

Initial Seismic Vulnerability Assessment
of Equipment, Utilities,
Architectural Shell and Contents
at
Kanti Children's Hospital, Kathmandu, Nepal



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Executive Summary

The 300-bed Kanti Children's Hospital is the only tertiary referral hospital for children in the Kathmandu Valley catering to children up to the age of eighteen. It has developed into the national centre for child health in Nepal and offers paediatric specialties such as a Neonatal Intensive Care Unit (NICU), Pediatric Intensive Care Unit (PICU), Neonatal Intermediate Care Unit (NIMCU), Surgical Intensive Care Unit (SICU), Burn Unit, Department of Paediatric Surgery, Oncology Department, Paediatric Radiology, Physiotherapy Department, Paediatric Cardiology, Paediatric Nephrology, Paediatric Neurology and Child Development Clinic, Immunization, Blood Bank, AIDS and HIV Clinic, Institute of Child Health, and Department of Pathology with 24 hour laboratory services for investigations. Almost half of the patients are reported to be from outside the Kathmandu Valley, with families travelling from far and remote areas to access care for their children. The Government has plans to upgrade the facility to a 500-bed hospital in the near future.

The Advisory Group for the Nepal Risk Reduction Consortium (NRRC) Flagship Project 1, which is tasked with improving hospital earthquake safety in Nepal, identified Kanti Children's Hospital as having high priority for assessment due to the critical paediatric services it provides. As part of the assessment process, GeoHazards International (GHI) sent a team to Kathmandu in May and June 2013 to assess the potential seismic vulnerabilities of building utility systems, equipment, architectural shell elements and contents (*i.e.*, nonstructural elements) in Kanti Children's Hospital and two others, which are assessed separately. The seismic vulnerability assessment of equipment, utilities, architectural shell and contents complements a structural assessment and a functionality/emergency preparedness assessment being conducted by others as part of the larger project.

The assessment is intended to provide the hospital, the Ministry of Health and the Regional Office for South-East Asia (SEARO) of WHO with recommendations to improve the hospital's ability to deliver medical care following a major earthquake. The team obtained the information included in this report by conducting in-person evaluations of building contents and utility systems over several days at the hospital; reviewing available technical reports and drawings; holding discussions with the hospital administration and engineering, maintenance, and medical staff; and obtaining technical information from the literature. This report presents the GHI evaluation team's findings and recommendations.

The present hospital was built in three stages: the Medical Ward Block (and Administrative Building) built by the Government of Nepal in the 1970s, the Emergency (Surgical) Block constructed with support from the Government of Japan in the mid-1990s, and the Annex Ward constructed by the Government of Nepal in 2007. The hospital facility has some seismic vulnerability in its utility systems, equipment, architectural shell and contents, which should be addressed as part of a larger effort to improve the seismic performance and functionality of the facility. Results of the detailed structural assessments were not available at the time of this report, but are of critical importance. The hospital's buildings built in the 1970's are unlikely to contain the earthquake-resistant features required by modern building codes. Though structural assessment is outside GHI's scope for this project, it is worth mentioning that the GHI team noted seismic vulnerabilities in these hospital

buildings, and GHI anticipates that the results of the structural assessments will indicate that these are likely to experience structural damages in a strong earthquake.

Of the vulnerabilities in GHI's assessment scope, those in the Medical Ward Block present the highest threat to the hospital's post-earthquake functionality. In the Emergency (Surgical) Block, it is evident that seismic safety of equipment, utilities, architectural shell and contents were given much thought in the design and execution of the facility. However, equipment and contents added later were not seismically protected. As a result, many parts of the Emergency (Surgical) Block have become vulnerable to earthquake-induced losses. Furthermore, engineering calculations to assess the adequacy of existing seismic protection measures for the design level of earthquake shaking were outside the scope of GHI's assessment, but such calculations should be done.

GHI recommends that the hospital immediately take steps to seismically protect utilities in the Medical Ward Block and Annex Ward and to implement additional necessary seismic protection measures for the electrical power backup system. Other immediate-priority recommendations include restraining medical gas cylinders against toppling in the manifold and in the storage areas, wards, ICUs, and Burn Unit; providing backup communications capacity; repairing the non-functional fire suppression system; and ensuring that exit pathways are clear of impediments.

The mitigation and preparedness measures necessary to help keep the hospital functional will take time to implement, and will need to be integrated with the overall seismic safety improvement plan, then planned and spread out over a number of years. The Kanti Children's Hospital will then be better prepared to serve the community in the event of an earthquake.

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Background

The Nepal Risk Reduction Consortium (NRRC) was established in May 2009 to emphasize the shift in focus of development assistance to a disaster risk reduction perspective. Out of five flagship projects under NRRC, Flagship Project 1 is "School and Hospital Safety-Structural and non-Structural aspects of making Schools and Hospitals Earthquake Resilient." Currently, the World Health Organization (WHO) is coordinating the 'Hospital Safety' component of the Flagship 1 Project with the Government of Nepal Ministry of Health and Population (MOHP) as the lead government agency. The Department for International Development, UK (DFID) is supporting a three-phase project "Improved Seismic Safety of Priority Hospitals in Nepal."

An Advisory Group comprised of relevant Government of Nepal agencies, development partners, and other stakeholders was formed for Phases 1 and 2. Phase 1 includes rapid seismic vulnerability screening of 60 hospitals with more than 50-bed capacity. Phase 2 consists of more detailed structural, nonstructural and functional (i.e., preparedness) surveys of 20 hospitals, including six priority hospitals identified by the Advisory Group. The project also has a Phase 3, in which engineers will conduct detailed structural assessments and analyses, design seismic retrofits and estimate retrofit costs for 10 hospitals. Engineers will present retrofit recommendations and initial cost estimates at a donor conference at the end of 2013. WHO has engaged GeoHazards International (GHI) to assess the potential seismic vulnerabilities of nonstructural components in several priority hospitals as part of the Phase 2 survey. The Advisory Group identified the Kanti Children's Hospital (KCH) along with National Academy of Medical Sciences (Bir Hospital), and Paropakar Maternity and Women's Hospital, and several others, as having high priority for assessment due to the critical medical services they provide on a day-to-day basis.

KCH was established with 50 beds in 1963 with support from the then USSR government. In 1968, the hospital was handed over to the Ministry of Health, Government of Nepal. In 1970, 100 more beds were added by the Nepalese government, and the hospital started providing medical services to children up to the age of fourteen (all cases) and eighteen (oncology cases). With no specialized hospital for children in the Valley, KCH was forced to increase its bed capacity to 190, using corridors, circulation and store spaces to accommodate more beds. In 1994-1995, with Japan International Cooperation Agency (JICA) support, the hospital added another 100 beds. With the last addition of 50 beds in 2002 by the Nepalese government, it is now a 300-bed hospital. A planned upgrade in the near future will increase capacity to 500 beds. Today, KCH has developed into a national centre for child health in Nepal. It is the only tertiary referral facility in the Valley catering to children. Almost half of the patients are reported to come from outside the Kathmandu Valley, with families travelling from far and remote areas to access care for their children. Situated in Maharajgunj, Kathmandu right next door to the Tribhuvan University Teaching Hospital (TUTH), KCH is located in northern Kathmandu, off Maharajgunj Road and also accessible from the Ring Road, about 1km from Maharajgunj Road and Ring Road intersection, as Figure 1 shows.

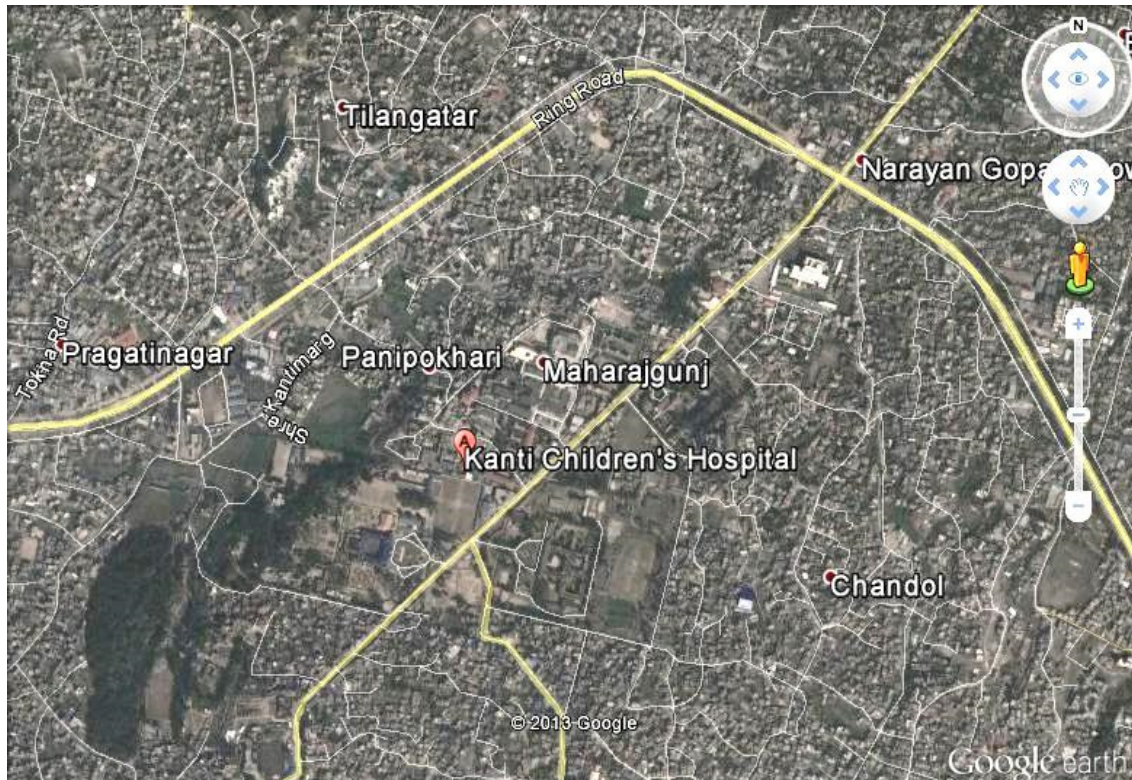


Figure 1: Kanti Children's Hospital in the urban context

Assessment Team and Methodology

GHI's field assessment team consisted of Mr. Hari Kumar, GHI South Asia Regional Director, and Dr. Keya Mitra, Professor of Architecture, Bengal Engineering and Science University Shibpur, India. Dr. Janise Rodgers, GHI Project Manager, and Mr. William T. Holmes, Senior Consultant, Rutherford & Chekene Structural and Geotechnical Engineers of San Francisco, California helped develop the assessment methodology and recommendations.

Prior to conducting the on-site assessment, the GHI team reviewed available DFID-supported Phase I survey reports, papers, and plan drawings generated during the structural and functional assessments, as provided by WHO. Upon arrival in Nepal, the field team attended a meeting comprised of the WHO Representative (WR) to Nepal, DFID, and the structural assessment and functional (i.e., preparedness) assessment experts.

In late May and early June 2013, the GHI field team conducted site visits to assess the seismic vulnerability of equipment, building utility systems, architectural shell elements and contents – often collectively referred to as *non-structural components* – in three major hospitals in the Kathmandu Valley, including the Kanti Children's Hospital. During the surveys, GHI used the PAHO (Pan American Health Organization) Hospital Safety Index checklist forms and the ISDR (United Nations Office for Disaster Risk Reduction)/WHO Safe Hospital Indicators document as data collection tools. The team conducted walk through surveys to assess the potential seismic vulnerabilities of the critical areas of service under normal and post-earthquake conditions, such as the out-patient department (OPD),

wards, intensive care units, operation theatres, emergency ward, and the CSSD. The team assessed the following on-site utility systems: fire suppression; electrical power; drinking water supply; medical gas; communication; heating, ventilation and air conditioning (HVAC); lifts; wastewater and solid waste management; major and specialty medical equipment such as X-ray, laboratory, specialty diagnostics; and architectural shell elements such as brick partition walls and suspended ceilings.

The team obtained the information included in this report by conducting in-person evaluations of building contents and utility systems over several days at the hospital; reviewing utility service as-built drawings where available; and interviewing or holding discussions with the hospital administration and engineering, maintenance, and medical staff; and obtaining supporting technical information from the relevant literature. The field team held discussions with members of the hospital administration including Medical Superintendents, Maintenance Engineers, Nursing Superintendents and hospital staff in the different departments that were surveyed. The team made efforts to visit all important areas of the hospital without disrupting patient care, but some areas were not accessible due to ongoing medical service delivery.

Scope

The scope of this report includes an initial seismic assessment of the equipment, architectural shell and contents of the hospital's medical buildings, and on-site utility infrastructure, and on-site engineering and maintenance office called Repairs and Maintenance Services (RAMS). The privately run medical store, located in a stand-alone single storied building next to the driveway leading to the hospital, and the canteen located on the first floor above the Nutrition Clinic, in the Administrative Block are excluded from the scope of this report. Engineering calculations to determine the adequacy of seismic protection measures for equipment, utility systems and architectural shell elements were outside the scope of this assessment.

Assessments of structural performance of the buildings during earthquake shaking, potential ground failure and its impacts, and the hospital's level of emergency preparedness are excluded from the scope of this assessment, because they are being conducted by other teams. Knowing the structural performance and potential for ground failure are crucial in order to determine whether the hospital will likely be able to deliver essential medical care after the shaking stops. The findings in this report must be integrated with the results of assessments of structural performance and potential ground failure in order to draw conclusions regarding whether specific buildings will be usable following a major earthquake.

Earthquake Hazard

Nepal lies in a region of high seismic activity and has a long history of destructive earthquakes. Large earthquakes with magnitude of 5 to 8 on the Richter scale have been experienced throughout the country during the past 200 years, of which 279 earthquakes had epicenters in and around Nepal. In the last century, over 11,000 people lost their lives in major earthquakes in Nepal. The 1934 Nepal Bihar earthquake severely affected the lives and building stock of Kathmandu Valley. This earthquake was not an isolated event. Three earthquakes of similar size occurred in Kathmandu Valley in the 19th century alone, in 1810, 1833, and 1866 AD. Kathmandu Valley is widely known as

one of the most seismically active areas in the central Himalaya, having experienced large earthquakes in the past centuries. Major damage of probable seismic origin is reported to have occurred in 1255, 1408, 1681, 1803, 1810, 1833, 1866, 1934, 1988 and 1991. The levels of ground shaking expected, and the effects of site conditions, are discussed in the Location and Site Conditions section.

Description of the Hospital

Kanti Children's Hospital, Maharajgunj, Kathmandu, was established in 1963 with support from the then USSR, and has developed into Nepal's most important children's hospital, and the only tertiary referral hospital in Kathmandu Valley providing care to children. The hospital has an 8-bed Neonatal Intensive Care Unit (NICU), a 4-bed Paediatric Intensive Care Unit (PICU), a 4-bed Surgical Intensive Care Unit (SICU), a Burn Unit, Department of Pathology with 24 hour laboratory services for investigations, Department of Paediatric Surgery, Paediatric Radiology, Physiotherapy Department, Outpatient (OPD), Paediatric Cardiology, Paediatric Nephrology, Paediatric Neurology and Child Development Clinic, Neonatal Intermediate Care Unit (NIMCU), Immunization, Family Planning and Direct Observed Therapy Clinic, Oncology Department, Emergency Ward, Observation Ward, Blood Bank, AIDS and HIV Clinic, Institute of Child Health, and the Repair and Maintenance Section (RAMS). Residential facilities are available for doctors and nurses, as is a hostel for doctors on duty and medical residents. The hospital provides post-graduate training in pediatrics for students of NAMS (Bir Hospital). The Emergency (Surgical) Block, Annex Ward, Medical Ward Block, and Administration Block house various departments and facilities as Figure 2 shows. A bridge connects the Emergency (Surgical) Block to the Annex Ward, Medical Ward Block and Administration Block.

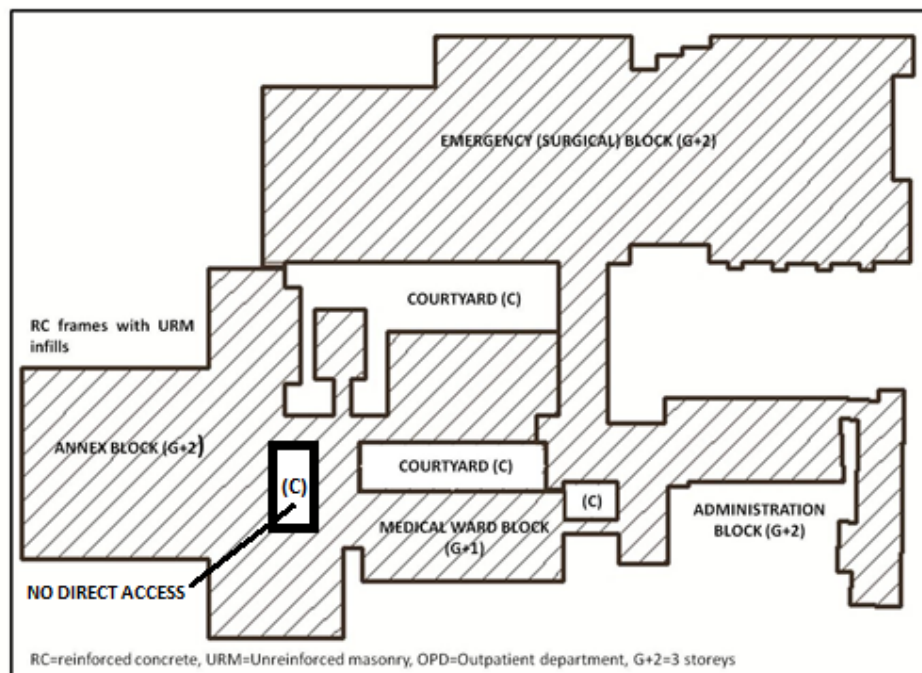


Figure 2: Site Plan (adapted from John Sanday Associates, Pvt. Ltd)

Location and Site Conditions

Kathmandu Valley evolved during the Pliocene and early Pleistocene. It was submerged and after emergence accumulated fertile soil from late Quaternary sediments. The Kathmandu Valley infilling consists of three-million-year-old fluvial and lacustrine sediments delivered mainly from the mountains in northern parts of the basin. The basement is formed by Precambrian to Devonian rocks, which are mainly meta-sediments, intensely folded, faulted and fractured. They consist of quartzite, phyllite, schist, slates, limestone and marbles. They are overlain by Quaternary sediments in the valley. The sediment cover has a thickness of 550 to 600m in the central part of the valley. Kanti Children's Hospital is located in the northern part of Kathmandu Valley (Figure 3), in the Maharajgunj area lying between Maharajgunj Road and the Ring Road (Figure 4).

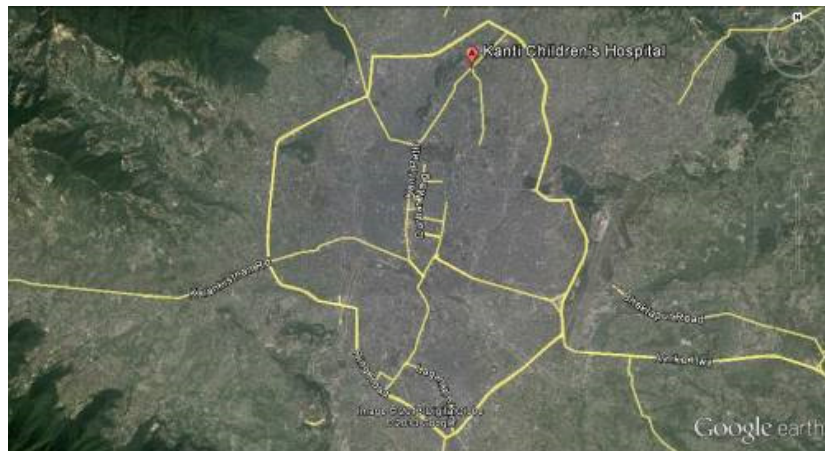


Figure 3: Location of Kanti Children's Hospital in Kathmandu Valley

According to a WHO-Ministry of Health Report from 2002¹, Kathmandu Valley has a very shallow aquifer usually found at a depth of 1-2m. In areas located at the foot of the hills, this aquifer is assumed to be “confined” and therefore experiencing hydrostatic pressure that can produce liquefaction. A Japan International Cooperation Agency (JICA)² study indicates that extensive pumping of water from the aquifer between 1972 and 2001 caused the piezometric head of the confined aquifer to drop 8-12m in northern Kathmandu (Maharajgunj). This has significantly reduced the liquefaction potential in those areas which are prone to liquefaction due to presence of shallow, sandy layers.

¹ WHO (2002). Mitigating Earthquake Risk in Health Facilities. A Structural Vulnerability Assessment of Hospitals in the Kathmandu Valley.

² Japan International Cooperation Agency (JICA), 1990. The Ground Water Management Project in Kathmandu Valley.

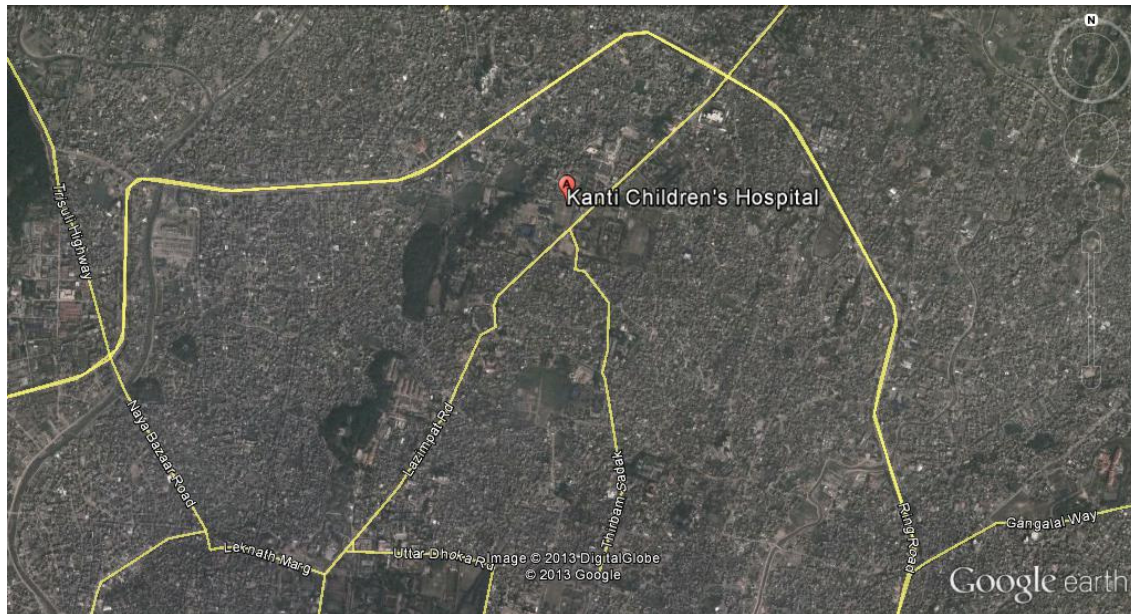


Figure 4: Local transportation routes

Assessing the potential for ground failure and site effects is outside the scope of this project, but the level of ground shaking at the Kanti Children's Hospital site is likely to be affected by these factors. A JICA study in 2000-2001³ found amplification rates ranging from 100% to 200% for an intensity MMI-VIII earthquake, considering peak ground acceleration (pga) values to be between 0.2g to 0.35g. Site specific studies should be carried out during the detailed assessment phase to determine the likely values of ground shaking parameters and the potential for ground failure. The WHO-Ministry of Health Report (WHO, 2002) on structural vulnerability assessment had assumed pga values of 0.2g to 0.35g for MMI-VIII shaking, 0.1g-0.2g for MMI=VII shaking and above 0.35g for MMI=IX shaking. If current site specific studies determine that the anticipated ground shaking will be significantly different than the ground shaking assumed in that report, the conclusions of this assessment will need to be revisited and potentially adjusted.

Buildings

The hospital has its different departments and facilities located in three blocks, namely the Emergency (Surgical) Block, the Medical Ward Block and Administrative Block and the Annex Ward. The Emergency Block is connected with the Medical Ward Block and Administration Block through a Bridge. Table 1 shows key characteristics of hospital buildings included in this report.

³ Japan International Cooperation Agency (2002). The Study on Earthquake Disaster Mitigation in the Kathmandu Valley, Kingdom of Nepal. Volume 1. Summary. Nippon Koie Co., Ltd. and OYO Corporation.

Table 1. Characteristics of Kanti Children's Hospital Buildings

Block	Year Built	No. Stories	Type	Major Departments
Emergency (Surgical) Block	1995	G+2	RC frame or shear wall w/ brick infill*	Emergency Out Patient Department Medical Diagnostics Post Operative Ward Pathology Blood Bank Post Operative ICU (PICU) Neonatal ICU (NICU) Surgical Ward Surgical ICU (SICU) Operation Theatres (OT) Intensive Care Units (ICU) Central Sterile Supply Department (CSSD)
Annex Ward	Begun in 2000 and completed in 2007	G+2	RC w/ brick infill	Out Patient Department
Medical Ward Block	1970	G+1	RC w/ brick infill	Medical Wards Special Cabins General Store Burn Ward Paid Ward Temporary Stay for Families
Administration Block	1970	G+2	RC w/ brick infill	Expanded Programme on Immunization (EPI) Nutrition Clinic Physiotherapy Library Housekeeping Medical Records Administrative Offices Auditorium

* GHI was unable to obtain the structural drawings in order to conclusively determine the structural system.

The original building constructed in 1963 with support from the former USSR was demolished in 1994 and replaced with the Emergency (Surgical) Block in 1995, with support from JICA. GHI understands that the Emergency Block was built according to Japanese codes in place at that time, which included provisions for anchoring equipment, utility systems and architectural shell elements⁴, though drawings and calculations were not available to confirm the adequacy of the seismic restraints for equipment, utility systems and architectural shell elements. This Block contains some of the most critical departments such as Emergency, Medical Diagnostics, Post -operative Ward,

⁴ Relevant Japanese codes in place at the time would have been the *Guideline for Seismic Design of Building Nonstructural Components* (Public Buildings Association, 1987) and *Guideline for Seismic Design of Building Equipment* (Building Center of Japan, 1984), in addition to the 1981 revision of the Japan building code governing structures.

Pathology, and Blood Bank- all of which will have important post-earthquake functions when they will experience a surge in patient demand. It is important that the critical intensive care wards (Paediatric ICU, Neo-natal ICU, Surgical ICU, ICU) remain functional after an earthquake to protect the critically ill. The location of ICUs in the Emergency Block, built according to Japanese codes, is appropriate. The Central Sterile Supply Department CSSD located in this Block is also a positive feature in this hospital, as the functionality of the CSSD determines whether or not the hospital will have sterile supplies and will be able to keep its Operation Theatres (OTs) functioning.

The Medical Ward Block and the adjoining Administration Block were built in 1970 by the Government of Nepal. The Administration Block is located on the eastern side (see site plan, Figure 2). The Annex Ward is on the west of the Medical Ward Block. In the Medical Ward Block on the ground floor, the Oral Rehydration Therapy (ORT) and Diarrhoea Therapy Units are on the northern side of a rectangular internal courtyard with a covered walkway affording access to the courtyard on the south. On the southern side of the courtyard, there are a number of medical wards. The first floor of the Medical Ward Block and part of the Administration Block contain medical wards. The second floor has the Burn Ward which is functionally not accessible from the eastern part of the Administration Block.

Nepal did not begin efforts to develop a national building code until 1992, and the code was not released until 1994. The Medical Ward Block was built by the Government of Nepal in 1970, and is therefore unlikely to have been built to a code with modern earthquake resistant design provisions. The Emergency (Surgical) Block is a reinforced concrete moment-resisting frame or shear wall building with brick infill walls, built in 1995. GHI was not able to confirm the structural system type. The building was built according to the provisions of the Japanese earthquake resistant codes at the time, and it will likely be safe in an earthquake. However, continued occupancy post-earthquake depends on the level of structural damage.

The Annex Ward to the west of the Medical Ward Block is a later addition that was begun in 2000 and completed in 2007 by the Government of Nepal. At present, only the ground floor of the 3-storey Annex Ward is being used, for OPD. GHI team was not able to obtain any information on the designers or agency constructing the buildings, so it was not possible to determine which code may have been used to design the buildings. Therefore, a structural assessment is required to determine the likely seismic performance of these buildings.

Kanti Children's Hospital was built in a number of Phases, in 1970, 1995, and 2000-2007. The buildings use different structural systems, are designed and detailed according to different earthquake and structural design codes, and were constructed by different agencies. It is likely therefore that each phase will have a different earthquake response. The buildings abut one another, and the transition zones assume great importance (especially in the absence of any visible seismic joints) in the overall earthquake behavior of the facility and the functioning of the hospital as a whole.

Infrastructure and Utility Services

The hospital's electric power supply comes from the local grid. The 11kV HT feeder line from the Nepal Electricity Authority (NEA) comes to a substation located right in front of the Emergency Block.

A single step-down transformer of 750kVA capacity supplies 400V electrical power to the hospital through LT panels. The adjoining Generator Room has two generators, an automatic 250 kVA which is used regularly and a 36kVA generator that is presently inoperational. The hospital plans to install another automatic 300 or 400kVA generator to meet increasing demand due to expansion. The maximum power interruption before the generator would start in event of power outage is 15 seconds. The generator is tested daily. The hospital is served by a "hunting line" so there is no scheduled load shedding, and the hospital does not have power cuts. Under normal circumstances, the hospital never experiences disruptions in power supply, and if there is a rare disruption in power supply, this is never for longer than 15 minutes.

The generators provide backup power, with 100% backup in critical areas of the hospital including ICUs and Water Supply. Laboratories have 80% backup. The wards have nominal backup support for lights only. Though the CSSD is not covered by backup power, the hospital has three mini autoclaves (of which two were under repair at the time of the assessment) running on 1500w power; these have generator support and would remain functional in the event of power failure. A low power consumption 100mA X-Ray machine is also expected to remain functional in the event of power failure. Lifts are not covered by generator supply.

The automatic generator has an underground fuel tank of 6000L capacity and a day tank of 300L capacity. At any point of time, the hospital stores only about 700L of fuel in reserve. There are two distribution systems for power: one from the generator, and a second from the distribution panel boards located in the substation. Life support equipment such as ventilators all have inbuilt battery capabilities to run for at least 30 minutes without power. When running to full capacity, the generator consumes approximately 18L of diesel fuel per hour, and at decreased capacity it consumes about 10-12L of diesel fuel per hour.

The hospital does not depend on the Municipal water distribution system. Water is drawn from one bore well from aquifers 100-200m below ground level, through two submersible 7.5Hp pumps that are used alternately. In summers the water levels go down slightly. The water is pumped into four surface-level water tanks of 15,000L each. The filtration system, though present, has not been functioning for some time. The pressure filter has a damaged membrane. Currently, untreated water is pumped to overhead tanks located on the roofs of the Emergency (Surgical) Block (50,000L) and the Medical Ward Block (15,000L). The average water consumption for a 24-hour period is 200,000L, of which the hospital consumes 150,000L and the staff quarters use the rest. The automatic pumping system uses sensors that automatically start the pumps whenever the water level drops to below half in the surface tanks.

The hospital has no central boilers for supply of hot water. A solar water heating system is installed for providing hot water to wards, nurses' stations and critical care areas such as ICUs. There is no central HVAC system in place. Window and split-type air conditioners with heating and cooling functions are used. Many of these air conditioning split units, placed on metal trays supported by brackets outside windows, could be dislodged in earthquake shaking in the absence of any horizontal restraints. The hospital relies on the city sewer system for wastewater disposal and treatment. Medical waste is incinerated on site.

The hospital does not have a bulk oxygen tank at present. The oxygen plant was discontinued because the equipment, installed in 1986 with JICA support, is obsolete and can neither be repaired nor replaced. The hospital plans to build a new and modern oxygen plant. Medical gas is supplied via oxygen cylinders that are brought in by a supply company truck on a daily basis from a distributor agency located about 10KM from the hospital. The hospital has a permanent reserve of around 90 oxygen cylinders to avoid any interruption in supplies and a daily supply of 35 cylinders per day. Piped oxygen is provided to the OTs and critical areas such as Neonatal Intensive Care Unit (NICU), Postoperative Intensive Care Unit (PICU), and Surgical Intensive Care Unit (SICU) through a manifold that is fed by 11 cylinders. Piping for nitrous oxide and vacuum (suction) exists, but neither is in working condition.

Observed Earthquake Vulnerabilities

The team assessed the hospital for vulnerabilities in its utility systems, equipment, architectural shell and contents. Because this was an initial assessment, performing calculations to assess the adequacy of seismic protection measures, presumably designed using Japanese codes from the mid-1980s, was outside of GHI's scope. GHI recommends that the adequacy of seismic protection measures for the expected level of earthquake shaking be verified.

As noted in the Scope section, an assessment of the seismic structural performance of the buildings was excluded from the scope of this assessment, as others are responsible for structural assessment. Results of the detailed structural assessments were not available at the time of this report, but are of critical importance. The team that the Medical Ward Block predates Nepal's building code as well as modern reinforced concrete code provisions for ductile reinforcement detailing, and GHI anticipates that the assessment will show seismic vulnerabilities as a result. The Emergency (Surgical) Block would benefit from a detailed structural assessment to determine the anticipated structural damage and whether the building might be able to achieve a higher level of seismic performance than life safety.

Vulnerability of Utility Systems and Backup Capabilities

The Kanti Children's Hospital relies on utility systems such as electrical power, water, and medical gases to function following an earthquake or other emergency. Kanti Children's Hospital has a hunting line supply in place and is therefore not affected by any load shedding under normal circumstances. It was reported that the hospital has never experienced power outage of more than 15 minutes. However, in the event of an earthquake, grid power supply may remain unavailable for a much longer time period. The single automatic generator has sufficient reserve fuel storage to run to maximum capacity for a little under 40 hours, but overheating could pose a challenge as there is no alternative generator to share the load. The generator is bolted to the floor but several vulnerabilities may lead to earthquake damage that prevents the backup power system from functioning properly, as described in detail below.

For other utilities, such as medical gas, supply systems can be vulnerable to earthquake damage, because the supplier's factory is located at a distance of 10km from the hospital, and supply to the hospital can be affected by blocked or damaged roads after an earthquake. To safeguard against this

possible interruption in medical gas supply, the hospital maintains a permanent reserve of 90-100 cylinders at all times. The manifold system has provision for adequate restraining of inline cylinders through chains, but the chains are not being used. Distribution system for medical gases seems seismically adequate. The following sections present utility system vulnerabilities that were observed by the evaluation team.

Electrical power system

The hospital's most important utility system is the electrical power system. Without power, the hospital's essential medical equipment, life support equipment, lighting, and other safety-critical items will not function. The power supply system comprises a 11kV HT feeder line that connects to the municipal power supply. According to a study conducted in 2002 (JICA, 2002)⁵, the municipal power supply would become unstable during an earthquake generating Intensity VII shaking. This would cause power disruption. Estimates of the time it would take to restore grid power following earthquakes of different magnitudes were outside the scope of this investigation, but GHI recommends that the hospital obtain these estimates from Nepal Electricity Authority for planning purposes.

The hospital's electric power supply comes from the local grid. The 11kV high tension (HT) feeder line from the Nepal Electricity Authority (NEA) comes to a substation located right in front of the Emergency Block (Figure 5). A single step-down transformer of 750kVA capacity supplies 400V electrical power to the hospital through Low Tension (LT) panels. The transformer is bolted to the floor (Figure 6).



Figure 5: 11kV HT Feeder line supply point



Figure 6: Transformer bolted to the floor

⁵ JICA, 2002.



Figure 7: Generator bolted to the floor



Figure 8: Anchored fuel tank

The generator is bolted to the floor and is unlikely to be dislodged in moderate earthquake shaking (Figure 7). The day fuel tank is also anchored and braced (Figure 8). Calculations, which are outside the scope of this report, would be necessary to determine whether the anchorage systems for the generator and day tank have adequate capacity to meet the expected seismic demands. The batteries for the generator rest on racks that are bolted to the floor. However, the current set of batteries seems to be larger than the rack, hence the batteries have been placed on a set of bricks inside the rack (Figure 9). These batteries are likely to slide off from the racks in spite of the presence of a continuous guard piece. The exhaust system is vertically supported but is not laterally braced against earthquake forces (Figure 10), and as a result could be damaged by shaking, potentially rendering the generator inoperable.



Figure 9: Batteries placed on bricks in the battery tray may slide off in earthquake shaking



Figure 10: generator exhaust and muffler system anchored vertically only



Figure 11: Inlet pipes of generator fuel anchored to external wall



Figure 12: Lack of flexible piping in generator fuel supply lines

The inlet piping from the underground fuel tank is anchored on the external wall of the building (Figure 11). However, both the fuel tank and the supply lines for fuel from the underground fuel storage tank lack flexible piping (Figure 12). The supply of generator fuel would be affected if these rigid lines were to break during earthquake shaking.

At any point of time, the hospital maintains a fuel reserve of about 700L despite having much greater storage capacity in its two fuel tanks (a 6000L underground fuel tank located outside the electrical room and a 300L day tank inside the generator room). Under normal conditions, the 700L of fuel would be sufficient to power the critical areas of the hospital for 70 hours. If the generators run to full capacity, the hospital can be powered for about 38 hours. PAHO recommends that hospitals store enough fuel for five days. The generator is tested daily. However, the generator has not been tested for extended running and could develop heating problems if run continuously for over six hours, as it is cooled with water, which must be added manually. There is currently no alternative generator to help share the load, though the hospital is planning to procure an additional 300 or 400kVA generator to cope with increasing demand.

The generators are housed in a reinforced concrete single-storey structure abutting the corridor that connects the Emergency (Surgical) Block with the older Medical Ward Block. The brick masonry infill walls are full height and lined with absorbent padded fabric for damping of sound. The absorbent panels are bolted to the walls to prevent loosening and peeling. The hospital is located in an elevated area and is unlikely to ever experience water logging or flooding.

The electrical distribution system appeared well organized with individual conduits bolted to the wall and cables in trays (Figure 13 - Figure 15). The electrical conduits are clamped to the walls at regular intervals to prevent slippage during shaking. There did not appear to be flexible connections across joints between buildings, and the distribution system could be damaged by differential building movement in these locations. Cable trays are hung from the ceiling and not laterally braced, but this is unlikely to cause significant damage.



Figure 13: Electrical conduits clamped to walls



Figure 14: Trays for electrical cable layout



Figure 15: Hangers for cable trays

Water Supply System

Water storage tanks for untreated water are located on the ground and are anchored by four diagonally placed supports (Figure 16) which will prevent displacement in moderate shaking. However, in higher earthquake shaking and under full storage conditions, the anchors could damage the tanks, as they go up only to about one-third of the height of the tall water tanks (Figure 17). All water pipes, water tanks and equipment installed during the construction of the Emergency (Surgical) Block and the Medical Ward Block buildings have anchorage to prevent sliding, toppling or differential movements during earthquake shaking. A solar-powered water heating system has been installed on both the roofs for supplying hot water to the Nurses' Stations, Patients Cabins, Burn Ward, and ICU. A tower tank with a storage capacity of 100,000L was built, but has not been commissioned; as the automatic cut-off systems in the roof top tanks have not been installed yet. Most of the rooftop water tanks are of fibre and have been anchored by bolts to the roof slab. However, the rigid inlet and outlet pipes may break during earthquake shaking and cause leakages.



Figure 16: Anchored water storage tanks



Figure 17: Anchors reach only to about one third the height of the tanks as shown by the yellow arrow

Fire Suppression System

The fire suppression system installed at the time of construction of the Emergency (Surgical) Block is out of commission. There is no separate water tank for fire-fighting, nor does the hospital have an operational fire-fighting system in place. The alarm panel system has been de-activated due to it being randomly used by curious visitors. There is no external fire hydrant on or near the hospital premises. The nearest Fire Services Unit is located 5km from the hospital. The field team observed a number of fire extinguishers which will presumably be used in case of a fire. None of the staff members the team interviewed had received training for using fire extinguishers, and there have been no fire drills in the recent past. The lack of a proper fire suppression and fire-fighting system and training on fire safety is a major deficiency in the hospital.

Medical Gases

Piped oxygen is provided to the OTs and critical areas such as Neonatal Intensive Care Unit (NICU), Postoperative Intensive Care Unit (PICU), and Surgical Intensive Care Unit (SICU) through a manifold that is fed by 11 cylinders. The cylinders are unrestrained and are connected to the manifold by semi-flexible copper tubing (Figure 18). These cylinders are expected to topple during earthquake shaking and disconnect from the manifolds (Figure 19 left). The oxygen cylinders have the provision for additional restraints, however these have not been put in place (Figure 19 right). The hospital stores 90 to 100 cylinders of oxygen, each with 680L capacity, in various places. The cylinders stored within the oxygen supply room are accessible, and the cylinders and related equipment are well protected in exclusive storage areas operated by trained personnel. However, oxygen cylinders are not restrained in any of the storage locations in the hospital, and in many locations these cylinders will fall down in earthquake shaking and hamper egress (Figure 20). This is discussed in more detail in the section on Egress.



Figure 18: Flexible tubing connecting the cylinders with manifold

In addition to the reserve of 90-100 cylinders, the hospital procures 35 cylinders daily. This three-day-plus supply is significantly less than the PAHO-recommended 15 day supply for medical oxygen. However, the hospital may be able to readily obtain additional medical gas supplies, since the supply outlet is located within Kathmandu. However, the hospital's emergency plan should account for the possibility that the supplier's facilities may be damaged, and that roads between the hospital and the supplier may be blocked with debris from collapsed buildings. (Assessment of the medical gas supplier's facility was outside the scope of this assessment.)



Figure 19: Oxygen manifold with unrestrained oxygen cylinders (left); provision for restraining the oxygen cylinders not put to use (right).



Figure 20: Oxygen cylinders stored in circulation areas (left) and at the lift lobby in the top floor of the Emergency Block (right)

Communication Systems

The hospital currently uses landline and mobile phones as the major communication systems. There are eleven lines to the telephone exchange. The internet networking through Local Area Network (LAN) is extended to all departments, with wireless connectivity in doctors' rooms. Internet and telephone lines are neatly laid out and fixed to the walls. However, neither landline nor mobile phone systems are likely to be functional in the aftermath of a significant earthquake affecting Kathmandu Valley. As numerous past earthquakes have shown, phone systems often become overloaded with calls and go down even if damage is limited. In more damaging earthquakes, phone system equipment, such as mobile phone transmission towers and landline central switching stations, can be damaged. While the length of the outage depends on vulnerabilities in Kathmandu's landline and mobile phone systems (which are outside the scope of this assessment), the hospital should assume neither will be available for several days or more following a major earthquake.

There is no radio or satellite communication system available, leaving the hospital with no backup communications system.

Wastewater System

The evaluation team observed that wastewater pipes have solid vertical supports via hangers from the slab, but are not laterally braced (Figure 21). Waste piping typically uses weak and flexible connections between sections of piping and is vulnerable to damage. During shaking, these pipes could swing, become damaged and leak, creating infection control problems.



Figure 21: Wastewater pipes not laterally braced

Heating, Ventilation and Air Conditioning Systems

While the hospital does not have a central HVAC system or boilers, the buildings do have numerous small air conditioning units. A number of these units are placed unanchored on narrow exterior façade ledges or steel cages; these can fall during strong shaking and kill or injure those below (Figure 22 shows a typical support arrangement). The OTs have a central air conditioning system, with heating and cooling of 15T capacity. The ICUs have split air conditioning units with heating and cooling functions.



Figure 22: AC unit showing typical supports from which units can easily topple

Lifts and Vertical Transportation

The hospital has three lifts: two in the Medical Ward Block and one in the Emergency (Surgical) Block, none of which are operational during generator power supply. The lift in the Emergency (Surgical) Block is equipped with an earthquake sensor; shaking will cause it to stop automatically at the nearest floor and open. This lift is likely to have been designed for seismic forces, but this would need to be verified through a detailed investigation and calculations. The seismic shut-off switch may render the lift inoperable until a trained life mechanic is available, possibly days or weeks.

The evaluation team assumes that the lifts in the Medical Ward Block were not designed for earthquake forces, because the building was constructed prior to development of the Nepal National Building Code. The lift rails and counterweights are likely to be vulnerable to earthquake damage. During strong shaking, the counterweights can derail and potentially crash through the top of the lift car. It should be noted that lift machinery is located at the top of buildings, where shaking tends to be strongest, and where the building will amplify earthquake motions.

Medical Equipment and Contents

The field team conducted a visual survey of the medical equipment and contents in some critical areas of the hospital that will play an important role in providing diagnostic and treatment facilities after an earthquake, listed in Table 2.

Table 2: Areas Assessed for Seismic Vulnerabilities of Medical Equipment and Contents

	Block	Department
1.	Emergency/Surgical Block	Emergency OPD Medical Diagnostics Post operative Ward Pathology Blood Bank Post operative ICU (PICU) Neonatal ICU (NICU) Surgical Ward Surgical ICU (SICU) OT (Operation Theatres) ICU (Intensive Care Unit) CSSD (Central Sterile Supplies Department)
2.	Medical Ward Block & Administration Block	Medical Wards Special Cabins General Store Burn Ward Paid Ward Nutrition Clinic Physiotherapy Medical Records
3.	Annex Ward	Out Patient Departments (OPDs)

Medical equipment and storage systems in the Emergency (Surgical) Block, designed and constructed with JICA support and to Japanese codes and standards, are secured or anchored for protection against earthquake shaking. The X-ray imaging equipment is fixed to the roof (Figure 23: X-Ray equipment attached to the roof) and rails are embedded in the floor and walls (Figure 24). However, the control equipment is freestanding and could topple and be damaged in earthquake shaking (Figure 25 left). Some of the imaging equipment such as the Ultrasonography (USG) machine are on rollers, and if these are not kept locked in position they could roll during an earthquake and lose functionality for post-earthquake diagnostic use (Figure 25 right).



Figure 23: X-Ray equipment attached to the roof



Figure 24: Bolted floor rails and anchored upper rails for sliding imaging equipment



Figure 25: Ancillary equipment that could topple or slide(left) and equipment on rollers (right)

In the Operation Theatres, lamps, anesthesia equipment and surgical tables are in good condition, and operational (Figure 26, left). It was reported that the OT lights are firmly secured to the roof slabs, but the appropriateness and depth of the anchor bolts for the long extended arms needs to be ascertained to ensure stability of this critical equipment (Figure 26, right). Ancillary equipment in the OT is not secured and may topple or slide in earthquake shaking (Figure 27 left). Heavy stainless steel storage cupboards with glass fronts are placed next to walls but not secured to them. Several items are stored on top of these cupboards and these would easily slide off in moderate earthquake shaking (Figure 27 right).



Figure 26: Operation Theatre (left) and anchoring of OT lights (right)



Figure 27: Equipment on rollers in OT (left); partial height infill wall with storage units lined against it (right)

Oxygen cylinders either free standing or on trolleys, are located in the wards and in the intensive care units, near bedsides and exits. They could fall or topple and block exits or cause leakages and injuries (Figure 28). Storage of unrestrained oxygen cylinders in several locations near the OTs and other critical areas of the hospital poses a serious threat, as toppling of these cylinders would likely block exits and impede evacuation and egress of the critically ill (Figure 29).



Figure 28: Unrestrained oxygen cylinders in ICU (left) and cylinders in wheeled carriers not fastened with the bed in Emergency Block (right)



Figure 29: Unrestrained cylinders blocking egress in OT and Burn Ward

The Central Sterile Supplies Department (CSSD), where all instruments and equipment are sterilized and stored, is a critical facility for any hospital. The Kanti Children's Hospital uses two large autoclaves (Figure 30) and three mini autoclaves for sterilization of equipment. The main autoclaves in the CSSD have been encased and bolted to the ground to prevent lateral movement in earthquake shaking. The connecting water pipes have vertical supports but no lateral bracing for seismic forces (Figure 31). The pipes do not have flexible connectors and could break during strong shaking if the vertical supports permit significant lateral movement, but a detailed evaluation (outside the scope of this assessment) would be necessary to determine the likelihood of pipe breakage. If they occurred, pipe breaks would cause water leaks and disrupt the functioning of the CSSD (Figure 32).

The sterilized equipment, cloths, gloves, and other materials are sorted and dispatched to various departments in a large room within the CSSD. This room has a few racks and cupboards that could topple in earthquake shaking (Figure 33). The CSSD has a suspended ceiling which conceals the air-conditioning ducts and lighting lines. The three mini autoclaves are placed on counter tops with no restraining elements; these could slide and fall in lateral shaking. The entry to the CSSD and the windows has glass panels that could break and impede egress.



Figure 30: Autoclaves

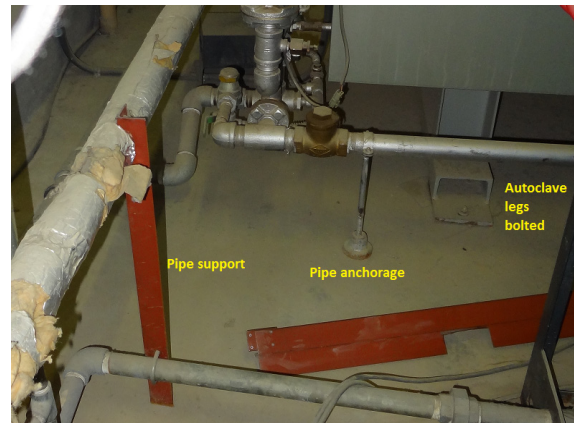


Figure 31: Water supply pipe supports in CSSD



Figure 32: Lack of flexibility in the supply pipes



Figure 33: Central sorting and dispatch room with unrestrained shelves

Good Practices

There are several examples of good practices in a number of areas in the hospital. These include built-in storage with sliding glass doors that will not topple or slide, and that will not cause spillage or damage to contents (Figure 34 left). The glass windows have a layer of protective metal mesh panelling to prevent the glass from shattering and falling inside (Figure 34 right). The shelving system in the Diagnostic Laboratory has an additional vertical support from the roof and restraining bars on the front of the shelves to prevent toppling of shelves and spillage of contents (Figure 35). The rails for curtains in the wards are well connected with the framework of the suspended ceiling through vertical and diagonal ties (Figure 36).



Figure 34: Inbuilt storage (left) and wire mesh panels to prevent falling hazards due to shattering of glass (right)



Figure 35: Post anchoring shelving to ceiling (left) Shelf restraints (right)



Figure 36: Diagonal bracing members in the curtain rail in wards

Architectural Shell and Egress

The architectural shell of the Emergency (Surgical) Block— built as per Japanese code provisions —is expected to experience little damage in moderate earthquake shaking. However, the central courtyard near the reception area has a sun roof which could be damaged and result in broken glass in the entrance hall courtyard, an area used by patients' parents for resting, drying clothes and other such activities (Figure 37, left). The suspended ceilings are connected with the slab through vertical anchors (Figure 37, right)). However, there is no lateral bracing against earthquake forces. While the ceilings might swing and become damaged, this type of suspended ceiling is relatively less vulnerable than some other types. Any large areas of suspended ceiling should be investigated in further detail, as these are more prone to earthquake damage.



Figure 37: Sun roof over central atrium (left); Suspended ceiling hung from roof slab but not laterally braced (right)

In the Medical Ward Block, the masonry infill walls are not attached to the frame and could crack and fall during strong earthquake shaking. Many partition walls are also made of unreinforced masonry and could be similarly affected. Falling masonry is a threat to those nearby and affects the ability of medical staff to work in disrupted areas. Some exterior walls of the Medical Ward Block have large glass panels, especially at the staircase adjoining the open courtyard (Figure 38).



Figure 38: Large glass panels on Medical Ward Block possibly susceptible to breakage from building sidesway

The main egresses from the Emergency (Surgical) Block are wide, but later additions have restricted the spaces available for people to exit. One such area is beside the recently-added play area, where a large corridor exits to the narrower space beside the play area fence. The fence is bolted to the ground, but it could still be dislodged and block the exit space. Old radiographic equipment has been placed in the corridors outside the radiography department in the Emergency (Surgical) Block. These could be displaced in any earthquake shaking and can block the exits for patients and staff from the department. Many cupboards, lockers etc. are placed adjoining doors and will block or hinder

smooth exit when toppled by earthquake shaking. The reserve oxygen cylinders stored outside several wards and in corridors are all unrestrained, and will fall and cause rolling hazards and block exits during earthquake shaking.

The Annex Ward, built in 2007, was constructed next to the old Medical Ward Block. Due to an oversight, there is no access to the courtyard between the Annex and the older building (Figure 39). As a result, this courtyard has become a dumping area, overgrown with tree-size weeds and overflowing wastewater pipes. The lack of access means that this courtyard cannot be maintained on a regular basis and is also a breeding ground for mosquitoes, a highly undesirable condition in the country's only referral hospital for children (Figure 40). Access to this courtyard should be immediately ensured, at the cost of one or two rooms, so that the courtyard can be converted into a positive outdoor space like other such enclosed courtyards in the hospital.

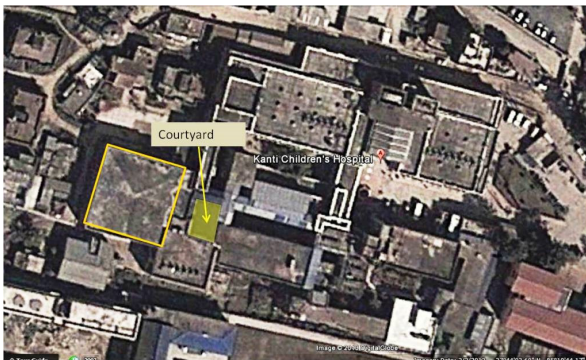


Figure 39: Internal courtyard with no access at ground level



Figure 40: Internal courtyard without access at ground level and no maintenance

Recommendations and Conclusions

The Emergency (Surgical) Block of the Hospital has been constructed following earthquake-resistant norms and contents and systems have some protective measures. As a result, the building may be usable after moderate earthquake shaking, if critical utilities such as electrical power, water and medical gas are available (which they may not be, due to seismic vulnerabilities in these systems).

By contrast, the Medical Ward Block which houses most of the wards, likely lacks earthquake-resistant provisions in design and construction. This building was constructed by the Government of Nepal in the 1970s and likely does not have the earthquake resistant features required by modern building codes. The possibility of severe structural damage to the Medical Ward Block presents the greatest threat to the safety of the hospital staff and patients. For this reason, conducting a detailed assessment of the earthquake vulnerabilities of the hospital's buildings, as is occurring during the second and later phases of the current project, must take the highest priority. In addition, the Medical Ward Block may not be functionally suited to delivering modern medical care. GHI recommended that the hospital consider moving critical services, such as the Burn Ward, to other, more earthquake resistant buildings such as the Emergency block. The Medical Ward Block has numerous seismic vulnerabilities in its utility systems, equipment, architectural shell and contents,

which should be addressed as part of a larger effort to improve the seismic performance and functionality of this important hospital.

Experiences in major, ongoing hospital seismic safety improvement programs in Turkey and California demonstrate that there are a number of serious and significant issues involved when seismically retrofitting hospitals. These include disruption to existing operations if hospital buildings cannot be vacated; increased construction time and cost to manage the disruption; cost to construct the extensive structural retrofit measures often needed in older buildings to provide the high level of seismic performance desired for hospitals; cost to anchor and brace utilities and the architectural shell, to prevent damage that would induce shutdown of critical services areas; cost to repair building elements in poor or deteriorated condition; and the fact that for all the effort, medical staff are still using a building that may not suit their care delivery needs. As a result, a number of hospital buildings in Turkey and California have been replaced with new buildings designed for high seismic performance and modern medical care delivery, rather than being retrofitted. Replacement may well be a preferable option for some Nepal hospital buildings as well.

The recommendations in this section must be integrated into decisions to replace or seismically retrofit seismically vulnerable buildings. While GHI recommends that the highest priority recommendations be implemented as soon as possible, without waiting for retrofit or replacement to take place, the remaining recommendations will be most cost effective if performed in conjunction with a seismic retrofit or other construction. If a building is replaced quickly, the remaining recommendations for that building would not need implementing.

The following sections list specific recommendations to address seismic vulnerabilities identified in prior sections, organized by the major utility system and/or element type.

Backup Electrical Power

The Kanti Children's Hospital has a backup power system that automatically starts when the grid supply fails, and has some seismic protection measures in place. However, the backup system still has some significant vulnerabilities, and the distribution system to the older parts of the hospital can be disturbed in an earthquake, as older buildings and their utilities have not been designed for earthquake safety. The fuel storage capacity is not utilized fully, and only a fraction of the 6000L capacity is available at any time on site. GHI recommends that the hospital utilize the tank's currently unused capacity to store enough fuel for the PAHO-recommended five days or the estimated length of time to restore grid power, whichever is longer. Also, since the hospital rarely suffers extended power outages, and the maximum outage has been for 12 hours with an early warning, it is important that the hospital plan for extended runs as may be required in an emergency. The allocation of the Repair and Maintenance Services (RAMS) staff for generator maintenance for extended runs must be incorporated in the preparedness plan for the hospital. While the backup power system is partially seismically protected, GHI recommends that the hospital install seismic protection for the batteries and generator exhaust, and verify, via engineering calculations, the adequacy of existing protection measures for the expected level of shaking.

The GHI team was informed that the hospital is planning to purchase and bring online another generator of 300 to 400kVA capacity. It is imperative that all the precautions taken for anchoring the existing generator and ancillary equipment be carried out for the new generator system as well.

Communications

The hospital should obtain backup communications capability, internally and externally, to enable coordination with other hospitals, government agencies and responders after a major earthquake.

Water Systems

A tower overhead tank, which will provide adequate water backup for the hospital, must be commissioned at the earliest. The roof overhead tanks, though anchored, should be given flexible connections at the water inlet and outlet, to prevent breakage and leakage in any lateral shaking. The new water tanks need to be anchored to the roof slabs (a few are already anchored, others are not), and the adequacy of the anchorage for existing tanks should be verified. Water supply lines crossing building joints should have flexible connections to accommodate differential movements.

Medical Gas

Cylinders in the oxygen bank, in the various wards and in other locations, need restraints to prevent them from toppling during earthquake shaking. Oxygen cylinders stored in corridors and near exits from critical wards are among the most important vulnerabilities noticed in this assessment.

At present the hospital has backup supply of oxygen cylinders to last just over two days of normal use; PAHO recommends a 15-day supply be kept on the premises. Medical gas lines crossing building joints should be provided with flexible connections to accommodate differential movements.

Lifts and Vertical Transportation

The earthquake safety of the lifts (especially the lift in the Medical Ward Block) should be ascertained by a qualified structural engineer, and corrective actions should be taken if found necessary. The electric panel in these two lifts should also be anchored /bolted to prevent damage in any earthquake shaking. Post-earthquake planning should include consideration of returning the lift to normal operations after the earthquake, if the seismic switch disables it.

Medical Equipment, Contents and Furnishings

The hospital needs to make an inventory of the most critical medical equipment and determine whether or not it is adequately anchored/ protected against seismic forces. Most of the equipment in the Medical Ward Block needs to be anchored. For any new equipment, seismic anchorage should be included as part of the purchase contract. The furnishings in the Medical Ward Block, and the later additions in the Emergency (Surgical) Ward, have no anchorage and in many cases have been located in such a manner that these will cause injuries and/or hinder a smooth exit during earthquake shaking. The hospital staff needs to be educated about the damage that displaced equipment can cause due to earthquake shaking, and must understand the intent behind various anchoring measures built into the equipment, contents and furnishing in the Emergency (Surgical) Block.

Architectural Shell and Egress

The structural assessment report of the Medical Ward Block (not included in the scope of this report) may suggest remedial measures for reducing risk due to falling masonry. In the reinforced concrete buildings, single wythe brick partitions that are located in areas where critical care is delivered, or where patients and staff could be struck by falling masonry, could be braced with strong-backs to prevent partition collapse if so determined in the structural assessment report. Exterior glass elements located above hospital entrances and locations where people congregate need to be evaluated to verify that they will remain in place during the expected earthquake shaking. The hospital administration should make a concerted effort to ensure that all egresses are cleared of furniture, oxygen cylinders, out of use machinery, and other extraneous debris.

Recommended Priorities for Implementing Mitigation Measures

The table below shows recommended priorities to help guide implementation efforts.

Table 3: Recommended Priority Levels for Specific Mitigation Measures

Priority Level	Specific Mitigation Measures
Highest (Critical safety)	<ul style="list-style-type: none"> • Commission the tower water tank, to ensure that the hospital has adequate back up of water supply at any point of time • Purchase and commission the new 300-400kVA generator as planned, to ensure that backup power supply is not dependent on one generator • Complete seismic protection measures for the existing generator system • Utilize additional capacity of the underground fuel storage tank, to ensure adequate fuel supply for running the generator for longer periods of main grid failure • Repair the existing fire suppression system and ensure adequate fire safety training to staff • Provide backup communications capacity • Create 'parking' spaces for storing oxygen cylinders in various wards, to enable storage and prevent cylinders from toppling and hampering exits • Verify via calculations that seismic protection of critical systems is adequate
High (Critical care delivery)	<ul style="list-style-type: none"> • Seismically protect water system components • Install flexible connectors and shutoff valves on tanks, to prevent a pipe break from draining the system • Anchor rooftop tanks that are not anchored already • Install flexible connectors on all tanks • Assess the potential for shaking or liquefaction damage to the bore holes, submersible pump and pipe connections in the water supply • Anchor free-standing equipment, cupboards, racks etc. in critical areas, to secure items that might fall, slide or topple and impede exits in earthquake shaking. Train staff members to anchor falling hazards. • Restrain brick partitions with strongbacks in critical care areas, or replace with

	<p>lightweight partitions, especially in the Medical Ward Block</p> <ul style="list-style-type: none"> • Install shelf restraints in CSSD, in key storage serving critical care areas, and in medical records to reduce cleanup required post-earthquake • Brace or remove exterior falling hazards including glass above areas where people congregate. • Anchor the mini autoclaves • Ensure maintenance/ refilling of fire extinguishers. Train staff members in the use of emergency firefighting equipment
Medium	<ul style="list-style-type: none"> • Restrain brick partitions near patient beds in wards, or replace with lightweight partitions • Relocate or anchor remaining large and heavy furnishings in work or patient areas • Install flexible connectors on water and medical gas pipes
Lower	<ul style="list-style-type: none"> • Restrain remaining brick partitions • Secure remaining medical equipment

Conclusions

Kanti Children's Hospital has at least one important block designed to Japanese earthquake resistant codes—a significant positive feature of this hospital. Many of the utility systems, equipment, architectural shell and contents in this block have been at least partially seismically protected. However, the utility systems, equipment, architectural shell and contents in the two other blocks will need remedial measures for earthquake vulnerability reduction.

Preparedness training for hospital staff is an integral part of mitigation planning. Mitigation and preparedness measures necessary to help keep the hospital functional will need to be integrated with the overall seismic safety improvement plan, then planned and spread out over a number of years. The hospital will then be much better prepared to serve the community in the event of an earthquake. Because Kanti Children's Hospital is the only central referral facility for children in the Kathmandu Valley, these measures are of critical importance to help keep the hospital functioning after a damaging earthquake.