Chapter 4

Project Design and Construction

1. Introduction

Having selected the correct site for the facility, the time has arrived to design a project that will provide a level of safety commensurate with the performance objective chosen. The protection systems must be feasible to build as well as effectively maintained. Poor design at this stage will hinder the remaining stages of the project to such an extent that it may prove difficult, even impossible, to meet the overall performance objective for the intended facility.

The acceptable level of damage to structural and nonstructural components should be directly linked to the time—and expense—needed for recovery, as defined by the client institution for the various hazards and levels of risk. Table 4.1 shows the acceptable levels of damage to the facility's components in terms of the recovery time for different degrees of risk. While recovery times cannot be guaranteed in advance, the matter must be addressed thoroughly, since it will affect the institution's pressing need to predict when it will be able to recommence operations after a natural disaster has struck.

Table 4.1 Acceptable levels of damage to components

	Intensity of the hazard		Acceptable level of damage	
Recovery time	Credible maximum desired	Minimum recommended	Structural components	Nonstructural components
Immediate (hours)			Minor	Minor
Short (weeks)			Minor to moderate	Minor to moderate
Moderate (months)			Moderate	Moderate
Long (more than one year)			Moderate to severe	Severe
Very long (or never)			Severe	Not considered

The design process involves seven clearly differentiated stages:

- Drafting of a medical-architectural design and construction program;
- Selection of a development team for the preliminary project;
- Development of the preliminary project;
- Selection of the design team;
- Development of the actual project;
- Selection of the building contractor;
- Construction.

In order to implement these stages, it is vital for the client institution, which sets the goals and requirements, to act rigorously in the selection of three key teams:

- The institution's representatives who establish the objectives and reqiremens.
- The execution team, which carries out the various tasks required at each stage;
- The reviewing team, whose job is quality assurance in compliance with the project goals and needs of the client institution.

Chapter 5 describes the various professional disciplines needed for the project, and the standards they must meet. A key part of the quality assurance strategy is the role played by the reviewing team in ensuring that the performance objectives are met. The team must establish coordination mechanisms for evaluating the implementation of the project and the application of the agreed-upon protection measures. At each stage of the design process, and for each service to be provided, the team must evaluate whether the protection objectives have been achieved.

2. Stages in the design and construction of the facility

Stage 1: Drafting of a medical-architectural program

The design process has, as its starting point, a medical-architectural program, defined by the institution, which stipulates the services the new facility will provide and the physical space it will require to do so. The program typically specifies all the services to be provided, the functional areas needed, and the desired dimensions in square meters.

Stage 2: Selection of a development team for the preliminary project

This is the time to define the requirements that must be met by the specialists who will develop the preliminary project. The requirements that this group must meet are presented in *Chapter 5*.

Stage 3: Development of the preliminary project

It is on the basis of this program that the preliminary plan will be drafted, which will define how the services and spaces will be handled. This process must include the definition of the physical characteristics of the facility and its operation.

Taking into consideration the hazards the facility may face, it will be necessary to choose protection methods and systems that can meet the challenges posed by these hazards. For instance, in areas of high seismicity, buildings must be regular in their geometric plan and elevation, and systems that do not lead to sharp deviations in the structural system must be selected. In addition, it is desirable at this stage to establish whether there will be constraints on the form and distribution of the facility as a result of the structure's protection systems. For instance, if a seismic base isolation system is used, a discontinuity at the isolation interface will be required not only throughout the entire floor plan but also in the immediate perimeter in order to accommodate any displacements that may occur. This situation demands the use of special designs that must be considered at this stage. Likewise, in high-wind areas, the type of roof covering and façade elements is highly relevant. In flood-prone areas, meanwhile, it may be necessary to employ fills above the level of reference that would normally not be considered[5].

Usually, more than one preliminary plan will be produced for each facility. The selection of the definitive plan, in addition to any functional and aesthetic considerations that may influence the final choice, should be guided by how thoroughly the existing regional and local risks have been taken into account, along with the necessary solutions to secure the protection objective set for the project. Among the variables to be considered in this assessment, in connection with the protection objective chosen, the following may be listed:

- Ways in which the hazard could affect the facilities;
- Ways in which the preliminary project addresses potential effects of the various hazards;
- Location;
- Shape of structure;
- Structural system and form and degree of protection;
- External services and dependencies;
- Contemplated special protection features;
- Overall design considerations;
- Guarantees that the performance objectives will be met.

Since it is during the preliminary planning stage that the requirements of the medical-architectural program will be interpreted, and formal solutions found for the protection challenges it poses, it is essential that the execution team have enough experience to perform this correctly.

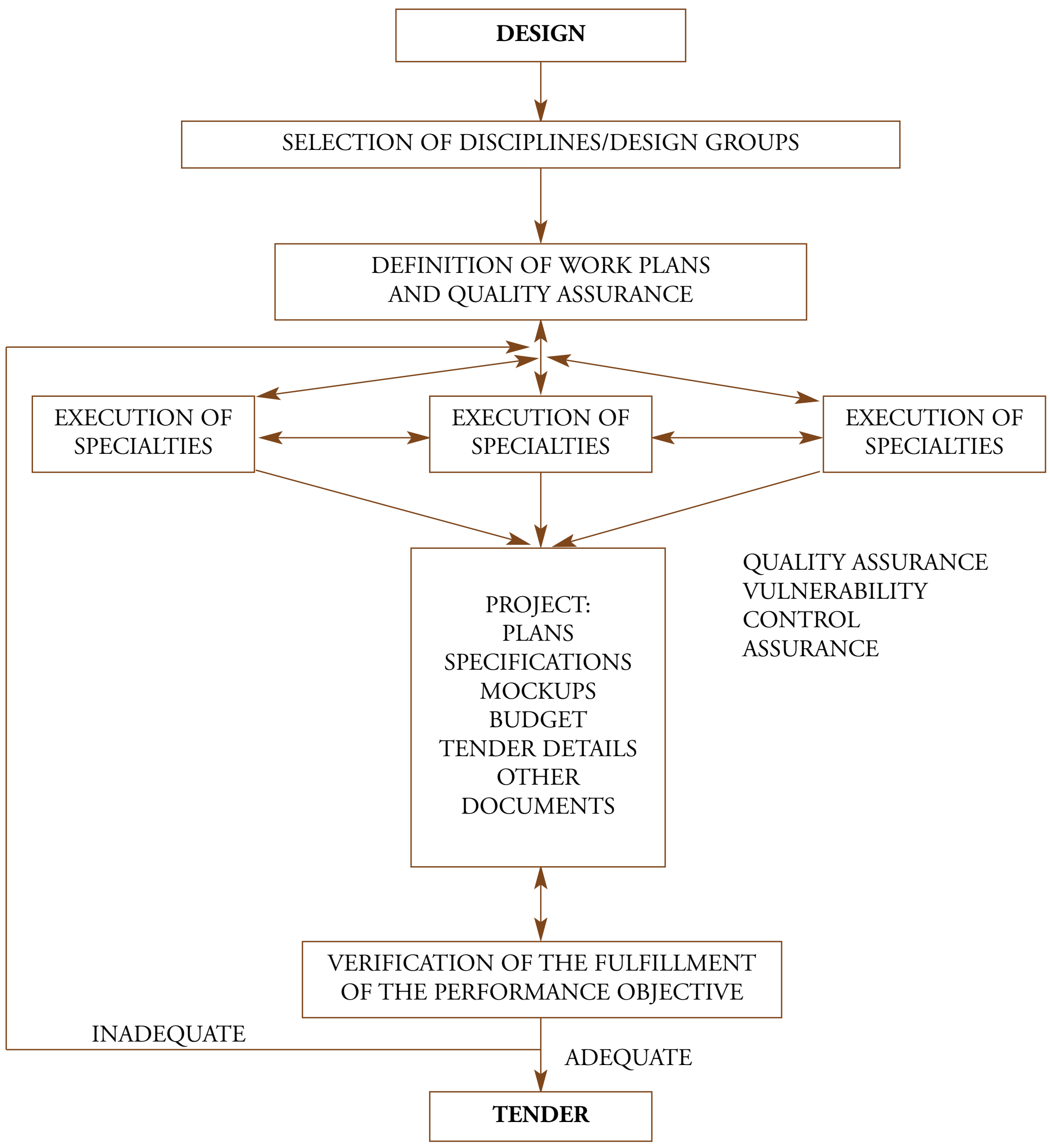
5 *Principles of Natural Disaster Mitigation in Health Facilities* (Pan American Health Organization, 2000), *Disaster Mitigation for Health Facilities: Guidelines for Vulnerability Appraisal and Reduction in the Caribbean* (PAHO, 2000), and *FEMA 55: Coastal Construction Manual* (Federal Emergency Management Agency, 1996), list the basic requirements for each hazard

Stage 4: Selection of the design team

This is the time to define the requirements that must be met by the specialists who will develop the definitive project, and to select the various work groups. The requirements that these groups must meet are presented in *Chapter 5*.

Stage 5: Development of the actual project

The first step in this stage is to carry out the detailed studies needed for the production of the definitive project, which will consist of technical specifications, plans, mockups, and tender documents. The chart below summarizes the necessary steps.



Due to the complexity of any health facility in comparison with ordinary buildings, a large number of professionals grouped by discipline as specified in *Chapter 5, Table 5.3* must participate. Each team of specialists will be in charge of developing a specific subproject: the structure, the heating, ventilation and air conditioning (HVAC) system, the various support services, and so on. Coordination is required for all these activities, and therefore clear procedures and protocols must be defined for the generation and sharing of information. Appropriate coordination is the key to the successful completion of this stage.

From the point of view of vulnerability reduction and the fulfillment of the performance objective, the design coordination team must advise each of the specialized work groups on the functional and protection requirements specified for the facility and its services. Each team of specialists will be called on to prepare a document in which it clearly explains how it will achieve these objectives and, most importantly, what their requirements and restrictions will be in relation to the other disciplines.

The design of the project will be the result of the integration of the work of all the participating disciplines on each section of the contemplated facility, so it bears repeating that coordination is indispensable. The safety criteria chosen for each section have to be the same across all disciplines, and the ways in which these criteria will be satisfied must be established in advance by all teams. The protection systems that will be incorporated must then be included in the construction documents outlining the physical details of the system to be built: the technical specifications and the various plans.

When considering the overall safety of the infrastructure in question, it is common to divide its components in two groups: the structure itself, and the nonstructural elements. Generally, the design team in charge of the structure is proficient in two disciplines: structural engineering and architecture. In the design of the nonstructural elements, all disciplines must be equally involved.

Design of the structure

Characteristics of the structural design

The structural system must meet the protection objectives defined for the facility as a whole and the services it will provide. The structural engineering team is chiefly responsible for the safety of the structure. When the performance objectives of the facility and its services call for investment and functional protection, the team must provide a structural system that not only safeguards the structure itself but also the nonstructural elements. Put differently, the structure not only must protect—it must make it feasible to implement procedures for protecting the nonstructural systems. For this reason, the structural system needs to be approved by all the disciplines represented in the project.

At present, non-traditional structural systems provide different levels of safety both for the structural and the nonstructural elements. For instance, in the case of seismic demand, several hospitals have been built successfully employing seismic base isolation systems, which create an interface between the foundations and the structure through the use of rubber or friction-pendulum bearings that simulate an automobile's suspension system. Such systems keep the seismic energy from reaching the structure, through dissipation, reducing significantly the impact of strong ground motion on the structural and nonstructural elements.

The structural system and its components must be designed to withstand the permanent and potential forces that affect a structure, including its dead load (its own weight) as well as its live load (the structure in operation), its seismic load, wind load, snow or ash load, temperature changes, hydrostatic and hydrodynamic soil factors, total and relative settlements of foundations, and so on, all of which are defined and regulated by existing design standards.

In general terms, the design must incorporate structural detailing that can effectively meet the protection objective for each level of risk. It is also important to incorporate in the design any systems that, in case of damage and functional losses, may enable the facility's services to recover within a predefined timeframe. Given the materials that are employed in construction, there will always be some degree of damage. For instance, damage to reinforced concrete buildings may present itself as fissures, cracking, or the partial or total collapse of the material. However, no level of damage is acceptable if it puts the lives of the users or staff at risk. To the fullest extent possible, moreover, situations must be prevented that can cause panic among the staff and the evacuation of the facility when it is technically unnecessary.

Information provided by the structural design team

The structural design team must provide the information required by the other disciplines for the design of the equipment, systems, and other nonstructural components. In return, it must also be informed by the other teams of any issues that may have a bearing on structural design, such as unusually heavy equipment to be installed in higher stories. Among the information that should be provided by the structural team are such data as story drift ratio, forces acting on the points of support, and acceleration at each level.

The project coordination committee must ensure that this information is taken into account by all the other disciplines working on the design of the project.

Safety assessment of the structural system

The specialists in charge of the structural design of the facility must be able to guarantee that the protection criteria set by the client institution will be met.

The design of nonstructural components

Characteristics of the design of nonstructural components

Nonstructural elements are those components that, while not part of the resistant system of the structure, are crucial to the effective operation of the facility. In the case of hospitals, close to 80 percent of the total cost of the facility goes into nonstructural components, among them architectural elements, medical and laboratory equipment, office equipment, electrical and mechanical-industrial equipment, distribution lines, and basic installations (*Table 4.2*).

Table 4.2 Typical nonstructural components that require protection

Architectural	Equipment and furnishings	Basic facilities
Partitions and interiors	Medical equipment	Medical gases
Façades	Industrial equipment	Industrial gas
Suspended ceilings	Office equipment	Electrical distribution
Roofs or decks	Furniture	Telecommunications
Cornices	Contents of furniture	Vacuum
Terraces	Supplies	Drinking water
Chimneys	Clinical files	Industrial water
Plaster	Pharmacy shelves	Air conditioning
Glass windows		Steam
Appendages		General piping
Canopies		
Antennas		

Source: Boroschek, R. and Astroza, M. *Disaster mitigation in health facilities: nonstructural aspects*, Pan American Health Organization, 2000.

The impact of damage to the facility's nonstructural components may vary. For instance, damage to medical equipment or to the lifelines that supply medical and support services can actually cause loss of lives or—what often amounts to the same thing—the loss of the functional capacity of the facility. While less dramatic, partial or total damage to certain components, equipment, or systems may entail prohibitive repair and replacement costs.

Secondary effects of the damage to nonstructural components are also important, for instance the fall of debris in hallways or escape routes, fires or explosions, or the rupture of water or sewage pipes. Even relatively minor damage, it should be stressed, can compromise aseptic conditions in the affected areas, putting critical patients at risk. Major damage to systems, components, or equipment containing or involving harmful or hazardous materials may force the evacuation of some parts of the facility, resulting in a loss of operational capacity.

Nonstructural components must incorporate a level of protection that is proportional to the performance objective that has been defined for the medical or support service in question, as well as all other services that are directly or indirectly related to them. Each team of specialists must be responsible for the design of the protection systems required by the components of their competence, and must certify, by following the procedures described in *Annex 4.1, Safety assessment of the nonstructural systems*, that the performance objective defined by the institution has been met.

The project coordination committee must ensure that the subprojects designed by the various disciplines are correctly integrated and compatible with each other, and it should hold regular coordination meetings in which representatives of each team are present. Moreover, the coordination committee will be responsible for ensuring that each work group is provided in timely fashion with the most up-to-date information regarding the work of the other teams and the overall progress of the project.

The protection of nonstructural systems calls for a logical sequence: first, interior safety and the stipulation of requirements for the immediate exterior (characteristics of supports, anchoring, etc.); secondly, the safety of the immediate exterior (furnishings, ceilings, supplies and others); and, finally, the safety of the overall structure. The following table summarizes the main ways to

Table 4.3 Main forms of protection

Nonstructural component to protect	Protection provided by:		
	Structure	Architecture	Furnishings
Architectural	✔		
Industrial equipment	✔		
Medical and laboratory equipment	✔	✔	✔
Distribution systems	✔	✔	

Assessing the safety of nonstructural components

Nonstructural components require protection systems that can guarantee the achievement of the performance objective set for the project. Assessing the degree to which the protection goals for the different disaster scenarios have been met may be done in several ways, most commonly through mathematical modeling or certificates issued by the supplier or manufacturer of the component or system.

In the event that the assessment of the protection systems is done through mathematical analysis or modeling, detailed financial reports must be drafted. The records should include the following information: qualifications of the specialist; the type of system, equipment or component; the performance objective for the components; which service area they will be located in; what standards and codes were applied in the analysis; what type of behavior will determine the response of the system (internal safety, support or anchoring element, resistance to tipping over or sliding, deformation, resistance, level of damage it can sustain, interaction with other elements, dependency on other elements, and so on); description of the system, equipment or component (general description, weight, shape, type of material, support systems, drawings of details, certificates of safety issued by the provider or manufacturer, performance in previous earthquakes or other disasters, description of built-in protection systems, etc.); characteristics of the equipment when operating; bracing and anchoring systems; support elements; load considered in the analysis; description of analysis method; main results of analysis (internal stresses, use factors, deformations, stability, etc.); verification of interaction with other elements; certification of fulfillment of performance objectives; and others.

If the safety assessment is to be done by means of certification by the provider or manufacturer, two methods are acceptable. The first will be certification through analysis, which must be accompanied by all the information mentioned in the previous paragraph. The second method will be certification through testing. In that case, a document should identify the lab where the tests were carried out, the standards used, a description of the procedures employed, the load applied and the results, the requirements for certification (conditions of use and operation, conditions of placement and attachment, etc.), conformity with the standards specified in the contract documents and description of limitations and applicability of the certification.

Annex 4.1 specifies the procedures that must be carried out by each team of specialists to assess the effectiveness of the safety systems to be implemented.

The design stage concludes with the production of the final plans, technical specifications, mock-ups, budgets, and tender documents. At this stage, both the design execution team and the project reviewing team must deliver a document certifying that the protection objective has been met.

Stage 6: Selection of the building contractor

The selection of the contractor who will carry out actual construction of the facility must meet all relevant national legislation and standards. Among the selection criteria, the experience of candidate firms in the building of disaster-resistant health facilities should be considered. *Chapter 5* describes the requirements that must be met by the companies interested in bidding for the contract.

Stage 7: Construction

It is at this stage that the protection objectives set for the facility as a whole must be realized. While the project's specifications and plans developed during the design phase should guide the construction process, in practice it is often necessary to introduce modifications or clarify the meaning of certain requirements. In such situations, any request for modifications presented by the contractor must be meticulously evaluated, and any alteration to the original plans should be approved by the client institution, the design team, and the reviewing team. Modifications to the facility's protection objective must be subjected to careful analysis and documented—thereby ensuring that the facility's real operational capacity within the overall health network has been correctly determined. Quality assurance procedures such as those mentioned in *Chapter 6* must now be rigorously followed in order to ensure that protection goals for the facility are met.

References

General protection standards, codes, and reference material

American Society of Civil Engineers, *ASCE 7-98: Minimum Design Loads for Buildings and Other Structures*.

Applied Technology Council, *ATC 51: U.S.-Italy Collaborative Recommendations for Improving the Seismic Safety of Hospitals in Italy*, California, 2000.

Building Officials Code Administrators International, *International Building Code 2000*.

Building Seismic Safety Council (BSSC), *FEMA 368: NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*, Washington, D.C., 2001.

Building Seismic Safety Council (BSSC), *FEMA 369: NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, Commentary*, Washington, D.C., 2001.

Departments of The Army, The Navy and The Air Force, *NAVY NAVFAC P-355.1: Seismic Design Guidelines for Essential Buildings*, Technical Manual, Washington, D.C., December 1986.

Departments of The Army, The Navy and The Air Force, *NAVY NAVFAC P-355.2: Seismic Design Guidelines for Upgrading Existing Buildings*, Technical Manual, Washington, D.C., September 1988.

Deutsches Institut für Normung, *DIN 4149-1: Buildings in German Earthquake Zones; Design Loads, Dimensioning, Design and Construction of Conventional Buildings*, 1981.

European Committee for Standardization, *Eurocode 8: Design of Structures for Earthquake Resistance. Part 1: General Rules, Seismic Actions and Rules for Buildings*, Brussels, 1998.

Federal Emergency Management Agency, *FEMA 276: Example Applications of the NEHRP Guidelines for the Seismic Rehabilitation of Buildings*, Washington, D.C., April 1999.

Federal Emergency Management Agency, *FEMA 310: Handbook for the Seismic Evaluation of Existing Buildings*, Washington, D.C., 1998.

Federal Emergency Management Agency, *FEMA 356: Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, Washington, D.C., November 2000.

Federal Emergency Management Agency, *FEMA 55: Coastal Construction Manual.*

Federal Emergency Management Agency, *FEMA 74: Reducing the Risk of Nonstructural Earthquake Damage, A Practical Guide*, Washington, D.C., September 1994.

International Standard Organization, *ISO 3010:2001: Basis for Design of Structures -- Seismic Actions on Structures.*

International Standard Organization, *ISO 4354:1997: Wind Actions on Structures.*

Office of Statewide Health Planning and Development (OSHPD), *Building Standard Administrative Code, Part 1, Title 24, C.C.R*, December 2001.

U.S. Army Corps of Engineers, engineering Division, Directorate of Military Programs, *TI 809-4: Seismic Design for Buildings*, Technical Instructions, Washington, D.C., December 1998.

Guidelines, codes and references for the design and analysis for the protection of the structural and nonstructural components

Annex 4.2 lists examples of standards, codes and literature to be considered in the design of the protection systems of structural and non-structural components.

Annex 4.1 Safety assessment of non-structural systems

The procedures that should be developed within each discipline for the assessment of the security of the system, equipment and nonstructural components are: 1) proof of security through analysis and design, 2) certification of security by the provider or manufacturer.

The following table lists in detail the content of the financial report needed to certify the safety of systems, equipment and components in the event that the design team chooses to demonstrate safety through mathematical analysis and modeling.

Safety assessment of systems, equipment and nonstructural components through mathematical analysis[1]
Minimum required financial report[2]
Identity of the specialist
Name of the specialist
Specialty
Classification of the system, equipment or component
Architectural element
Lifeline
Medical or laboratory equipment
Industrial equipment
Isolated electrical or mechanical equipment
Distributed electrical or mechanical equipment
Level of protection under consideration
Protection objective for the overall facility and the area where the system, equipment or component is located
Protection objective for the services supported by the system, equipment or component
Protection objective for the system, equipment or component itself
Standards considered in the analysis
National standards
International standards
Other standards specific to the project
Description of the structure where the system, equipment or component will be located
Geometrical dimensions
Number of stories
Height of stories
Estimated load of the various stories of the building
Background on the dynamic properties of the building
Other essential facts

Behavior determining the response of the system, equipment or component
Interior safety
Support element or anchoring
Anchoring
Bracing
Stability (overturning, sliding)
Deformation
Resistance
Highest level of damage tolerated
Interaction with other elements
Dependence on other elements
Other (specify)
Description of the system, equipment or component
General description, function, and dependence on other systems, equipment or components
Weight, distribution of the weight, and location of the center of mass in different conditions of use and operation
Geometrical dimensions
Principal materials and mechanical characteristics
Support systems
With vibration isolation system
Without vibration isolation system
Detail plans or drawings
Interior safety certificate issued by the supplier or manufacturer
Background facts on performance in previous emergencies
Description of built-in protection systems
Systems used for the interior safety of the component
Systems used to increase the safety of the support element
Systems used for anchoring and stabilization
Systems used for damage control
Systems used to prevent interaction with other components
Other systems used to provide safety to the system, equipment or component
Characteristics of the equipment when in operation (evaluate only relevant equipment)
Frequency of operation
Storage capacity
Loads produced during the operation of the equipment
Operational temperature
Operation in corrosive environment
Identification of least favorable actions and load combinations[3]

Bracing characteristics of systems, equipment and components
Description of the structural concept
Angle of the braces
Length of the braces
Profile section of braces
Thickness of the bracing element
Capacity of the material
Elasticity of the material
Distance between braces
Detail plans
Anchorage characteristics of systems, equipment and components
Description of the structural concept
Resistance of the materials
Number of anchoring elements
Diameter of the anchoring elements
Embedded length of the anchoring elements
Plans of the anchoring elements
Characteristics of system, equipment or component support elements
Material
Shape of the elements
Resistance of the materials
Other characteristics of the support elements
Classification of the system, equipment or component
Fundamental period
Rigid equipment or component
High deformability
Limited deformability
Low deformability
Flexible equipment or component
High deformability
Limited deformability
Low deformability
Spatial distribution
Isolated element
Distributed element
Number of points of support
Response
Sensitive to acceleration
Sensitive to deformation
Contents
Hazardous or difficult-to-replace materials
Materials are neither dangerous nor difficult to replace

Interaction with other systems, equipment and components
Not linked
Linked
Dependence on other systems, equipment and components
Independent
Not independent
Other relevant classifications
Method of analysis
Equipment included in structure analysis model
Equipment not included in structure analysis model
Static analysis
Dynamic analysis
Characteristics of (seismic or other) demand
Summary of factors that determine the demand
Return period associated with the expected demand
Damping considered
Factors that may modify the response
Demand as considered in the design
Results
Internal stresses
Utilization factors of bracing elements
Utilization factors of anchoring elements
Estimated deformation
Assessment of the system, equipment or component's bracing or anchoring elements
Stability
Assessment of interaction with other systems, equipment or components
Assessment of potential impacts
Assessment of potential contamination by hazardous or harmful materials
Certification that objectives have been met

Notes: 1 This table applies to architectural elements, industrial equipment, medical and laboratory equipment, lifelines and other components of the services that need to be protected. In the case of each item, the data regarding the equipment or component analyzed should be evaluated individually.

2 The financial report should include all computational processes and the results of the intermediate calculations.

3 In addition to the load generated by the emergency, attention must be paid to the permanent load (the dead load, the live load), the loads caused by equipment ceasing to function, the loads associated with electrical or mechanical failure, the loads derived from the interaction with other equipment or components, and the loads stipulated in the contract.

The following table lists the safety certificates that must be issued by the provider or manufacturer of the standard systems, equipment or components to be employed in the project in case certification is not issued by the professional in charge of designing the project.

Standardized safety assessment of systems, equipment and nonstructural components through certification by the supplier or manufacturer[1]
Analysis-based certification
A financial report must be attached covering the contents specified in Table 5.2, in accordance with the level of detail required by the study. This document will be used for reviewing the safety of the component.
Experimental certification
Identity of accredited laboratory
Standards of reference employed in the tests
Description of test procedures
Demand applied in the tests
Results of the tests
Certification requirements
Conditions of use and operation
Conditions of installation
Other conditions
Date and period of validity of the certificate
Certification of compliance with standards specified in the contract
Description of limitations to, and applicability of, the certification

Notes: 1 This table applies to architectural elements, industrial equipment, medical and laboratory equipment, lifelines and other standard components related to the services that will be protected.

Annex 4.2

Standards, codes and references specific to protection of structural components and nonstructural components

Protection of Structural Components

Natural hazard	Standards, Codes and References Specific to Design and Analysis
Strong winds	American Society of Civil Engineers, *ASCE 7-98: Minimum Design Loads for Buildings and Other Structures*. Building Officials Code Administrators International, *International Building Code 2000*. Deutsches Institut für Normung, *DIN 4149-1: Buildings in German Earthquake Zones; Design Loads, Dimensioning, Design and Construction of Conventional Buildings*, 1981. European Committee for Standardization, *Eurocode 8: Design of Structures for Earthquake Resistance. Part 1: General Rules, Seismic Actions and Rules for Buildings*, Brussels, 1998. Federal Emergency Management Agency, *FEMA 55: Coastal Construction Manual*. Federal Emergency Management Agency, *FEMA 74: Reducing the Risk of Nonstructural Earthquake Damage, A Practical Guide*, Washington, D.C., September 1994. International Standard Organization, *ISO 4354:1997: Wind Actions on Structures*.
Seismic event	American Society of Civil Engineers, *ASCE 7-98: Minimum Design Loads for Buildings and Other Structures*. Applied Technology Council, *ATC 51: U.S.-Italy Collaborative Recommendations for Improving the Seismic Safety of Hospitals in Italy*, California, 2000. Building Seismic Safety Council (BSSC), *FEMA 368: NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*, Washington, D.C., 2001. Building Seismic Safety Council (BSSC), *FEMA 369: NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, Commentary*, Washington, D.C., 2001. Building Officials Code Administrators International, *International Building Code 2000*. Departments of The Army, The Navy and The Air Force, *NAVY NAVFAC P-355.1: Seismic Design Guidelines for Essential Buildings*, Technical Manual, Washington, D.C., December 1986. Departments of The Army, The Navy and The Air Force, *NAVY NAVFAC P-355.2: Seismic Design Guidelines for Upgrading Existing Buildings*, Technical Manual, Washington, D.C., September 1988. Deutsches Institut für Normung, *DIN 4149-1: Buildings in German Earthquake Zones; Design Loads, Dimensioning, Design and Construction of Conventional Buildings*, 1981. European Committee for Standardization, *Eurocode 8: Design of Structures for Earthquake Resistance. Part 1: General Rules, Seismic Actions and Rules for Buildings*, Brussels, 1998. Federal Emergency Management Agency, *FEMA 74: Reducing the Risk of Nonstructural Earthquake Damage, A Practical Guide*, Washington, D.C., September 1994. Federal Emergency Management Agency, *FEMA 276: Example Applications of the NEHRP Guidelines for the Seismic Rehabilitation of Buildings*, Washington, D.C., April 1999. Federal Emergency Management Agency, *FEMA 310: Handbook for the Seismic Evaluation of Existing Buildings*, Washington, D.C., 1998. Federal Emergency Management Agency, *FEMA 356: Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, Washington, D.C., November 2000. International Standard Organization, *ISO 3010:2001: Basis for Design of Structures -- Seismic Actions on Structures*. Office of Statewide Health Planning and Development (OSHPD), *Building Standard Administrative Code, Part 1, Title 24, C.C.R*, December 2001. U.S. Army Corps of Engineers, engineering Division, Directorate of Military Programs, *TI 809-4: Seismic Design for Buildings*, Technical Instructions, Washington, D.C., December 1998.

Protection of Nonstructural Components

Nonstructural Component	Standards, Codes and References Specific to Design and Analysis	Professional Team Required
Isolated (not distributed) electrical and mechanical equipment Industrial equipment	American Petroleum Intitute, *API 650: Welded Steel Tanks for Oil Storage", Washington, D.C.* Deutsches Institut für Normung, *DIN EN 61587-2: Mechanical Structures for Electronic Equipment - Tests for IEC 60917 and IEC 60297 - Part 2: Seismic Tests for Cabinets and Racks (IEC 61587-2:2000)*, 2001. Ishiyama, Y., *Criteria for Overturning of Rigid Bodies by Sinusoidal and Earthquake Excitations*, Earthquake Engineering and Structural Dynamics, Vol. 10, 1981. Institute of Electrical and Electronic Engineers, *IEEE C 37.81: Guide for Seismic Qualification of Class 1E Metal-Enclosed Power Switchgear Assemblies*, New York, 1989. Institute of Electrical and Electronic Engineers, *IEEE C 37.98: Seismic Testing of Relays*, New York, 1987. Institute of Electrical and Electronic Engineers, *IEEE 344-1987: Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations*, New York, 1987. International Electrotechnical Commission, *IEC 60068-3-3: Environmental Testing – Part 3, Seismic Test Methods for Equipment*, 1991. International Electrotechnical Commission, *IEC 60255-21-3: Electrical relays - Part 21: Vibration, Shock, Bump and Seismic Tests on Measuring Relays and Protection Equipment - Section 3: Seismic Tests*, 1988. International Electrotechnical Commission, *IEC 61166-21-2: High-Voltage Alternating Current Circuit-Breakers - Guide for Seismic Qualification of High-Voltage Alternating Current Circuit-Breakers*, 1993. International Electrotechnical Commission, *IEC/TS 61463: Bushings - Seismic Qualification*, 2000. International Electrotechnical Commission, *IEC 61587-2: Mechanical Structures for Electronic Equipment – Tests for IEC 60917 and IEC 60297 - Part 2: Seismic Tests for Cabinets and Racks.*	Electrical engineer Mechanical engineer Seismic engineer Structural engineer Vulnerability assessment specialist Hospital architect Industrial equipment specialist
Pipes, ducts and electrical conduit systems Fire safety systems	National Fire Protection Association, *NFPA 13: Standard for the Installation of Sprinklers Systems.* Sheet Metal and Air Conditioning Contractors National Association, *Seismic Restraint Manual: Guidelines for Mechanical Systems*, second edition, February 1998. Sheet Metal and Air Conditioning Contractors National Association, *Addendum No.1 To Seismic Restraint Manual: Guidelines for Mechanical Systems*, September 2000 WSP 029, *Aseismatic Design Manual for Underground Steel Water Pipelines*, 1989.	Electrical engineer Mechanical engineer Seismic engineer Structural engineer Vulnerability assessment specialist Fire Protection Specialist
Medical and laboratory equipment Furniture	International Electrotechnical Commission, *IEC 60068-3-3: Environmental Testing - Part 3: Guidance. Seismic Test Methods for Equipment"*, 1991. Ishiyama, Y., *"Criteria for Overturning of Rigid Bodies by Sinusoidal and Earthquake Excitations*, Earthquake Engineering and Structural Dynamics, Vol. 10, 1981.	Hospital architect Medical equipment specialist Seismic engineer Structural engineer Vulnerability assessment specialist Furniture designer

Protection of Nonstructural Components

Nonstructural Component	Standards, Codes and References Specific to Design and Analysis	Professional Team Required
Systems of suspended ceilings Lighting fixtures systems	American Society for Testing and Materials, *ASTM E 580: Standard Practice for Application of Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels in Areas Requiring Moderate Seismic Restraint*, 2000. Ceilings and Interior Systems Construction Association, *Guidelines for Seismic Restraint, Direct Hung Suspended Ceilings Assemblies: Seismic Zones 3-4*, 1991. *"Uniform Building Code Standard 25-2: Metal Suspension Systems for Acoustical Tile and for Lay-in Panel Ceiling"*.	Hospital architect Specialist lighting fixtures Seismic engineer Structural engineer Vulnerability assessment specialist
Elevator/escalator systems	American Society of Mechanical Engineers, *ASME A17.1: Safety Code for Elevators and Escalators*, 2000. Deutsches Institut für Normung, *DIN EN 61587-2: Mechanical Structures for Electronic Equipment - Tests for IEC 60917 and IEC 60297 - Part 2: Seismic Tests for Cabinets and Racks (IEC 61587-2:2000)*, 2001. Japanese Elevator Association, *Guide for Earthquake Resistant Design and Construction of Vertical Transportation*. Standard New Zealand, *NZS 4332:1997: Non Domestic Passenger and Goods Lifts*. 1997.	Elevator/escalator specialist Mechanical engineer Electrical engineer Seismic engineer Structural engineer Vulnerability assessment specialist
Roofing structures	Federal Emergency Management Agency, *Against the Wind*, 1993 Federal Emergency Management Agency, FEMA 361: *Design and Construction Guidance for Community Shelters*, Fist Edition, July 2000	Hospital architect Seismic engineer Structural engineer Vulnerability assessment specialist
Partitions and façade elements	American Architectural Manufacturers Association, Aluminum Curtain Wall Design Guide Manual American Architectural Manufacturers Association, Aluminum Store Front and Entrance Manual American Architectural Manufacturers Association, Design Windloads for Buildings and Boundary Layer Wind Tunnel Testing American Architectural Manufacturers Association, Installation of Aluminum Curtain Walls American Architectural Manufacturers Association, Maximum Allowable Deflection of Framing Systems for Building American Architectural Manufacturers Association, Cladding Components at Design Wind Loads American Architectural Manufacturers Association, Metal Curtain Wall Fasteners American Architectural Manufacturers Association, Metal Curtain Wall Manual American Architectural Manufacturers Association, Rain Penetration Control – Applying Current Knowledge American Architectural Manufacturers Association, Structural Design Guidelines for Aluminum Framed Skylights American Architectural Manufacturers Association, Voluntary Specifications for Hurricane Impact and Cycle Testing of Fenestration Products. Federal Emergency Management Agency, Against the Wind.	Hospital architect Seismic engineer Structural engineer Vulnerability assessment specialist
Doors and windows	American Architectural Manufacturers Association, *Glass and Glazing*. Federal Emergency Management Agency, *Against the Wind"*. International Standard Organization, *"ISO 6612:1980:Windows and Door Height Windows Wind Resistance Tests*.	Hospital architect Structural engineer

Chapter 5

Evaluating the Work Teams

1. Professional requirements

Particularly in the case of health facilities with high protection requirements, a key consideration is the hiring of experienced professionals who keep abreast of their field of expertise. If the performance objectives set for the intended facilities are to be met, careful siting and the implementation of an across-the-board quality assurance program will not suffice unless the right personnel is chosen.

The choice of the individuals and firms that will be responsible for the design and for providing oversight of all of the design and construction activities of the project must be based on an objective appraisal of their merits. Among the matters to be scrutinized are their professional qualifications, participation in national and international seminars and conferences, number of projects completed, square meters built, and specific expertise in health sector projects designed and constructed in accordance with national or international standards.

Three main players will be involved in the process: the client institution, the execution team, and the oversight team. The institution's job is to define its needs as clearly and specifically as possible, coordinate the various stages and components of the project, and provide the physical, technical, and financial resources needed. The execution team's mission is to meet the institution's needs by first envisioning and then materializing the most appropriate and cost-effective response to those needs. As a priority, the team should develop the design criteria for the project. It is the job of the oversight team to review the design criteria developed by the execution team, review every stage of the work, and implement the quality assurance program so that the final product meets the performance and other objectives set by the institution.

In order to ensure the smooth coordination of the project, the client institution must set up an effective management structure. The latter must have clearly defined roles and responsibilities in order to ensure accountability and efficiency. The management must engage competent persons with the experience and qualifications set out in *Table 5.1*. The persons or firms engaged should be able to certify that they meet the criteria specified in *Table 5.1*, adjusted to the realities of each country, with greater emphasis being placed on the quality of the projects carried out in the past rather than on academic qualifications.

It is desirable that nationals of the country where the project is to be built be intimately involved in the design and execution of the project, partly because this will contribute to local capacity-building in the field of disaster mitigation, but also because nationals should, in principle, be more aware of the hazards and cultural responses to them.

The oversight team must have the level of experience shown in *Table 5.1* and should review the design criteria for all elements of the project. It should also be prepared to offer advice where appropriate to the design teams.

A stable team of specialists in the design teams who can supervise the project from start to finish would best serve the client's purposes. It will almost certainly be necessary to rely on a succession of specialist ad hoc teams when dealing with specific stages such as risk assessment, site selection, design, and construction, involving different areas but also degrees of specialization. However, this does not overrule the need for constant oversight and quality assurance by an experienced team of professionals who work for the client institution or have been specifically hired to represent its interests.

Table 5.1 Professional requirements for project design, execution, and oversight

Position	Minimum certified experience	Experience in hospital design (last 10 years)	
		Total surface built	Other requirements
Oversight Teams	10 years	> 150.000 m^2	At least two health facilities with areas > 10,000 m^2
Execution Teams			
Risk Assessment Specialists	10 years	-	-
Design Teams	10 years	> 100.000 m^2	At least one health facility with area > 10,000 m^2
Construction Teams	10 years	> 100.000 m^2	At least 1 health facility with area > 5,000 m^2

2. Specialists required for the preliminary stage, including risk assessment and site selection

Risk assessment and site selection call for specialists in such disciplines as urban development, topography, geology, soil mechanics, seismology, hydrology, meteorology, and volcanology, as well as hydraulic, wind, seismic and structural engineering, as specified in *Table 5.2*. The choice of specialists will depend on the hazards prevalent in the area, particularly in the siting options for the new facilities.

These specialists must assess the potential impact of such hazards on the various siting options, as outlined in *Chapter 3*. While they cannot all be expected to have experience in the design of health infrastructure, it would be desirable if they did. What is indispensable is experience in risk assessment of natural and man-made hazards.

Table 5.2 Professionals required for hazard assessment

	Natural hazards					
Professionals Needed	Mudslides	Landslides	Hurricanes	Floods	Seismic events	Volcanic eruptions
Urban Development Specialists	❑	❑	❑	❑	❑	❑
Topographers	❑	❑	❑	❑	❑	❑
Geologists	❑	❑			❑	❑
Soil Mechanics Specialists	❑	❑		❑	❑	❑
Meteorologists	❑		❑	❑		
Hydrologists	❑	❑	❑	❑		
Hydraulic Engineers	❑	❑	❑	❑		
Seismologists		❑			❑	❑
Wind Engineers (specialized in hydrodynamics)			❑			
Seismic Engineers		❑			❑	❑
Structural Engineers	❑	❑	❑	❑	❑	❑
Volcanologists						❑

3. Specialists required for the preliminary plan, design, construction, and inspection of the project

The preliminary planning team, the coordination committee, the participating specialists, and the building contractor must prove they have at least 10 years' experience in the design, construction or inspection of health infrastructure, not only generally, but with specific reference to the role they intend to play in the construction of the new health facility. Some of the key disciplines that must participate in the design, construction, and inspection of the project are listed in *Table 5.3*.

Participating professionals as listed in *Table 5.2* must establish their academic and other professional credentials, as validated by professional associations and other bodies, certify their professional experience, and be able to show that their experience meets the criteria listed in *Table 5.1*.

If partnerships with external consultancy firms are required, such firms must assume full responsibility for their portion of the work. Groups or companies that provide specific quality assurance guarantees in writing should be favorably regarded. Special consideration should also be given (as noted above) to the development of local professional capacity through the transfer of expertise and useful methodologies.

Table 5.3 Disciplines required for the design, construction and technical inspection of the works

Air conditioning[1]	General safety	Signage
Architecture[2]	Geotechnical engineering[5]	Structural design[6]
Budgeting and finance	Industrial equipment[4]	Telecommunicactions[7]
Built-in furnishings	Lighting fixtures	Vulnerability
Clinical gases	Medical and laboratory equipment	Waste management
Construction methods	Medical furnishings	Water treatment[8]
Electrical installations	Medicine and nursing	Other (specify)
Elevator/escalator	Pneumatic mail	
Fire safety[3]	Sanitation facilities[5]	

Notas: 1 Included in this discipline: air conditioning systems, heating, ventilation, etc.

2 The architect is responsible for the overall architectural design of the facility. The structural engineer must carry out or supervise the safe design of the structural components of his or her competence, including façade elements, interior partitions, suspended ceilings, and appendages as required by the architect.

3 Included in this discipline: dry and wet networks, sprinklers, etc.

4 Included in this discipline: laundry, food or dietary services, sterilization, etc.

5 Included in this discipline: drinking water and sewerage networks, natural gas, etc.

6 Depending on the conditions of the contract, the specialist must carry out structural design and/or the structural review of the nonstructural components' protection systems.

7 Included in this discipline: closed-circuit TV, telephones, internal communications, etc.

8 Included in this discipline: dialysis equipment, boiler room, sterilization, laboratory, etc.

4. Criteria for selecting professional teams and consultants

In order to make an informed choice when selecting the individual professionals and firms that will make up the execution team or carry out advisory tasks, interested parties must present all relevant information and fill out forms such as those in this section.

Individual professionals interested in participating in the project shall fill out a form containing such information as name, contact information, and qualifications, and attach copies of their diplomas and any other certificates issued by academic, professional or governmental institutions

They must also fill out a form with the information indicated in *Annex 5.1* for each significant project they have been involved in. This document should include the professional's name, the name of the project, the client institution, the field in which the professional worked (administration, planning, architecture and urban planning, basic engineering, detail engineering, other studies, construction, inspections and so on, the position occupied by the professional, (administrator, chief of a given team, assistant, etc.), a description of the specific activity carried out, cost of the project, and the period required for completing the project, as well as special standards or codes applied in carrying out the project.

Firms interested in participating in the project should provide information such as their legal name, address, year of incorporation, legal representative, and list of directors and in-house or sub-contracting professionals who collaborate with the consulting firm. Name, title, area of expertise and position in the firm should be provided for all professionals. Diplomas and any other certificates issued by academic, professional or governmental institutions to the professionals and the firm should also be included.

Additional information should include the firm's particular fields of expertise, the nature of any projects the company may be involved with at the time of tender, an estimate of the firm's annual operational capacity, and its average annual work load over the past five years measured in US dollars, as certified by the firms' bankers.

Firms should provide proof of their experience in similar projects. As in the case of individual professionals interested in participating, firms should fill out a form with the information required in *Annex 5.1* for every relevant project carried out in the past, providing all the information mentioned in the previous paragraph, and specifying the disciplines and technologies involved.

The same must be done by the professionals who may be assigned by the firm to be in charge of the project or its components.

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Annex 5.1 Summary of information required of professionals and consulting firms

Information required of consulting firms

General information	
Identity of the firm	
	Full legal name of firm
	Legal domicile of the firm
	Year established
	Legal constitution of firm
	Legal representative
	Name
	Professional or technical title
	Professional or technical specialties
	Position in firm (if applicable)
Field of expertise of firm	
List of directors, professionals and subcontractors	
	Name
	Professional or technical title
	Professional or technical field of expertise
	Position in firm (if applicable)
Certification by academic, professional, governmental, or labor union organizations	
Square meters built	
Current activities and projects underway	
Financial solvency of firm	
	Estimated annual capacity in US dollars
	Average annual volume of work in last five years, in US dollars
	Backing of banking firm(s)
Technical information	
Certified summary of firm's experience (works and services)	
	Name of project
	Client institution
	Surface of project
	Financial size of project
	Built surface of project
	Total surface of project
	Period of execution
	Disciplines involved
	Technologies used
	Standards and codes applied
	Experience in similar projects
List of equipment, machinery and tools	
Other technical requirements that the institution or the coordination committee considers relevant to the project.	

Information required of consultants or specialists

Certified resume
Name of project
Client institution
Financial amount of project
Total built surface
Total surface of project
Period of execution
Field of professional endeavor (project director, designer, mitigation or other consultant, assistant, other)
Activities carried out by the professional (only certified activities)
Field of activities
Planning and feasibility
Administration
Basic engineering studies
Engineering
Architecture and urbanism
Construction
Inspections
Varied studies
Special expertise to be applied
Experience in similar projects
Standards and codes applied

Chapter 6

Managing Project Quality

1. Introduction

In order to ensure quality throughout the various stages of the project, as stipulated in the performance objectives established by the client institution, a project quality management program should set out in writing the scope of the activities to be carried out by the various professionals and firms involved, as well as the criteria they should meet, based on quality assurance standards such as those set by the International Organization for Standardization (ISO).

Such a document must specify the quality assurance activities that shall accompany the project development stage, the selection of the professionals, and the activities aimed at risk assessment, site selection, project design, tendering processes, construction, and project oversight. It should also define explicitly the functions and responsibilities of the parties and the oversight and follow-up mechanisms. Such a document must be drafted clearly, without ambiguities that might lead to errors of interpretation, in line with the general principle that the quality assurance program (QAP) should be guided by preventive, rather than corrective, measures.

The client institution must ensure that all project participants are fully aware of the provisions contained in the QAP. It must also ensure that they are met. Such a quality assurance program, in tandem with the safety certifications required at the various design and construction stages of the project, should contribute significantly to fulfilling the performance and other objectives set out for the intended facilities.

2. Guiding principles for the review and inspection of the project

Since the high performance objectives required by health facilities call for highly qualified specialists, professionals, technicians, and laborers, as well as special assessments and the production of detailed drawings and specifications, it is essential to implement systematic review and inspection procedures. Such procedures will generally require higher standards than those applied to ordinary construction projects.

At each stage of the project cycle, for instance, ongoing independent monitoring should be carried out for each discipline involved. Attention must also be paid to the degree of synergy achieved by those disciplines. The purpose of such monitoring is to ensure that the project components for which each team is responsible are compatible with each other. Another virtue of this approach is that it can identify weaknesses in the implementation or coordination of the project, reducing the risk of not meeting the performance objectives for the facility.

The oversight team should specify in writing their review and monitoring procedures. Reporting dates should be set in advance, based on the project design and construction program. The various professionals involved in the project must be aware of such dates, so that their actions can be coordinated, reviewed and, if necessary, corrected.

Before the final drawings and specifications are issued, each team of specialists must produce a work program, in writing, to be handed out to the other teams in order to facilitate a final round of cross-checking regarding disaster mitigation measures. Every review, inspection and testing mechanism to be employed in the project must also be stated in the document. The procedures to be applied should explicitly heed existing standards, and their application must be documented. No undocumented procedures are to be tolerated.

Histograms and other project management tools should be used to set the start and completion dates for the execution and delivery of each component. Communication channels and protocols must also be defined in advance. Each team must have access to up-to-date reports on how the project components managed by the other teams are advancing. The project monitoring team must call for periodic coordination meetings of the heads of teams in order to review the progress achieved and any problems that may affect the other teams' performance.

Whether during the design or construction stages, every modification to the original concept, including changes in methods or standards used, must be documented and conveyed to the other disciplines involved.

Every project whose performance objective is functional or investment protection must compile as-built reports on the progress of the works. The same is true if the objective is life safety, should the client institution require it.

Every modification to the original project must be approved in writing by the client institution. Every modification to the works during the construction stage must be approved in writing by the building contractor, the project inspectors and the relevant teams of specialists, and it must be recorded in the as-built reports.

The following sections cover specific quality assurance issues that must be considered during the various stages of the project.

3. Project quality assurance during the preliminary and design stages

The project's quality assurance program (QAP) must specify the tasks required to ensure the quality of the project during the preliminary stage, including the various risk assessments and the actual design of the facilities. This document must state the performance objective expected by the client institution, based on the criteria listed in *Chapter 2* in connection with the project's design philosophy.

Start and completion dates for the various risk assessment studies must be set in advance, so that the project design team can benefit from these inputs when incorporating disaster mitigation measures. Likewise, a histogram should be produced showing the progress required of all disciplines at any given date, so that their interaction can be effectively coordinated and corrections can be made to prevent haphazard phasing of the project or its use of resources.

At a minimum, the contract must state that the following documents will be subject to review and monitoring:

- Records of quantities and overall budget;
- General drawings and specifications;
- Architectural and structural drawings and specifications;
- Detailing plans;
- Equipment, installation, and furnishing plans.

Other tender documents should also be reviewed, including the technical specifications, equipment installation procedures, the construction manual, the manual of procedures, the construction schedules, and the general contractual terms and conditions.

Special attention must be paid to the detailing plans and respective financial reports on all the components of the building, in order to verify that the final design will match the performance objectives sought by the client institution. The professionals in charge of designing the project must specify which procedures, components, or services will require general inspections or specialized inspection during the construction stage. They should also state the characteristics of the inspections required.

Annex 6.1 summarizes the minimum requirements of a quality assurance program (QAP) to guarantee the quality of the project during its preliminary and design stage.

4. Project quality assurance: The construction stage of the project

Well-documented procedures guarantee the quality of the project during the design stage. The same is true at the construction stage. Accordingly, a compendium should be drawn up containing the specifications and other information that can ensure quality during the construction process. This compendium must contain all information needed to start construction of the intended health facility, including the final, approved drawings and specifications, the tender documents and the signed contract.

The quality assurance program must identify all professionals, consultants, and contractors who will participate in the construction. It must define the roles and responsibilities of all stakeholders, including the teams that participated in the design stage.

The client institution and the execution and review teams must fulfill the following obligations: delivering to the contractor a feasible project; making interim and final payments based on agreed-upon methods and dates; providing a suitable site that meets project requirements; choosing the correct mechanisms for inspecting the quality of the work, materials, and so on; taking the lead in decision-making when unforeseen circumstances arise; communicating in timely fashion to all parties any changes to the original project; and monitoring the progress of the work.

During the construction stage, it will be the responsibility of the design team to assist in the inspection of the work they designed, help in decision-making when unexpected circumstances or aspects not contemplated in the contract documents arise, assess the merits of any variation the contractor may propose, participate in specialized on-site inspections, certify the satisfactory completion of the various components, and recommend that interim payments be made. Either the client institution or the design team may recommend that the work be stopped or payments held back if the performance and quality objectives set for the project are not being met.

The contractor's functions will include, at a minimum: taking all the administrative and legal steps needed such as securing permits, reviewing the architectural, structural, nonstructural, equipment and detailing drawings and specifications; being faithful to these specifications; requiring that providers issue quality and safety certificates; controlling the pace of the work and the use of the resources allocated for the project; carrying out all quality assurance tests needed; keeping a builder's log; producing regular reports on the progress of the work; and any other requirements contained in the contract documents. It will be the contractor's duty to be fully aware of the objectives and details of the project; acquire materials and hire workers that meet the quality requirements of the project; take responsibility for the subcontractors' work and for the building methods and schedules applied; update the builder's log regularly and make it available as required; and report the results of any tests in a timely fashion to the client institution, project administrator, works inspectors, specialists, design team, and external inspectors.

The function of the inspection team (or teams) is to act on behalf of the client's interests by ensuring that the construction methods, materials and labor supplied meet, at all times, the standards required by the project's performance objectives. The tasks required of the inspectors in the course of the contract include making sure that the construction program is being met according to the agreed-upon start and completion schedule, reviewing the construction methods employed by the contractor, reviewing the builder's log regularly, inspecting the quality of the building materials and labor employed, providing technical assistance to the contractor in specific areas, monitoring the work of the external inspectors, participating in critical decisions regarding contingencies, defining when payments are to be made, verifying that safety measures are taken, and safeguarding and controlling the contract documents and test reports. The inspection team must be fully aware of the objectives and details of the project, know the standards applied during the design, be familiar with construction processes and the project contract and subcontract documents, and remain in constant communication with the client institution.

In order to ensure the quality of the materials and procedures employed, the QAP must include a detailed program of inspections and tests listing the deadlines for these inspections and tests and the responsibilities of the external bodies in charge of such activities. These entities must be involved in every stage of the construction process so they can evaluate the quality of representative samples of each material, piece of equipment or procedure employed in the works. The inspection or test-result reports must be delivered to the contractor in timely fashion in order to implement any necessary corrective measures.

Each inspection, trial or test must lead to a report containing general information such as date, time, and people in charge, a description of the procedure employed, relevant standards, a list of the equipment used, certificates by the body or bodies in charge of calibrating the tools and equipment used, and the results of the inspection, trial or test. The report must certify conformity with the drawings and specifications of the project and the standards chosen. In case of nonconformity with contract documents, a report must be produced detailing which aspects do not conform to the contract, including their quantity, characteristics, effects, and so on.

One of the final requirements is the production of an as-built report for every structure with an operational or investment protection objective. In the case of less demanding objectives, the as-built report may still be required contractually by the client institution. This report must include a full list of the professionals and firms that participated in the project, the studies of local and regional hazards, a list of the codes and standards applied, the final financial report, construction logs, results of trials and tests, inspection reports, component safety certificates, certificate of practical completion and final certificate, and as-built structural and architectural drawings, as well as the plans regarding furnishings, equipment, mechanical and electrical systems, clinical gases, pipes and ducts, fire-extinguishing network, etc.

A maintenance manual for the facilities in normal conditions, and an emergency plan in the event of a disaster, must also be part of the quality assurance program.

Finally, the criteria for possession and completion of the works must be stated explicitly, such as dates, certification of conformity with the specifications and standards that governed the project, an approved as-built report, certificates that the equipment and systems have met all necessary tests, liquidated damages and cancellation of bonds posted, acceptance of the works by the relevant fiscal bodies, signed minutes of final possession of works by the client institution, and any other requirements stipulated in the contract documents.

Annex 6.2 summarizes the minimum characteristics of a quality assurance program for the construction stage.

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Annex 6.1 Summary of the quality assurance program (QAP) during the construction stage

The following table lists some of the tasks that can be carried out in order to ensure the correct execution of the project during its preliminary stages, hazard assessments, and the design of the project.

Project definition
Definition of the objectives and scope of the project
Definition of the work team (*Chapter 5*)[1]
The client institution
The execution team
The oversight team
Assignment of functions and responsibilities and limits thereof[1]
Of the client institution
Of the execution team
Of the evaluating team
Definition of the Work Program
Procedures for evaluating the professional teams
Completion schedules for preliminary risk assessments and other studies, and for designing the facility
Overall budget for the assessments, design, and construction of the facility
Definition of communication channels and protocols
Between the specialists on the execution team and the institution
Between the specialists on the execution team and the oversight team
Among the specialists on the execution team
Schedule of coordination meetings among specialists and between specialists and the institution
Deadlines for the delivery and update of plans and specifications[2]

Continued

Definition of oversight of site selection process
Review of contemplated performance objectives
Review of general background (restrictions due to economic, socio-political, technical restraints; nature of existing healthcare network; population demand for treatment, etc.)
Review of the size and impact of identified hazards
Review of feasibility of protecting structure
Review of considerations for selection of the site
Definition of review, follow-up, and control mechanisms during the project phase
Reviews by the oversight team
Reviews by internal teams of specialists[3]
Reviews across disciplines[4]
Reviews by outside professionals
Definition of review mechanisms for the final project[5]
General review regarding the fulfillment of design criteria
Review of financial reports
Review of site plans
Review of architectural plans
Plans of the various sections of the facility
Floor plans
Section and elevation plans
Architectural detailing and finishing plans
Other architectural components (doors, windows, stairs, appendages, signs, etc.)
Review of structural plans
Review of layout plans for basic facilities, lifelines, clinical gases, A/C ducts, electrical wiring, etc.
Review of installation plans for equipment, furnishings and other components
Review of plans for details, connections and anchoring of components
Review of other plans
Review of tender documents
Review of technical specifications
Review of equipment installation specifications
Review of construction and procedures manual
Review of general contract conditions
Review of units of measures, quantities of materials and so on, completion schedule, construction budget and forms of payment
Review of other tender documents
Definition of inspection procedures during the construction process
Listing of construction procedures that require inspection or specialized inspection, and type of inspection required
Listing of components and services that require inspection or specialized inspection, and type of inspection required
Characteristics of the expected reports (*see annex 6.3*)

Notes: 1 The selection of the participating design professionals, as well as the assignment of responsibilities, must be carried out with special care. Conflicts of interest will compromise the quality of the project.
2 The work by each discipline must be based on the most up-to-date information issued by the other disciplines.
3 Each plan, technical specification, or tender document must be checked by at least one expert from a discipline other than that of the expert who produced it.
4 Multidisciplinary projects need to be checked at each stage by all the disciplines involved.
5 Before the final plans are issued, they must be submitted to the other disciplines for review and commentary.

Annex 6.2 Summary of requirements for the quality assurance program (QAP) during the construction stage

Conditions for initiating the construction
Final drawings approved
Technical specifications approved
Tender documents approved by the parties
Contract signed
Responsibilities of the client institution and administrative and design review teams
Present the builder with a feasible project
Provide the necessary financing
Provide an adequate site
Choose the most suitable technical inspection team(s)
Participate in the decision-making process in matters critical to the project or unregulated issues
Inform participating specialists and the contractor of any modifications to the project
Keep abreast of the progress and state of the construction
Meet any other responsibilities stipulated in the contract
Design team's functions during the construction stage
Inform the client institution and review team in timely fashion of any changes to the original project
Assist the technical inspection team(s) in protection matters
Participate in decision-making concerning matters critical to the project or unregulated issues that require attention
Evaluate protection options presented by the contractor to the technical inspection team(s)
Carry out on-site specialized inspections
Issue certificates of satisfactory completion of the works
Definition of consultancy firms
Review background of firm
General information (name, address, legal representative, etc.)
Titles and specialties of the firm
Directors and professionals at the firm
Financial situation of firm
Square meters built
Certified experience of the firm (works and services)

Continued →

Review background of professionals or firm's qualified personnel
Name of project, chief of project, and project budget
Area constructed and project total
Area of professional expertise (chief of project, specialist, designer, assistance, etc.)
Professional activities completed (only certified activities)
Field of specialty
Standards and regulations applied in other projects
Evaluate feasibility of achieving project objectives
Definition of the builder's main functions and responsibilities
Manage the administrative and legal aspects of the intended construction
Review upon receipt the architectural, structural, equipment, and detail plans
Review upon receipt all technical specifications
Ensure that the construction meets all the plan and specification requirements
Ask suppliers to provide all safety certificates required
Supervise the pace at which the construction advances
Control all resources used in the construction of the project
Carry out any tests needed to ensure the quality of the project
Produce reports on the progress of the construction
Establish program of payments to suppliers and subcontractors
Keep a builder's log
Be fully aware of the details and objectives of the project
Acquire materials, hire labor, and arrange subcontracts of a quality befitting the requirements of the project
Assume responsibility for the actions of all subcontractors
Assume responsibility for the construction methods and sequences employed
Update the builder's log in timely fashion
Respond in timely fashion to requests for information by the client institution and coordination team, technical inspection team, specialists, and external inspectors
Provide access to external inspections, inspections by the project administrator, by the technical inspection team and the other disciplines in charge of the design of the project[1]
Inform the technical inspection team of any modification, voluntary or involuntary, to the original project
Assume responsibility for on-site safety during the construction process
Carry out any other tasks called for in the contract

Continued →

Technical inspection team's functions
Maintain ongoing control of the construction program
Review construction procedures
Regularly engage in inspections regarding the quality of the construction materials used
Verify the quality of the labor employed
Assist the contractor in specific technical matters
Supervise the work of the external inspectors
Verify compliance with project specifications
Participate in the decision-making process in matters critical to the project or unregulated issues
Act as permanent liaison between the contractor and the institution, the project administrator, and the coordination committee
Continually check the builder's log
Safeguard and control contract documents
Verify the application of correct safety measures during the construction process
Develop inspection and testing program[2,3]
Inspect the materials, teams and procedures used for the project continually and effectively[4]
Obtain representative samples fo the materials used in line with the methods and materials employed in the construction
Distribute builder's and technical inspectors reports in a timely manner *(see annex 6.3)*
Carry out any other contractual obligations
Definition of channels and protocols of communication for conveying test results
From the inspection team to the contractor
From the contractor to the inspection team
From the technical inspection team to the design team and the client institution
As-built report on the facility[5]
Listing of professionals and specialists that participated in the project
Reports of geological and soil mechanic studies of the chosen site
Reports on regional and local risks (if applicable)
Definitive financial reports
Builder's log and related documents
Inspection reports
Test results
Safety certificates for the components and certification of correct construction practices
Listing of codes and standards applied
As-built plans of architectural components and furnishings
As-built plans of the structural system
As-built plans of the mechanical and electrical systems and equipment
As-built plans of basic facilities, clinical gases, ducts, A/C, fire extinguishing network, etc.
Other as-built information as defined by the institution and the coordination committee

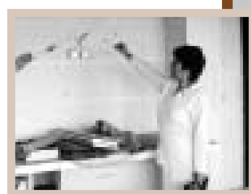
Continued →

Definition of criteria for acceptance of the works
Effective conclusion of the works as stipulated in the contract
Compliance with the specifications of the project
Certification of fulfillment of security requirements
Approval of as-built report
Satisfactory implementation of tests on the operation of services, systems and equipment
Fines paid
Return of deposits
Approval of the construction by financing agencies
Delivery of the construction to the institution
Signed minutes of final receipt of the works
Other criteria stipulated in the contract

Notas:
1. The client institution or the specialists that participated in the design stage may demand that the contractor stop the works if the safety requirements and quality standards stipulated in the project documents are not being met.
2. All equipment and tools used in the inspections, trials or tests must have certificates of calibration issued by a recognized institution.
3. The entity in charge of the trials and tests must have permanent access to the construction site.
4. The entity in charge of the trials and tests may reject the use of particular materials and equipment.
5. An as-built report must be produced for any building with a functional or infrastructure protection objective. For buildings with a life-safety performance objective, the as-built report must be produced if it is expressly requested by the client institution or coordinating team.

Annex 6.3
Characteristics of inspection reports

Report on inspection or test
General information (date, hour, etc.)
Staff in charge of the inspection or test
Procedures employed during inspection or test
List of equipment used during the inspection or test
Certificate from entity in charge of calibrating the equipment and tools used in the inspection process
Results of the inspection or test
Characteristics of the materials inspected or tested
Characteristics of construction processes inspected
Results of the tests of materials or tests of correct operation
Inspected activities carried out or completed in compliance with project plans and specifications
Aspects in which there is no compliance with the project plans, specifications, standards and/or codes
Report of non-compliance
Description of the non-compliant feature (including text and/or sketch specifying how feature does not comply with the plans, etc.).
Location of the non-compliant feature
Qualitative description of the non-compliant feature
Other characteristics of the non-compliant feature
Actions needed to correct non-compliance
Processes that must be modified in order to prevent the recurrence of non-compliance




HOSPITAL DE NIÑOS
BENJAMIN BLOOM

Appendix
Terms of Reference for Vulnerability Reduction in the Design of New Health Facilities

The following text is included for illustrative purposes only. Its aim is to provide suggestions for reducing the vulnerability of health facilities through the inclusion of the provisions recommended in this handbook in the traditional Terms of Reference for the design of a hospital or other kind of health facility. Underlined sections or phrases should be adjusted to the specific hazards faced by the project.

1. General terms

1.1 The present Terms of Reference are an integral part of the call to tender for the design of ________________________________ Hospital, and state the additional requirements that must be met in the design of the facility's protection systems to ensure that they meet the protection objectives defined for the facility in both normal and emergency conditions. The protection objectives are in *Table A.1*.

1.2 These provisions set minimum requirements only. Each consultant, specialist or supplier must establish and identify additional conditions that its design or product must meet in order to satisfy the protection objectives set by the institution.

1.3 Quality assurance principles and means applied in this project will be recorded in a single document. No tacit agreements or implicit demands will be tolerated.

2. Definition of protection objectives

2.1 The facility and its services must withstand the following hazards: landslides, mudslides, strong winds and hurricanes, floods, earthquakes, and volcanic activity, as well as any others that may be identified in the course of the project. For each hazard, two or more levels of intensity are specified. For each hazard and level of intensity, the institution has defined performance objectives for the intended services as stipulated in *Table A.1*.

Table A.1 Performance objectives based on varying intensity of hazards

Event	Minimum level recommended			Maximum credible level desired		
	%/Years	Time for rehabilita-tion	Protection objective (LS/IP/OP)	%/Years	Time for rehabilita-tion	Protection objective (LS/IP/OP)
Landslide						
Mudslide						
Flood						
Earthquake						
Strong winds						
Volcanic activity						
Other						

2.2 The standby capacity (i.e., the capacity to remain isolated from critical utilities and services external to the hospital) is specified in *Table A.2*.

Table A.2 Facility's standby capacity

Service	Standby capacity
Drinking water	# hours
Electricity	# hours
Oxigen	# days
Oil	# days
Other	# days/# hours

2.3 The stipulated times for recovery of functional capacity in the case of each service are presented in *Tables A.1* and *A.2*.

2.4 The hazard characterization documents, design procedures specific to each one of the hazards, and geotechnical properties of the proposed site, as specified below, are an integral part of this tender. (All relevant tender documents should be listed here).

3. General design of the hospital

3.1 The design procedures must meet ISO9000 quality standards.

3.2 The head of each team of design specialists must have at least 10 years' experience in hospital infrastructure design that is relevant to the job he or she must perform. In addition, his or her participation must be documented and certified in the design of hospitals with a total built surface greater than 100,000 m^2, and at least one hospital built with a surface larger than 10,000 m^2 in the same period.

3.3 Candidates to the various professional teams must present documents that certify their participation in the design of hospitals that have met investment-protection and functional-protection standards.

3.4 The documents produced during the design stage, including specific protection considerations, must include the following:

- Financial reports
- Certificates that the performance objectives defined by the institution have been met
- Mockups
- Siting plans
- Architectural drawings such as general distribution plans, floor plans, section and elevation plans, architectural detailing plans and any other relevant plans
- Structural plans, including general specification plans, foundation plans (based on the information provided by the soil mechanics specialists), floor, section and elevation plans, structural detailing plans, etc.
- Drawings showing the layout of basic facilities, lifelines, clinical gases, air conditioning, electrical distribution, etc.
- Industrial, mechanical, and electrical equipment floor plans
- Furniture floor plans
- Technical specifications
- Specifications on proper installation of the equipment
- Construction and maintenance manual
- General conditions contained in the contract
- Work program, including units of measure, quantities of materials and labor, completion schedule, and forms of payment, inter alia
- Terms of reference and other tender documents
- Maintenance manual and emergency plan for the facility

3.5 The documents listed above shall be written clearly and explicitly to prevent errors of interpretation.

3.6 The systems used for component protection shall be feasible to build and amenable to effective maintenance.

3.7 Each team of specialists shall prepare a document setting out clearly how it will meet the facility's performance objectives and, particularly, what their requirements and restrictions are in relation to the other disciplines. Such documents must define, moreover, the criteria for hazard analysis and design, and the standards and codes employed. They must be produced at the beginning of the project, and approved by the client institution.

3.8 The project administrator and the client institution's project coordination committee will supervise the correct integration of the participating teams, including those involved in structural, architectural, and installation matters. In order to do this, they shall coordinate all the specialist teams. The teams will obtain from the project administrator and coordination committee drawings and specifications setting out in detail the layout of all systems, equipment and components of the facility, including those that do not belong to their specialty. These drawings will superimpose the subprojects developed by all the disciplines and specify the layout and the points at which installations will meet, as well as the location of the various components, such as suspended ceilings, lighting fixtures, electrical and other outlets, sanitary devices, HVAC devices, built-in furnishings, industrial equipment, medical equipment, and fire safety systems. Likewise, they will specify the layout of all the wiring, piping and ducts and their passage through walls, beams, foundations, columns, etc. These plans must be studied in detail by the coordination committee and the specialist teams in order to ensure that the protection systems will work in integrated fashion.

3.9 Before the final plans are issued, drafts must be delivered to the other disciplines for review and commentary.

4. The design of the structure

4.1 The structural system chosen for the facility must meet the performance objectives set both for the hospital as a whole and its component services.

4.2 The team of structural engineers will be in charge of guaranteeing the safety of the structure. When the protection objective of the facility and its services is functional and investment protection, the team must provide a structural system that not only safeguards the structure but also the nonstructural elements. In other words, the structure must not only protect itself and its occupants but also the nonstructural systems on which investment or functional protection are to be based. For this reason, the structural system needs to be explicitly approved by all participating disciplines.

4.3 The structural team must coordinate its design decisions with the architectural and other design teams (sanitary, air conditioning, electrical, etc.) so as to meet their protection requirements, including such matters as drilling, bracing, or anchoring.

4.4 The structural system and its components must be designed to withstand permanent and eventual demands on the structure, taking into account its dead load, live load, seismic and wind loads, snow and ash loads, temperature changes, hydrostatic and hydrodynamic thrust forces, total and relative foundation settlement, etc.

4.5 Structural design shall incorporate such detailing as will ensure, for each level of risk, that the performance objective will be met. It is important to include in the design any systems needed for guaranteeing that, in the event of damage or functional loss, services can be restored within a predefined period.

4.6 The structural team must provide the information required by the other disciplines for the design of the equipment, systems, and other nonstructural components.

4.7 The structural team must certify that the protection objective set by the institution for the facility has been met.

5. Design of nonstructural components

5.1 Nonstructural components must enjoy a level of protection commensurate with the performance objectives set for the medical or support services to which they belong or with which they are directly or indirectly linked in functional terms.

5.2 Each team shall be responsible for the design of the protection systems for the components of their competence, and shall certify that the protection objective set by the institution has been met.

5.3 All nonstructural components to be protected must be adequately supported. The points of support of these components must enjoy a level of safety comparable to that of the components themselves.

5.4 In cases where nonstructural components exert pressures or lean on other nonstructural components, their joint stability must be guaranteed.

5.5 Safety of any equipment containing hazardous materials must be tested and certified.

5.6 Safety of nonstructural components must be assessed, either by mathematical analysis and modeling, or by certification of safety by the supplier or manufacturer.

5.7 If a safety assessment of nonstructural systems, equipment, and components is to be carried out through mathematical analysis and modeling by the relevant team of specialists, the team shall present a financial report recording, at a minimum, the following: The type of system, equipment or component contemplated; a description of the component; the performance objective considered in the design of the protection systems in question; the standards applied in the analysis; a description of the structure in which the component is to be embedded; any behavior that may determine the response of the component; characteristics of the component when in operation; characteristics of the component's bracing, anchoring and support systems; the method of analysis; the likely load; the results obtained, and an assessment of the component's interaction with other systems, equipment or components.

5.8 If the safety assessment of standard nonstructural systems, equipment, and components is based on the supplier or manufacturer's certification through in-house analysis, that supplier or manufacturer must present a calculation log with the same contents described in provision 5.7.

5.9 If the safety assessment of standard nonstructural systems, equipment, and components is based on the supplier or manufacturer's certification through experimental means, the supplier or manufacturer must present a document with the following information: identification of the laboratory, standards of reference considered in the tests, description of the testing procedures, and test results.

5.10 In addition to the certificates described in provisions 5.7, 5.8 and 5.9, the following information should also be provided: Requirements for meeting the certification conditions (conditions of use, operation, installation, etc.); date of certification and period of validity of the certification; certification of compliance with the standards specified in the contract; and description of the applicability and limitations of the certificates.

Glossary
Definition of Basic Concepts

As-build report	Set of documents concerning project management, such as the contract, a list of the professionals involved in regional and local risk assessments and their qualifications and reports, the design of the project, construction and inspection procedures applied, applicable codes and standards, certificates of component safety, final plans for the structure, its components and protection systems, and certificates of compliance with project specifications.
Critical services	Services that are life-saving, involve hazardous or harmful equipment or materials, or whose failure may generate chaos and confusion among patients or staff.
Natural hazard	A likely event of natural origin and sufficient intensity to cause damage in a particular place at a particular time.
Nonstructural components	Elements that are not part of the load-bearing system of the building. They include architectural elements and the equipment and systems needed for operating the facility. Among the most important nonstructural components: architectural elements such as façades, interior partitions, roofing structures, and appendages. Nonstructural systems and components include lifelines; industrial, medical and laboratory equipment; furnishings; electrical distribution systems; HVAC systems; and elevator/escalator systems.
Nonstructural detailing	A set of measures, based on the theoretical, empirical, and experimental experience of the various disciplines, aimed at protecting and improving the performance of nonstructural components.
Protection systems	Devices and procedures aimed at providing safety to the structural and nonstructural components of the facility and meeting its performance objectives.
Quality assurance	A set of actions aimed at ensuring that project performance objectives are met.
Resistant system	A structural system especially designed to withstand the impact of gravity and other natural phenomena. The structural system must be designed in such a way that its detailing is proportional to the protective objective chosen for the structure.

Continúa

Risk	Extent of the likely losses in the event of a natural disaster. The level of risk is intimately associated with the level of protection incorporated into the structure.
Specialized inspection	A set of activities aimed at ensuring that the requirements of the project are met in matters such as quality of the work, the use of construction processes and materials commensurate with the performance objectives of the project, the fulfillment of the provisions established in the standards and codes referenced in the contracts, and the procurement of component safety certificates and others.
Structural components	Elements that are part of the resistant system of the structure, such as columns, beams, walls, foundations, and slabs.
Structural detailing	A set of measures, based on the theoretical, empirical and experimental experience of the various participating disciplines, for protecting and improving the structural component performance.
Tender documents	Legal documents that stipulate the characteristics of the design or building contract or contracts (parties involved, financial amounts, deadlines, forms of payment, etc.) and the technical characteristics of the construction (general and detail plans, structural and nonstructural components, standards and codes to be followed, specialized inspection requirements, recommended and unacceptable construction methods, etc.).
Vulnerability	The likelihood of a facility enjoying a particular level of protection suffering physical damage or being affected in its operations when exposed to the impact of a natural hazard.