of earthquakes, for instance, the minimum protection level should shield the facility from a seismic event with a 10 percent probability of being exceeded over a 50-year period. On the other hand, the high-protection level would withstand an earthquake so exceptionally strong that it would only have a 2 percent probability of being exceeded in 50 years. A minimal objective is to avoid a sudden, forced evacuation following an event.

In order to sensitize all project participants concerning the need for disaster mitigation, it is advisable that the various stakeholders agree in writing on the performance objective to be met, defining protection goals for the facility in normal times and in the event of various disaster scenarios. The form *Security objectives for the facility (Annex 2.1)* may help in this awareness-raising effort. For each hazard present in the area where the infrastructure will be sited, one such form should be filled, bearing in mind the recovery time expected for the facility.

2. Basic services

The overall performance objective for the facility should be directly dependent on the level of protection its services will require. *Tables 2.1a* and *2.1b* list some of the medical and support services for which protection levels should be set. The level of protection must likewise be aligned with the overall performance objective desired for the facility. However, it is not necessary for all services to enjoy the same level of protection established for the facility as a whole. The level of protection should be defined for one or more intensity levels for each hazard.

Table 2.1a - Typical medical services in a hospital

Blood Bank	Kinesiotherapy	Pediatric Neurology
Cardiology	Laboratory	Pediatric Surgery
Dental Services	Neonatology	Pharmacy
Dermatology	Nuclear Medicine	Plastic Surgery - Burns
Ear, Nose and Throat	Obstetrics and Gynecology	Pneumology
Emergencies - Adults	Oncology	Psychiatry
Emergencies - Children	Ophtalmology	Recovery Rooms
Endoscopy	Ophthalmology	Sterilization
General Inpatient Care	Orthopedics and Traumatology	Surgery
Hemodyalisis	Other Medical Services	Surgical Wings
ICU/ITU	Outpatient Clinic	Urology
Imaging, Diagnostic	Pathological Anatomy	
Internal Medicine	Pediatrics	

Table 2.1b - Typical Support Services and Systems

Administration	Emergency Standby Electrical System	Mobilization and Transport
Air Conditioning (HVAC)	Escape Routes	Non-sterile Materials Storage
Boilers, Thermal Power Station	Filing and Case Management	Oxygen System
Clinical Gases	Fire Alarm/Supression System	Sewerage
Communications	Food Services	Sterile Materials Store-Rooms
Drinking Water	Industrial Gases	Elevator/Scalator System
Electricial Distribution	Industrial Water	Other Support Servics, Systems
Electrical Power Station	Laundry	

3. Classification of medical and support services

In order to properly choose the correct protection objective for each service, it is advisable to consider the risks to which it will be exposed, the activities involved in providing the service, the characteristics of its components, and its relative importance:

Classification of medical and support systems

Critical Services and Systems	Must be classified as specified below:
Critical services involving life-saving or other essential functions	Those services that must remain in operation to meet the vital healthcare needs of inpatients and provide first aid and other services to the victims of the disaster. Also included in this group are services whose failure could cause prolonged delays in the recovery of critical services.
Critical services involving hazardous or harmful materials	Damage to these services increases the risk of fires, explosions, air pollution, or water contamination that could injure the staff, patients, or visitors.
Critical services whose failure may cause the patients or staff to panic	Those services whose failure may cause alarm, chaos or confusion among the staff, patients, or visitors to such a degree that the quality or even the provision of health care may be compromised.
Special Services and Systems	Services that, while not critical, involve components that would be difficult or expensive to replace.
Other Services and Systems	Those services that can suffer minor failure and can be repaired quickly, without causing significant decreases in health service quality.

4. Protection levels required for each service

Just as a performance objective must be set for the facility as a whole, its services and support systems should also be classified in accordance with the performance goals and various hazard scenarios that may affect them:

Definition of service protection levels

Functional protection (FP)	The facility is able to operate normally immediately after an emergency. Losses in functional capacity, if any, are temporary and do not endanger patients or staff. To meet this goal, infrastructural (structural and nonstructural) components and organizational or functional components must perform with a similar degree of success. Such components are only allowed a limited degree of damage. The functional protection objective implicitly incorporates the investment protection and life-safety performance objectives.
Investment protection (IP)	At this intermediate level of protection, the goal is to prevent damage to the infrastructure of those services that it would be difficult or costly to replace. To meet this goal, both the structural and the nonstructural components must perform similarly. In some cases, investment protection may result indirectly in functional protection.
Life safety (LS)	It is acceptable for the service to suffer considerable damage to its structural or nonstructural components as long as such damage does not put lives at risk. As a result, it may be necessary to carry out significant repairs after the disaster. Such repairs may not be economically feasible.

Depending on the classification of each service, as dictated by the importance of the activities and components of the service in question, performance objectives such as those recommended in *Table 2.2* should be set.

Table 2.2 Protection objectives for the services

Classification of the Service	Protection objective		
	FP	IP	LS
Critical services			
Vital or essential	✔		
Hazardous or harmful	✔		
Likely to cause chaos or confusion	✔		
Special services		✔	
Other services		✔	✔

The protection goals contained in *Table 2.2* may be redefined, as agreed upon by the project coordination committee, depending on the economic capacity of the client institution and the project's role and importance within the overall health network. In any case, priority should be given to functional protection.

5. Definition and characterization of objectives for protecting infrastructural components

Once a protection objective has been set for the facility as a whole, as well as for each of its services, it should determine the organizational, safety, and control performance criteria for the prevention or mitigation of any damage to infrastructural components. Infrastructure is typically divided into two groups: the structural, and the nonstructural elements. The structure comprises all those essential elements that determine the overall safety of the system, such as beams, columns, slabs, walls, braces, or foundations. The nonstructural elements are those that ultimately enable the facility to operate; they are divided into architectural elements, equipment and content, and services or lifelines.

A reasonable level of protection for the nonstructural components of each service should be chosen:

Protective systems for the facility's systems, equipment and components

Protection of Operations (PO)	The structural system must perform in such a way that the building can continue to be used safely both during, and immediately after, an adverse event. The structural elements must remain nearly as rigid and resistant as before the emergency. Any damage that occurs should be minimal, with no repairs required for operational continuity (what is known as controlled damage). Nonstructural components should continue to function without alteration, both during and after the emergency. Any damage should be minimal and allow for immediate occupancy of the premises.
Infrastructure Protection (IP)	Damage to the structural system is acceptable so long as the replacement of service components is not unduly arduous or expensive. It should be possible to repair any damage that occurs, at a reasonable expense and in a short period of time, so as to minimize interference with the functions ordinarily performed.
Life Safety (LS))	Damage to structural and nonstructural components is acceptable so long as it does not endanger the patients, visitors, or staff. Repairs may be expensive and interfere severely with the operations of the facility in the medium and even long term.

The protection objective for any component must be at least equal to that established for the overall service to which it belongs, or with which it interacts.

6. Setting the protection objective for each service

The form *Performance objectives for support systems and services,* in *Annex 2.2* may be used to define the disaster mitigation performance objective for the health facility as a whole and the services it provides. This form should be completed jointly by the client institution's representatives and the professionals involved in the design and execution of the project. A similar form should be completed for each likely disaster scenario, as well as for each protection objective contemplated.

7. Degree of detail of the project

The protection objective set for the facility as a whole, together with the level of risk estimated by the multidisciplinary group of specialists who participate in its conception, should determine the degree of detail with which the project is to be designed. Broadly speaking, two levels of detail may be considered—each having significant implications for the site studies to be carried out, the design procedures to be followed, and the qualifications of the professionals hired to build the project or practice quality assurance. *Table 2.3* below, shows the available options in relation to the protection objective chosen.

Table 2.3 - Level of detail of the required studies

Protection objective	Level of risk	
	High	Low
Functional protection	D	D
Infrastructure protection	D	B
Life safety	D	B

D: Detailed Study
B: Basic Study

Table 2.4, in turn, summarizes the main features of the studies referred to in the previous table, including the requirements that must be met by the various teams.

Table 2.4 - Project requirements

	Degree of Detail of the Study	
	Detailed Study	Basic Study
Requirements that must be met by the participating professional teams	(See *Chap. 5*)	(See *Chap. 5*)
Site studies required		
Pre-selection of siting options	✔	✔
Compilation of information on hazards presentat the egional level	✔	✔
Compilation of information on hazards present at the local level for each of the potential sites	✔	
Definition of facility protection options	✔	
Identification of minimum services requiring protection		
Definition of the level of protection for the various services and their components	See *Table 2.2* and *Annex 2.2*	See *Table 2.2* and *Annex 2.2*
Design requirements for structural components, nonstructural components, and medical and industrial equipment		
Requirements based on national and international standards	✔	✔
Requirements specific to the project or to health facilities in general	✔	
Expected results (See *Chapter 6*)		
Detail drawings	✔	✔
Technical specifications	✔	✔
Tender documents	✔	✔
Certificates	✔	✔
Financial reports	✔	✔
Typical completion schedule[1]	8-12 months	6-10 months
Quality assurance program for the project (See *Chapter 6*)	✔	✔

Notes: 1 Completion schedules are only meant to serve as examples. The duration of any given study will depend, among other variables, on the dimensions and protection objectives of the facility and the natural hazards prevalent in the area

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Annex 2.1
Form: Facility safety objectives

FACILITY'S SAFETY OBJECTIVES

Name ....

Location ....

Health System ....

Natural Hazard ....

DESIRED RECOVERY TIME

	Level of Demand	
	Max. Feasible	Min. advisable
Immediate (hours)	☐	☐
Brief (weeks)	☐	☐
Moderate (months)	☐	☐
Long (over 1 year)	☐	☐
Very long (never)	☐	☐

PROTECTION LEVEL

For maximum possible demand or desired level

☐	☐	☐
FUNCTIONAL PROTECTION INFRASTRUCTURE PROTECTION LIFE SAFETY	INFRASTRUCTURE PROTECTION LIFE SAFETY	LIFE SAFETY

For minimum recommended level

☐	☐	☐
FUNCTIONAL PROTECTION INFRASTRUCTURE PROTECTION LIFE SAFETY	INFRASTRUCTURE PROTECTION LIFE SAFETY	LIFE SAFETY

....

Signature 1 Signature 2

Annex 2.2
Form: Performance objectives for support systems and services

Hazard level[1]:

☐ Likely or credible maximum

☐ Minimum recommended

Type of hazard ....

....

Variable that characterizes the hazard ....

....

Hospital performance objective[1]:

☐ Functional protection(FP) ☐ Investment protection (IP) ☐ Life safety (LS)

Performance objectives for medical and support systems and services[2]:

Medical services

	FP	IP	LS
Blood bank			
Cardiology			
Clinical gases			
Dental services			
Dermatology			
Ear, Nose and Throat			
Emergencies - Adults			
Emergencies - Children			
Endoscopy			
General In-patient Care			
Hemodyalisis			
ICU/ITU			
Imaging, Diagnostic			
Internal Medicine			
Kinesiotherapy			
Laboratory			
Neonatology			
Non-sterile Storage			
Nuclear medicine			
Obstetrics and Gynecology			

	FP	IP	LS
Oncology			
Ophtalmology			
Orthopedics and Traumatology			
Oxygen System			
Outpatient Clinic			
Pathological Anatomy			
Pediatric Neurology			
Pediatric Surgery			
Pediatrics			
Pharmacy			
Plastic Surgery - Burns			
Pneumology			
Psychiatry			
Recovery rooms			
Sterile Storage Area			
Sterilization			
Surgery			
Surgical Wings			
Urology			
Other Medical Services			

Continued →

Support systems and services:

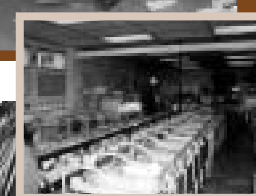
	FP	IP	LS
Administration			
Air Conditioning (HVAC)			
Boilers, Thermal Power Station			
Communications			
Drinking water			
Electrical distribution			
Stand-by electrical System			
Escape Routes			
Filing and Case Management			
Fire Alarm/Suppression System			

	FP	IP	LS
Food Services			
Industrial Gases			
Industrial Water			
Laundry			
Mobilization and Transport			
Electrical Generator			
Sewerage			
Vertical Transport System			
Other Support Systems/Services			

Performance objectives of other support systems and services[2]:

	FP	IP	LS
Critical services or components			
Life-saving or essential			
Hazardous or harmful			
Likety to cause panic or chaos			
Special services or components			
Other services			

Notes: 1 For each facility that is to be part of a national or local healthcare network, a general performance objective must be set.
2 The protection objectives cited provide a minimum of protection. It would be desirable that safety systems be built with functional protection as their performance objective. In any case, the performance objectives must be the result of a joint agreement by the client institution, the medical team and the project specialists. Functional protection necessary implies infrastructure protection and life safety. Investment protection often implies protection of the operation.


Chapter 3

General Criteria for Selecting a Safe Site

1. Introduction

The identification of siting options and the selection of the definitive site for the facility must be based on an assessment of the healthcare needs of the population and the characteristics of the existing health network. The choice of the definitive site will also be determined by public health policies and any demographic, geographical, sociopolitical, or economic criteria the client institution may have stipulated.

Minimum criteria for characterizing the site should contemplate the following issues:

- Location and accessibility
- Supply and quality of essential services
- Urban questions: climate, esthetics, conditions in adjacent areas
- Common risks: noise, dust, vibrations, others
- Topographic and geotechnical issues
- Legal issues
- Economic issues

Other key considerations include the performance objectives sought for the facility at normal times and during emergencies, the comparative analysis of the natural and technological hazards present at the various potential sites, the estimated cost and technical feasibility of implementing protection systems to withstand such hazards, the economic resources available, and the findings of a cost/benefit analysis of the options as illustrated in *Flowcharts 3.1* and *3.2*.

Such an assessment must not confine itself to the potential building sites. It should also consider the characteristics of the overall surroundings and the way adverse natural phenomena can affect the referral population and local infrastructure, particularly lifelines and access roads.

2. The process for selecting potential sites

Variables governing site selection

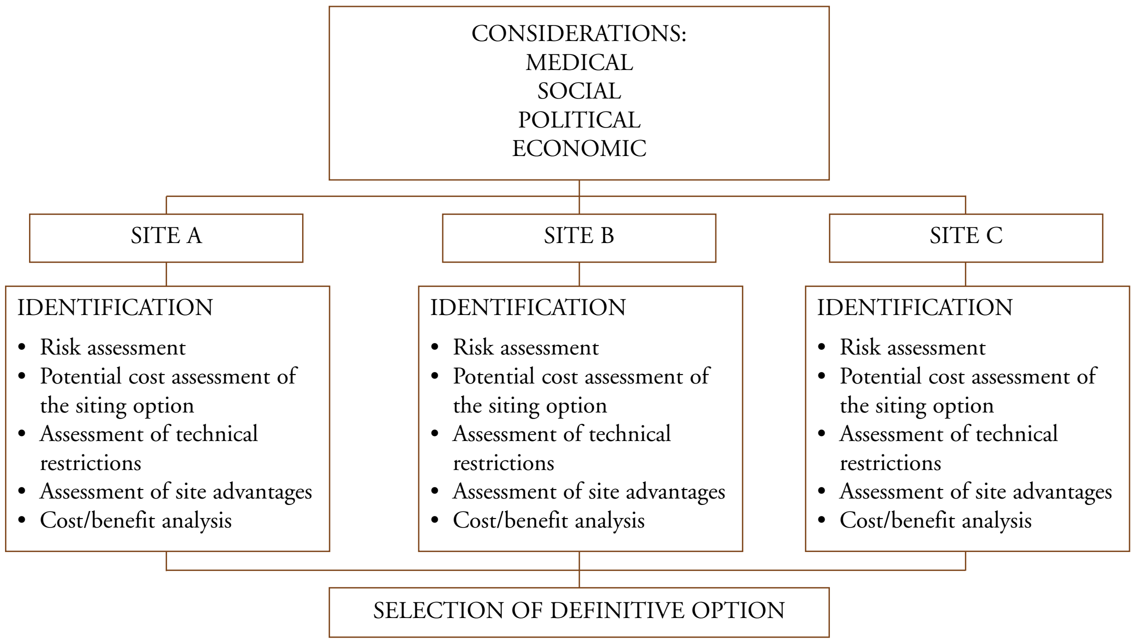
It is not the purpose of this handbook to explain at length how to rank the various siting options. Instead, relevant criteria, such as the key factors to be taken into account when selecting an adequate and safe location will be mentioned; it is advisable that the client institution issue qualitative and quantitative specifications for assessing and comparing each of the siting options.

These specifications may be of varying degrees of complexity. What matters is that they facilitate the decision-making process by testing each site's capacity to meet the desired protection objective. If none of the siting options can meet it, a less ambitious protection objective should be chosen—or more acceptable siting options should be sought.

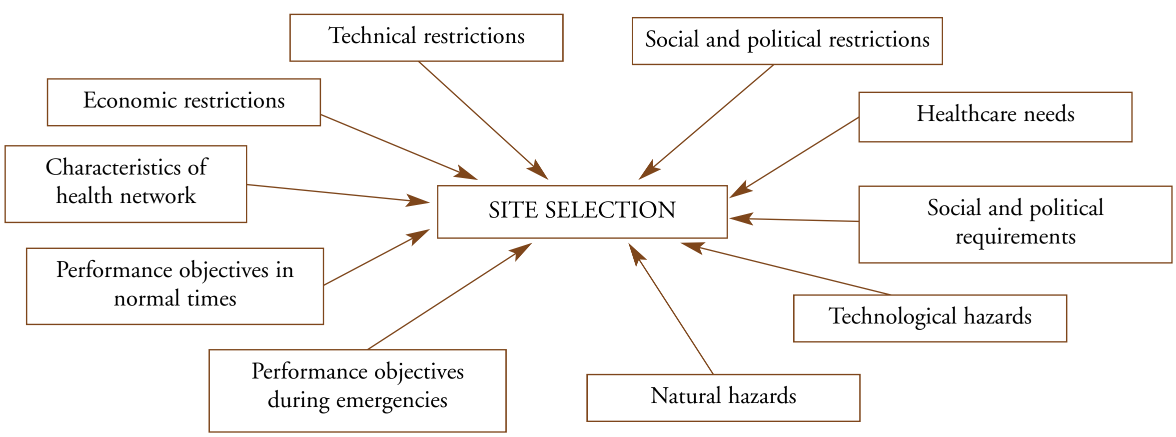
When preselecting the siting options, existing data on prevailing hazards, found in land-use management plans, local or regional development plans, technical reports, local zoning laws and regulations, or expert opinions, may suffice. Even so, an on-site inspection of each of the options and their surroundings should be carried out by the siting team.

If the health facility is designed to meet a high protection objective in the face of a natural event, however, detailed studies must be carried out to characterize the prevailing hazards. No site should be selected if any of the information required is lacking.

Flowchart 3.1 - Site preselection



Flowchart 3.2 - Site selection



In selecting the site, moreover, a key consideration is proximity to industrial facilities (chemical plants, refineries, mining processing plants, etc.), military facilities, landfills, airports, routes used for the transport of hazardous materials, and so on. Because of their operations, the habitual or accidental emission of toxic agents, or the possibility of accidents at normal times or during an emergency, having such facilities as neighbors might compromise the safety of the contemplated health facility.

In this connection, another course of action well worth exploring by the client institution is having local zoning regulations modified so that in future no building permits can be issued, within a given radius, to facilities that might endanger the hospital or its operations.

Site selection procedures

The selection of the site involves three stages, each with its own set of requisite procedures. The three stages are the following:

Stage 1: Compilation of background data;

Stage 2: Assessment of siting options;

Stage 3: Site selection.

Stage 1: Compilation of background data

Preliminary data compilation

At the start of the project, the client institution must appoint a siting coordination team that must in turn hire the professionals who will advise on the correct selection of the project site. It must also set the performance objective for the facility in the event of a natural disaster—that is, the level of damage, or time needed for functional recovery, that will be acceptable to the institution.

The client institution must also define overall siting criteria based on factors such as total surface required (construction plus grounds), lifelines and other infrastructural requirements, and the facility's intended perimeter of influence and reference population. Site preselection should consider the criteria outlined at the beginning of this chapter.

Once siting options have been selected it will be necessary to examine all available records on the natural hazards that threaten the potential sites. They include general information on the location, relevant characteristics of human settlements and infrastructure in the region, existing zoning regulations, regional and local development plans, existing maps, records of natural disasters that have occurred there, available geotechnical and other scientific information, data compiled by other projects carried out in the region, and the opinions of government bodies, professional associations, academic institutions and nongovernmental organizations.

The siting team should determine whether additional data must be compiled to compare the risk factors at the various siting options. At this point, the team must consider whether the likelihood of various natural disasters in the area is high or low, so as to define the degree of detail required in the risk assessments to be carried out. In the event that not enough information is available, or there are doubts regarding its validity, the team must inform the project administrator and coordination committee, and recommend additional studies needed to assess the hazards at each potential site. The level of detail of the studies will also be determined, naturally, by the performance objective (from life safety to functional protection) chosen for the facility.

Table 3.1 lists some of the activities that should be carried out during this phase.

Table 3.1 Preliminary tasks

Selection of professional team (see Chapter 5)
Definition of protection objectives and expected level of damage
Definition of siting options
Delimitation of the boundaries within which the potential site must be located
Surface area to be occupied by the facility
Perimeter of influence
Roads
Lifelines
Review of local regulatory plans
Preliminary studies
Human settlements and infrastructure in the region
Inhabited area
Services
Roads and available forms of transportation
Review of existing laws and regulations
Review of regional development plans
Review of existing maps
Review of general information regarding the sites of interest and their surroundings
Review of background data regarding adverse natural phenomena that have taken place in the region, such as landslides or mudslides, strong winds, floods, seismic events or volcanic eruptions
Compilation of preliminary geotechnical data regarding the potential sites
Compilation of information gathered for other projects developed in the area
Opinion of government bodies and NGOs
Opinion of experts

Stage 2: Assessment of the siting options

At the beginning of this phase, the siting team must determine if the information compiled during the preliminary phase is sufficient to preselect the facility's potential sites. If the information required is not available, the team of specialists must carry out all studies necessary for producing the information that will characterize the hazards prevalent at each siting option and produce a "short list" of the most likely candidates (see *Annex 3.1*).

Processing background data

The information compiled during the preliminary studies, or that obtained later as needed, must be processed in order to characterize the level of risk of all recorded or potential natural hazards at each of the siting options. *Table 3.2* summarizes the main variables that must be quantified in order to determine the natural hazards present at each siting option.

Table 3.2 - Quantification of risk

Quantification of risk					
Earthquake	Snow	Strong winds	Landslides and mudslides	Floods	Volcanic activity
Dimension Magnitude Duration Likelihood of occurrence Affected area	Dimension Magnitude Duration Likelihood of occurrence Affected area	Dimension Magnitude Duration Likelihood of occurrence Affected area	Dimension Magnitude Duration Likelihood of occurrence Affected area	Dimension Magnitude Duration Likelihood of occurrence Affected area	Dimension Magnitude Duration Likelihood of occurrence Affected area
Description Design spectrum Seismic verification records Direct geotechnical impact Mitigation potential	Description Design load Mitigation potential	Description Design speed Mitigation potential	Description Volume Height Speed Mitigation potential	Description Volume Height Speed Mitigation potential	Description Volume Speed

The variables listed in this table must be quantified through geological, geomechanical, seismological, meteorological, and hydrological studies.

The following information must be processed and evaluated:

- Data suggesting the possibility of **landslides:** historical records, stratification maps, and information about vegetation, natural deposits, steep slopes, soil strata cohesion, shear strength, watercourse hazards, drainage and permeability conditions, seismic activity, climatic conditions, and human intervention. The stability of slopes in the area must be examined, and an assessment made of the likelihood of a landslide, its probable speed and volume, surface potentially affected, and so on.

- **Seismic risk** information affecting the potential site must also be taken into account, including active faults and other potential triggers of seismic activity, as well as the soil mechanics of the site and its potential for liquefaction or densification of the foundation soil and the resultant risk of landslides. An assessment must likewise be made concerning the maximum probable intensity and duration of an earthquake in the area, the influence of attenuation laws, and the linear response spectrum.

- **Volcanic risk** must be assessed by examining the historical records and current topography in order to determine the likely routes of pyroclastic flows in relation to potential sites for health facilities. The area of influence of lateral explosions and gas emissions, ashfall and the ejection of solid and particulate material, as well as the likelihood of lahars as a result of ice melting must also be evaluated. The likely severity of an event must be determined, including the total land surface that might be affected, the likely speed of the various flows, the degree of toxicity of the released gases and the magnitude of related seismic phenomena, not to mention the probability of such an event. In the case of coastal areas, attention must be paid to the likelihood of tsunamis as a result of submarine seismic or volcanic activity.

- Background information regarding the possibility of floods caused by **tsunamis**, originated by underwater seismic activity or volcanic activity.

- Historical records and other background information should also be reviewed regarding the **meteorological and hydrological conditions** of potential sites to assess the risk of floods, mudslides, and hurricanes. At least one year's worth of such information should be assessed, so long as the data represent historical conditions regarding spatial and temporal distribution of precipitation, thermic oscillations, location of the snow line, and so on. The risks posed by nearby watercourses, lakes, dams, and reservoirs should be examined, including available historical records of flash floods, areas affected by floods in the past, population affected, gauged water height, and the precipitation levels that led to such phenomena. An assessment must also be made of surface drainage and soil permeability, and soil use in the area. Wind patterns should also be examined, taking into account the intensity, direction and height-distribution of gusts. Topography should similarly be looked into, to rule out the possibility that the site's relative altitude might make it susceptible to floods, or that local morphology might encourage turbulences.

- Characteristics of **strong winds** in the region, evaluating historical data and determining at least the intensity, direction and height distribution of the probable winds.

- **Topography of the site** to ensure the site is not located in a low zone, **prone to flooding**, and to ensure that no morphologic conditions are present that could cause an incidence in the formation of turbulence.

- Safety of the specified site with regard to its **geotechnical** characteristics: support capacity and stability against different demands. Sites that should be particularly avoided include those with liquefaction potential, collapsibility, or important terrain settlements.

Annex 3.1 summarizes the questions that must be answered when assessing the risk posed by various natural hazards at any given site, and the variables that should be examined when assessing the merits of that site.

Technical and economic feasibility of protection systems

In the case of each likely natural hazard, an assessment must be made of the technical and economic feasibility of implementing overall protection systems for the structure through the execution of peripheral works and other actions aimed at mitigating known local hazards.

- The risk of **landslides**, for instance, calls on mitigation experts to examine the cost and difficulty of increasing slope stability through the building of retaining walls and alluvial terraces, the use of geotextiles, compacting unstable soil, reforestation, the clearing of watercourses that might undermine the soil in the event of flood, and the implementation of permanent monitoring and early warning systems.
- ∑ A similar cost/benefit and technical feasibility assessment must be made regarding **strong winds** and the development and implementation of technical specifications for appropriate detailing, reforestation, or early warning systems.
- In the case of **flood risk**, attention should be paid to how realistic it would prove, in technical and financial terms, to implement prevention measures such as the building of protective dams in critical flow points, gavions along the embankments, the clearing of watercourses, water diversion through canals and drainage facilities, or improved collection of rainwater.
- **Seismic hazards** call for a cost/benefit analysis of the application of seismic-resistant standards.
- Where **volcanic activity** is a major hazard, an assessment should be made of the feasibility of permanent monitoring of acitivity and early warning systems.

Annex 3.2 lists several of the options available for the overall protection of health facilities in the face of the natural hazards considered in this handbook.

Impact of hazards on the sites under consideration

In the case of each prevailing hazard, an assessment must be made of its likely impact on the population to be served, as well as on local lifelines, related services, and overall access to health care. The likely impact of the phenomenon on the health network of the region—and, where appropriate, of the country—must also be assessed. This assessment should not only consider the network's infrastructure but also the health, economic, and political aspects. All too often, while damage to health infrastructure may be manageable from a technical viewpoint, the political and social impact can be devastating.

Stage 3: Site selection

Selection of the best option

The information compiled must be processed in order to select the safest and most convenient site for the facility. This process includes the following activities: classification of hazards and evaluation of risk for alternative sites; production and superimposition of risk maps; analysis of technical feasibility, costs of overall protection of the structure, impact of hazards, and comparative cost/benefit studies of alternative sites; and finally, definitive selection of the structure's location.

In some circumstances it may not be possible to meet the desired performance objective due to the extreme conditions in which the reference population lives. Given the lack of safe locations, the project's performance standards should guide alternative site decisions such as the following:

- Divide the functions of the facility so that they are carried out in different locations, remote from each other;
- Ensure that mobile or temporary facilities are available in the event of a disabling event;
- Create effective referral systems, allowing the smooth transfer of patients to health facilities in other areas.

Such approaches can help to distribute or decrease the risk, however they increase costs and make operations more complex than might be desired, but they may be the only reasonable alternative.

Production of summary document

The information obtained during the three stages of site selection must be summarized in a document that should contain, at the very least, the following:

- Explanation of the reasons for the choice of site;
- Description of the risks identified at the site;
- Causes of those risks;
- Characterization of the risks;
- Design recommendations for the facility, including the length of time it can remain cut off from basic services (water, electricity, etc.);
- Design and protection recommendations for the area of influence;
- Protection objectives for the intended health facility.

3. Assessment of site safety

The form *Site selection*, included in *Annex 3.3*, should assist the project administrator and the coordination committee in selecting a safe site for the hospital.

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Annex 3.1: Summary of additional tasks required for risk assessments

The scope of the studies needed to characterize natural hazards depends in large part on local conditions in each region. However, as reference, this table summarizes the additional information that should be obtained in order to assess the risk posed by a variety of natural hazards to contemplated health facilities.

Assessment of landslide risk
Assessment of conditions for a landslide
Historical background
Vegetation
Geological conditions
Topographical conditions
Soil conditions (based on soil mechanics studies)
Hazards due to water-courses
Seismic hazard
Human intervention
Assessment of slope stability
Preliminary and detailed assessment
Likely impact of a landslide
Affected surface and volume of displaced soil, debris, other material
Speed of landslide
Safety factors for landslide
Likelihood of event
Production of risk maps (microzoning)

Assessment of mudslide risk
Assessment of conditions for a mudslide
Historical background
Meteorological conditions
Vegetation
Geological conditions
Topographical conditions
Soil conditions
Drainage and permeability
Human intervention
Likely impact of a mudslide
Affected surface and displaced soil, debris, other material
Speed of mudslide
Likelihood of event
Production of risk maps (microzoning)

Assessment of risks due to strong winds
Assessment of conditions for strong winds
Historical background
Meteorological conditions
Topographical conditions
Likely impact of strong winds
Gust speeds and other load parameters
Likelihood of event
Production of wind maps (microzoning)

Flood risk assessment
Conditions for floods to occur
Historical background
Meteorological conditions
Water courses in the area
Topographical conditions (low-lying areas)
Permeability and use of the soil
Risk of tsunami-induced flooding
Human intervention
Critical point identification
Identification of points along watercourses likely to overflow in conditions of extreme precipitation
Likely impact of flood hazard
Affected surface
Flood elevation (inches or centimeters above ground level)
Flow speed and other load parameters
Likelihood of event
Production of risk maps (microzoning)

Seismic risk assessment
Characterization of sources of seismic risk
Determination of frequency/magnitude ratio
Estimation of maximum likely earthquake
Estimation of seismic risk
Estimation of strong ground movement in probabilistic or deterministic terms
Definition of one or more attenuation factors
Estimation of likely duration of strong ground movement
Estimation of predominant period of strong ground movement
Likely impact of seismic risk
Spectrum of responses, records and other load parameters
Potential for liquefaction of foundation soil
Potential for landslide (see section on landslides)
Likelihood of tsunami (see section on floods)
Production of seismic risk maps for the various siting options

Risk assessment of volcanic activity
Assessment of likelihood of volcanic activity
Possibility of lateral explosions
Possibility of pyroclastic flows
Possibility of lava flows
Possibility of landslides or rock slides
Possibility of mudslide
Possibility of contamination due to gases and ashes
Possibility of ejection of solid and particulate materials
Possibility of flood due to tsunami
Likely impact of volcanic risk
Affected surface (area of influence)
Speed of flows
Degree of toxicity of expelled gases
Magnitude of associated tremors
Characterization of derivative loads (landslides, floods, etc.)
Likelihood of event
Production of volcanic risk maps (microzoning)

Annex 3.2: Summary of options for the overall protection of the structure

The following table lists some of the options available for ensuring the overall protection of the intended structure.

Actions that can assist in the overall protection of the structure
Strategies for protection against landslides and mudslides
Slope stabilization
Soil stabilization through the use of geotextiles
Knocking down unstable masses
Reforestation
Cleaning natural watercourses, canals
Construction of drainage facilities
Construction of alluvial terraces
Constant monitoring (instrumentation); early warning systems
Other
Strategies for protection against strong winds
Production of technical detailing specifications
Reforestation
Permanent monitoring of meteorological conditions; early warning systems
Other
Strategies for flood protection
Construction of protection barriers at critical points of the watercourse
Construction of gavions [retaining walls made of rocks and chicken wire] along the full length of the watercourse
Cleaning natural watercourses and canals
Construction of drainage facilities
Reassessment and improvement of rainwater collection and drainage
Reinforcement of the structural system
Other
Strategies for seismic protection
Production of technical specifications for seismic-resistant design
Other
Strategies for protection against volcanic activity
Permanent monitoring and early warning system
Other

Annex 3.3
Form: Site selection

Site selection[1]

General information on planned hospital

Name of hospital: ....

Health system: ....

Siting option: ....

Natural hazards prevalent in siting option:

	Available information		Hazard level		Assessment	
Hazard	Sufficient	Insufficient	High	Low	Detailed	Basic
Landslide or mudslide						
Earthquake						
Volcanic eruption						
Flood						
Hurricane						

Disciplines required for risk assessment:

Urban development	
Topography	
Geology	
Soil mechanics	
Meteorology	
Hydrology	

Hydraulic engineering	
Seismology	
Wind and hydrodynamic engineering	
Seismic engineering	
Structural engineering	
Vulcanology	

Other aspects to consider in site selection:

Near:	Yes	No
Industrial sites		
Chemical plants		
Refineries		
Processing centers		
Military facilities		

	Yes	No
Landfills		
Airports		
Major trasnport routes		
Other (please specify):		

Hazard characteriscis [2]

Landslide

Affected surface and volume displaced: ....

Slide speed: ....

Landslide safety factors: ....

Likelihood: ....

Feasibility of controlling impact: Yes ☐ No ☐

Continúa →

Form for Site selection[1] (continued)

Mudslides

Affected surface and volume displaced: . . . .

Slide speed: . . . .

Likelihood: . . . .

Feasibility of controlling impact: Yes ☐ No ☐

Hazard characteristics [2]

Strong winds

Likelihood: . . . .

Feasibility of controlling impact: Yes ☐ No ☐

Flooding

Affected surface: . . . .

Flood altitude: . . . .

Flow speed: . . . .

Likelihood: . . . .

Earthquake

Design spectrum: . . . .

Direct geotechnical consequences (description): . . . .

Feasibility of controlling impact: Yes ☐ No ☐

Otro

(Description) . . . .

Feasibility of controlling impact: Yes ☐ No ☐

Approximate cost of implementing protection systems (US$):

Landslide	---------------------------	+
Earthquake	---------------------------	+
Volcanic activity	---------------------------	+
Flood	---------------------------	+
Strong winds	---------------------------	+
Other	---------------------------	+
Total	---------------------------	=

Notes: 1 A similar form must be completed for every siting option. This table complements the site selection from different points of view: sanitary, urban, accesibility, basic services, topography, geotechnical, legal and economic.

2 The team of specialists in charge of assessing the risk of the various hazards prevalent in the area must present a written report to the project administrator and the coordination committee on those hazards and their likely effect on the siting option.


DISEÑO COMPLETO DE LA REPARACION ESTRUCTURAL