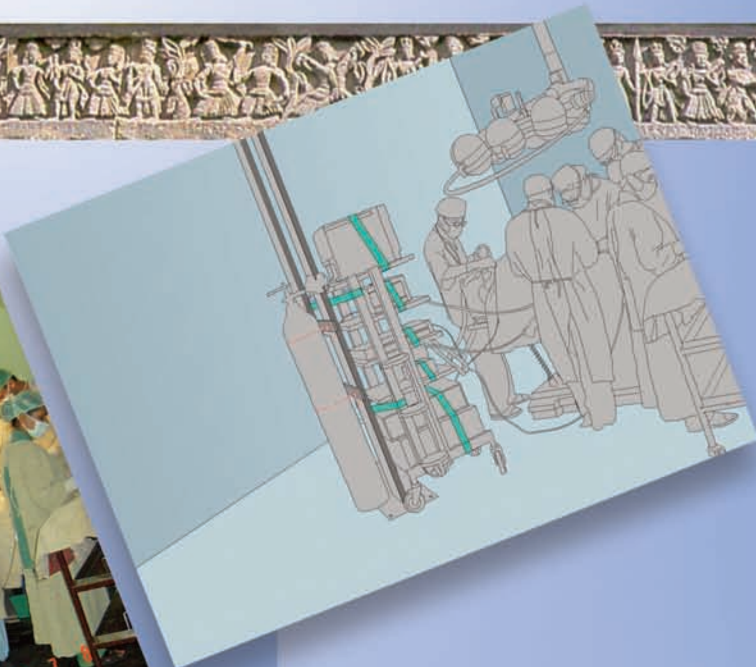
Non-Structural Vulnerability Assessment of Hospitals in Nepal



His Majesty's Government of Nepal

Ministry of Health

Department of Health Services

Epidemiology & Disease Control Division

World Health Organisation

Emergency & Humanitarian Action

National Society for Earthquake Technology-Nepal

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This document was prepared based on the study on Non-structural Vulnerability Assessment of Hospitals in Nepal commissioned by WHO-Nepal and implemented by NSET in 2003.

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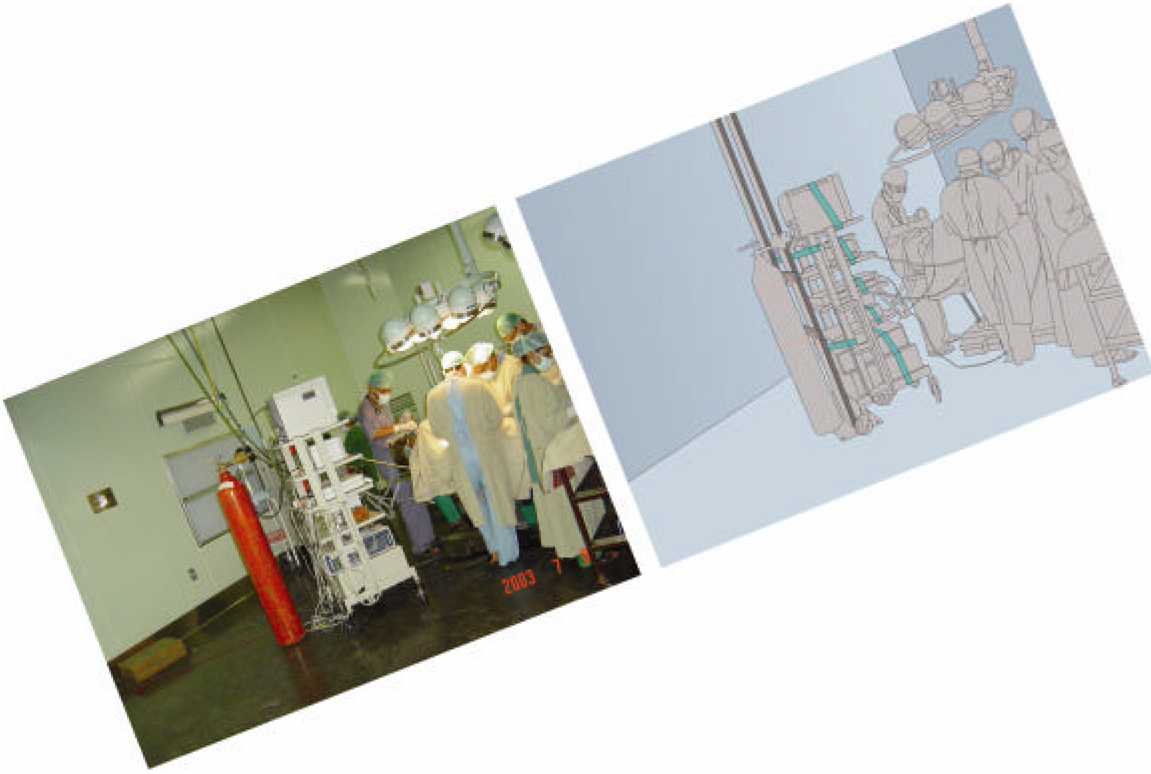

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Preface

The finalisation of the non-structural assessment and the dissemination of the findings is a significant achievement that will enable the national health system to take the appropriate measures to ensure the functionality of the hospitals after a major earthquake.

Experiences from around the world have demonstrated that one of the first casualties from earthquakes may in fact be the very hospitals and other health institutions whose task is to take care of the victims. Functional hospitals are a cornerstone in a coordinated national disaster response and without it the health consequences could be disastrous.

This report outlines the possible extent of non-structural damage to 9 hospitals in the country in case of earthquakes, but even more importantly, it also outlines very practical and easy to use mitigation measures, many of which the maintenance sections of the hospitals themselves can carry out at low costs.

However, in order to achieve full functionality even after severe earthquakes a concerted effort must be made, and that is why I sincerely hope that all emergency planners will take notice of this report and that the findings and recommendations will be taken into consideration in the future planned activities at all levels of emergency preparedness.

I would like to extend my appreciation towards WHO for supporting this initiative and to reassure that the Ministry of Health, Department of Health Services and Epidemiology and Disease Control Division remain committed to the task of reducing the vulnerability and enhancing the capacity of the health sector to deal with all types of emergencies.

Dr. M. B. Bista
Director
Epidemiology and Disease Control Division
Director

Dr. B. D. Chataut
Director General
Department of Health Services
Director General

FOREWORD

The World Health Organization is very happy to be able to present the report ***Non-Structural Assessment of Hospitals in Nepal*** prepared by the National Society for Earthquake Technology – Nepal (NSET) in collaboration with the Epidemiology and Disease Control Division (EDCD), Department of Health Services (DHS), Ministry of Health (MoH) and WHO.

The publication of this report is yet another important step in the process of assessing the vulnerability of the health sector of Nepal in future earthquakes. The first step was taken when MoH, WHO and NSET carried out a structural assessment of 14 hospitals in Kathmandu Valley in 2001-2002.

This study found that one of the biggest threats to the functionality of these hospitals could in fact be the damage stemming from non-structural components being overturned, falling down or sliding into other objects. In addition to rendering the hospital non-functional, non-structural elements could also pose a major threat to the lives of staff and patients alike.

Therefore, it was recommended to carry out a detailed non-structural assessment of essential emergency facilities throughout the country in order to come up with appropriate mitigation measures, set priorities and outline actions to minimize the risk and enhance the emergency response capacity of the health sector.

The fact that such a non-structural assessment has now been carried out for 9 hospitals and the findings documented demonstrates the continuous commitment of MoH and the Disaster Health Working Group towards ensuring adequate emergency response capacity, and here I would particularly like to thank Dr B.D. Chataut, Director General, DHS and Dr M.B. Bista, Director, EDCD for their support and involvement.

The findings provide us with the knowledge we need in order to begin the challenging but crucial efforts to prepare the hospitals for dealing with a potential major earthquake in Nepal. However, the knowledge alone is not sufficient. It is imperative that the recommendations find reflection in realistic action plans and are implemented in a phase-wise manner. Given the importance and magnitude of the task, I would like to express my hope and my confidence that this responsibility will be successfully shouldered by all concerned parties in the years to come.

Dr Klaus Wagner
WHO Representative to Nepal

ACKNOWLEDGEMENTS

Successful implementation of the study on *Non-structural Vulnerability Assessment of Hospitals in Nepal* was possible due to the support and cooperation received from several individuals and institutions to which NSET expresses its sincere gratitude.

We thank WHO-Nepal for supporting and entrusting NSET for carrying out the study. We appreciate the unstinted cooperation, support and guidance from Mr. Erik Kjaergaard, Miss Trine Ladegaard and Mr. Umesh Kattel of the Emergency and Humanitarian Action Program (EHA) of WHO-Nepal. Miss Trine Ladegaard also edited the language of this report

We are thankful to the Ministry of Health, the Department of Health Services, Epidemiology and Disease Control Division (EDCD), for administrative support, which facilitated our access to the hospitals and conduction of the survey. We deeply appreciate the efforts of Dr. B. D. Chataut, Director General, Department of Health services, Dr. M. B. Bista, Director, EDCD, Dr. P. B. Chand, former Director, EDCD, and Dr. K. D. Shrestha, Chief of Epidemiology Section, EDCD, who always support encouraged us in the course of the study.

We also extend our sincere gratitude to the Disaster Health Working Group for allowing us access to the meetings for presenting interim progress, and for their critique.

Constant encouragement and guidance from Dr. Luis J. Perez, Regional Advisor, EHA of South East Asian Regional Office (SEARO) of WHO is highly appreciated.

The study might not have been successful without the active support from the superintendents and the staff especially of their maintenance division of the hospitals that were assessed: Bir Hospital, Teaching Hospital, Patan Hospital, Bhaktapur Hospital, Western Regional Hospital, Koshi Zonal Hospital, Bheri Zonal Hospital, Seti Zonal Hospital and Bharatpur Hospital. We thank them all.

We are also thankful to all participants from government and non-government organizations, donors, professionals and others, who participated in the workshop to discuss findings of the study. Suggestions and comments received from them were invaluable.

Shiva Bahadur Pradhanang

President

National Society for Earthquake Technology-Nepal (NSET)

Table of Content

ANNEX

1 Introduction

1.1 Background

This report presents the methodology and findings of a seismic non-structural vulnerability assessment of 9 major hospitals in Nepal. The study was conducted by National Society for Earthquake Technology-Nepal (NSET) under a contract with WHO- Nepal during March-November 2003.

This study has been carried out considering the high seismic risk of the country and low level of preparedness in critical infrastructures including health facilities. In the past, big earthquakes in Nepal have caused huge numbers of casualties and damage to structures. The Great Nepal - Bihar earthquake in 1934 reportedly killed 8519 persons and damaged 80,000 buildings in Nepalese territory. In recent years, the Kathmandu Valley Earthquake Risk Management Project and other projects (e.g. The Study on Earthquake Disaster Mitigation in Kathmandu Valley) estimated high potential losses and casualties including the potential losses of medical facilities during a large earthquake affecting Kathmandu Valley. Although a seismic country, earthquake-resistant standards have not been effectively applied and guidelines have not been published and practiced for hospital facilities in general, in Nepal. For this reason, there is a higher possibility of hospital buildings not being functional during a large seismic event.

National Society for Earthquake Technology-Nepal (NSET) conducted the project "Structural Assessment of Hospitals and Health Institutions of Kathmandu Valley" with WHO-Nepal and the Ministry of the Health, HMGN in 2001. The assessment estimated that most of the hospitals would withstand the occasional earthquake of MMI VII without collapsing. It was found that 10% of the hospitals might be functional, 30 % partially functional, and 60% out of service. The major cause of possible functional loss was considered to stem from non-structural damage and one of the recommendations of the project was to conduct detailed non-structural assessment of major hospitals.

This project is the recommended follow-up of the aforementioned study. Both studies were envisaged by the *Health Sector Emergency Preparedness & Disaster Response Plan Nepal* prepared by the Health Disaster Working Group, Epidemiology and Disease Control Division (EDCD), Department of Health Services (DHS), the Ministry of Health and WHO-Nepal.

The current project emphasizes the development of appropriate methodology for carrying out such non-structural vulnerability assessment and has conducted an assessment of selected 9 major hospitals located within and outside Kathmandu Valley.

Since structural vulnerability assessment is a pre-requisite for a comprehensive non-structural assessment, a structural assessment was also conducted for those hospitals for which it was not done previously.

1.2 Structure of the Report

Section 1 of this report presents the introduction of the study project and section 2 the objective, scope and approach while section 3 includes the methodology. The result on hospitals performance assessment and recommendations to improve seismic performance has been given in section 4. Section 5 presents examples of mitigating non-structural vulnerability of hospitals. Annex 1 presents the definition of terms, Annex 2 the significance of non-structural damage, Annex 3 the causes of non-structural damage and Annex 5 presents the sample report on individual hospital.

The results and the recommendations drawn are from the reports of individual hospitals. The individual reports are produced as appendices to this main report and are given to the concerned hospitals. These reports are detailed in such a way to enable the implementation for non-structural mitigation options. The sample report of individual hospital given in this report shows the level of work done in each hospital.

Prioritisation and phasing of recommendations are made considering the cost involvement and the effectiveness of implementing the recommendations.

Some doable and cost effective non-structural vulnerability options are identified considering the availability of materials and technology as well as the feasibility of implementation. The examples given in this report might be useful to other hospitals as well.

2 Objective, Scope and Approach

Objectives

The main objectives of the assessment study were:

- Development of a systematic approach towards assessment of non-structural vulnerability of hospital buildings and health institutions of Nepal through the implementation of such assessment of selected major hospitals in the country.
- Identification of appropriate measures for improving seismic performance of selected hospitals of the country.
- Dissemination of the findings in order to facilitate the implementation of the identified earthquake risk reduction measures.

Scope

The scope of the project was:

a. Undertake quantitative assessments of the non-structural vulnerability of 5 hospitals in Kathmandu valley.

b. Undertake structural and non-structural vulnerability assessment of 5 hospitals outside Kathmandu valley using qualitative methodology.

c. Among the ten hospitals undertake rigorous qualitative analyses of 2 hospitals: one in Kathmandu valley and one outside it.

d. Quantitative assessment of the typical non-structural elements for 1 hospital in Kathmandu valley.

e. Identification of measures to improve the earthquake safety of the selected hospitals.

f. Organization of a workshop for dissemination of the findings.

g. Preparation of this report.

However, during the course of the methodology development and implementation of the assessment of the hospitals, the following modifications / alterations were made to the scope of the work:

a. Only 4 hospitals were assessed in Kathmandu. Due to security reasons, the planned assessment of Birendra Army Hospital had to be cancelled.

b. Rigorous qualitative non-structural assessment was made for all 9 hospitals in order to ensure that the proposed mitigation measures could in fact be implemented.

c. It was not necessary to carry out a quantitative assessment of typical non-structural elements, as the level of the qualitative assessment and the recommended measures derived thereby was sufficient to start implementation.

Approach

Following approaches were taken during implementation of the assessment work:

a. Collect primary data to make assessment and recommendation statement for each system and its components for mitigating the risk.

b. Hospital staff, mainly maintenance personnel and doctors were involved during the visit and in the exploration of mitigation options.

c. The choice of non-structural measures was made based on availability of materials / tools and local capacity to implement.

d. The assessment work was taken as an awareness and education tool to promote personal and collective safety of hospital personnel.

3 Methodology

One of the objectives of the study was to develop a methodology for seismic vulnerability assessment of hospitals in Nepal. This was done by adopting and adapting the provisions spelt out for such non-structural assessment in different documents.

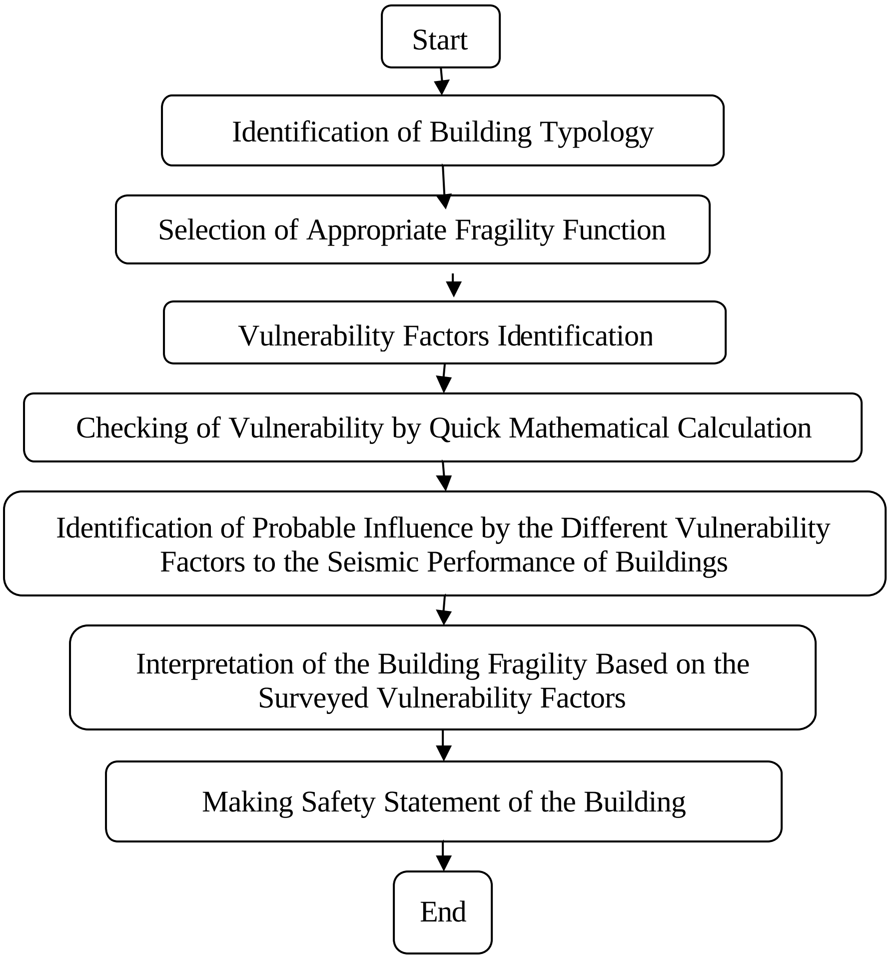
Seismic Reliability Assessment of Critical Facilities the technical report MCERR-99-0008, Protocol for Assessment of the Health Facilities in Responding to Emergencies by WHO, *New Zealand standards NZS 4104:1994* and *NZS 4219:1983* and *NEHRP Guidelines for the Seismic Rehabilitation of Buildings,* (FEMA-273) were all used as references and the methodology defined in these documents were used to some extent to develop the methodology for this study.

It was necessary to develop such a methodology because of the non-applicability of similar methodologies used in developed countries. In Nepal, there is a lack of data about the design and the construction methodology, and this data is normally used as input parameters in the established software used for making such assessments in developed countries. The methodology, which was developed and used for the study is described below.

3.1 Structural Vulnerability Assessment

The flowchart below shows the major steps of an assessment of a typical hospital in this study. The description of the different steps is presented in the following sections.

Fig 1: Flow Chart for Structural vulnerability Assessment (Qualitative)



3.1.1 Identification of Building Typology

The targeted hospital buildings were classified as below. This typology classification is global, and is based on the performance of different types of buildings during past earthquakes. Building typologies defined in *The Development of Alternative Building Materials and Technologies for Nepal: Seismic Vulnerability Analysis* (Appendix-C), a Nepal National Building Code document, were also considered when defining the different building types. The types of buildings are:

Type 1: Adobe, stone, adobe & stone, stone & brick-in-mud.

Type 2: Un-reinforced masonry made of brick in mud.

Type 3: Un-reinforced masonry made of brick in lime, brick in cement, and well-built brick in mud, stone in cement (well built brick in mud: with wooden bands, corner posts with very good wall / area ratio and proper connection; original courtyard type).

Type 4: Reinforced concrete ordinary-moment-resistant-frames (OMRF).

A: ORMF with more than three stories.

B: ORMF less or equal to three stories.

Type 5: Reinforced concrete intermediate-moment-resistant-frames (IMRF).

Type 6: Reinforced concrete special-moment-resistant-frames (SMRF).

Type 7: Other (must be specified and described).

3.1.2 Selection of Appropriate Fragility Function

The performance level of specific building types was decided upon based on the internationally available descriptions of seismic performance during past earthquakes. The description of both structural and non-structural damage was taken as basis. However, such descriptions are not available for all building types found in Nepal, and a combination of international and Nepalese Standards were therefore used. For this evaluation, the damage extent at different intensities was taken from fragility functions derived in *The Development of Alternative Building Materials and Technologies for Nepal: Seismic Vulnerability Analysis* (Appendix-C) and *European Micro-seismic Scale*, 1998.

3.1.3 Vulnerability Factors Identification

The right vulnerability factors for the different types of buildings were selected using the set of appropriate checklists available in FEMA 310, *Handbook for the Seismic Evaluation of Buildings*.

The basic vulnerability factors related to building systems, lateral force resisting systems, connections, diaphragms, geologic and site hazard, and non-structural hazards were evaluated based on visual observation. Critical vulnerability factors that were necessary to check with quick calculations were identified in this step.

3.1.4 Checking of Stress Conditions of Some Components by Mathematical Calculations

The severity of different vulnerability factors was checked by quick calculations wherever found necessary. These calculations were quick shear checks, strong column-weak beam condition etc., and they sometimes revealed the critical status of the building.

3.1.5 Identifying Probable Influence of the Different Vulnerability Factors on the Seismic Performance of Buildings

Based on the observations and short calculations, probable effects of different vulnerability factors were assessed. Table 1 provides a checklist of the vulnerability factors and their effects.

Table 1: Identifying Probable Influence of the Different Vulnerability Factors on the Seismic Performance of Buildings

Vulnerability Factors		**Increasing Vulnerability of the Building by different vulnerability factors**				
		High	**Medium**	**Low**	**N/A**	**Not known**
Building System	Load Path					
	Weak Storey					
	Soft Storey					
	Geometry					
	Vertical Discontinuity					
	Mass					
	Torsion					
	Deterioration of Material					
	Cracks in Infill Wall					
	Cracks in Boundary Columns					
Lateral Force Resisting System	Redundancy					
	Shear Stress Criteria					
Connection	Connectivity between different structural elements					
Others	Pounding Effect					

3.1.6 Interpretation of the Building Fragility Based on the Surveyed Vulnerability Factors

The probable damage to a building was judged using the general fragility curve chosen for the building combined with the assessed influence of different vulnerability factors. Based on this, the target building was classified as" average", "good" or " weak" for that particular typology. The classification “good” means that the building behaves better than average buildings of that type whereas a “weak” building behaves worse than an average building of that type.

3.1.7 Making Structural Safety Statement about the Building

The expected structural performance of hospital buildings during different MMI intensities was then figured out. The following table shows the format for making the safety statement about the building.

	Performance of the Building			
	MMI = VI	**MMI = VII**	**MMI =VIII**	**MMI = IX**
Structural Safety				

3.2 Non-Structural Vulnerability Assessment

The major steps carried out for the non-structural assessment of hospitals are described below.

3.2.1 Identifying Critical Systems and Facilities

Identification of critical systems and essential functions of hospitals was carried out based upon the functional requirements of the hospital during and after an earthquake. The main critical systems and facilities, which are important for continued functionality, were identified after visiting the hospital. The following steps were followed to identify the critical systems.

Steps for Identifying the Critical Systems and Facilities

Step 1: Visit the hospital and explain the scope of work to the hospital administration.

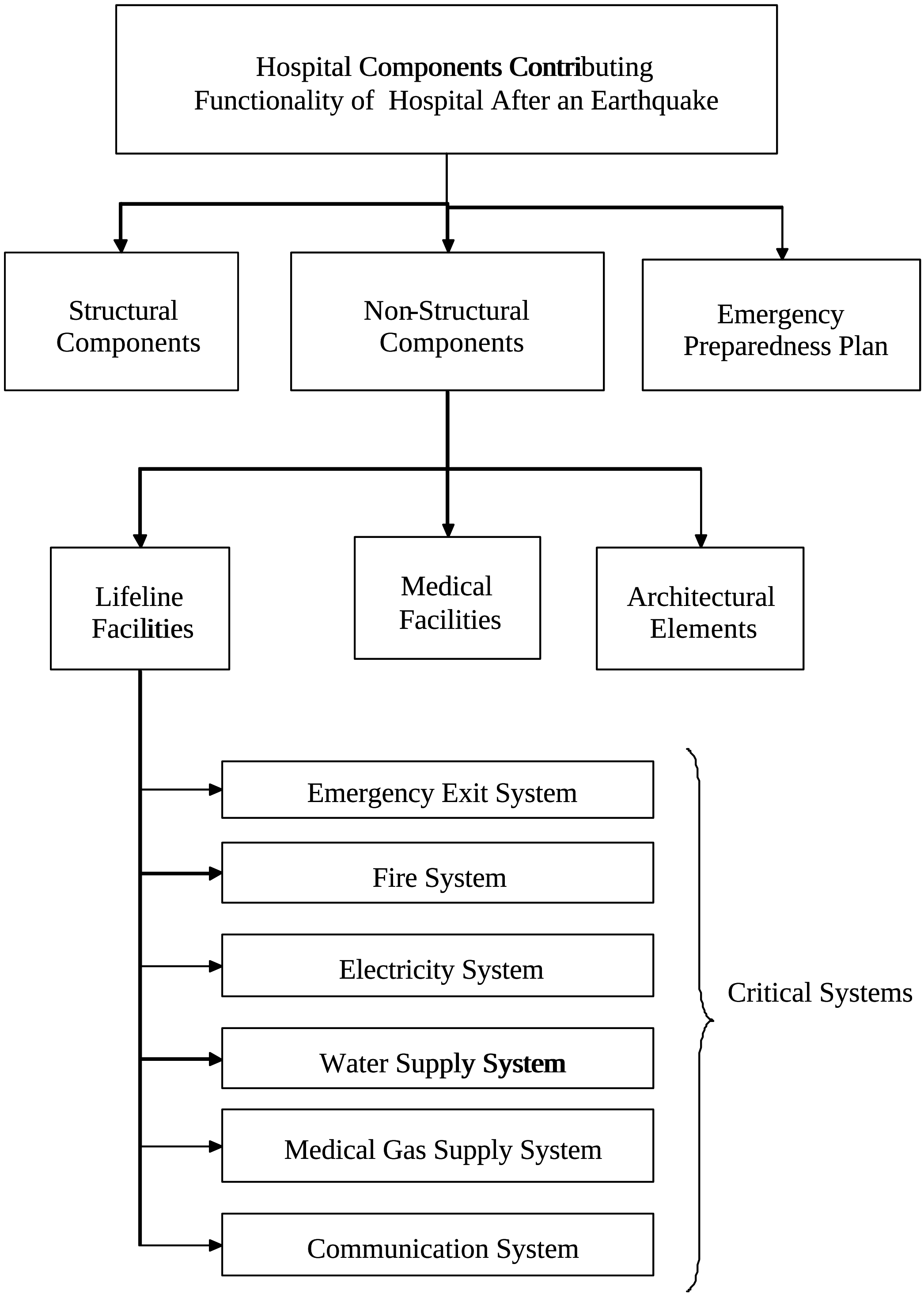
Step 2: Collect information.

Step 3: Visit essential and critical facilities (after collecting information).

Step 4: Visit lifeline facilities (after collecting information).

Step 5: Cross correlation among structural system, medical facilities and lifeline systems.

Fig 2: Major Systems of the Hospital



3.2.2 Assessment of Individual Components

All the identified critical systems and facilities were visited to evaluate the vulnerability of the individual components. All equipment and components were rated against two earthquakes, i.e. a medium size earthquake (MMI VI-VII) and a severe earthquake (MMI VIII-IX), in terms of different levels of damage; very high, medium and low. Vulnerability reduction options, implementation priority and cost estimation for implementation of mitigation options were identified for all equipment.

3.2.3 Assessment of Systems' Vulnerability

Based on the assessment of the individual components of the respective systems, the critical systems and medical facilities were examined to find out the possible level of damage in the two earthquake scenarios. The different levels of potential damage and its consequences for the performance of the individual components and the systems are given in Table 3.

Mitigation options for each system were identified and critically evaluated in terms of ease and cost of implementation and of their expected efficiency regarding vulnerability reduction.

The feasibility of implementing mitigation options are defined as either: easy to implement or difficult to implement.

Easy to Implement: *The maintenance division of the hospital can implement the mitigation options after a short training from outside. The materials necessary for implementing mitigation options are available at local market.*

Difficult to Implement: *Experts from outside the hospital are necessary to implement the mitigation options. The materials necessary for implementing mitigation options are not available at local market.*

The terms used to define the cost involvement for implementing the mitigation options to reduce the risk are described as low and high cost as defined below.

Low Cost: *The cost involvement is less than NRs. 100,000 (The hospital administration / maintenance division can allocate the budget to implement the mitigation option).*

High Cost: *The cost involvement is more than NRs. 100,000 (The hospital administration / maintenance division can not allocate the budget to implement the mitigation option and needs external financial support.*

3.2.4 Performance Assessment of Hospital

The performance of the hospital in terms of non-structural vulnerability is evaluated at five distinct levels of damage to different critical systems and facilities that the hospital might sustain. The performance levels used here are defined in Table 3. The structural safety of the hospital is also considered while assessing the performance level.

Table 3: Non-structural Performance Levels and Damage Descriptions (Adapted from *NEHRP Guidelines for the Seismic Rehabilitation of Buildings*, FEMA-273)

Performance Levels and Overall Damage	Expected Levels of Damage to the Different Systems		
	Critical Systems / Components	**Contents and Equipment of Medical Facilities**	**Architectural Elements**
Operational (Slight Damage)	Lifts operate; ducts and piping sustain negligible damage; the fire response system is functional; transformer / generators are functional and electricity can be provided; water can be provided.	Medical equipment on floors and walls are secure and operable; power is available; equipment on rollers slide but do not tip and do not impact with anything; cupboards, racks cabinets and book shelves do not tip; negligible damage to chemical bottles in the lab; oxygen cylinders and blood stands are not tipped over.	Negligible damage to false ceilings, chimneys, light fixtures and stairs; minor damage to parapets and doors; minor cracks in cladding and partitions.
Immediate Occupancy (Slight to Moderate Damage)	All system components are secured; generators start but may not be adequate to service all power requirements; minor leaks in some joints of water supply pipelines; fire systems and emergency lighting systems are functional; medical gas supply systems are secure and functional if electricity is available, lifts are operable and can be started when power is available.	Medical equipment on floors and walls are secure but power may not be available; some equipment on rollers slide and impacts with something; cupboards, racks cabinets and book shelves do not tip; negligible damage to chemical bottles in the lab; blood stands may tip.	Minor damage to ceilings, chimneys, light fixtures, doors; some window glasses crack; some cracks to partition walls.
Life Safety (Moderate to Heavy Damage)	Lifts out of service, some breakages to pipelines and ducts; some fixtures broken; electrical distribution equipment shifts and may be out of service; breakages in medical supply systems near heavy equipment.	Medical equipment shift and disconnect from cables but do not overturn; most equipment on rollers slide; some cupboards, racks cabinets and book shelves tip; some damage to chemical bottles in the lab; lab equipment slide from table.	Extensive cracked glass, some broken glass; severe cracks in partitions and parapets; doors jammed; some fracturing to cladding.
Hazards Reduced Levels (Heavy to Very heavy Damage)	Some critical systems equipment slide or overturn; some piping lines rupture; generators will be out of function; some damage to the fire response system.	Equipment roll, overturn, slide, and cables are disconnected; some equipment require reconnection and realignment; sensitive equipment may not be functional; cupboards, cabinets and racks overturn and spill contents; severe damage to lab chemicals.	Generally shattered glass and distorted frames; widespread falling hazard; damage to partitions and parapets; severe damage to claddings; extensive damage to light fixtures.

4 Seismic Assessment of Hospitals in Nepal

The seismic assessment of hospitals was carried out using the developed methodology defined in chapter 3 above. In Kathmandu Valley, only non-structural assessments were made whereas both structural and non-structural assessment was carried out outside the valley.

4.1 Selection of Hospitals

Ten hospitals, five from Kathmandu Valley selected amongst 14 major hospitals and five from outside the valley selected amongst regional and zonal hospitals, were chosen for the non-structural assessment. The list of hospitals is given in Table 4 and Table 5.

Following criteria were considered when selecting the hospitals:

Hospitals within Kathmandu Valley

- Recommendations from the structural assessment study that was conducted in 2001.
    - Those hospitals are chosen where a detailed qualitative structural assessment was performed in 2001 and a non-structural assessment specifically recommended.
- Importance.
    - Importance in terms of emergency management is considered. All selected institutions are general hospitals and are main hospitals of Kathmandu Valley.

Hospitals outside Kathmandu Valley

General criteria such as number of beds and geographical distribution are considered when selecting hospitals outside Kathmandu Valley.

Table 4: List of Hospitals Selected for Non-Structural Assessment within Kathmandu Valley

Code	Name of Hospital	Type	Location				Structure Type	Number of Storeis	Date of Completion	No of Beds	Total Doctor	Total Nurses	Remarks
			District	Municipality	Ward No.	Place							
Government Hospitals													
GH-1	Bir Hospital	General	Kathmandu	Kathmandu	30	Mahaboudha	RC	5	1985	392	180	210	
							BM	4	1968				
							BM	3	_				
GH-2	Birendra Army Hospital	General	Kathmandu	Kathmandu	14	Chauni	RC	3	_	380	80	85	
GH-3	Birendra Police Hospital	General	Kathmandu	Kathmandu	3	Maharajganj	RC	2	1985	150	40	42	
							RC	3	1983				
GH-5	Sukra Raj Tropical and Infectious Disease	Infectious	Kathmandu	Kathmandu	12	Teku	BC	2	1982	103	13	50	
							BC	1	1999				
GH-6	Kanti Hospital	Children		Kathmandu	3	Maharajanj	RC	2	1993	250	75	107	
							RC	2	1993				
GH-7	Maternity Hospital	Maternity	Kathmandu	Kathmandu	2	Thapathali	BC	3	1965	310	60	110	
							BL	2	1959				
							RC	5,4,3	1975				
GH-9	Patan Hospital	General	Lalitpur	Lalitpur	5	Lagankhel	RC	4	1982	200	60	250	
GH-11	Bhaktapur Hospital	General	Bhakutapur	Bhaktapur	17	Dudh Pati	BC	3	1978	50	11	25	
							HC	1	2001				
GH-14	Military Hospital					Mohaboudha							
Teaching Hospitals													
TH-1	Teaching Hospital	General	Kathmandu		3	Maharajanj	RC	2,4	1984	401	200	350	
Private Hospitals													
TH-2	Nepal Medical College	General	Kathmandu		7	Aterkhel	RC	1	1997	394	140	87	
							RC	6	1997				
							BC	1	_				
TH-3	Kathmandu Medical College	General	Kathmandu	Kathmandu	7	Sinamangle	RC	7	2000		62	54	
PH-8	Medicare National Hospital & Research Center	General	Kathmandu	Kathmandu	1	Naxal	RC	4	_	60	70	39	
							RC	1					
							RC	4					
PH-20	B & B Hospital	Orthopedic	Lalitpur	Lalitpur	7	Gwarko	RC	5	1997	100	50	110	
Non-Governmental Hospitals													
NH-1	Model Hospitals	General	Kathmandu	Kathmandu	31	Baghbazar	BM	3	_	50	8	34	
							RC	5	_				

Selected Hospitals

Table 5: List of Hospitals Selected for Structural and Non-Structural Assessment outside Kathmandu Valley

RH-1	WESTERN REGIONAL HOSPITAL	General	Kaski	Pokhara	-	-	-	-	-	230	-	-	-	*
ZH-1	Koshi Zonal Hospital	General	Morang	Biratnagar	-	-	-	-	-	150	-	-	-	*
ZH-2	Mechi Zonal Hospital	General	Jhapa	Bhadrapur	-	-	-	-	-	75	-	-	-	*
ZH-3	Narayani Zonal Hospital	General	Parsa	Birgunj	-	-	-	-	-	76	-	-	-	*
ZH-4	Lumbini Zonal Hospital	General	Rupandehi	Butwal	-	-	-	-	-	75	-	-	-	*
ZH-5	Seti Zonal Hospital	General	Kailali	Dhangadhi	-	-	-	-	-	75	-	-	-	*
ZH-6	Janakpur Zonal Hospital	General	Dhanusha	Janakpurdham	-	-	-	-	-	75	-	-	-	*
ZH-7	Mahakali Zonal Hospital	General	Kanchanpur	Mahendra	-	-	-	-	-	75	-	-	-	*
ZH-8	Bheri Zonal Hospital	General	Banke	Nepalgunj	-	-	-	-	-	-	-	-	-	*
ZH-9	Sagarmatha Zonal Hospital	General	Saptari	Rajbiraj	-	-	-	-	-	75	-	-	-	*
DH-1	Bharatpur Hospital	General	Chitawan	Bharatpur	-	-	-	-	-	140	-	-	-	*

Notes:

Code	Description	Code	Description
GH	**Government Hospital**	**RC**	**Reinforced Concrete Frame**
TH	**Teaching Hospital**	**BM**	**Brick in Mud**
PH	**Private Hospital**	**BC**	**Brick in Cement**
NH	**Nongovernmental Hospital**	**BL**	**Brick in Lime**
ZH	**Zonal Hospital**		
DH	**District Hospital**		

Selected Hospitals

4.2 Hospital Performance Assessment

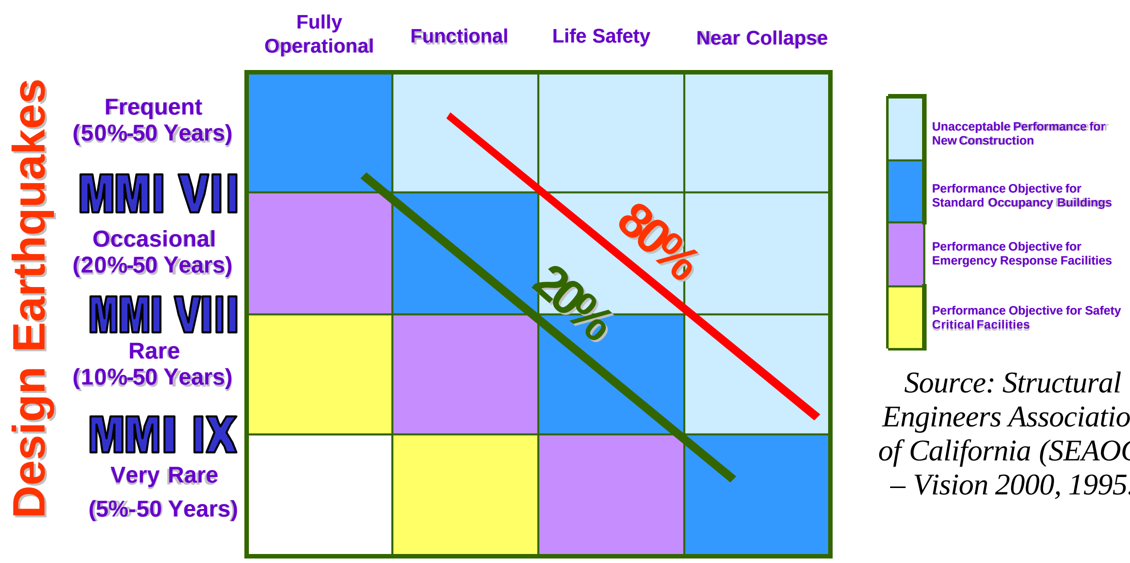
Based upon the structural and non-structural vulnerability assessment of the hospital buildings and different critical systems and facilities, the functional assessment of the hospitals was made for two different earthquake scenarios.

Table 6: Expected Seismic Performance of Assessed Hospitals in Different Earthquake Scenarios

<table>
<tr><th rowspan="2">Hospitals</th><th colspan="2">Earthquake Scenario</th></tr>
<tr><th>Moderate Earthquake
(MMI VI – MMI VII)</th><th>Severe Earthquake
(MMI VIII – MMI IX)</th></tr>
<tr><td>1. Bir Hospital</td><td>Out of Service for Some Time
• Severe damage to the water supply system, electricity system, medical gas system.
• Many partition walls will fail.
• Most of the medical facilities will not be operational.
• Some OPDs may be functional after some hours of maintenance.</td><td>Out of Service
• Critical systems and most hospital departments will be out of service for a long time.
• There will be heavy structural and non-structural damage.</td></tr>
<tr><td>2. Teaching Hospital</td><td>Partially Operational
• All critical systems will be functional.
• There may be electric power losses and some damage to the medical gas system may occur.
• The labs and operation theatres may not be functional.</td><td>Partially Operational after Some Time
• There will be moderate damage to the medical gas supply system.
• Many medical facilities might not be operational for some time, some hours or even days.</td></tr>
<tr><td>3. Patan Hospital</td><td>Partially Operational
• Most of the critical systems, OPD, Emergency Department, X-ray and CSSD may be operational after some hours.</td><td>Partially Operational or Out of Service
• Some critical systems and most hospital departments will be out of service for a long time.</td></tr>
<tr><td>4. Bhaktapur Hospital</td><td>Partially Operational
• Some medical facilities like OPD, Emergency Department, and CSSD may be operational after some hours.
• The electricity system and water supply system may be out of order for a long time.</td><td>Out of Service
• Critical systems and most hospital departments will be out of service for a long time.</td></tr>
</table>

5. Western Regional Hospital	**Partially Operational** • Electricity and water supply systems may be interrupted. • There is a possibility of heavy damage to the lab, maternity ward and some parts of the OPD. • Most of the wards and the OPD will be functional after some hours.	**Out of Service** • All critical systems and most hospital departments will be out of service for a long time. • There will be heavy damage to most facilities.
6. Koshi Zonal Hospital	**Partially Operational** • The water supply system will be functional. The electricity system may be partially operational. • X-ray, CSSD and some wards may be operational after some hours. • The OPD and laboratory block, ICU block and maternity cabin block may be heavily damaged.	**Out of Service** • All critical systems and most hospital departments will be out of service for a long time. • There will be heavy damage to most of the facilities. • Some buildings may have been destructed.
7. Bheri Zonal Hospital	**Partially Operational** • The electricity system may not be functional. • X-ray, CSSD and some wards may be operational after some hours. The OPD and laboratory block, ICU block and maternity cabin block may be heavily damaged.	**Out of Service** • All critical systems and most hospital departments will be out of service for a long time. • There will be heavy damage to most of the facilities. • Some buildings may have been destructed.
8. Seti Zonal Hospital	**Partially Operational** • The water supply system may be interrupted. • The electricity system may work. • X-ray and OPD may be operational after some hours.	**Out of Service** • All critical systems and most hospital departments will be out of service for a long time. • There will be heavy damage to most of the facilities.
9. Bharatpur Hospital	**Partially Operational** • The electricity and water supply systems may be interrupted. • X-ray, CSSD and Lab will be out of function for several hours. • Some parts of the hospital like the general store may be severely damaged.	**Out of Service** • All critical systems and most hospital departments will be out of service for a long time. • There will be heavy damage to most of the facilities.

The comparison of the expected seismic performance of the hospitals with an internationally accepted standard risk assessment matrix shows that about 80% of the hospitals assessed will be partially operational after a moderate earthquake and out of service after a severe earthquake. The remaining 20% of the hospitals will be partially operational even after severe earthquakes.



Source: Structural Engineers Association of California (SEAOC) – Vision 2000, 1995.

4.3 *Recommendations for Improving Seismic Performance*

Based upon the Structural and Non-structural assessment of the hospitals, the following priority-wise recommendations are made to improve the seismic performance of different hospitals. The seismic vulnerability of different systems, technical and economical feasibility of implementing mitigation options, structural vulnerability and importance of the different critical systems and departments in order to operate the hospital after an earthquake are taken as basis for the prioritization.

Phase I: To expect the Hospitals Fully Operational after a Moderate Earthquake

Activities: Fixing of all equipment and contents, Strengthening of critical systems, Training to hospital personnel and Providence of some redundancy in critical system.

Estimated Cost: **US$150,000.00 to phase I recommendations in assessed 9 hospitals**

Phase II and III: Additional Recommendations for Improving Performance of the Hospital to a Desirable Level after a Severe Earthquake

Activities: Seismic retrofitting of hospital buildings, further strengthening of critical systems and providence of extra redundancy in the systems.

Estimated Cost: US$1,200,000.00 to implement structural and non-structural mitigation options in 5 hospitals outside Kathmandu valley and implementation of non-structural mitigation options in 4 hospitals within valley.

Bir Hospital

Phase I: Recommended Improvements of the Non-structural Performance Expected to Render the Hospital Fully Operational after a Moderate Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
1. Fixing of all equipment and contents.	First	500,000.00	Work is expected to be done by the maintenance section. The cost is to pay for locally available materials.
2. Provision of extra fuel for the generator.	First	60,000.00	
3. A yearly one-day training or workshop on non-structural safety for all maintenance, medical and administrative staff.	First	40,000.00	The cost covers one training programme and is meant to pay for local resource persons and awareness materials.
4. Plastic lamination of glass windows in important departments.	Second	1,000,000.00	
5. Bracing of partition walls.	Second	3,000,000.00	
Total cost for Improvement		**4,600,000.00**	

Phase II: Additional Recommendations for Improving the Non-structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
6. Installation of flexible couplings in the water supply system and in the electricity system.	Third	2,000,000.00	
7. Provision of redundancy in the system (extra generator, spare pumps).	Third	2,000,000.00	
Total additional cost		**4,000,000.00**	

Note: *The second phase of the non-structural mitigation measures should only take place after the seismic retrofitting recommended in the previous structural vulnerability assessment has been carried out. This cost is not included in the total additional cost above but is detailed in the structural assessment report from 2002.*

Teaching Hospital

Phase I: Recommended Improvements of the Non-structural Performance Expected to Render the Hospital Fully Operational after a Moderate Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
1. Fixing of all equipment and contents.	First	500,000.00	Work is expected to be done by the maintenance section. The cost is to pay for locally available materials.
2. A yearly one-day training or workshop on non-structural safety for all maintenance, medical and administrative staff.	First	40,000.00	This cost is for one training programme and is meant to pay for local resource persons and awareness materials.
3. Plastic lamination of glass windows in selected important places.	Second	100,000.00	
Total cost for Improvement		**640,000.00**	

Phase II: Additional Recommendations for Improving the Non-structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
4. Plastic lamination of remaining windows.	Second	1,000,000.00	
5. Installation of another generator to supply power to CSSD and X-ray.	Third	2,000,000.00	
6. Installation of another deep boring.	Third	3,000,000.00	
Total additional cost		**6,000,000.00**	

Note: *The second phase of the non-structural mitigation measures should only take place after the seismic retrofitting recommended in the previous structural vulnerability assessment has been carried out. This cost is not included in the total additional cost above but is detailed in the structural assessment report from 2002.*

Patan Hospital

Phase I: Recommended Improvements of the Non-structural Performance Expected to Render the Hospital Fully Operational after a Moderate Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
1. Fixing of all equipment and contents.	First	300,000.00	Work is expected to be done by the maintenance section. The cost is to pay for locally available materials.
2. Provision of extra fuel for generator.	First	30,000.00	
3. A yearly one day training or workshop on non-structural safety for all maintenance, medical and administrative staff.	First	40,000.00	The cost is for one training programme and is meant to pay for local resource persons and awareness materials.
4. Plastic lamination of glass windows in important departments.	Second	200,000.00	
Total cost for Improvement		**5,70,000.00**	

Phase II: Additional Recommendations for Improving the Non-structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

Recommendati ons	Priority	Estimated Cost (NRs.)	Remarks
5. Bracing of partition walls.	Second	200,000.00	The work is expected to be carried out by the maintenance section using local materials. The cost is to pay for those materials.
6. Installation of flexible couplings in the water supply system and the medical gas system.	Second	500,000.00	
7. Improvement of the solar heater system.	Third	50,000.00	
8. Provision of redundancy in the system (extra generator, spare pumps).	Third	20,00,000.00	
Total additional cost		**2,550,000.00**	

Note: *The second phase of the non-structural mitigation measures should only take place after the seismic retrofitting recommended in the previous structural vulnerability assessment has been carried out. This cost is not included in the total additional cost above but is detailed in the structural assessment report from 2002.*

Bhaktapur Hospital

Phase I: Recommended Improvements of the Non-structural Performance Expected to Render the Hospital Fully Operational after a Moderate Earthquake

Recommendati ons	Priority	Estimated Cost (NRs.)	Remarks
1. Fixing of all equipment and contents.	First	80,000.00	Work is expected to be done by the maintenance section. The cost is to pay for locally available materials.
2. Provision of extra fuel for the generator.	First	30,000.00	
3. A yearly one day training or workshop on non-structural safety for all maintenance, medical and administrative staff.	First	40,000.00	The cost is for one training programme and is meant to pay for local resource persons and awareness materials.
4. Plastic lamination of glass windows in important departments.	Second	250,000.00	
5. Repair of the deep boring system.	Second	200,000.00	
Total cost for Improvement (Phase I)		**600,000.00**	

Phase II: Additional Recommendations for Improving the Non-structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
6. Installation of flexible couplings in the water supply system and the electricity system.	Third	500,000.00	
7. Provision of redundancy in the system (extra generator, spare pumps).	Third	1,200,000.00	
Total additional cost (Phase II)		**1,700,000.00**	

Note: *The second phase of the non-structural mitigation measures should only take place after the seismic retrofitting recommended in the previous structural vulnerability assessment has been carried out. This cost is not included in the total additional cost above but is detailed in the structural assessment report from 2002.*

Western Regional Hospital

Phase I: Recommended Improvements of the Non-structural Performance Expected to Render the Hospital Fully Operational after a Moderate Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
1. Fixing of all equipment and contents.	First	300,000.00	Work is expected to be done by the maintenance section. The cost is to pay for locally available materials.
2. Provision of extra fuel for the generator.	First	50,000.00	
3. A yearly one day training or workshop on non-structural safety for all maintenance, medical and administrative staff.	First	50,000.00	This cost is for one training programme and is meant to pay for local resource persons and awareness materials.
4. Plastic lamination of glass windows in important departments.	Second	500,000.00	
Total cost for Improvement (Phase I)		**900,000.00**	

Phase II: Additional Recommendations for Improving the Non-structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
5. Installation of deep boring system for water with a 50,000 liters overhead tank and treatment plant.	Second	5,000,000.00	
6. Installation of a new 50 KVA Generator.	Second	600,000.00	
7. Retrofitting of OPD block 1.	Third	1,000,000.00	
8. Retrofitting of OPD block 2.	Third	1,500,000.00	
9. Retrofitting of X-Ray block.	Third	1,000,000.00	
10. Retrofitting of inpatient block 1.	Third	1,500,000.00	
11. Retrofitting of inpatient block 2.	Third	1,500,000.00	
12. Retrofitting of administration and maternity block	Second	2,700,000.00	Maternity and laboratory buildings were found relatively weaker and should be given highest priority.
13. Retrofitting of Laboratory Block	Second	1,200,000.00	
14. Bracing of partition walls of the new building.	Third	900,000.00	
Total cost for Improvement (Phase II)		**16,900,000.00**	

Phase III: Additional Recommendations for Improving the Non-Structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
15. Installation of flexible couplings in the water supply system and the electricity system.	Fourth	500,000.00	
16. Provision of redundancy in the system (extra generator, spare pumps).	Fourth	2,000,000.00	
Total additional cost (Phase III)		**2,500,000.00**	

Koshi Zonal Hospital

Phase I: Recommended Improvements of the Non-structural Performance Expected to Render the Hospital Fully Operational after a Moderate Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
1. Fixing of all equipment and contents.	First	150,000.00	Work is expected to be done by the maintenance section. The cost is to pay for locally available materials.
2. Provision of extra fuel for the generator.	First	50,000.00	
3. A yearly one day training or workshop on non-structural safety for all maintenance, medical and administrative staff.	First	50,000.00	The cost is for one training programme and is meant to pay for local resource persons and awareness materials.
4. Plastic lamination of glass windows in important departments.	Second	500,000.00	
Total cost for Improvement (Phase I)		**750,000.00**	

Phase II: Additional Recommendations for Improving the Non-structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
5. Repair and maintenance of existing small boring (75mm diameter).	Second	300,000.00	
6. Installation of a new 100 KVA generator.	Second	1,000,000.00	
7. Retrofitting of OPD + laboratory block.	Third	2,000,000.00	
8. Retrofitting of ICU + emergency + training center block.	Third	2,000,000.00	
9. Retrofitting of inpatient + OT + labor block.	Third	3,500,000.00	
10. Retrofitting of new OT + CSSD block.	Third	750,000.00	
11. Retrofitting of maternity cabin block.	Third	2,000,000.00	
12. Retrofitting of administration block.	Third	1,000,000.00	
13. Bracing of infill walls in pediatric block, oral health + X-ray block and the medical blocks.	Third	1,500,000.00	
Total cost for Improvement (Phase II)		**14,050,000.00**	

Phase III: Additional Recommendations for Improving the Non-Structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
14. Installation of flexible couplings in the water supply system and the electricity system.	Fourth	500,000.00	
15. Provision of redundancy in the system (extra generator, spare pumps).	Fourth	2,000,000.00	
Total additional cost (Phase III)		**2,500,000.00**	

Bheri Zonal Hospital

Phase I: Recommended Improvements of the Non-structural Performance Expected to Render the Hospital Fully Operational after a Moderate Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
1. Fixing of all equipment and contents.	First	200,000.00	Work is expected to be done by the maintenance section. The cost is to pay for locally available materials.
2. Provision of extra fuel for the generator.	First	50,000.00	
3. A yearly one day training or workshop on non-structural safety for all maintenance, medical and administrative staff.	First	50,000.00	The cost is for one training programme and is meant to pay for local resource persons and awareness materials.
4. Installation of a new 100 KVA generator.	Second	1,000,000.00	
5. Plastic lamination of glass windows in important departments.	Second	300,000.00	
Total cost for Improvement (Phase I)		**1,600,000.00**	

Phase II: Additional Recommendations for Improving the Non-structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
6. Retrofitting of main block.	Third	11,500,000.00	
7. Retrofitting of operation theater block.	Third	400,000.00	
8. Retrofitting of emergency block.	Third	800,000.00	
9. Retrofitting of ramp.	Third	800,000.00	
10. Retrofitting of trauma ward block.	Third	600,0000.00	
11. Retrofitting of one masonry column overhead tank.	Third	400,000.00	
Total cost for Improvement (Phase II)		**14,500,000.00**	

Phase III: Additional Recommendations for Improving the Non-Structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
12. Installation of flexible couplings in the water supply system and the electricity system.	Fourth	500,000.00	
13. Provision of redundancy in the system (extra generator, spare pumps).	Fourth	2,000,000.00	
Total additional cost (Phase III)		**2,500,000.00**	

Seti Zonal Hospital

Phase I: Recommended Improvements of the Non-structural Performance Expected to Render the Hospital Fully Operational after a Moderate Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
1. Fixing of all equipment and contents.	First	150,000.00	Work is expected to be done by the maintenance section. The cost is to pay for locally available materials.
2. Provision of extra fuel for the generator.	First	30,000.00	
3. A yearly one day training or workshop on non-structural safety for all maintenance, medical and administrative staff.	First	40,000.00	This cost is for one training programme and is meant to pay for local resource persons and awareness materials.
4. Plastic lamination of glass windows in important departments.	Second	100,000.00	
Total cost for Improvement		**3,20,000.00**	

Phase II: Additional Recommendations for Improving the Non-structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
5. Installation of deep boring system.	Second	2,000,000.00	
6. Retrofitting of the old building.	Third	3,600,000.00	
7. Retrofitting of OPD block.	Third	300,000.00	
8. Retrofitting of the mother children centre.	Third	600,000.00	
9. Bracing of partitions and infill wall of the new building.	Third	800,000.00	
10. Retrofitting of the encephalitis block.	Third	200,000.00	
Total cost for Improvement (Phase II)		**7,500,000.00**	

Phase III: Additional Recommendations for Improving the Non-Structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
11. Installation of flexible couplings in the water supply system and the electricity system.	Fourth	500,000.00	
12. Provision of redundancy in the system (extra generator, spare pumps).	Fourth	2,000,000.00	
Total additional cost		**2,500,000.00**	

Bharatpur Hospital

Phase I: Recommended Improvements of the Non-structural Performance Expected to Render the Hospital Fully Operational after a Moderate Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
1. Fixing of all equipment and contents.	First	150,000.00	Work is expected to be done by the maintenance section. The cost is to pay for locally available materials.
2. Provision of extra fuel for the generator.	First	30,000.00	
3. A yearly one day training or workshop on non-structural safety for all maintenance, medical and administrative staff.	First	40,000.00	The cost is for one training programme and is meant to pay for local resource persons and awareness materials.
4. Plastic lamination of glass windows in important departments.	Second	100,000.00	
5. Installation of a new 50 KVA generator.	Second	400,000.00	
Total cost for Improvement		**6,70,000.00**	

Phase II: Additional Recommendations for Improving the Non-structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

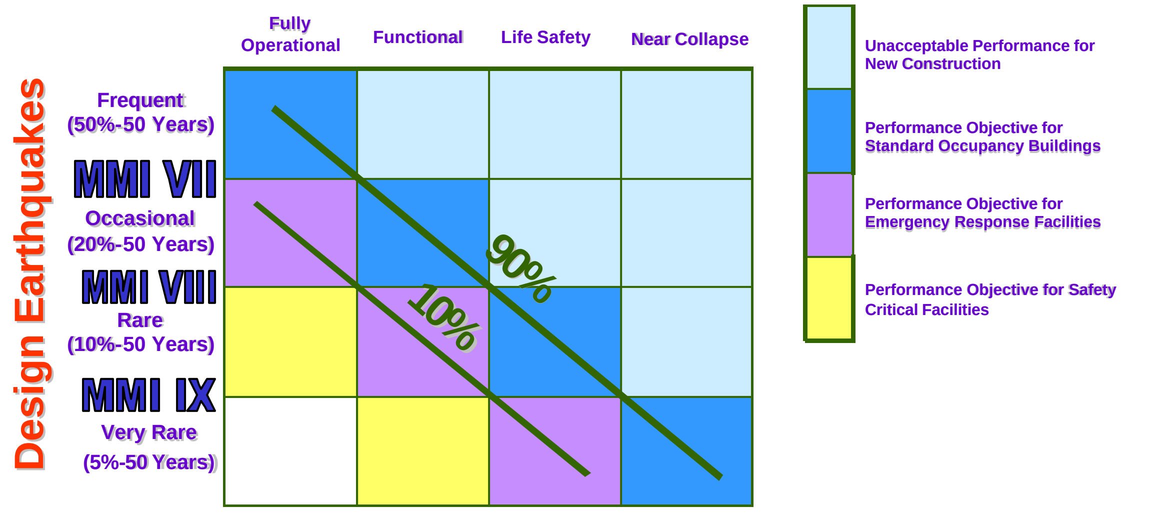
Recommendations	Priority	Estimated Cost (NRs.)	Remarks
6. Construction of a new overhead water tank of 100,000.00 litre capacity.	Second	600,000.00	
7. Retrofitting of the main building.	Third	1,000,000.00	
8. Retrofitting of the inpatient block.	Third	1,400,000.00	
9. Retrofitting of the maternity and the medical ward block.	Third	1,100,000.00	
10. Retrofitting of the paediatric ward block.	Third	700,000.00	
11. Retrofitting of the orthopaedic ward block.	Third	600,000.00	
12. Reconstruction of the store block.	Second	200,000.00	Retrofitting is not feasible.
13. Bracing of the partition walls of the OPD block.	Third	600,000.00	
14. Retrofitting of the administration block.	Third	400,000.00	
Total cost for Improvement (Phase II)		**6,600,000.00**	

Phase III: Additional Recommendations for Improving the Non-Structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
15. Installation of flexible couplings in the water supply system and the electricity system.	Fourth	500,000.00	
16. Provision of redundancy in the system (extra generator, spare pumps).	Fourth	2,000,000.00	
Total additional cost (Phase III)		**2,500,000.00**	

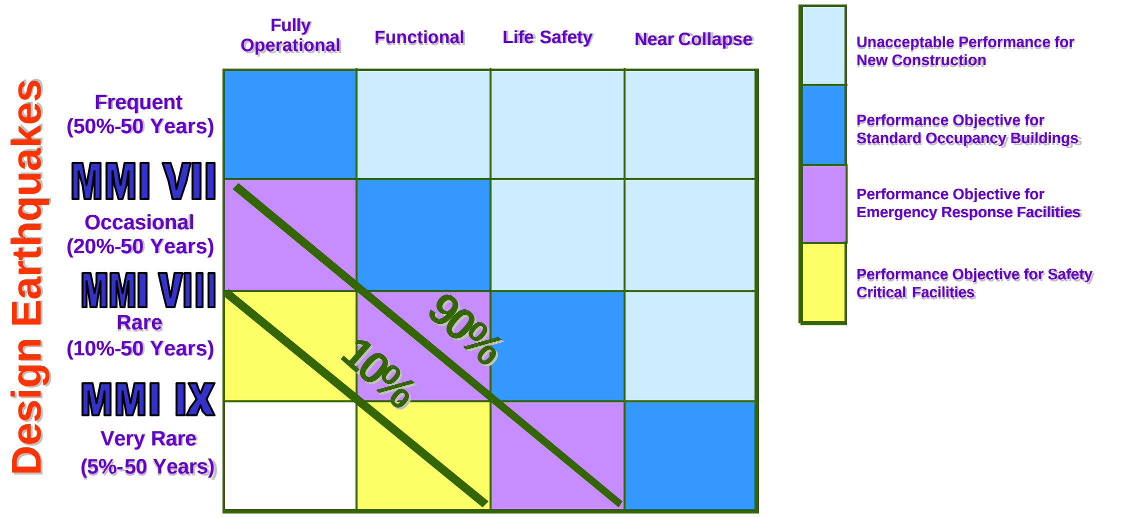
4.4 Expected Performance of Hospitals after Implementation of Recommendations

The expected performance of hospitals after implementation of Phase I recommendations is compared with the standard risk assessment matrix. The study shows that about 90% of the hospitals assessed would be functional after a moderate earthquake and out of service after a severe earthquake whereas 10% would be fully operational after a moderate earthquake and functional after a severe one.



Total cost required to implement Phase I = NRs. 10,700,000.00 (US$ 150,000.00)

The expected performance of hospitals after implementation of Phase II recommendations is compared with the standard risk assessment matrix. The study shows that about 90% of the hospitals assessed would be fully operational after a moderate earthquake and functional after a severe earthquake whereas 10% would be fully operational even after a severe earthquake.



The cost required to implement Phase II & III = NRs. 86,300,000.00 (US$ 1,200,000.00)

*[**Note:** The cost includes the construction cost for structural retrofitting of the five hospitals assessed outside Kathmandu Valley and the cost for non-structural vulnerability reduction for all 9 assessed hospitals. It does not include the cost for retrofitting of hospitals within Kathmandu Valley. To achieve this expected performance, retrofitting of hospitals within Kathmandu Valley should be carried out as detailed by the study A Structural Vulnerability Assessment of Hospitals in Kathmandu Valley, 2002.]*

5 Examples of Non-Structural Vulnerability Mitigation of Hospitals

Once a non-structural element has been identified as a potential threat and its priority established in terms of loss of lives, of property and / or function, the appropriate measures must be adopted to reduce or eliminate the hazard. Some of these possible mitigation measures are given below.

5.1 Removal

Removal is probably the best mitigation option in many cases. In all hospitals, the survey team found several examples of unnecessary or non-essential documents and materials stored near the working place or near important equipment. One solution would be better fastenings or the use of stronger supports, but the most effective solution would be removal and replacement.

Photo 1: These document packs stored on the top of book shelves and cupboards are a life safety hazard.

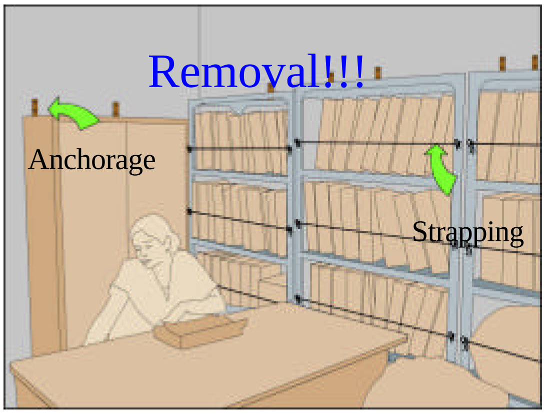


Fig 1: Life safety hazards can be reduced just by removing less important things from the working place.

5.2 Relocation

Relocation would reduce danger in many cases. For example, a very heavy object on top of a shelf could fall and seriously injure someone as well as break thereby causing economic losses. But by relocating heavy equipment and materials from upper shelves to lower shelves the risk could be mitigated. This is the case in most of hospitals where the functionality of the stores of operation theatres could be improved by doing so.

Cupboards and book shelves kept near an exit door or passage, which can obstruct the way and cause human death or injury during an earthquake event, are typical examples that were found in all hospitals. These book shelves and cupboards could easily be relocated to other places where the potentia l dangers would be reduced.

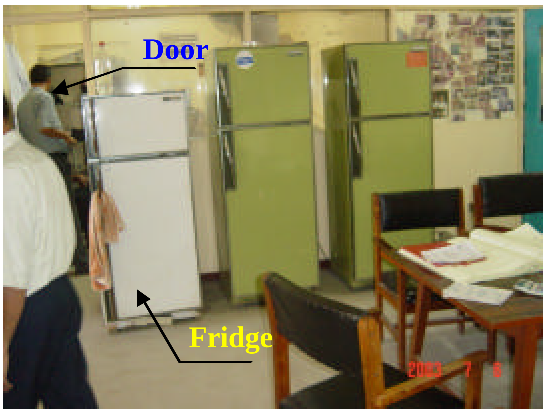


Photo 2: The fridge kept near an exit door is a life safety hazard.

Photo 3: These cupboards can block the corridor and are a life safety hazard.

5.3 Restricted Mobility for Certain Objects

Restricted mobility for certain objects such as gas cylinders and power generators is a good measure. It does not matter if the cylinders shift as long as they do not fall and break their valves. Sometimes back-up power generators are mounted on springs to reduce the noise and vibrations when they are working, but these springs would amplify ground motion. Therefore, restraining supports or chains should be placed around the springs to keep the generator from shifting or being knocked off its stand.

Photo 4: A generator on rollers can slide and overturn in an earthquake causing functional loss.

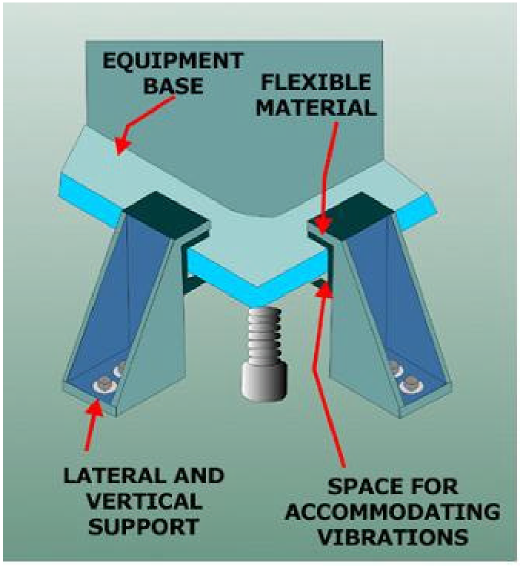


Fig 2: Generators and other vibrating equipment can be fixed by special brackets, which allow some movement but prevent them from overturning.

5.4 Anchorage

Anchorage is the most widely used precaution. It is a good idea to use bolts, cables or other materials to prevent valuable or large components from falling or sliding. The heavier the object, the more likely it is that it will move due to the forces produced by an earthquake. Autoclave machines in all hospitals are good example. They are heavy and can easily fall and break. The simple solution is to anchor the feet of the machines to the concrete floor.

Photo 5: Autoclave machine without anchorage.

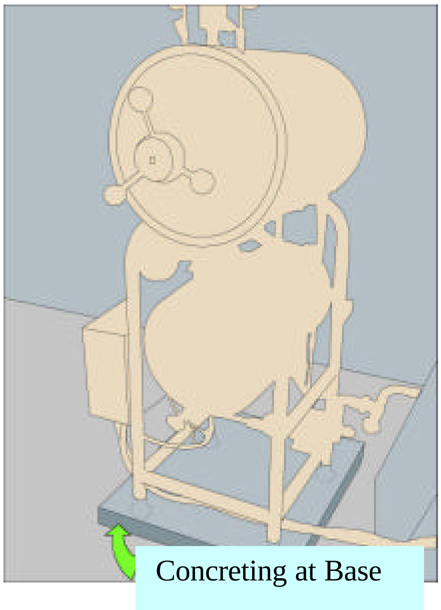


Fig 3: This machine can be fixed to the floor by casting a concrete base.

Some equipment and components of a system can easily be bolted to the floor. Transformers, water treatment tanks, communication equipment and control panels of X-ray are typical examples of equipment that can be anchored to the floor.

Photo 6: Water treatment tank which has a provision for bolting at the base but was found not bolted.

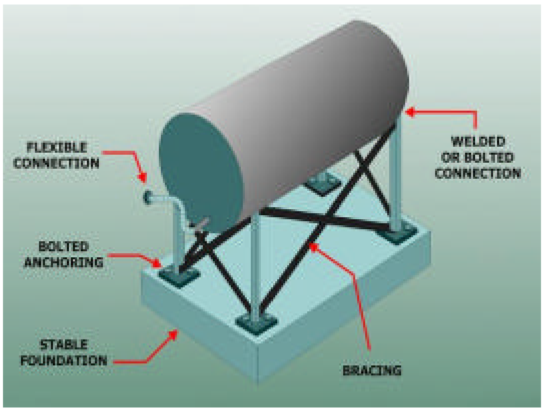


Fig 4: Bolting at the base can prevent overturning of heavy objects during an earthquake.

In most medical facilities and administration sections, cupboards, fridges and racks storing medical equipment, books, documents or chemicals pose life safety hazards as well as functional and / or property losses. This can easily be prevented by anchoring them to the wall using angles and nails as this will stop them from overturning.

Photo 7: Tall and narrow objects like fridges can easily overturn during earthquakes.

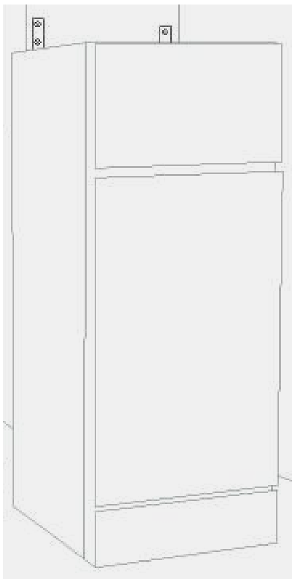


Fig 5: Such objects can be protected from overturning by bolting them to the wall.

5.5 Hooking

In all hospitals, much equipment like ECG monitors, suction units, ventilators, incubators, B.P. monitors, resuscitation equipment, etc. were found on rollers or roller trolleys, and the roller systems are necessary for better mobility. But this equipment on rollers can slide and impact with people, the walls, beds or other things causing impact hazard to the other object or person and damage to the piece of equipment itself.

Development of a proper hooking system using chains and hooks can protect this equipment and can decrease the impact hazard the time of use or storage. Provision of a hooking system on beds could be one way of hooking equipment at the time of use. At the time of storage, the equipment can be hooked to the wall by chains.

Photo 8: ECG monitors on rollers with potential risk of sliding and overturning.

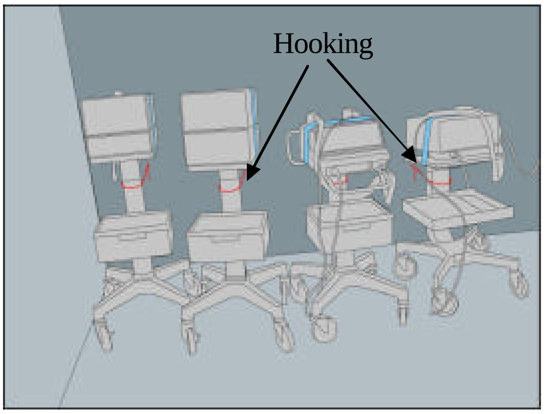


Fig 6: Provision of chains on the wall to hook such machines.

Photo 9: Mobile X-ray on rollers.

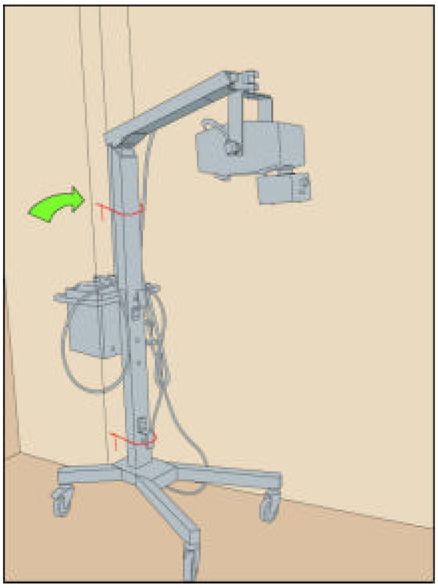


Fig 7: Hooking of mobile X-ray to the wall.

Some equipment on roller trolleys can also be protected from falling by strapping the equipment to the trolley and hooking the trolley to the wall. Some slender objects like oxygen cylinders can also be hooked using chains.

Photo 10: Resuscitation equipment on roller trolleys.

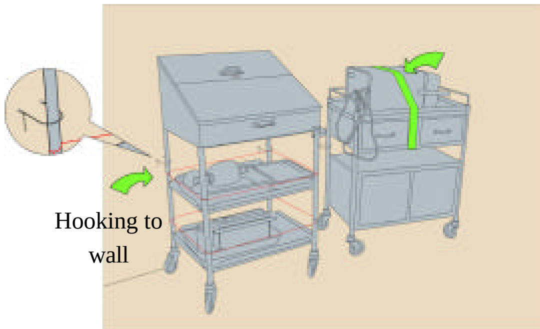


Fig 8: Hooking of the trolley and strapping of the equipment.

Photo 11: Un-hooked oxygen cylinders may fall over.

Fig 9: Hooking the cylinder with a chain can save the cylinder from falling.

5.6 Strapping

In most of the hospitals, the supplies and contents of laboratories, medical stores, general stores, CSSD stores and OT stores were kept unsecured on shelves and in racks and would fall down and brake during earthquakes. To mitigate this risk is not difficult; once the racks and cupboards have been anchored to the wall, the contents can easily be secured by using strapping thus preventing chemical bottles and medicine stored on the shelves from falling down.

Photo 12: Chemical and medicine bottles on shelves pose a risk of falling.

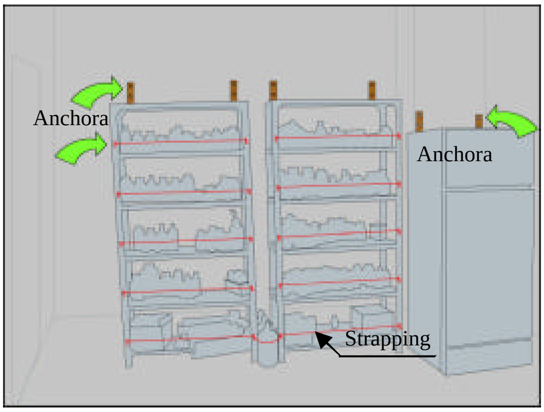


Fig 10: Strapping the shelves by nylon rope after anchoring the rack to the wall is an easy way of making these bottles safe.

5.7 Flexible couplings

If there is a tank outside the building with a rigid connection pipe joining the building and the tank together, the tank will vibrate at frequencies, in directions and at amplitudes different to those of the building, which will cause the pipe to break. A flexible pipe between the two parts would prevent ruptures of this kind. Flexible couplings are necessary because separate objects each move independently in response to an earthquake; some move quickly, others slowly.

Consequently, flexible piping is necessary near heavy equipment, at the joint of two buildings and in seismic joints of the same building.

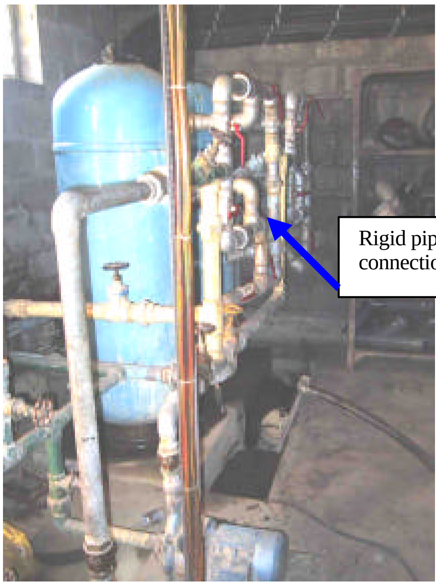


Photo 13: Rigid pipes connected with a heavy water tank can break during an earthquake.

Photo 14: Flexible piping on heavy equipment protects it from breaking during earthquake.

5.8 Supports

Supports are suitable in many cases. For example, ceilings are usually hung from cables that only withstand the force of gravity. When subjected to the horizontal stresses and torsion of an earthquake, they easily fall. They can cause serious injury to people underneath them and obstruct evacuation routes. Extra support by additional wires can protect the ceiling or light fixtures from falling.

Photo 15: This type of fan needs extra support.

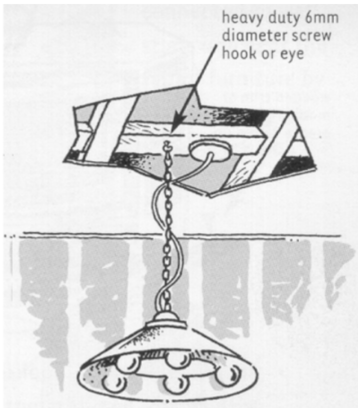


Fig 11: Extra support to the lighting system.

5.9 Substitution

Substitution with something that does not represent a seismic hazard is appropriate in some situations. For example, a heavy, tiled roof does not only make the roof of a building heavy, it is also more susceptible to the movement of an earthquake. The individual tiles tend to come off thus creating a hazard for people and objects. One solution would be to change it with a lighter, safer roofing material.

5.10 Modification

Modification is a possible solution for an object that represents a seismic hazard. For example, earth movements twist and distort a building possibly causing the rigid glass in the windows to shatter and launch sharp glass splinters onto the occupants and the passers-by around the hospital. Rolls of transparent adhesive plastic may be used to cover the inside surfaces and prevent them from shattering and threatening those inside. The plastic is invisible and reduces the likelihood of a glass window causing injuries.

Photo 16: This window glass can cause a life safety hazard.

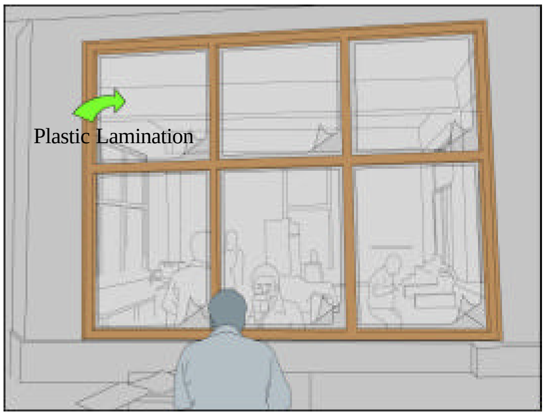


Fig 12: Simple plastic lamination can protect lives.

5.11 Reinforcement

Reinforcement is feasible in many cases. For example, an un-reinforced infill wall or a chimney may be strengthened without great expense by covering the surface with wire mesh and cementing it.

5.12 Redundancy

Redundancy or duplication of items is advisable. Emergency response plans that call for additional supplies are a good idea. It is possible to store extra amounts of certain products providing a certain level of independence from external supplies, which could be interrupted in case of an earthquake.

5.13 Rapid Response and Repair

Rapid response and repair is a mitigation measure used on large oil pipelines. Sometimes it is not possible to do anything to prevent the rupture of a pipeline in a given place, therefore spare parts are stored nearby and arrangements are made to enter the area quickly in case a pipe breaks during an earthquake. A hospital should have spare plumbing, emergency power supplies and other necessary components on hand together with the suitable tools in order to ensure that repairs can be easily made if something is damaged. For example, during an earthquake the water pipes may break; it may be impossible to take prior measures to totally eliminate this risk, but it is possible to ensure that everything necessary for quick repairs is at hand. With prior earthquake planning it is possible to save the enormous costs of water damage with a minimum investment in a few articles.

These general measures are applicable to almost all situations. However, in many cases, it is enough to be creative and to devise one’s own way of mitigating the effects of disasters.

5.14 Improving Safety of Operation Theatres

Almost all equipment in the operation theatres of Nepalese hospitals were found to be on rollers or roller trolleys without any fixity and are therefore highly vulnerable. However, for everyday use this equipment must be flexible and mobile and cannot be permanently fixed. Thus a special system for anchoring the equipment is necessary; anchoring which can fix the equipment during operations and can be removed afterwards.

The system can be a steel frame consisting of vertical and horizontal angles attached to the equipment rack. The system should have a numbers of chains, straps, hooks and guide bars in the rack for fixing and securely placing the equipment in the rack. The frame can then be fastened in a location near to the operation table during the operation. By providing anchor bolts in the ceiling and in the floor of the room the equipment rack can be placed in position near the OT table. Similarly, anchor bolts should be provided in the walls in appropriate locations so that the equipment can be removed and fixed in a safe placed when not used.

Photo 17: Most equipment is on roller trolleys (equipment racks) in operation theatres. The risk of falling down is high.

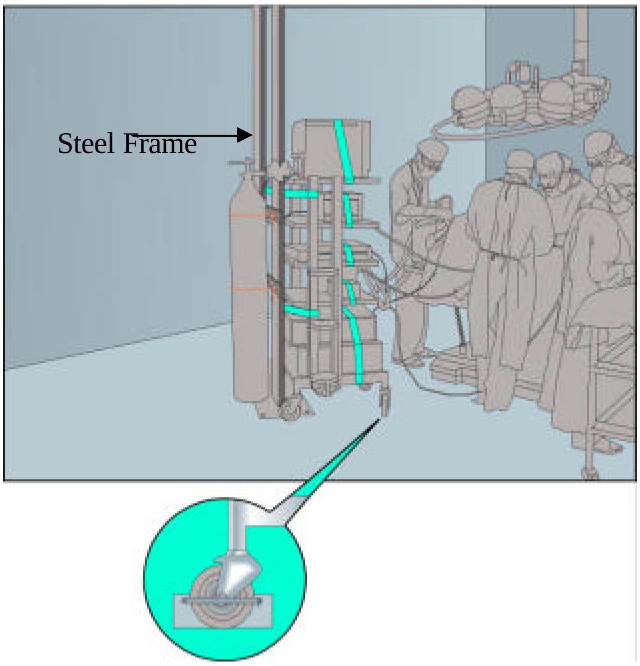
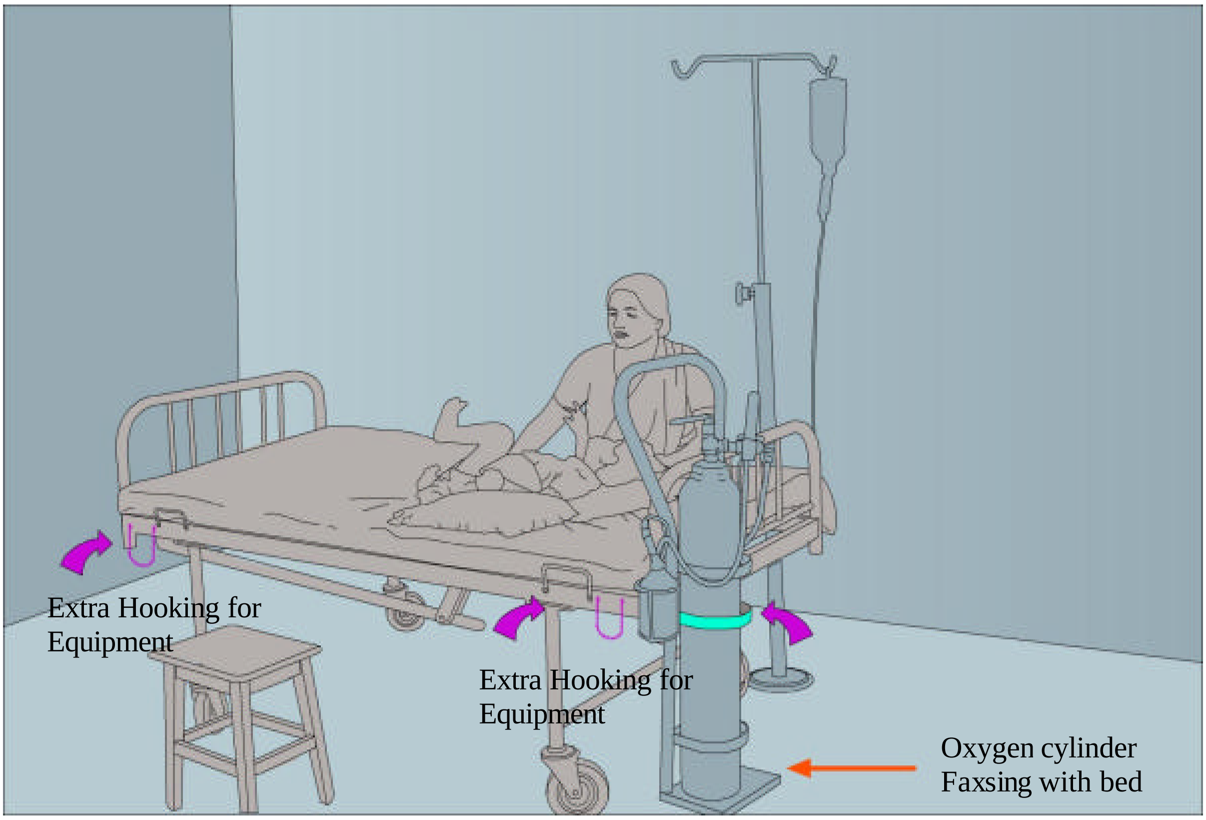


Fig 13: Tying all equipment to a steel frame can improve the situation.

5.15 Development of Chaining System on Beds

During the survey, it was found that in important wards like ICU, CCU, post operative, and maternity wards the equipment and the accessories needed for the treatment are generally placed near to the beds but without any anchor or support. This equipment and accessories should be fixed to reduce the vulnerability and enhance the hospital performance after an earthquake. Providing chains and anchor hooks on each bed could solve the problem.



Annex#1: Definition of Terms

1. Structural Component

The structural parts of a building are those that resist gravity, earthquakes, wind and other types of loads. These are called structural components and include columns (posts, pillars); beams (girders, joists) and foundations (mat, spread footings, piles). For engineered construction, the structure is typically designed and analysed in detail by a structural engineer, but for non-engineered construction masons or labour contractors generally construct these elements directly without an analysed design.

2. Non-Structural Component

The non-structural parts of a building include all parts of the building and its contents with the exception of the structure, in other words, everything except the columns, floors, beams etc. Common non-structural components include ceilings; windows; office equipment; computers; inventory stored on shelves; file cabinets; water tanks; generators; transformers; heating, ventilating, and air conditioning (HVAC) equipment; electrical equipment; furnishings; lights etc. Typically, non-structural items are not analyzed by engineers and may be specified by architects, mechanical engineers, electrical engineers, and interior designers. In most cases, they are purchased by the owners after the construction is finished without the involvement of any design professional.

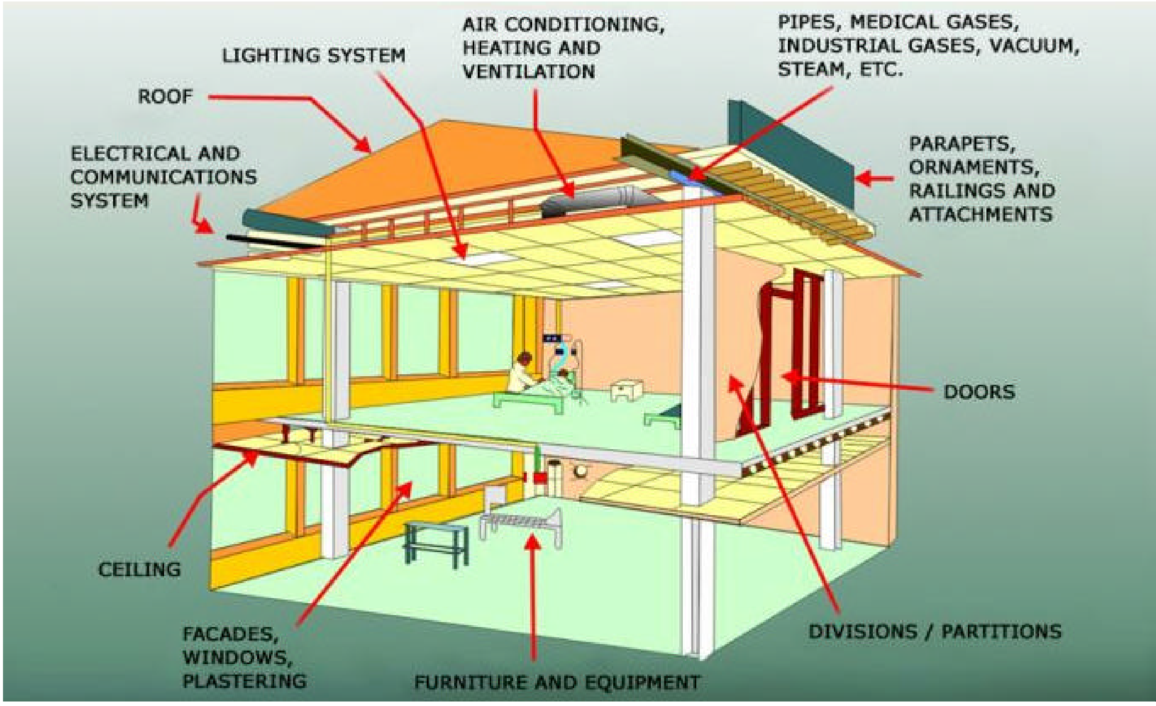


Fig A1-1: Non-Structural Components in a Hospital

Annex#2: Significance of Non-Structural Damage

The following discussion covers three types of risk associated with earthquake damage to non-structural components: life safety, property loss, and interruption or loss of essential functions. Damage to a particular non-structural item may pose differing degrees of risk in each of these three categories. In addition, damage to the item may result in direct injury or loss, or the injury or loss may be the secondary effect or consequence of the failure of the item.

1. Life safety

The first type of risk is that people could be injured or killed by damaged or falling non-structural components. Even seemingly innocuous items can be lethal if they fall on an unsuspecting victim. Examples of potentially hazardous non-structural damage that has occurred in past earthquakes include broken glass overturned tall and heavy cabinets or shelves, falling ceilings or overhead light fixtures, ruptured gas lines or other piping containing hazardous materials, damaged friable asbestos materials, falling pieces of decorative work such as brick, stone or marble cladding and falling masonry partition walls and fences.

2. Loss of Function

In addition to the life safety there is the risk that non-structural damage will make it difficult or impossible to carry out the normal functions of the facility. After the serious life safety threats have been dealt with, the potential for post earthquake downtime or reduced productivity is often the most important risk.

During the 1994 Northridge earthquake, non-structural damage caused temporary closure, evacuation, or patient transfer at ten essential hospital facilities. These hospitals generally had little or no structural damage but were rendered temporarily inoperable, primarily because of water damage. At over the dozen of these facilities, water leaks occurred when fire sprinkler, chilled-water, or other pipelines broke. Hospital personnel were apparently unavailable or unable to shut off the water, and in some cases water was flowing for many hours. At one facility, water up to 2 feet deep was reported at some locations in the building as a result of damage to the domestic water supply tank on the roof. At another, the emergency generator was disabled when its cooling water line broke where it crossed a separation joint. Other damage at these facilities included broken glass, dangling light fixtures, elevator counter weight damage, and lack of emergency power due to failures in the distribution or control systems.

3. Property Loss

Contents such as movable partitions, furniture, files and office or medical equipment represent a significant cost in case of hospitals. Damage to the non-structural elements and content of a building can be costly since these components account for the vast majority of building costs. Immediate property losses attributable to contents alone are often estimated to be one third of the total earthquake losses. Property losses may be the result of direct damage to a non-structural item or a secondary effect. If water pipes, fire sprinklers or fire sprinkler lines break, the overall property losses will include the cost of repairing the water damage in the facility. If the gas line to a water-heater ruptures and causes a fire, clearly the property loss is much greater than the cost of a new pipefitting. On the other hand, if many file cabinets overturn and all the contents end up on the floor, the direct damage to the cabinets and documents will probably be negligible (unless they are also affected by water), but employees may spend many hours or days sorting out the documents. If a reserve water tank is situated on the roof of a building, the consequences of its damage may be more severe than they would be if it was in the basement or outside the building in the parking lot.

Annex#3: Causes of Non-Structural damage

Earthquake ground shaking has three primary effects on non-structural elements in buildings. These are inertial or shaking effects on the non-structural elements themselves, distortion imposed on non-structural components when building structures sways back and forth or the effect of structural on non-structural components, and the pounding effects at the interface between adjacent structures.

1. Direct Effect

When a building is shaken during an earthquake, the base of the building moves in harmony with the ground, but the entire building and the building contents above the base will experience inertial forces. These inertial forces can be explained by using the analogy of a passenger in a moving vehicle. As a passenger, you experience inertial forces whenever the vehicle is accelerating or decelerating rapidly. If the vehicle is accelerating, you may feel yourself pushed backward against the seat, since the inertial force on your body acts in the direction opposite that of the acceleration. If the vehicle is decelerating or breaking, you may be thrown forward in your seat. Although the engineering aspects of inertial forces are more complex than a simple principle of physics, the law first formulated by Sir Isaac Newton, F=ma, or force is equal to the mass times acceleration, is the basic principle involved. In general, the earthquake inertial forces are greater if the building or object within the building weighs more or if the acceleration or severity of the shaking is greater.

File cabinets, emergency-power generating equipment, freestanding bookshelves, office equipment, water tanks, flower pots and items stored on shelves or racks can all the damaged because of inertial forces. When an earthquake shakes unstrained items, inertial forces may cause them to slide, swing, strike other objects, or overturn. Items may slide off shelves and fall to the floor. One misconception is that large, heavy objects are stable and not as vulnerable to earthquake damage as lighter objects, perhaps because we may have difficulty moving them. In fact, since inertial forces during an earthquake are proportional to the mass of the object, heavy objects are more likely to overturn than *lighter ones with the same dimensions.*

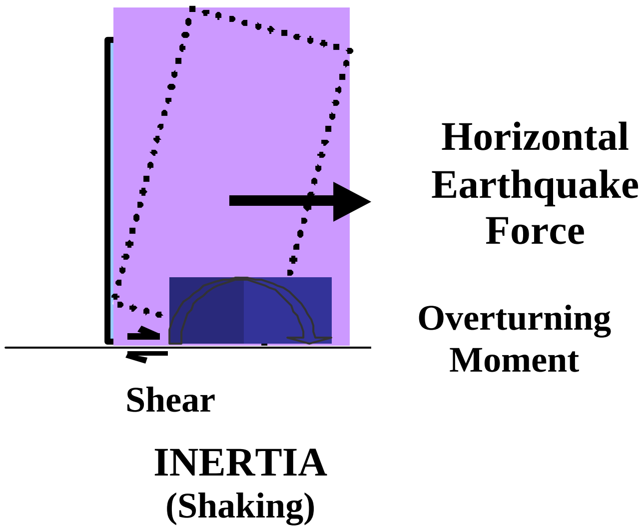


Fig A3-1: Direct Effect on Non-Structural Elements.

2. Effect of Structure to Non-Structural Components

During an earthquake, building structures distort, or bend, side to side in response to the earthquake forces. For example, the top of a tall building may incline a feet in each direction during an earthquake. The distortion over the height of each story, known as the story drift, might range from ¼ inches to several inches, depending on the size of the earthquake and the characteristics of the particular building structure. Windows, partitions and other items that are tightly locked into the structure are forced to go along for the ride. As the columns or walls distort and become slightly out of square, if only for an instant, any tightly confined windows or partitions must also distort the same amount. The more space there is around a pane of glass where it is mounted between stops or moulding strips, the more distortion the glazing assembly can accommodate before the glass itself is subjected to earthquake forces. Brittle materials like glass, plaster and masonry infill cannot tolerate any distortion and will crack when the perimeter gaps close and the building structure pushes directly on the brittle elements. Most architectural components such as glass panes, partitions and veneer are damaged because of this type of building distortion, not because they themselves are shaken or damaged by inertial forces.

There have also been notable causes of structural – non-structural interaction in past earthquakes, when rigid non-structural components have been the cause of structural damage or collapse. These causes have generally involved rigid, strong architectural components such as masonry infill that inhibit the movement or the distortion of the structural framing and cause premature failure of column or beam elements. While this is a serious concern for structural designers, the focus of this report is on earthquake damage to non-structural components.

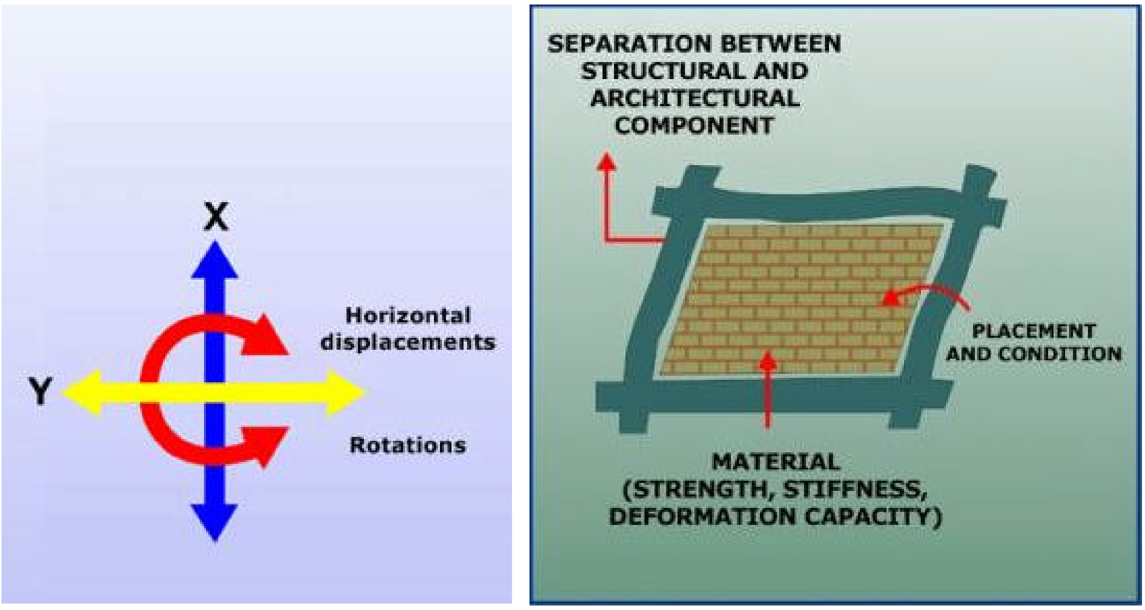
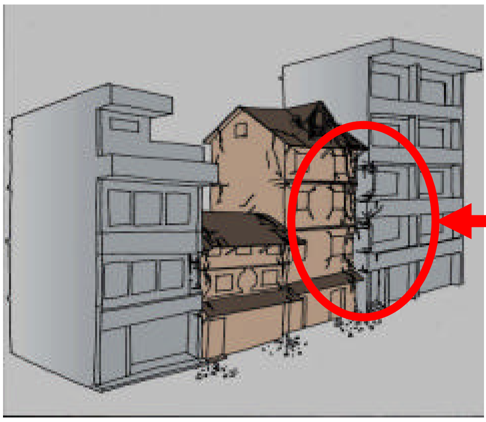


Fig A3-2: Effect of Building Deformation on Contents

3. Pounding Effect

Another source of non-structural damage involves pounding or movement across separation joints between adjacent structures. A separation joint is the distance between two different building structures - often two wings of the same facility - that allows the structures to move independently of one another.

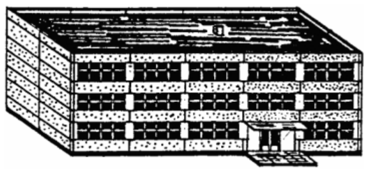
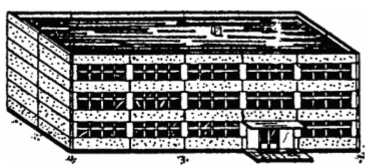
A seismic gap is a separation joint provided to accommodate relative lateral movement during an earthquake. In order to provide functional continuity between separate wings, building utilities must often extend across these building separations, and architectural finishes must be detailed to terminate on either side. The separation joint may be only an inch or two in older constructions or as much as a foot in some newer buildings, depending on the expected horizontal movement, or seismic drift. Flashing, piping, fire sprinkler lines, HVAC ducts, partitions, and flooring all have to be detailed to accommodate the seismic movement expected at these locations when the two structures move closer together or further apart. Damage to items crossing seismic gaps is a common type of earthquake damage. If the size of the gap is insufficient, pounding between adjacent structures may result in damage to structural components such as parapets, veneer, or cornices on the facades of older buildings.

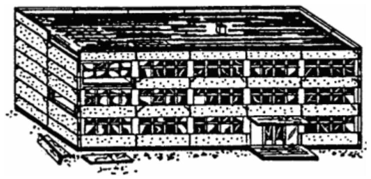
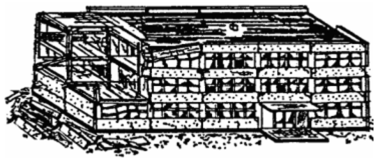


Breakage of piping or ducts may occur at seismic joints or in the joint of two buildings due to differential displacement (separa-tion and pounding).

Fig A3-3: Pounding Effect on Buildings

Annex #4: Damage Grades of Buildings

Illustration of Damage on Buildings		Damage Grade as per EMS 98	Damage Grade as per Nepal National Building Code
Masonry	**Reinforced Concrete**		
		**Grade 1 (DG1): Negligible to Slight Damage** (No structural Damage, Slight Non-structural Damage) **Masonry Buildings** • Hair-line cracks in very few walls • Fall of small pieces of plaster only • Fall of loose stones from upper parts of buildings in very few cases. **Reinforced Concrete Buildings** • Fine cracks in plaster over frame members or in walls at base • Fine cracks in partitions and infills	**Grade 1: Slight Damage** • Fine cracks in plaster • Fall of small pieces of plaster
		**Grade 2 (DG2): Moderate Damage** (Slight Structural Damage, Moderate Non-Structural Damage) **Masonry Buildings** • Cracks in many walls • Fall of fairly large pieces of plaster • Partial collapse of chimneys **Reinforced Concrete Buildings** • Cracks in columns and beams of frames and in structural walls • Cracks in partition and infill walls; fall of brittle cladding and plaster • Falling mortar from the joints of wall pannels	**Grade 2: Moderate Damage** • Small cracks in walls • Fall of fairly large pieces of plaster • Pan tiles slip off • Cracks in chimneys • Parts of chimney falls down

		**Grade 3 (DG3): Substantial to Heavy Damage** (Moderate Structural Damage, Heavy Non-Structural Damage) **<u>Masonry Buildings</u>** • Large and extensive cracks in most walls • Roof tiles detach; chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls) **<u>Reinforced Concrete Buildings</u>** • Cracks in columns and beam column joints of frames at the base and at joints of coupled walls • Spalling of concrete cover, buckling of reinforced rods Large cracks in partition and infill walls, failure of individual infill pannels	**Grade 3: Heavy Damage** • Large and deep cracks in walls • Fall of chimneys
		**Grade 4 (DG4): Very Heavy Damage** (Heavy Structural Damage, Very Heavy Non-Structural Damage) **<u>Masonry Buildings</u>** • Serious failure of walls; partial structural failure of roofs and floors **<u>Reinforced Concrete Buildings</u>** • Large cracks in structural elements with compression failure of concrete fracture of rebar; bond failures of beam reinforced bars; tilting of columns. • Collapse of few columns or of a single upper floor	**Grade 4: Destruction** • Gaps in wall • Parts of buildings may collapse • Separate parts of the building loose their cohesion • Inner walls collapse
		**Grade 5 (DG5): Destruction** **(Very Heavy Structural Damage)** **<u>Masonry Buildings</u>** • Total or near total collapse **<u>Reinforced concrete Buildings</u>** • Total or near total collapse	**Grade 5: Total Damage** • Total collapse of building

Annex#5: Sample Report on Individual Hospital (Seismic Vulnerability Assessment of Western Regional Hospital)

1. Structural Assessment

The qualitative structural earthquake vulnerability assessment of Western Regional Hospital includes the identification of building typology and systems of the different buildings, vulnerability of identified building systems, identification of vulnerability factors, different identified factors' influence on the vulnerability of the buildings, interpretation of the building performance and recommendations for reducing the vulnerability of the building as per the result of the study.

1.1 Building Typology

Based on the visual observation, the different buildings of Western Regional Hospital were identified as specified in table A2-1 below.

Table A2-1: Main Buildings Used by Western Regional Hospital and Their Type

S.N.	Building	No. of Stories	Building Typology	Remarks
1	OPD block 1.	1	Stone in Cement.	Surgical, medical, eye.
2	OPD block 2	2	Stone in Cement.	Dental, Ultrasonography, ECG block.
3	X-ray block.	2	Stone in Cement.	X-ray, OT block.
4	In-patient block 1.	2	Stone in Cement.	North block.
5	In-patient block 2.	2	Stone in Cement.	South block.
6	Administration and maternity block.	2	Stone in Cement.	
7	Laboratory block.	2	Stone in Cement.	
8	New building.	2	Reinforced Concrete (Ordinary-Moment-Resisting-Frame).	The building was under construction during study.
9	Small attachment.	1	Stone in Cement.	Skin OPD and Ortho OPD block attached with OPD 1.

Stone in Cement Building: These are stone masonry buildings with boulder stones or block stones in cement mortar.

Reinforced Concrete (Ordinary-Moment-Resistant-Frame) Buildings: Reinforced concrete structures and infill masonry walls without earthquake-resistant design. The brick masonry infill has cement sand mortar. In most cases, the thickness of the infill wall is 230mm.

1.2 Fragility of the Identified Building Typology

The probable damage to the Stone in Cement and Reinforced Concrete (Ordinary-Moment-Resistant-Frame) buildings at different intensities is listed in Table A2-2 and A2-3 below. Table A2-2 shows that the weaker buildings of this category will sustain damage degree of five at intensity IX whereas good buildings of this category will suffer damage degree of three for the same intensity. Different grades of damage to different types of buildings are derived based on the vulnerability functions of Nepalese buildings as defined in Nepal National Building Code.

Table A2-2: Fragility of the Stone in Cement Buildings

MMI		VI	VII	VIII	IX
PGA (% g)		5-10	10-20	20-35	>35
Damage Grades for Different Classes of Buildings	Weak	DG2	DG3	DG4	DG5
	Average	DG1	DG2	DG3	DG4
	Good	-	DG1	DG2	DG3

Table A2-3: Fragility of the Ordinary Reinforced Concrete Buildings [£ 3 Story]

MMI		VI	VII	VIII	IX
PGA (% g)		5-10	10-20	20-35	>35
Damage Grades for Different Classes of Buildings	Weak	DG1	DG2	DG3	DG4
	Average	-	DG1	DG2	DG3
	Good	-	-	DG1	DG2

(Note: The description of different damage degrees is provided in Annex#4).

1.3 Identification of Vulnerability Factors

Different vulnerability factors associated with the particular type of buildings was checked with a set of appropriate checklists from FEMA 310, *Handbook for the Seismic Evaluation of Buildings.* The basic vulnerability factors related to building systems, lateral force resisting system, connections, diaphragms, geologic- and site hazard as well as non-structural hazards were evaluated based on visual observations.

The checklist used to identify the different vulnerability factors for Stone in Cement buildings and Reinforced Concrete buildings is given below.

Checklist for Identifying Seismic Vulnerability of Stone in Cement Buildings

(Note: C = Compliance with the statement; NC = Non-Compliance with the statement; N/A = Not Applicable).

Building System

C NC N/A LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation.

C NC N/A WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy.

C NC N/A SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy.

C NC N/A GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses.

C NC N/A VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation.

C NC N/A MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy.

C NC N/A TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy.

C NC N/A DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements.

C NC N/A MASONRY UNITS: There shall be no visible deterioration of masonry units.

C NC N/A MASONRY JOINTS: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no areas of eroded mortar.

C NC N/A UNREINFORCED MASONRY WALL CRACKS: There shall be no existing diagonal cracks in all elements greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy or out-of-plane offsets in the bed joint greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy.

C NC N/A OPENINGS AT EXTERIOR MASONRY SHEAR WALLS: Diaphragm openings immediately adjacent to exterior masonry shear walls shall not be greater than 8 feet long for Life Safety and 4 ft. long for Immediate Occupancy.

Lateral Force Resisting System

C NC N/A REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy.

C NC N/A SHEAR STRESS CHECK: The shear stress in the un-reinforced masonry shear walls shall be less than 15 psi for clay units and 30 psi for concrete units for Life Safety and Immediate Occupancy.

C NC N/A PROPORTIONS: The height-to-thickness ratio of the shear walls at each story shall be less than the following for Life Safety and Immediate Occupancy

Top story of multi-story building: 9

First story of multi-story building: 15

All other conditions: 13

C NC N/A MASONRY LAY-UP: Filled collar joints of multi-wythe masonry walls shall have negligible voids.

Connections

C NC N/A WALL ANCHORAGE: Exterior concrete or masonry walls shall be anchored for out-of-plane forces at each diaphragm level with steel anchors or straps that are developed into the diaphragm.

C NC N/A ANCHOR SPACING: Exterior masonry walls shall be anchored to the floor and roof systems at a spacing of 4 ft. or less for Life Safety and 3 ft. or less for Immediate Occupancy.

Geologic Site Hazards

C NC N/A LIQUEFACTION: Liquefaction susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 feet under the building for Life Safety and Immediate Occupancy.

Additional Checklist for Stone Buildings (Not given in FEMA 310)

C NC N/A THROUGH STONE: There is existence of through stones in each layer at a distance of 3-4 feet.

C NC N/A SHAPE OF STONE: Rubble Stones are dressed and are made into regular block shapes to use in masonry wall construction.

Checklist for Identifying Seismic Vulnerability of Reinforced Concrete (Ordinary-Moment-Resistant-Frame) Buildings

(Note: C = Compliance with the statement; NC = Non-Compliance with the statement; N/A = Not Applicable).

Building System

C NC N/A LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation.

C NC N/A ADJACENT BUILDINGS: An adjacent building shall not be located next to the structure being evaluated closer than 4% of the height for Life Safety and Immediate Occupancy.

C NC N/A MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure.

C NC N/A WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy.

C NC N/A SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy.

C NC N/A GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses.

C NC N/A VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation.

C NC N/A MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy.

C NC N/A DETERIORATION OF WOOD: There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members and none of the metal accessories shall be deteriorated, broken, or loose.

C NC N/A DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements.

C NC N/A MASONRY UNITS: There shall be no visible deterioration of masonry units.

C NC N/A MASONRY JOINTS: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no areas of eroded mortar.

C NC N/A CRACKS IN INFILL WALLS: There shall be no existing diagonal cracks in infill walls that extend throughout a panel greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy, or have out-of-plane offsets in the bed joint greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy.

C NC N/A CRACKS IN BOUNDARY COLUMNS: There shall be no existing diagonal cracks wider than 1/8" for Life Safety and 1/16" for Immediate Occupancy in concrete columns that encase masonry infill.

Lateral Force Resisting System

C NC N/A REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy.

C NC N/A SHEAR STRESS CHECK: The shear stress in the reinforced masonry shear walls, calculated by using the Quick Check, shall be less than 50 psi for Life Safety and Immediate Occupancy.

C NC N/A SHEAR STRESS CHECK: The shear stress in the un-reinforced masonry shear walls, calculated using the Quick Check procedure, shall be less than 15 psi for clay units and 30 psi for concrete units for Life Safety and Immediate Occupancy.

C NC N/A WALL CONNECTIONS: All infill walls shall have a positive connection to the frame to resist out-of-plane forces for Life Safety and the connection shall be able to develop the out-of-plane strength of the wall for Immediate Occupancy.

Connections

C NC N/A TRANSFER TO SHEAR WALLS: Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the shear strength of the walls for Immediate Occupancy.

C NC N/A CONCRETE COLUMNS: All concrete columns shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the tensile capacity of the column for Immediate Occupancy.

1.4 Influence of Different Vulnerability Factors on the Seismic Performance of the Building

The influence of different seismic vulnerability factors on the buildings as per the observations made during the field survey and based on the checklist above is listed in table A2-4 to 11 below.

OPD 1 Block:

The OPD 1 Block is a single-story stone masonry building with cement-sand as mortar. The main walls are of 14-inch width with some buttressing. There are some internal columns connected with heavy beams. The building was constructed in 2041-2043 BS.

Table A2-4: Influence of Different Seismic Vulnerability Factors on the OPD 1 Block

Vulnerability Factors		Increasing Vulnerability of the Building by different vulnerability factors				
		High	Medium	Low	N/A	Not known
General	Load Path			v		
	Weak Story				v	
	Soft Story				v	
	Geometry				v	
	Vertical Discontinuity				v	
	Mass				v	
	Torsion		v			
	Deterioration of Material			v		
	Cracks in Wall		v			
	Cantilever			v		
	Openings		v			
Lateral Force Resisting System	Redundancy			v		
	Shear Stress Criteria			v		
	Proportions		v			
	Masonry Lay-up		v			
Connection	Connectivity between Different Structural Elements	v				
Others	Pounding Effect	v				
	Non-structural Elements		v			
	Through Stones	v				
	Shape of Stones	v				
	Liquefaction Susceptibility				v	

OPD 2 Block:

The OPD 2 block is a two-story stone in cement building. The first story was constructed in 2041 BS and the second story was added in 2058BS. The main walls are of 14-inch width. Some cracks were observed in the building.

Table A2-5: Influence of Different Seismic Vulnerability Factors on the OPD 2 Block

Vulnerability Factors		Increasing Vulnerability of the Building by Different Vulnerability Factors				
		High	**Medium**	**Low**	**N/A**	**Not known**
General	Load Path			v		
	Weak Story			v		
	Soft Story			v		
	Geometry			v		
	Vertical Discontinuity		v			
	Mass			v		
	Torsion		v			
	Deterioration of Material			v		
	Cracks in Wall	v				
	Cantilever			v		
	Openings		v			
Lateral Force Resisting System	Redundancy			v		
	Shear Stress Criteria			v		
	Proportions		v			
	Masonry Lay-up		v			
Connection	Connectivity between Different Structural Elements	v				
Others	Pounding Effect	v				
	Non-structural Elements		v			
	Through Stones	v				
	Shape of Stones	v				
	Liquefaction Susceptibility				v	

X-Ray Block:

The X-ray block is a two-story stone in cement building. The main walls are of 14-inch width.

Table A2-6: Influence of Different Seismic Vulnerability Factors on X-ray Block

Vulnerability Factors		Increasing Vulnerability of the Building by Different Vulnerability Factors				
		High	**Medium**	**Low**	**N/A**	**Not known**
General	Load Path			v		
	Weak Story			v		
	Soft Story			v		
	Geometry			v		
	Vertical Discontinuity		v			
	Mass			v		
	Torsion		v			
	Deterioration of Material		v			
	Cracks in Wall	v				
	Cantilever			v		
	Openings		v			
Lateral Force Resisting System	Redundancy			v		
	Shear Stress Criteria		v			
	Proportions		v			
	Masonry Lay-up		v			
Connection	Connectivity between Different Structural Elements	v				
Others	Pounding Effect	v				
	Non-structural Elements		v			
	Through Stones	v				
	Shape of Stones	v				
	Liquefaction Susceptibility				v	

Inpatient Block 1 and 2:

The inpatient blocks are two-story stone in cement buildings with some buttressing from outside. The main walls are of 14-inch width and the buildings have rigid floor and roofing systems.

Table A2-7: Influence of Different Seismic Vulnerability Factors on the Inpatient Blocks

Vulnerability Factors		Increasing Vulnerability of the Building by Different Vulnerability Factors				
		High	Medium	Low	N/A	Not known
General	Load Path			v		
	Weak Story			v		
	Soft Story			v		
	Geometry		v			
	Vertical Discontinuity		v			
	Mass			v		
	Torsion	v				
	Deterioration of Material		v			
	Cracks in Wall		v			
	Cantilever			v		
	Openings		v			
Lateral Force Resisting System	Redundancy			v		
	Shear Stress Criteria		v			
	Proportions		v			
	Masonry Lay-up		v			
Connection	Connectivity between Different Structural Elements	v				
Others	Pounding Effect	v				
	Non-structural Elements		v			
	Through Stones	v				
	Shape of Stones	v				
	Liquefaction Susceptibility				v	

Administration and Maternity Block:

The administration and maternity block is a two-story stone masonry building with cement-sand mortar. The building has a rigid floor and flexible roof systems. Cracks in many walls were observed in this building. The proportions (height to width ratio) of some walls were found very high, which have made the walls more vulnerable to earthquakes.

Table A2-8: Influence of Different Seismic Vulnerability Factors on the Administration and Maternity Block

Vulnerability Factors		Increasing Vulnerability of the Building by Different Vulnerability Factors				
		High	Medium	Low	N/A	Not known
General	Load Path			v		
	Weak Story			v		
	Soft Story			v		
	Geometry		v			
	Vertical Discontinuity		v			
	Mass			v		
	Torsion	v				
	Deterioration of Material		v			
	Cracks in Wall		v			
	Cantilever			v		
	Openings		v			
Lateral Force Resisting System	Redundancy			v		
	Shear Stress Criteria		v			
	Proportions	v				
	Masonry Lay-up		v			
Connection	Connectivity between Different Structural Elements	v				
Others	Pounding Effect	v				
	Non-structural Elements		v			
	Through Stones	v				
	Shape of Stones	v				
	Liquefaction Susceptibility				v	

Laboratory Building:

The laboratory building is a two-story stone masonry building with cement sand mortar. The building has a flexible roofing system.

Table A2-9: Influence of Different Seismic Vulnerability Factors on the Laboratory Building

Vulnerability Factors		Increasing Vulnerability of the Building by Different Vulnerability Factors				
		High	Medium	Low	N/A	Not known
General	Load Path			v		
	Weak Story			v		
	Soft Story			v		
	Geometry			v		
	Vertical Discontinuity			v		
	Mass			v		
	Torsion			v		
	Deterioration of Material		v			
	Cracks in Wall		v			
	Cantilever			v		
	Openings		v			
Lateral Force Resisting System	Redundancy			v		
	Shear Stress Criteria		v			
	Proportions	v				
	Masonry Lay-up		v			
Connection	Connectivity between Different Structural Elements	v				
Others	Pounding Effect				v	
	Non-structural Elements		v			
	Through Stones	v				
	Shape of Stones	v				
	Liquefaction Susceptibility				v	

New Building:

The new building, which was under construction during the study, is a reinforced concrete ordinary-moment-resisting-frame building. Improper configuration in terms of layout of structural elements, i.e. the position of columns and weak stone infill, was observed as the highest vulnerability factor in this building.

Table A2-10: Influence of Different Seismic Vulnerability Factors on the New Building

Vulnerability Factors		Increasing Vulnerability of the Building by Different Vulnerability Factors				
		High	Medium	Low	N/A	Not known
General	Load Path	v				
	Weak Story			v		
	Soft Story			v		
	Geometry		v			
	Vertical Discontinuity			v		
	Mass			v		
	Torsion		v			
	Deterioration of Material			v		
	Cracks in Wall		v			
	Cantilever			v		
	Openings			v		
Lateral Force Resisting System	Redundancy			v		
	Shear Stress Criteria			v		
	Proportions	v				
	Masonry Lay-up		v			
Connection	Connectivity between Different Structural Elements		v			
Others	Pounding Effect	v				
	Non-structural Elements		v			
	Liquefaction Susceptibility				v	

Small Attachment:

This is a newly added small block attached to the OPD 1 Block. As the seismic gap required between two buildings was not maintained, severe cracks in the structural walls were found in this block.

Table A2-9: Influence of Different Seismic Vulnerability Factors on the Small Attachment Building

Vulnerability Factors		Increasing Vulnerability of the Building by Different Vulnerability Factors				
		High	Medium	Low	N/A	Not known
General	Load Path			v		
	Weak Story				v	
	Soft Story				v	
	Geometry				v	
	Vertical Discontinuity				v	
	Mass				v	
	Torsion		v			
	Deterioration of Material			v		
	Cracks in Wall	v				
	Cantilever			v		
	Openings		v			
Lateral Force Resisting System	Redundancy			v		
	Shear Stress Criteria			v		
	Proportions		v			
	Masonry Lay-up		v			
Connection	Connectivity between Different Structural Elements	v				
Others	Pounding Effect	v				
	Non-structural Elements			v		
	Through Stones	v				
	Shape of Stones	v				
	Liquefaction Susceptibility				v	

1.5 Interpretation of the Buildings' Fragility Based on the Surveyed Vulnerability Factors

Based on the assessment of different seismic vulnerability factors, the probable degree of damage to the buildings is identified for different intensities. Table A2-13 gives the probable degree of damage to different buildings in different intensity earthquakes.

Table A2-13: Degree of Damage to Different Buildings in Different Intensity Earthquakes

S.N.	Buildings	MMI VI	MMI VII	MMI VIII	MMI IX
1	OPD Block 1	-	DG1	DG2	DG3
2	OPD Block 2	DG1	DG2	DG3	DG4
3	X-ray Block	DG1	DG2	DG3	DG4
4	Inpatient Block 1	DG1	DG2	DG3	DG4
5	Inpatient Block 2	DG1	DG2	DG3	DG4
6	Administration and Maternity Block	DG1	DG2	DG3	DG4
7	Laboratory Block	DG1	DG2	DG3	DG4
8	New Building	-	DG1	DG2	DG3
9.	Small Attachment	DG2	DG3	DG4	DG5

1.6 Probable Performance of the Building in Different Intensities

The performance of the buildings in terms of structural vulnerability is given in Table A2-14 below as per the qualitative assessment above.

Table A2-14: Probable Performance of the Buildings in Different Intensities

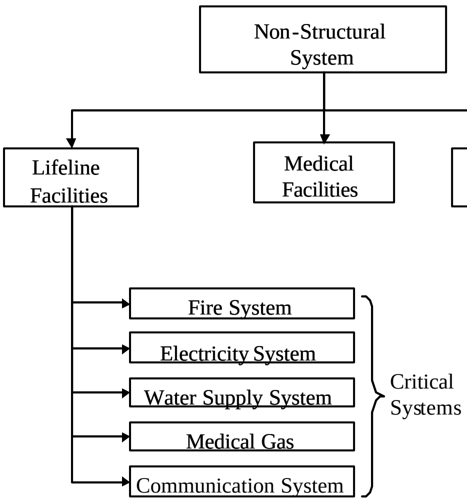
S.N.	Buildings	MMI VI	MMI VII	MMI VIII	MMI IX
1	OPD Block 1	Negligible	Negligible to slight	Moderate	Substantial to Heavy
2	OPD Block 2	Negligible to slight	Moderate	Substantial to Heavy	Very Heavy Damage
3	X-ray Block	Negligible to slight	Moderate	Substantial to Heavy	Very Heavy Damage
4	Inpatient Block 1	Negligible to slight	Moderate	Substantial to Heavy	Very Heavy Damage
5	Inpatient Block 2	Negligible to slight	Moderate	Substantial to Heavy	Very Heavy Damage
6	Administration and Maternity Block	Negligible to slight	Moderate	Substantial to Heavy	Very Heavy Damage
7	Laboratory Block	Negligible to slight	Moderate	Substantial to Heavy	Very Heavy Damage
8	New Building	Negligible	Negligible to slight	Moderate	Substantial to Heavy
9.	Small Attachment	Moderate	Substantial to Heavy	Very Heavy Damage	Destruction

2. Non-Structural Assessment

2.1 Identifying Critical Systems and Facilities

The identification of critical systems and essential functions of Western Regional Hospital was carried out based upon the functional requirements of the hospital during and after an earthquake. The following critical systems and facilities have been identified for non-structural assessment.

<u>Non-Structural Systems of Western Regional Hospital</u>



<u>Facilities Assessed for Non-Structural Vulnerability</u>

Pharmacy, Surgical OPD, Medical OPD, Paediatric OPD, Eye OPD, Gynaecology OPD, Skin OPD, Ortho OPD, Ultrasound Room, Dental OPD, Nero Psychiatry, ECG Room, Endoscopies Department, ICU/CCU, Operation Theatres, Recovery Room, Surgical Ward, Maternity Ward, Emergency Ward, ENT Room, X-ray, Medical Ward, CSSD, Laboratories, Administration.

Electricity System

Western Regional Hospital is supplied by a direct electricity line from Nepal Electrical Authority. The hospital does not have its own transformers. A 200 KVA transformer supplies the electricity to the hospital. The transformer is placed within the compound of the hospital and belongs to Nepal Electricity Authority. The transformer is not fixed properly and thus vulnerable to earthquakes.

As an alternative source of electricity, there is one generator of 30 KVA capacities. The generator is properly fixed, but only provides light to the hospital. The fuel tank is placed on a very thin stand without any anchorage and is thus very vulnerable. The capacity of the generator's fuel tank is 40 litres and the fuel consumption per hour is about 8 litres. The stock of fuel is 60 litres in general and will be sufficient for up to 8 hours. The generator will only start 15-20 minutes after the light goes off as it is manually operated.

Some distribution boxes are poorly anchored while others are properly fixed. There are no flexible couplings installed in the electricity cable network within the hospital.

It is necessary to install a new generator of 50 KVA to run all the essential facilities of the hospital.

Water Supply System

The Western Regional Hospital has no boring system of its own but is supplied with water from Nepal Water Supply Corporation (NWSC). The water is supplied by NWSC on alternate days from 7AM to 7PM. The water supplied by NWSC is not sufficient and the hospital is purchases 2-3 tanks of water from a tanker each week.

Some water is supplied from a small canal used for washing purposes. The canal water could become drinkable if a treatment plant is established, but the water from the canal is also not sufficient.

The hospital has a small rainwater harvesting system. The system has a 15,000 litres capacity tank to collect water. The water collected is used for cleaning medical equipment.

The hospital has about 200 m3 capacity underground reservoir tanks. There is one overhead tank of 10,000 litres capacity on old steel truss columns. The nuts and bolts used to anchor the steel columns on the concrete base are rusted and not functioning. Moreover, the concrete used to construct the base has deteriorated.

There are about 10 roof tanks supplying water to different medical facilities all of which are not provided with any lateral support and are vulnerable to earthquakes. The solar heaters and water tanks used for the heaters are functionless.

Flexible couplings are not installed in the water supply piping system.

Medical Gas System

Oxygen gas is the only medical gas used in Western Regional Hospital. There is no central gas supply system. On average the demand is 15 cylinders per day. There are about 10-30 cylinders in stock, which meets the normal demand for two days maximum.

Communication System

The central communication system of Western Regional Hospital consists of a 100 line capacity intercom service of which only 30 are in use. The three telephone lines are connected with the intercom service. There are about 9-10 external telephone lines in different departments of the hospital.

The intercom machine was found properly kept in a good frame but the battery charger and the connections are vulnerable.

According to the employer, the system gets damaged from time to time. It is recommended to carry out a complete maintenance / replacement to improve the communication system.

Fire Response System

The Western Regional Hospital has some fire extinguishers for fire response. However, some cylinders had not been changed in a long time. There is no regular system of fire drills for rehearsing the response to fire. It is necessary to check and replace the cylinders with new ones on a continuous basis as well as carry out training and exercises for fire response.

2.2 Medical Equipment and Contents

All medical facilities of the Western Regional Hospital were assessed during the study. In terms of earthquake safety of some of the most important departments, the main features are as follows:

CSSD: There are three autoclaves machines in the CSSD department. These autoclaves need fixing at the base as they have no lateral support and thus vulnerable to earthquakes. The CSSD supplies the sterilized equipment and clothes to different wards, operation theatres and ICU/CCU. There is also an autoclave machine in the operation theatre.

The sterilized equipment storing racks and cupboards are without any anchorage to the wall or floor and thus vulnerable. Some racks are fixed to the wall but the strapping was lacking.

X-Ray: The X-ray machines were found properly anchored in the X-ray unit. The control panel, X-ray monitor and chest X-ray, however, were not anchored and are vulnerable. The drier machine is on rollers so it is vulnerable if it is not hooked by a chain. The racks and cupboards should be anchored to the wall.

Laboratory: Relocation of chemical and medicine bottles as well as fixing of equipment to the table is necessary in order to be able to run the laboratory after an earthquake.

Out Patient Departments (OPD): Lack of anchorage of racks and cupboards are the main weaknesses found in all OPDs.

Inpatient Wards: Lack of hooking of oxygen cylinders, blood stands and anchorage of cupboards and racks was the survey's main findings in the different wards.

Operation Theatres: The fact that most of the equipment on rollers was without hooking and fixing and sterilized equipment storing racks without anchorage are the main reasons why the OT may be out of function during and after an earthquake. The OT light was fixed to a ceiling slab and was poorly anchored. This should be checked and anchored properly.

Emergency Ward: The emergency ward contains 15 beds with 2 observation beds. There is no emergency store. One cupboard given by Lion's club has been used to store emergency medicines and will be refilled after use. There is a minor OT facility within the emergency department.

The maximum mass casualty incidence managed in the emergency ward is 30-32. The emergency area can be extended to an open field but this needs proper planning beforehand. So far the emergency department has never even considered mass casualty management for 100 casualties.

Establishment of separate emergency store, an emergency plan and training is necessary to implement in order to improve the emergency department.

2.3 Architectural elements

Partition walls and window glass were identified and assessed for their vulnerability as architectural non-structural elements. All glass windows lack plastic lamination if they are to live up to seismic safety.

2.4 Assessment of Individual Components

Individual equipment and components of all critical systems, all medical departments and administration were assessed to identify the vulnerability of the components after an earthquake. All equipment and components were rated in terms of risk for two earthquakes; i.e. a medium size earthquake (MMI VI-VII) and a severe earthquake (MMI VIII-IX). Risk mitigation options, implementation priorities and cost estimations for implementation of mitigation options were also identified for all equipment. The inventory of all equipment, their risk rating, type of risk, linked equipment, risk mitigation options and implementation priorities are presented in different tables below. Tables A2-15 lists the evaluation of the different components of the critical systems whereas tables A2-16 to 20 list the evaluation of the different components of the medical facilities and the administration.

Table A2-15: Assessment of Equipment and Contents (Electricity, Communication and Water Supply System)

S.N.	Non-structural Element	Quantity	Earthquake	Risk Rating	Type of Risk	Location	Linked Equipments	Mitigation Options	Implementation Priority	Estimated Cost for Implementing Mitigation Option(NRs.)	Remarks
1	Transformer	1	Moderate	H	LF	Near generator house	-	support at top and Anchorage at base	First	2000.00	Transformer belongs to Nepal Electricity Authority
			Severe	VH							
2	Generator	1	Moderate	L	-	Generator house	Control pannel, fuel tank	-	-	-	Properly bolted
			Severe	L							
3	Control pannel	1	Moderate	VH	LF	Generator house	-	Anchorage at base	First	400.00	Necessary to run Generator
			Severe	VH							
4	Fuel tank	1	Moderate	VH	LF	Generator house	-	Bracing to stand and fixing of tank to stand	First	600.00	Necessary to run Generator
			Severe	VH							
5	main switch board	1	Moderate	L	-	Generator house	-	-	-	-	Properly bolted to wall
			Severe	L							
6	Distribution board	1	Moderate	H	LF	Near telephone exchange room	-	Proper fixing	First	500.00	Poorly anchored
			Severe	VH							
7	Electricity cable	-	Moderate	M	LF	At junctions of buildings	-	Installation of flexible couplings	Second	200000.00	No flexible couplings are installed
			Severe	H							
8	Intercome machine	1	Moderate	L	-	Telephone exchange room	-	-	-	-	Properly kept with good framing
			Severe	L							
9	Telephone exchange machine	1	Moderate	VH	LF	Telephone exchange room	Batteries	Proper placement and support	First	1000.00	The machine is on a weak table
			Severe	VH							
10	Battery charger	1	Moderate	VH	-	Telephone exchange room	-	support	First	400.00	
			Severe	VH							
11	Overhead tank	1	Moderate	VH	LS, LF	Near maintanance section	-	Complete rehabilation or reconstruction	Second	500000.00	Check the cost again
			Severe	VH							
12	Roof tanks	10	Moderate	H	LF	Roof of different buildings	-	Support	First	10000.00	
			Severe	VH							
13	Pumps	10	Moderate	M	LF	Different places	-	Anchorage	First	5000.00	
			Severe	H							
14	Pipelines	-	Moderate	M	LF	At the junction of buildings and near tanks	-	Installation of flexible couplings	Second	200000.00	
			Severe	H							

Table A2-16: Assessment of Equipment and Contents (Medical Facilities and Administration [1/9])

S.N.	Non-structural Element	Quantity	Earthquake	Risk Rating	Type of Risk	Location	Linked Equipments	Mitigation Options	Implementation Priority	Estimated Cost for Implementing Mitigation Option(NRs.)	Remarks
1	Racks	16	Moderate	VH	LS	Pharmacy	-	Strapping and Anchorage	First	4800.00	Medicines storing racks
			Severe	VH							
2	Ceiling fan	3	Moderate	M	LS	OPD reception	-	Support	First	600.00	Poorly anchored
			Severe	H							
3	Television Box	1	Moderate	M	LS	Reception lobby	-	Anchorage	First	200.00	Poorly anchored
			Severe	H							
4	X-ray view box	1	Moderate	VH	LF	Surgical OPD	-	Anchorage	First	200.00	
			Severe	VH							
5	X-ray view box	1	Moderate	VH	LF	Medical OPD	-	Anchorage	First	200.00	
			Severe	VH							
6	Oven	1	Moderate	H	LF	Eye OPD	-	Fixing on Table	First	500.00	
			Severe	VH							
7	Eye testing box	1	Moderate	L	-	Eye OPD	-	-	-	-	Properly bolted
			Severe	L							
8	Cupboard	1	Moderate	VH	LS	Skin OPD	-	Anchorage	First	200.00	
			Severe	VH							
9	X-ray view box	1	Moderate	L	-	Ortho OPD	-	-	-	-	properly bolted
			Severe	L							
10	Ultrasound machine	1	Moderate	M	LF	Ultrasonography	-	Hooking	First	400.00	On four wheels
			Severe	H							
11	Portable X-ray machine	1	Moderate	H	LF	Dental OPD	-	Hooking	First	400.00	
			Severe	VH							
12	Dental Chair	2	Moderate	L	-	Dental OPD	-	-	-	-	Stable
			Severe	L							
13	Dressing table	2	Moderate	VH	LF	Dressing room	-	Hooking	First	800.00	
			Severe	VH							
14	ECG machine	1	Moderate	VH	LF	ECG room	-	Hooking of tralley and fixing the machine on trolley	First	800.00	On roller trolley
			Severe	VH							
15	Oxygen cylinders	4	Moderate	VH	LS	ICU	-	Hooking	First	1600.00	One in each bed
			Severe	VH							

Table A2-17: Assessment of Equipment and Contents (Medical Facilities and Administration [2/9])

S.N.	Non-structural Element	Quantity	Earthquake	Risk Rating	Type of Risk	Location	Linked Equipments	Mitigation Options	Implementation Priority	Estimated Cost for Implementing Mitigation Option(NRs.)	Remarks
1	Pulse Oximeter	4	Moderate	VH	LF	ICU	-	Fixing on trolley and Hooking of trolley	First	1600.00	On roller trolley in each beds
			Severe	VH							
2	ECG monitor	4	Moderate	L	-	ICU	-	-	-	-	Properly kept on brackets in each bed
			Severe	L							
3	Suction machine	4	Moderate	H	LF	ICU	-	Hooking	First	1600.00	
			Severe	VH							
4	Oxygen concentrator	2	Moderate	VH	LF	ICU	-	Hooking	First	800.00	Oxygen producer and can be use as an alternative to cylinder during emergency
			Severe	VH							
5	Defribrilator	2	Moderate	VH	LF	ICU	-	Hooking	First	800.00	ON roller trolley
			Severe	VH							
6	Ventilators	2	Moderate	VH	LF	ICU	-	Hooking	First	800.00	ON roller trolley
			Severe	VH							
7	ECG machine	1	Moderate	VH	LF	ICU	-	Hooking	First	400.00	ON roller trolley
			Severe	VH							
8	Racks	2	Moderate	VH	LF	ICU	-	Strapping	First	400.00	The racks are fixed but there is no provision of strapping
			Severe	VH							
9	Shelve and cupboard	2	Moderate	VH	LS	ICU	-	Anchorage	First	400.00	
			Severe	VH							
10	Cupboards	3	Moderate	VH	LS	ICU changing room and office	-	Anchorage	First	600.00	Two in changing room and one in office room
			Severe	VH							
11	Cupboards	2	Moderate	VH	LS	Corridor of OT	-	Anchorage	First	400.00	May block the exit way also
			Severe	VH							
12	Cupboards	5	Moderate	VH	LS	Changing room OT	-	Anchorage	First	1000.00	
			Severe	VH							
13	OT light	1	Moderate	L	LS	OT 2	-	Reanchorage	Second	5000.00	The OT light is bolted on slab but the bolts are rusted and may need change
			Severe	M							
14	Cuttery Machine	1	Moderate	VH	LF	OT 2	-	Hooking	First	400.00	On roller trolley
			Severe	VH							
15	D.C. power supply	1	Moderate	VH	LF	OT 2	-	Anchorage	First	400.00	
			Severe	VH							

Table A2-18: Assessment of Equipment and Contents (Medical Facilities and Administration [3/9])

S.N.	Non-structural Element	Quantity	Earthquake	Risk Rating	Type of Risk	Location	Linked Equipments	Mitigation Options	Implementation Priority	Estimated Cost for Implementing Mitigation Option(NRs.)	Remarks
1	Anesthetic ventilator	1	Moderate Severe	VH VH	LF	OT 2	-	Hooking	First	400.00	On roller trolley
2	ECG monitor	1	Moderate Severe	VH VH	LF	OT 2	-	Hooking	First	400.00	On roller trolley
3	Ventilator	1	Moderate Severe	VH VH	LF	OT 2	-	Hooking	First	400.00	On roller trolley
4	Eye microscope	1	Moderate Severe	VH VH	LF	OT 2	-	Hooking	First	400.00	On roller trolley
5	Air Conditioning	1	Moderate Severe	M H	LF	OT 2	-	Support	First	400.00	Weak support
6	Rack	1	Moderate Severe	VH VH	LS	OT 2	-	Anchorage	First	200.00	
7	Cupboard and fridge	2	Moderate Severe	VH VH	LS	Internal corridor OT2 and OT 1	-	Anchorage	First	400.00	
8	Oxygen cylinder	2	Moderate Severe	VH VH	LS	OT 1	-	Hooking	First	400.00	Free standing
9	Air conditioning	1	Moderate Severe	L L	-	OT 1	-	-	-	-	Properly anchored
10	Anesthetic ventilator	1	Moderate Severe	VH VH	LF	OT 1	-	Hooking	First	400.00	On roller trolley
11	ECG monitor	1	Moderate Severe	VH VH	LF	OT 1	-	Hooking	First	400.00	On roller trolley
12	Cuttery Machine	1	Moderate Severe	VH VH	LF	OT 1	-	Hooking	First	400.00	On roller trolley
13	Cupboards	2	Moderate Severe	VH VH	LS	Corridor OT	-	Anchorage	First	400.00	
14	Autoclaves	1	Moderate Severe	VH VH	LF	Autoclave room OT	-	Anchorage	First	400.00	
15	Cupboards and racks	7	Moderate Severe	VH VH	LS	Autoclave room OT	-	Anchorage and relocation	First	1400.00	Sterilized equipments storing racks and cupboards, relocation of equipments from top of the cupboards is necessary

Table A2-19: Assessment of Equipment and Contents (Medical Facilities and Administration [4/9])

S.N.	Non-structural Element	Quantity	Earthquake	Risk Rating	Type of Risk	Location	Linked Equipments	Mitigation Options	Implementation Priority	Estimated Cost for Implementing Mitigation Option(NRs.)	Remarks
1	Portable OT light	1	Moderate Severe	VH VH	LF	Minor OT	-	Hooking	First	400.00	
2	Cupboards	3	Moderate Severe	VH VH	LS	Recovery room	-	Anchorage	First	600.00	
3	Cupboards	7	Moderate Severe	VH VH	LS	Changing room and night room	-	Anchorage	First	1400.00	
4	Cupboards	2	Moderate Severe	VH VH	LS	Post Operative room	-	Anchorage	First	400.00	
5	Portable X-ray	1	Moderate Severe	VH VH	LF	Passage near Post operative room	-	Hooking	First	400.00	On roller
6	Cupboards	4	Moderate Severe	VH VH	LS	Changing room, surgical ward	-	Anchorage	First	800.00	
7	Cupboards	2	Moderate Severe	VH VH	LS	Office, Surgical ward	-	Anchorage	First	200.00	
8	Cupboards	2	Moderate Severe	VH VH	LS	Changing room, Orthopedic ward	-	Anchorage	First	400.00	
9	Cupboards	2	Moderate Severe	VH VH	LS	Nurse station, orthopedic ward	-	Anchorage	First	400.00	
10	Ceiling fans	2	Moderate Severe	M H	LS	Orthopedic ward	-	Extra support	First	400.00	Poorly anchored
11	Resuscitate table	4	Moderate Severe	VH VH	LF	Maternity ward	-	Hooking	First	1600.00	On roller
12	Suction machines	4	Moderate Severe	VH VH	LF	Maternity ward	-	Hooking	First	800.00	On roller
13	Oxygen cylinder	4	Moderate Severe	VH VH	LS	Maternity ward	-	Hooking	First	1600.00	
14	Cupboards	4	Moderate Severe	VH VH	LS	Maternity ward	-	Hooking	First	1600.00	
15	Ceiling fans	2	Moderate Severe	M H	LS	Maternity ward	-	Extra support	First	400.00	Poorly anchored

Table A2-20: Assessment of Equipment and Contents (Medical Facilities and Administration [5/9])

S.N.	Non-structural Element	Quantity	Earthquake	Risk Rating	Type of Risk	Location	Linked Equipments	Mitigation Options	Implementation Priority	Estimated Cost for Implementing Mitigation Option(NRs.)	Remarks
1	Backup battery	1	Moderate	VH	LF	Maternity ward	-	Fixing	First	200.00	
			Severe	VH							
2	Gyeser	1	Moderate	M	LF	Maternity ward	-	Reanchorage	First	200.00	
			Severe	H							
3	Cupboards	2	Moderate	VH	LS	Changing room, predelivery	-	Anchorage	First	400.00	
			Severe	VH							
4	Racks	2	Moderate	VH	LS	Store, Gynae section	-	Anchorage	First	400.00	
			Severe	VH							
5	Blood stands	3	Moderate	VH	LF	Gynae ward	-	Hooking	First	1200.00	
			Severe	VH							
6	Cupboards	1	Moderate	VH	LS	Emergency ward	-	Anchorage	First	200.00	emergency medicine storing cupboards
			Severe	VH							
7	OT light	1	Moderate	VH	LF	Minor OT, Emergency ward	-	Hooking	First	400.00	Portable OT light on roller
			Severe	VH							
8	Cupboards	2	Moderate	VH	LS	Minor OT, Emergency ward	-	Anchorage	First	400.00	Sterilized equipments and medicines storing racks
			Severe	VH							
9	Suction machines	2	Moderate	VH	LF	Minor OT, Emergency ward	-	Hooking	First	800.00	
			Severe	VH							
10	Cupboards	2	Moderate	VH	LS	Examination room, Emergency ward	-	Anchorage	First	400.00	
			Severe	VH							
11	ECG machine	1	Moderate	VH	LF	Examination room, Emergency ward	-	Hooking	First	400.00	On roller trolley
			Severe	VH							
12	Oxygen cylinder	1	Moderate	VH	LF	Examination room, Emergency ward	-	Hooking	First	400.00	
			Severe	VH							
13	ECG machine	2	Moderate	VH	LF	ECG room	-	Hooking	First	800.00	On roller trolley
			Severe	VH							
14	Cupboards	3	Moderate	VH	LS	ECG room and corridor	-	Anchorage	First	600.00	
			Severe	VH							
15	Endoscopy machine	1	Moderate	VH	LF	Endoscopy room	-	Hooking	First	400.00	On roller trolley
			Severe	VH							

Table A2-21: Assessment of Equipment and Contents (Medical Facilities and Administration [6/9])

S.N.	Non-structural Element	Quantity	Earthquake	Risk Rating	Type of Risk	Location	Linked Equipments	Mitigation Options	Implementation Priority	Estimated Cost for Implementing Mitigation Option(NRs.)	Remarks
1	Cupboard	1	Moderate	VH	LS	Corridor, ENT Room	-	Anchorage	First	200.00	
			Severe	VH							
2	Audiogram	2	Moderate	VH	LF	ENT room	-	Fix at base	First	800.00	
			Severe	VH							
3	Tempronemeter	1	Moderate	H	LF	ENT room	-	Fix at base	First	400.00	
			Severe	VH							
4	Cupboards	2	Moderate	VH	LS	OT, ENT	-	Anchorage	First	400.00	
			Severe	VH							
5	Microscope	1	Moderate	VH	LF	OT, ENT	-	Hooking	First	400.00	On roller trolley
			Severe	VH							
6	BP machine	1	Moderate	VH	LF	OT, ENT	-	Fixing on table	First	500.00	Kept on table
			Severe	VH							
7	Suction machine	1	Moderate	VH	LF	OT, ENT	-	Hooking	First	400.00	On roller trolley
			Severe	VH							
8	X-ray machine	3	Moderate	L	-	X-ray Unit	Control pannels	-	-	-	Properly fixed, glide sliding type
			Severe	L							
9	Control pannels	3	Moderate	VH	LF	X-ray Unit	-	Anchorage	First	1200.00	
			Severe	VH							
10	X-ray monitor	1	Moderate	VH	LF	X-ray Unit	-	Hooking	First	400.00	On roller troley
			Severe	VH							
11	Chest X-ray	1	Moderate	VH	LF	X-ray Unit	-	Hooking	First	400.00	
			Severe	VH							
12	Racks	4	Moderate	VH	LS	X-ray Unit	-	Anchorage	First	800.00	
			Severe	VH							
13	Dryer machine	1	Moderate	VH	LF	X-ray Unit	-	Hooking	First	400.00	On roller trolley
			Severe	VH							
14	Cupboards and racks	4	Moderate	VH	LS	Medical ward	-	Anchorage	First	800.00	
			Severe	VH							
15	Oxygen cylinders	2	Moderate	VH	LS	Medical ward	-	Hooking	First	800.00	
			Severe	VH							

Table A2-22: Assessment of Equipment and Contents (Medical Facilities and Administration [7/9])

S.N.	Non-structural Element	Quantity	Earthquake	Risk Rating	Type of Risk	Location	Linked Equipments	Mitigation Options	Implementation Priority	Estimated Cost for Implementing Mitigation Option(NRs.)	Remarks
1	Autoclaves	3	Moderate	VH	LF	CSSD	-	Fixing at base	First	1200.00	Can easily fixed
			Severe	VH							
2	Racks and cupboards	8	Moderate	VH	LS	CSSD room and corridor	-	Strapping and Anchorage	First	3200.00	Sterilized equipments and clothes storing racks
			Severe	VH							
3	Cupboards	2	Moderate	VH	LS	Hematology lab	-	Relocation and anchorage	First	400.00	Near main door
			Severe	VH							
4	Microscope	1	Moderate	M	LF	Hematology lab	-	Fixing on table	First	500.00	
			Severe	H							
5	Colorimeter	1	Moderate	M	LF	Hematology lab	-	Fixing on table	First	500.00	
			Severe	H							
6	Centrifuge	1	Moderate	M	LF	Hematology lab	-	Fixing on table	First	500.00	
			Severe	H							
7	Transformer	1	Moderate	VH	LF	Hematology lab	-	Hooking	First	400.00	On roller trolley
			Severe	VH							
8	Racks	2	Moderate	VH	LS	Biochemistry lab	-	Relocation and anchorage	First	400.00	Near main door, chemicals storing racks
			Severe	VH							
9	Racks	2	Moderate	VH	LS	Biochemistry lab	-	Strapping and Anchorage	First	800.00	Strapping to protect the chemical bottles to topple
			Severe	VH							
10	Oven	1	Moderate	M	LF	Biochemistry lab	-	Fixing on table	First	500.00	
			Severe	H							
11	Stabilizer	1	Moderate	M	LF	Biochemistry lab	-	Fixing on table	First	500.00	
			Severe	H							
12	Centrifuge	1	Moderate	M	LF	Biochemistry lab	-	Fixing on table	First	500.00	
			Severe	H							
13	Cupboards	1	Moderate	VH	LS	Store, Biochemistrylab	-	Anchorage	First	200.00	
			Severe	VH							
14	Cupboards	1	Moderate	VH	LS	Microbiology lab	-	Anchorage	First	200.00	Chemicals storing cupboard
			Severe	VH							
15	Ovens	2	Moderate	M	LF	Microbiology lab	-	Fixing on table	First	500.00	
			Severe	H							

Table A2-23: Assessment of Equipment and Contents (Medical Facilities and Administration [8/9])

S.N.	Non-structural Element	Quantity	Earthquake	Risk Rating	Type of Risk	Location	Linked Equipments	Mitigation Options	Implementation Priority	Estimated Cost for Implementing Mitigation Option(NRs.)	Remarks
1	Incubator	1	Moderate	M	LF	Microbiology lab	-	Fixing on Table	First	500.00	
			Severe	H							
2	Coagulator	1	Moderate	M	LF	Microbiology lab	-	Fixing on Table	First	500.00	
			Severe	H							
3	Oven	1	Moderate	VH	LF	Sterilizing room, Microbiology	-	Fixing on Table	First	500.00	The oven can easily roll
			Severe	VH							
4	Autoclave machine	1	Moderate	VH	LF	Sterilizing room, Microbiology	-	Anchorage	First	400.00	
			Severe	VH							
5	Ovens	3	Moderate	M	LF	Parasitology room	-	Fixing on table	First	1500.00	
			Severe	H							
6	Centrifuge	1	Moderate	M	LF	Parasitology room	-	Fixing on Table	First	500.00	
			Severe	H							
7	Cupboards	6	Moderate	VH	LS	Main office, Lab	-	Anchorage	First	1200.00	
			Severe	VH							
8	Oven	1	Moderate	M	LF	Nursery room, maternity	-	Fixing on Table	First	500.00	
			Severe	H							
9	Cupboards	2	Moderate	VH	LS	Nursery room, maternity	-	Anchorage	First	400.00	
			Severe	VH							
10	Incubator	3	Moderate	VH	LS	Neo natal room	-	Hooking	First	1200.00	On roller and need hooking
			Severe	VH							
11	Child tray	4	Moderate	VH	LS	Neo natal room	-	Hooking	First	1600.00	On roller and need hooking
			Severe	VH							
12	Oxygen cylinder	1	Moderate	VH	LS	Neo natal room	-	Hooking	First	400.00	On roller and need hooking
			Severe	VH							
13	Cupboards	1	Moderate	VH	LS	Neo natal room	-	Anchorage	First	200.00	Near working chair
			Severe	VH							
14	Cupboards	5	Moderate	VH	LS	Padiatric ward-2	-	Anchorage	First	1000.00	
			Severe	VH							
15	Drawer	1	Moderate	VH	LS	Padiatric ward-2	-	Anchorage	First	200.00	
			Severe	VH							

Table A2-24: Assessment of Equipment and Contents (Medical Facilities and Administration [9/9])

S.N.	Non-structural Element	Quantity	Earthquake	Risk Rating	Type of Risk	Location	Linked Equipments	Mitigation Options	Implementation Priority	Estimated Cost for Implementing Mitigation Option(NRs.)	Remarks
1	Cupboards and rack	5	Moderate Severe	VH VH	LS	Administration	-	Strapping and Anchorage	First	1000.00	Near exit and working place, 4 cupboards and one rack
2	Photocopy machine	1	Moderate Severe	VH VH	LP	Financial Administration	-	Fixing on table and hooking of table	First	500.00	The photocopy machine on a table with wheel
3	Computer	1	Moderate Severe	VH VH	LP	Financial Administration	-	Fixing on Table	First	500.00	
4	Cupboards	1	Moderate Severe	VH VH	LS	Common room, Financial administration	-	Anchorage	First	200.00	
5	Computer	1	Moderate Severe	VH VH	LP	Record section	-	Fixing on Table	First	500.00	
6	Drawer	1	Moderate Severe	VH VH	LS	Nurshing Administration section	-	Anchorage	First	200.00	
7	Book racks	10	Moderate Severe	VH VH	LS	Library	-	Strapping and Anchorage	First	4000.00	
8	Overhead projector	1	Moderate Severe	VH VH	LP	Library	-	Fixing on Table	First	500.00	
9	Cupboard	1	Moderate Severe	VH VH	LS	Conference room	-	Anchorage	First	200.00	
10	Computer	1	Moderate Severe	VH VH	LP	Superintendent room	-	Fixing on Table	First	500.00	
11	Cupboards and racks	8	Moderate Severe	VH VH	LS	Store	-	Anchorage	First	1600.00	
12	Oxygen cylinders	8	Moderate Severe	VH VH	LS	Store	-	Fastening in group	First	1000.00	
13	Cupboards and racks	6	Moderate Severe	VH VH	LS	Family Planning room	-	Anchorage	First	1200.00	Medicine storing racks
14	Operation light	1	Moderate Severe	VH VH	LF	Family Planning room	-	Hooking	First	400.00	

3. Assessment of Systems' Vulnerability

All critical systems and medical facilities of the hospital have been assessed based upon the risk to the individual components of the respective system. Table A2-25 lists the expected damage to different non-structural systems.

Table A2-25: Expected Damage to and Probable Mitigation Feasibility of Western Regional Hospital

Critical Systems and Facilities		Expected Damage and Feasibility of Mitigation Option			
		Moderate Earthquake (MMI VI – MMI VII)		Severe Earthquake (MMI VIII - MMI IX)	
		Expected Damage	Mitigation Feasibility	Expected Damage	Mitigation Feasibility
1. Electricity System		Heavy	Easy to Implement Low Cost Involvement	Heavy to Very Heavy	Easy to Implement High Cost Involvement
2. Water Supply System		Heavy to Very Heavy	Easy to Implement Low Cost Involvement	Very Heavy	Difficult to Implement High Cost Involvement
3. Fire Response System		Slight	Easy to Implement High Cost Involvement	Slight	Easy to Implement High Cost Involvement
4. Communication System		Moderate to Heavy	Easy to Implement Low Cost Involvement	Heavy	Easy to Implement Low Cost Involvement
Important Departments and Wards	5. CSSD	Heavy to Very Heavy	Easy to Implement Low Cost Involvement	Very Heavy	Easy to Implement Low Cost Involvement
	6. X-Ray	Slight to Moderate	Easy to Implement Low Cost Involvement	Moderate to Heavy	Easy to Implement Low Cost Involvement
	7. Laboratory	Very Heavy	Easy to Implement Low Cost Involvement	Very Heavy	Easy to Implement Low Cost Involvement
	8. Out Patient Departments	Slight to Moderate	Easy to Implement Low Cost Involvement	Moderate to Heavy	Easy to Implement Low Cost Involvement
	9. Wards	Slights to Moderate	Easy to Implement Low Cost Involvement	Moderate to Heavy	Easy to Implement Low Cost Involvement
	10. Operation Theatre	Moderate to Heavy	Difficult but Low Cost	Heavy to Very Heavy	Difficult but Low Cost
	11. Emergency Department	Moderate to Heavy	Easy to Implement Low Cost Involvement	Heavy to Very Heavy	Easy to Implement Low Cost Involvement
	12. Administration	Moderate to Heavy	Easy to Implement Low Cost Involvement	Heavy to Very Heavy	Easy to Implement Low Cost Involvement

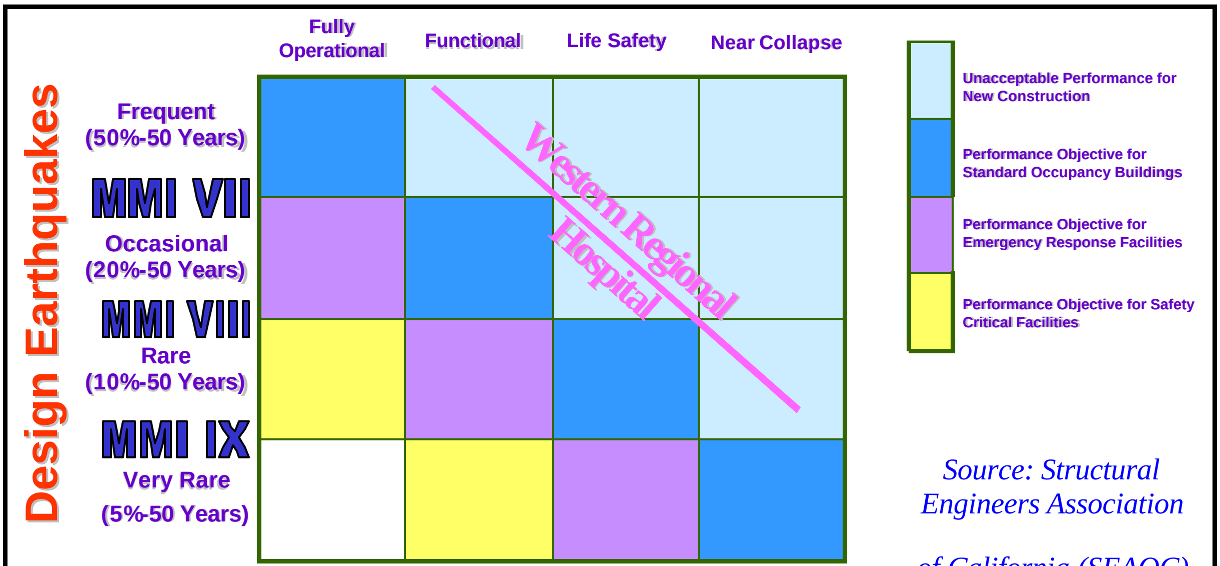
4. Hospital Performance Assessment

Based upon the structural and non-structural vulnerability assessment of the hospital buildings and different critical systems and facilities mentioned above, the functional assessment of the hospital was made for two scenario earthquakes. The result is shown in table A2-26 below.

Table A2-26: Expected Seismic Performance of Western Regional Hospital in Different Scenario Earthquakes

Scenario Earthquakes	
Moderate Earthquake (MMI VI – MMI VII)	Severe Earthquake (MMI VIII – MMI IX)
Partially Operational (the electricity and water supply systems may be interrupted. The laboratory, maternity and some part of OPD may suffer heavy damage. Most of the wards and OPD will be functional after some hours).	Out of Service (all critical systems and most hospital departments will be out of service for a long time. There will be heavy damage to most of the facilities).

The comparison of the expected seismic performance of Western Regional Hospital with the standard risk assessment matrix shows that the Western Regional Hospital falls outside the acceptable range.



Source: Structural Engineers Association of California (SEAOC) – Vision 2000, 1995.

5. Recommendations for Improving Structural and Non-Structural Seismic Performance

Based upon the structural and non-structural assessment of Western Regional Hospital, following priority-wise recommendations are made for improving the seismic performance of the hospital. The seismic vulnerability of different systems, technical and economical feasibility of implementing mitigation options, structural vulnerability and importance of the different critical systems and departments for operating the hospital after an earthquake are taken as basis for the prioritization.

Phase I: Recommended Improvements of the Non-structural Performance Expected to Render the Hospital Fully Operational after a Moderate Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
1. Fixing of all equipment and contents.	First	300,000.00	Work is expected to be done by the maintenance section. The cost is to pay for locally available materials.
2. Provision of extra fuel for generator.	First	50,000.00	
3. A yearly one-day training or workshop on non-structural safety for all maintenance, medical and administrative staff.	First	50,000.00	This cost is for one training programme and is meant to pay for local resource persons and awareness materials.
4. Plastic lamination of glass windows in important departments.	Second	500,000.00	
Total cost for Improvement (Phase I)		**900,000.00**	

Phase II: Recommendations for Improving the Structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

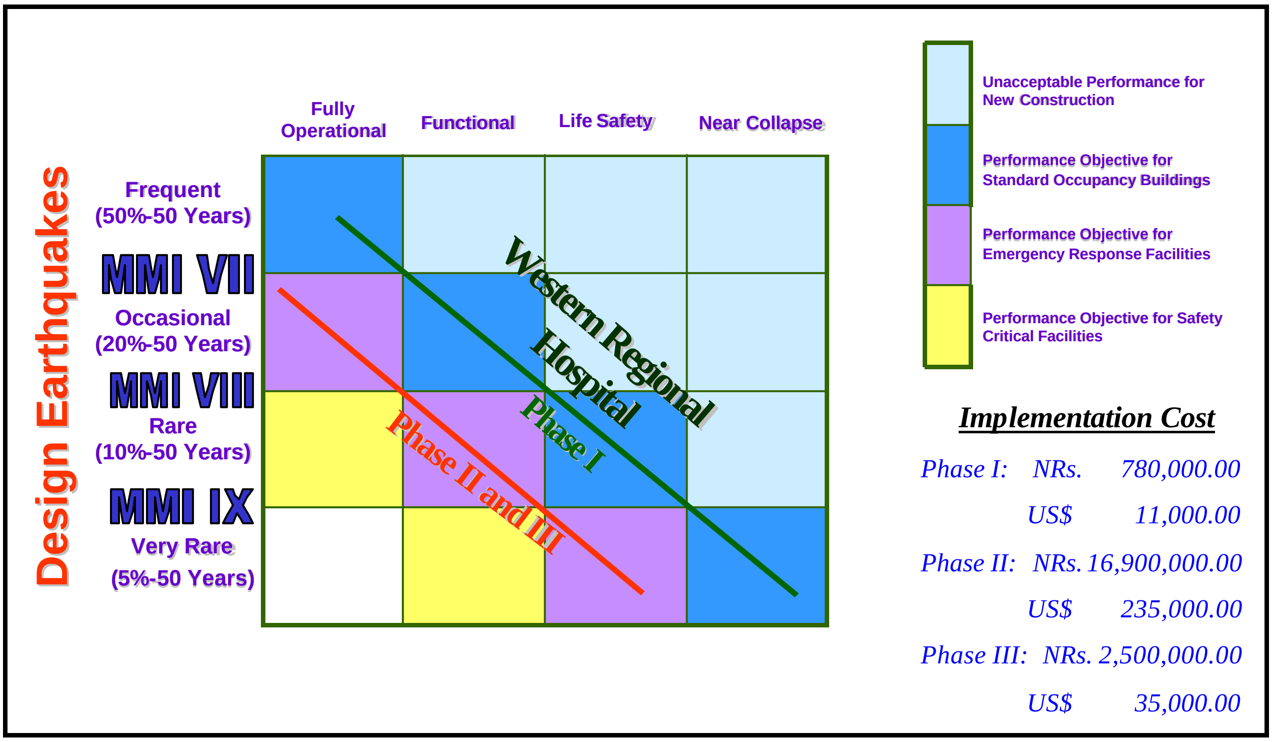
Recommendations	Priority	Estimated Cost (NRs.)	Remarks
5. Installation of a deep boring system for water with a 50,000 litres overhead tank and treatment plant.	Second	5,000,000.00	
6. Installation of a new 50 KVA generator.	Second	600,000.00	
7. Retrofitting of OPD block 1.	Third	1,000,000.00	
8. Retrofitting of OPD block 2.	Third	1,500,000.00	
9. Retrofitting of X-Ray block.	Third	1,000,000.00	
10. Retrofitting of inpatient block 1.	Third	1,500,000.00	
11. Retrofitting of inpatient block 2.	Third	1,500,000.00	
12. Retrofitting of administration and maternity block.	Second	2,700,000.00	Maternity and laboratory buildings were found relatively weaker and are given higher priority than others.
13. Retrofitting of laboratory block.	Second	1,200,000.00	
14. Bracing of partition walls of the new building.	Third	900,000.00	
Total cost for Improvement (Phase II)		**16,900,000.00**	

Phase III: Additional Recommendations for Improving the Non-Structural Performance of the Hospital to a Desirable Level after a Severe Earthquake

Recommendations	Priority	Estimated Cost (NRs.)	Remarks
15. Installation of flexible couplings in the water supply system and electricity system.	Fourth	500,000.00	
16. Provision of redundancy in the system (extra generator, spare pumps).	Fourth	2,000,000.00	
Total additional cost (Phase III)		**2,500,000.00**	

6. Expected Performance of the Hospital after Implementation of Recommendations

The expected performance of Western Regional Hospital after implementation of Phase I, II & III of the recommendations is given in comparison with the standard risk matrix in the following diagram.



7. Photographs

The following section contains photographs of different systems and medical facilities of Western Regional Hospital in order to show both the vulnerabilities and the good aspects.

Photo 1: Buildings of different height, shape and structural properties connected with each other can cause severe pounding during earthquakes.

Photo 2: A new attachment to existing buildings with no seismic gap has made both the existing and the new building vulnerable.

Photo 3: A stone masonry infill wall construction in the new building. There is no proper connection between the stone units making it a very vulnerable wall. The mortar used is 1:6 cement: sand mortar.

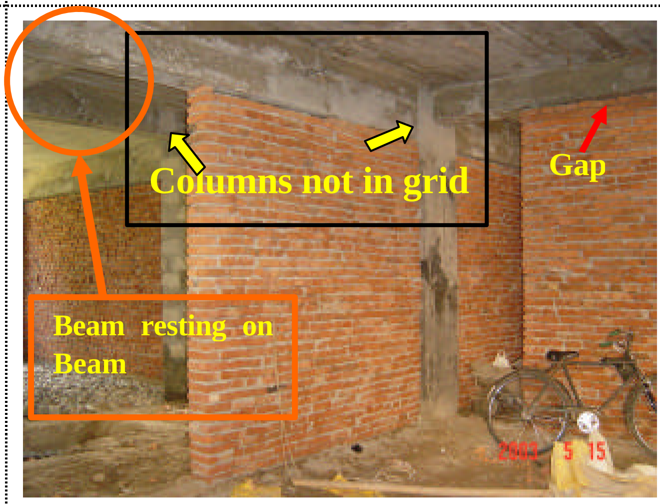


Photo 4: The structural system and load path of the new building is not proper. The columns are not in grid, beams are just connected with beams and there is a lack of columns. Improper connection of infill walls with the frame has made the infill walls more vulnerable.

Photo 5: The base of an overhead tank; the bolts are not properly fixed and are rusted, the base is weathered.

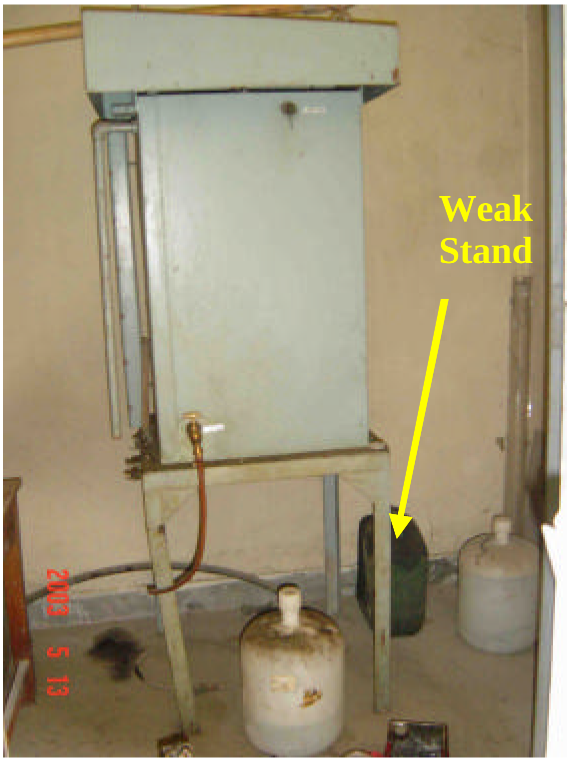


Photo 6: 300 litres fuel tank of the generator; on a weak stand without anchorage and lateral support.

Photo 7: Communication equipment on a temporary type stand. It needs a proper stand with anchorage and fixing.

Photo 8: The main board for electricity distribution within the hospital; properly anchored on the wall and with low vulnerability.

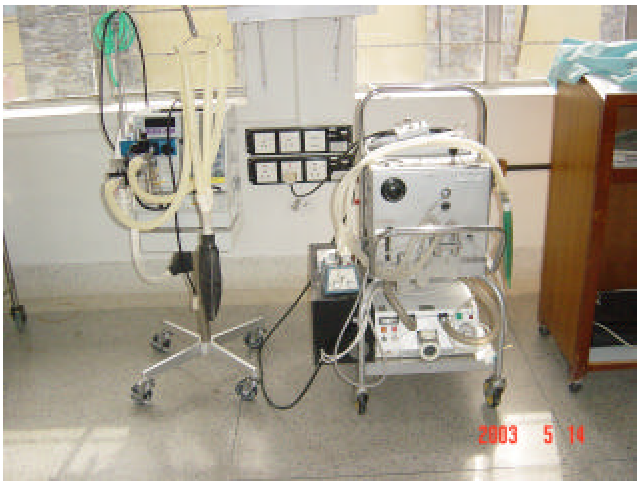


Photo 9: Equipment on rollers in the operation theatre and other places is vulnerable as it may roll and impact with other objects.

Photo 10: Cupboards and racks storing important equipment, medicines and chemicals are vulnerable because they are not fixed to the wall and strapped.

Photo 11: Autoclave machine needs anchorage at the base.

Photo 12: The cupboards and racks near working stations in the administration and other places of the hospital can are life safety hazards.

Photo 13: The air conditioning equipment for the OT is kept on the roof with no fixing.

Photo 14: Racks containing chemicals in laboratories should be anchored; chemical bottles should be strapped or relocated to improve safety conditions.

Photo 15: Cupboards and other objects in the corridors can block the exit ways during earthquakes.

Photo 16: Window glasses or glass partitions are life safety hazards and need plastic lamination.

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This document was prepared based on the study on Non-structural Vulnerability Assessment of Hospitals in Nepal commissioned by WHO-Nepal and implemented by NSET in 2003.

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