Vulnerability Analysis in Health Care Facilities

Risk Reduction in Hospitals

Regional Training Course on Mass Casualty Management and Hospital Preparedness

TOOLKIT
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Introduction

The hospital is a highly complex facility that, while providing health care, also functions as a hotel (inpatients), an office building (medical staff and administration), a laboratory and a warehouse. It has a high level of occupancy (patients, medical and support staff, visitors) and a lot of expensive medical equipment. The very nature and purpose of a hospital demand that it remains fully operational in the aftermath of a disaster. Although hospitals are essential for delivering essential services in disasters, their complexity, occupancy level and specific equipment and installations also make them very vulnerable in various aspects: structural (load bearing system), non-structural (architectural elements, installation and equipment) and administrative (organization of space, functions, staff, procedures, etc.).

Nevertheless, even if there is little or no structural damage, the facility may be unable to function effectively if non structural damage causes critical equipment to be dislodged or overturned, essential or dangerous chemicals to be thrown down from shelves, or lifeline services to be interrupted. Of all the elements that interact in the day-to-day operations of a hospital, the administrative and organizational aspects are among the most important. Disaster prevention and mitigation measures must be adopted before a disaster strikes, so that the hospital can continue to function after an earthquake or other catastrophic event.

Risk reduction in hospital design is a responsibility shared by architects, engineers, physicians, maintenance staff and administrators. The link between architecture and resistant structural systems must be clear to all involved in the design process in disaster-prone areas. An effective risk mitigation programme should consider the importance of health facilities in immediate post-disaster conditions, as well as their high seismic vulnerability. Owing to the high cost of health facilities, the impact on public finances and the production capacity of a country due to the high costs of repair and reconstruction should also be taken into consideration.

Given the importance of an efficient response to emergencies and the need for a functional health care infrastructure in the aftermath of a disaster, hospital administrators must consider all aspects of a facility’s vulnerability. A reliable and comprehensive hospital assessment can be carried out only by taking into account all three main categories of vulnerability (structural, non-structural and administrative/organizational, in that order).

In earthquake prone areas for instance it is the duty of authorities to assess a hospital’s vulnerability to earthquake damage and to obtain estimates of existing risk levels in order to ensure a proper response to emergency needs. Most hospital authorities have established disaster mitigation and response plans. It is necessary to plan in advance, with the support of public service providers such as the fire service, civil defence officials and transit authorities, in order to draw up cooperation and coordination agreements.

All these inter-institutional mechanisms must be taken into account in a hospital’s disaster mitigation and prevention plan, on the basis of the vulnerability of its structure, its equipment and its administration and organization.

Various methods for assessing the vulnerability of a hospital exist and they differ in cost, complexity and precision.

Most of them treat each vulnerability category separately, and their implementation usually demands a sound engineering background, software and comprehensive data set.

**Goal and objectives**

**Goal:** To offer to emergency managers methods aimed at identifying and assessing risks present in HCFs by studying the vulnerabilities with the aim of eventually developing risks reduction program (vulnerability reduction, risk management, and emergency response plans).

**Objectives**

- To discuss a framework for integrated risk management in HCFs (sanitary risks, medical risks and other risks)
- To discuss a methodology focusing on vulnerabilities (as a contributor to risks)².
  - To identify the vulnerabilities (identification of elements exposed to hazards, and their vulnerabilities) and the potential consequences on the functioning of the HCF; on

² Report on reducing the impact of disasters on health facilities -PAHO cd45/27

³ In the present tool kit the “medical risks” (iatrogenic risks) –risks linked to medical care delivery- will not be discussed.
To identify the characteristics of the hazards (focus only on actual hazards) and how they can interact with the vulnerabilities. To identify the elements of a qualitative assessment matrix (for overall risk and vulnerabilities).

**Toolkit on Vulnerability Analysis and the Field Manual for Capacity Assessment of the Health Facilities in Responding to Emergencies**

WPRO has published in 2006 a Field manual for capacity assessment. This publication is the core reference document for this toolkit. The emergency managers of HCFs should use extensively this publication for assessing the vulnerabilities existing in their HCF. The part II of the publication specifically deals with the assessment of vulnerabilities. It is the core content of the tool kit. It will not be reproduced in this document.

**Part 2: Risk Reduction in Health Care Facilities**

The goal of this toolkit is to contribute to the development of a systemic and systematic approach to risk management in HCFs. It is impossible to qualify and to quantify a risk without assessing the 2 elements that create the risks (hazard and vulnerabilities). Vulnerability analysis and their prioritization is a workable entry point for managing risks in HCFs. The assessment of vulnerabilities and the actions taken can be summarized on a simple chart below.

**Sample Chart: Vulnerability Assessment and Risk Management Plan**

<table>
<thead>
<tr>
<th>Vulnerability Assessment</th>
<th>Assessment of Risks</th>
<th>Risk Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elements of HCF exposed to hazards</td>
<td>List of the hazards (or any critical situation that can generate risks)</td>
<td>Identification of the vulnerabilities and of the consequences (for each element and for each hazard)</td>
</tr>
<tr>
<td>Basement of the buildings</td>
<td>earthquake</td>
<td>Vulnerabilities: non resistance to ground speed acceleration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Risks: collapse of the building with death of persons, loss of equipment, rupture of cables and pipes, etc.</td>
</tr>
</tbody>
</table>

4 Vulnerabilities are partly specific to each hazard (for instance the basement of a building has not the same vulnerabilities for earthquakes or for floods). This specificity of the vulnerabilities partly determine the type of corrective or preventive actions that can be considered.

A. Vulnerability Assessment

It is essential that every HCF develops a strategy aimed at reducing the most serious risks as soon as possible. The identification and the prioritization of vulnerabilities is a pragmatic approach to contribute to risk reduction.6

The five main categories of vulnerabilities

Usually the vulnerabilities in HCFs are classified into five major categories7:

- Structural vulnerabilities (basement of buildings, support walls, etc.)
- Non-structural vulnerabilities (internal walls, equipment, the water pipes, etc.)
- Functional vulnerabilities (systems, procedures, etc.)
- Administrative and organisational vulnerabilities (staff, emergency plan, etc.)
- External vulnerabilities (the vulnerabilities are present in the community outside the HCF but can threaten the functioning of the HCF (e.g. lifelines)

The WHO/EURO8 recent study on hospital seismic vulnerabilities proposes to regroup the vulnerabilities under 3 categories only: structural, non-structural, and administrative and organisational vulnerabilities.

Classifying and Prioritizing Vulnerabilities

1. The PAHO Scale

There are several methods using several scales for classifying the vulnerabilities in HCFs. PAHO9 has developed a 3 levels scale for classifying the vulnerabilities and for prioritizing them. The below classification is an adaptation of the PAHO scale. The present classification is only an approximation of the reality. But this is enough to identify the most urgent needs for corrective actions.

6 Review of key concepts

Hazard versus Risk

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard is a risk factor external to a subject or system. It involves a latent or potential danger associated with a physical phenomenon of natural or technological origin that could arise in a specific location over a given span of time, producing adverse effects on people, property, or the environment.</td>
<td>Risk is the expected level of destruction or loss that will take place given the probability of hazardous events taking place and the level of vulnerability of the elements exposed to these hazards.</td>
</tr>
</tbody>
</table>

Vulnerability is the intrinsic predisposition of a subject or element to suffer damage from potential external events. A vulnerability assessment therefore constitutes a fundamental contribution to the understanding of risk, by analyzing the interactions between susceptible elements and a hazardous environment.

7 This is the proposed classification adopted by WPRO and PAHO
9 Guidelines for Vulnerability Reduction in the Design of New Health Facilities.
**Level 1.** Major vulnerabilities creating risks endangering seriously the safety of the functioning of the HCF with threat of immediate death of persons (patients, staff, visitors) and or the major loss of essential equipment and or of critical services

**Level 2.** Vulnerabilities creating risks threatening the equipment and the buildings, and or causing loss of services but without immediate threat of death of persons

**Level 3.** Vulnerabilities creating risks threatening the normal functioning of the HCF with repercussion on the quality of services but neither threatening the critical equipment nor threatening the safety of the persons

### 2. Assessment of Seismic Vulnerability of HCF

WHO has developed a methodology for assessing the seismic vulnerabilities of HCFs. The methodology is complex. It consists of a series of assessments with scoring system. These comprise (a) Form HVE 001 for the general evaluation of the vulnerability of a health facility; (b) Forms HSVE 001 and HSVE 002 for evaluation of structural vulnerability; (c) Forms

#### Structure of the HVE method

<table>
<thead>
<tr>
<th>Seismicity Level</th>
<th>Assessment Level</th>
<th>1 - Structural Vulnerability</th>
<th>2 - Nonstructural Vulnerability</th>
<th>3 - Organizational Vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HSVE-001</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>HSVE-001 / 1, 2</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>HSVE-001 / 1</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The HVE method is a hybrid, mainly qualitative method using mainly rapid visual screening combined with the screener’s judgement. The evaluation process depends on the seismicity level (figure). It combines separate evaluation methods for the three main vulnerability categories.
HNVE 001/1, HNVE-001/2 and HNVE-001/3 for evaluation of non-structural vulnerability; and (d) Forms HOVE-001/1 and HOVE-001/2 for evaluation of administrative/organizational vulnerability

**B. Managing Risks in HCFs**

There are several methods for assessing risks in HCF (quantitative and qualitative). Most of them are complex and require special technical competences as well as computerized programs. Most of the HCFs in developed countries use such sophisticated methods. As a matter of fact these methods (difficult to adapt for developing countries) do not add much more to the simple qualitative approach described here for identifying the most critical situations, which require action. The health authorities of developing countries may start with a pragmatic, simple but nevertheless efficient first step (the use of the matrix and of the WPRO Field Manual). The risks are discussed within the major categories of the vulnerabilities. It is advisable to increasingly develop more sophisticated methods for assessing the risks in HCFs. The overall programs of risks management in HCFs include other elements than just the study of vulnerabilities, such as the management of regulated risks (blood safety, nosocomial infection control, etc.), the quality and accreditation programs, etc.

**Prioritizing vulnerabilities based on the notion of “risks.”**

The following indicators can be used for assessing the level of risk:

- Severity of the consequences of the event (approximation of the actual risk): interactions between the hazard and the vulnerabilities. The consequences can be: human, organisational, managerial, functional, financial
- Probability of occurrence of the event (assessment of the situation generating the critical event)
- Use of a simple matrix with 2 parameters: severity and frequency
  - There are 2 pondering factors:
    - The probability of non-detection of the event before it has already occurred (aggravating factor)
    - The possibility to develop control measures that may mitigate the consequences or detect early the precursors of the event (attenuating factor)
    - It is always possible to complete this rough estimate by using more complex assessment tools such as the technique named “failure mode effects and critically analysis FMECA” (risks assessment).
Methods for Assessing Risk in HCFs

1. Qualitative matrix – overall level of risk

The matrix presented below allows for a classification of the overall risk by using 2 indicators: the probability that the critical even will happen and the severity of the consequences if the event happens. The risk is largely determined by the existing vulnerabilities.

Qualitative Matrix - overall risk for determining which are the levels of risk for each potential critical event (hazard) interacting with the vulnerabilities under study

- Almost certain: recurrent events (at least once a year) under almost every condition: many such critical events already happened
- Likely: will certainly happen (at least every 5 years)
- Moderate: can happen, not frequent, every 20 years
- For each categories of risk identified on the matrix it is possible to quantify further the risk by using a simple scoring system such as:

<table>
<thead>
<tr>
<th>RISK</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>High</td>
<td>7</td>
</tr>
<tr>
<td>Medium</td>
<td>4</td>
</tr>
<tr>
<td>Low</td>
<td>1</td>
</tr>
</tbody>
</table>

2. The failure modes and effects analysis (FMEA)

Another possible method for assessing the risks in HCFs is the use of the simplified “default tree method”. This method assesses the failure modes in a process, the consequences and the criticality. The classification of the critical events by their frequency only is not enough for developing
a risk reduction program. The severity of the consequences must also be considered. The method allows for giving scores to the risks by integrating the following parameters:

- The frequency (F)
- The severity (S)
- The probability of non-detection (until the critical event has already happened so that no early warning is possible, no immediate corrective measures) (D)

The formula is the Criticality C = F x S x D

- For F: if very frequent (score 10), frequent (5) rare (1)
- For S: if death of persons (10), if economical and equipment losses (5), minor consequences (1)
- For D: if there is no possibility to detect (10); a detection system exist but cannot always detect (5); the detection system can detect always (1).

This method allows for a prioritization of the risks and therefore for developing priority corrective actions. This method is particularly adapted to assess the risks linked to the use of complex systems such as surveillance system for electrical power (back-up generators), etc. Many HCFs have adapted this method for assessing the risks in the HCF in the context of quality assurance and permanent improvement. The trend is more and more to develop a comprehensive risk management program within the HCF that integrates ALL risks (from iatrogenic risks to disaster risks).

Using this toolkit to accomplish the ‘Vulnerability Assessment and Risk Management Plan Chart’

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Annex 1: National and local records of natural and man made hazardous events

Annex 2: Categories of risks in HCFs

Annex 3: Possible action for reducing vulnerabilities

Methods for assessing risks

Annex 1: Detailed list of HCF vulnerabilities

Annex 2: Categories of risks in HCFs

Annex 3: Possible action for reducing vulnerabilities
1. Detailed Vulnerabilities of an HCF

Detailed description of vulnerabilities

The list presented below is not an exhaustive list of all vulnerabilities potentially existing in an HCF. It is a summarized list of the main vulnerabilities that must be considered first in the risk reduction approach. This section must be read together with the WPRO publication above mentioned.

A. Structural vulnerabilities

- Basement of the buildings
- Heavy walls, concrete roofs, columns, etc.
- Area where the buildings are located
- The type of soil on which the building are constructed
- The access to the buildings
- The green areas around the HCF (trees, etc.)
- Type of construction and the complexity
- Number of storeys
- The material used
- The access roads
- The roof of the buildings and their characteristics
- Alteration and remodelling
- The structural vulnerabilities must be assessed by considering the potential consequences on safety of persons, on the delivery of services, on the equipment and the property
  - For all structural vulnerabilities classified in level 1 and 2 there is a need to develop a complementary assessment by experts. It is a too serious matter for non-experts.
  - Only consider vulnerabilities for credible potential hazards (it is not a theoretical exercise)
  - It is necessary to assess the potential for domino effect. The structural vulnerabilities can create risks in the other categories of vulnerabilities (e.g., rupture of water pipes, cut of electrical wires, shortcuts and fires, sewage, etc.)
  - All buildings have not the same criticality. A warehouse is less critical than the building hosting the theatre rooms for instance
  - Any remodelling of the buildings should be considered as potential source of new vulnerabilities
  - It is important to carefully consider the previous assessments that have already been conducted in the past (and the recommendations made at that time, plus follow-up actions)
  - Has any structural element already been involved in generating serious risks?
  - What is the maintenance system in place for the buildings?
B. Non-structural vulnerabilities (elements to be considered)

The consequences of this type of vulnerabilities can be catastrophic even if the structural vulnerabilities are under control:

- Ceiling, doors, windows, divisions and partitions
- Covering elements of buildings, facades
- Separation walls
- Equipment
  - Mechanical
  - Electrical
  - Water pipes
  - Gasses pipes (medical and non medical gasses)
- Medical equipment
  - Anchored in the walls (fixed)
  - Mobile
- Some elements of the equipment are critical for the functioning of the HCF, such as:
  - Respirators
  - X-Ray machines
  - Sterilisation
  - Refrigerators (blood bank)
  - Water supply
  - Electrical generator (back-up system)
  - Etc.
- Furnishings
- Chemicals and toxic substances
  - Storage areas, quantity, products, safety measures
  - Etc.
- Radiological products
- Laboratory products
- Medicines
- Waste products
- Air conditioning
- Steam
- Chimney, piping
- Industrial fuel
- Other (to be determined by the HCF)
- Consider the consequences (default tree): heavy equipment can fall on a patient, can provoke a short cut, etc.
- This type of vulnerabilities is complex and regroups many elements. It is advisable to make a list of the main non-structural elements that will be discussed for assessing their vulnerabilities. A pragmatic approach is recommended: a visual visit of the various parts of the HCF in order to:
  - Establish the list of the elements
  - Their number and localisation
  - Establish a quantitative assessment by using the grid. For
some key elements it is advisable to complete the qualitative assessment by a more detailed quantitative assessment when possible

C. Functional, administrative and organisational vulnerabilities (elements to be considered):

- The accessibility of the HCF during the various possible disaster scenarios
- The repartition of services within the HCF
  - Medical services
    - Functions in connection with ambulatory patients
    - Function in connection with diagnosis and the care
    - Administrative functions and the management
    - Essential medicines and disaster stock
    - Blood bank
  - Support services
    - Food and catering
    - Laundry and accommodation of patients
    - Security and safety
    - Maintenance
    - Laboratories
    - Transport
    - Relation with the public and the community
    - Etc.
- Internal communications
  - Between the services
  - Among the personnel
  - With the outside world
- Management of the information
  - The computers and their networks
  - The relation with the family and the relatives
- It is necessary to assess how hazards can interfere with the exiting vulnerabilities of these elements (disturb the organisational systems; disrupt the delivery of services, etc.)
- The Emergency response Plan (Hospital Disaster Plan)
  - The main resources mobilized
  - The main areas
  - The traffic flow of patients
  - The staff
  - The potential dependencies of the various elements on each others
  - Specific procedures
  - Contingency plans (bomb threat, fire, chemical spills, etc.)
- The critical services (surgery, ICU, water, electricity)
  - Necessary equipment and supplies management
• Staff traffic
• Rehabilitation procedures (for emergency situations)
• Continuity of operations for critical services (including the re-localisation or evacuation procedures)

• Safety and security procedures
  • Fire (detection, fighting, etc.)
  • Alert systems
  • Security of the various areas
  • Emergency procurement of life lines (water, electricity)
  • Etc.

• The area for the dead
• The management function
• The human resources management function
  • The call back procedures
  • The skills of the staff (especially the training received to manage emergencies)
  • Etc.

D. External vulnerabilities (elements to be considered)

These vulnerabilities are specific to each HCF. Some elements are more common to almost all HCF, such as:
• Roads and access to the HCF (bridges, etc.)
• Procurement of water and electricity
• Communications
• Sewage
• Garbage removal
• Vicinity of hazardous sites such as chemical plant, etc.
• Network of HCF and their linkage (important for surge capacity in Mass casualty Incidents)

2. Categories of Risks in HCFs

NOTE. There is no internationally accepted classification of risks in HCFs. Usually the following categories are the most frequently mentioned:

• Risks linked to the medical activity and to the delivery of medical care
  • Bio-medical risk
    • Medical activities
    • Medico-technical activities
    • Blood
    • Etc.
  • Health products
    • Products used for diagnosis purpose
    • Medicines
    • Etc.
- Process
  - Nosocomial infections
  - Patient identification and record keeping
  - Coordination
  - Etc.
- Risks linked to technical events
- Risks linked to logistics
- Risks inherent to the management of any organisation
- Regulated risks (especially those included in the surveillance programs)
- Non-regulated risks (more frequent than the regulated risks, e.g. use of gas, oxygen, etc; green areas around the HCF, etc.)

3. Possible Actions for Reducing Vulnerabilities

A. Reduction of structural vulnerabilities
- Building codes (enforcement)
- Technical design selected for its resilience
- Buildings performance (even if the building is shaking during the earthquake, the water pipes can be secured and will not be disrupted)
- Retrofitting
- Re-localisation of critical services in buildings less vulnerable (sometimes a critical service is located in a highly vulnerable old building of the HCF)
- Protective barriers
- Water containment or water evacuation
- Etc.

B. Reduction of non-structural vulnerabilities
- Implementation of a comprehensive risk management program with focus on risks generated by this type of vulnerabilities (safety of persons and equipment, continuity of services delivery, emergency rehabilitation measures, etc.)
- Development of procedures by each care line and service line for ensuring the continuity of operations, the safety of the persons and the equipment
- The elements of vulnerability must be identified and the vulnerabilities must be prioritized (according to the consequences on the safety of the persons and of the equipment) in order to identify the most urgent preventive or corrective actions that must be developed. Usually these interventions are classified under the following headlines:
  - suppression of the vulnerability
  - re-localisation of the activity
  - limitation to the mobility of the equipment
- attaching (securing the equipment)
- flexible links between some elements (to avoid rupture)
- support (for ceiling for instance)
- substitution of the process by another process
- modification of the characteristics of the equipment
- reinforcement
- redundancy
- emergency repair and emergency rehabilitation procedures
- contingency plans
- etc.

C. Mitigation measures for the equipment and the furniture

Equipment used in hospitals is more and more expensive. Most of the equipment devices are necessary for the delivery of services, especially for critical services. In many cases it is possible to develop mitigation measures that are not expensive but efficient. It is also possible to develop measures aimed at preserving the functionality of the critical equipment even during a disaster situation. The main elements that can be considered for developing mitigation measures are:

- Essential equipment used for diagnosis purpose
- Beds for patients
- Trolleys and their content
- Respirators et vacuum devices
- Toxic substances (gas, chemicals)
- Monitors
- Operation tables
- Storing cupboards containing essential information (especially the medical chart)
- Computers and information system
- Refrigerators
- Radioactive source
- Fixed and mobile medical equipment (X-Ray, etc.)

D. Reduction of the functional, organisational and administrative vulnerabilities

- These elements are critical for ensuring the quality and the continuity of the services delivered (especially medical care)
- These elements must be localised within the HCF so as to ensure their normal functioning as much as possible (synergy and interactions are vital). Some possible measures:
  - Optimisation of the use of the various areas and the distribution of critical services within the HCF (especially for medical care)
  - Promote a culture of permanent quality improvement (quality of care and services, performance of the HCF)
  - Identify the potential synergies between the various services
- Early warning system for risk early identification and risk management (the most common risks in an HCF)
- Supervision of staff during emergencies (line of authority and of command clearly defined)
- Identify the lifelines that are provided by external partners (water, power, communications, etc.) and develop procedures for securing the delivery of these lifelines
- Maintenance of the equipment
- Special procedures for high risk situations such as fire, explosion, evacuation, (contingency plans), etc.