DEVELOPMENT OF DESIGN STRATEGIES TO SUPPORT EVACUATION PROCESS OF HOSPITAL BUILDINGS IN UNITED STATES

A Thesis

by

SHARMIN KADER

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2008

Major Subject: Construction Management

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Approved by:

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	Sarel Lavy
Committee Members,	George Mann
	Sherry Bame
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ABSTRACT

Development of Design Strategies to Support Evacuation Process of

Hospital Buildings in United States.

(December 2008)

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Co-Chairs of Advisory Committee: Dr. Ifte Choudhury
Dr. Sarel Lavy

The complete evacuation of hospital facilities is always a difficult and complex process. It has always been considered a last resort during any kind of threat. In recent years, the increasing number of manmade and natural disasters has generated a considerable interest in hospital evacuation issues, but very few studies have addressed this problem.

The purpose of this study is to develop design strategies for hospital facilities to support the complete evacuation process. The following three objectives are considered for fulfilling the requirements of the study: (a) identify the disaster threats for hospital buildings that drive the need for complete evacuation, (b) develop an understanding of the consequences and complexities of hospital evacuation, and (c) form the design strategies based on threat analysis, case-studies and experts' reviews.

For interpretation purposes, this study use the qualitative research with case-based reasoning approach to collect, summarize, and evaluate the recorded data. The study is only focused on design considerations of some specific parameters for hospital building evacuation design. This study provides a comprehensive assessment of best-suited design strategies that could be adopted by healthcare architects or planners in order to develop their designs in ways that improve the hospital building evacuation process.

DEDICATION

To my parents

Dr. Sk. Abdul Kader
Mrs. Hosneara Begum

and

my husband

Mohammad Ismat Amin

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I would like to express my gratitude to all those who made completing this thesis possible. I would like to express my gratitude to my co-chair Dr. Ifte Choudhury for his continuous support throughout my Texas A&M graduate study. I would like to give my heartiest thank to my co-chair Dr. Sarel Lavy, for his continuous support, guidance and criticism throughout the course of this research and giving me the opportunity to work with him. I would also like to thank Dr. Sherry Bame and Prof. George Mann, members of my committee, for their continuous help to develop my understanding about healthcare system and design.

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NOMENCLATURE

ADA	Americans with Disabilities Act
AIA	Americans Institute of Architects
CBPP	Center for Bioterrorism Preparedness Planning
CBR	Case-Based Reasoning
DHS	Department of Homeland Security
DSHS	Department of State Health Services
EAA	Emergency Assembly Area
EER	Evacuation Exit Route
EOS	Emergency Operation System
FEMA	Federal Emergency Management Agency
FSES	Fire-Safety Evaluation System
GDEM	Governor's Division of Emergency Management
ICU	Intensive Care Unit
IN	Indiana
IRB	Institutional Review Board
JCAHO	Joint Commission on Accreditation of Healthcare Organizations
NFPA	National Fire Protection Association
NYCTP	New York Center for Terrorism Preparedness and Planning
OSHA	Occupational Safety and Health Administration
SA	Site Access

TDSHS	Texas Department of State Health Services
UFAS	Uniform Federal Accessibility Standards
US	United States
VT	Vertical Transportation
ZF	Zoning of Function

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1. INTRODUCTION

1.1. Background

According to the Department of Homeland Security (DHS, 2008), emergency planning and preparedness for any kind of disaster is a key issue for the United States (US). During the early 20th century, hurricanes and floods were the major threats for the US, but in recent years a serious consideration has also been given to terrorist incidents and hazardous material spills (Taaffe et al., 2005). In general, a hospital is a place of immediate care for a large number of people during emergencies (FEMA, 2007). But sometimes hospitals themselves can be victims of disaster, which may necessitate the patients' evacuation from the facilities. A hospitals complete evacuation requires special considerations because a significant percentage of patients in hospitals are incapable of self-evacuation; they may be medically unstable and dependent on mechanical support equipment (Taaffe et al., 2005; NYCTP, 2006).

According to the National Fire Protection Association (NFPA, 2006), the Life Safety Code for Healthcare Occupancies considers complete evacuation as the last consideration of healthcare facilities because of the nature of the occupants. All hospitals should be developed with a "defend-in-place" principle to avoid the patients' vertical or complete evacuation. However, after the experience of the 9/11 terror attack, Hurricanes Katrina and Rita, the California wild fires and some other events, the concept of

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This thesis follows the style of *Journal of Construction Education.*

"hospital as a victim" is increasing day by day, and the issue of hospital evacuation is generating considerable interest.

Hospital evacuation is always a difficult and complex process, but the challenges that a hospital faces during evacuating their patients are still not focused (Taaffe et al., 2005). The complexities for patients' evacuation are not only a part of planning and preparedness, but also depend on hospital building design criteria. Hospital building design considerations should include all the necessary strategies to make the process smoother and easier. A few formal studies have addresses this issue, but more research and study is required to find out the suitable design approach for this issue. This research will focus on the constraints and complexities of the evacuation procedure and will also attempt to find out the possible design strategies for a successful hospital evacuation.

1.2. Problem Statement

The purpose of this research is to develop suitable design strategies for hospital buildings in the United States to support the evacuation process.

1.3. Sub Problems

a) To identify the disaster threats for hospital buildings those drive the need for evacuating patients.

The background behind this is to identify the possible disaster threats for hospital buildings that can necessitate a complete evacuation. The study considers detailed analysis about disaster threats to have a better understanding about their patterns and frequency. Also, the study has identifies the evacuation methods according to disaster threats.

b) To develop a better understanding about the consequences and complexities of hospital evacuation from which design strategies can be developed.

The research focuses on studying constraints and complexities of evacuation procedure due to different kinds of threats and finding out the suitable considerations for the consequences.

c) To form the design strategies based on the threat analysis, case-studies and experts' reviews.

The study focuses on some specific parameters: evacuation exit route, site access, vertical transportation, emergency assembly area, emergency operation system, and zoning of function.

1.4. Definitions

Evacuation: Organized, phased, and supervised withdrawal, dispersal, or removal of civilians from dangerous or potentially dangerous areas, and their reception and care in safe areas (NYCTP, 2006).

Evacuation Plan: The Evacuation Plan is designed to transfer patients from a unit, a wing or the facility in the event of a disaster (NYCTP, 2006).

1.5. Delimitations

- The strategies are focused on architectural design, not the structural or MEP design.
- Strategies are developed without considering the construction or maintenance cost.
- Only natural and manmade (terrorism) disaster threats are considered, not the personal crime or operational fault.
- The study is focused only on patients' evacuation and does not consider the evacuation of non-patient areas such as a pharmacy.
- The design strategies are focused only on specific parameters.
- The study does not consider patients' clinical illnesses.

1.6. Research Parameters

The following parameters have been considered in this study:

a) Evacuation Exit Route (EER)

b) Site Access (SA)

c) Vertical Transportation (VT)

d) Emergency Assembly Area (EAA)

e) Emergency Operation System (EOS)

f) Zoning of Function (ZF)

2. LITERATURE REVIEW

The literature survey has been done in two phases. The first phase focused on developing a better understanding of a hospital building evacuation system and design, and the second phase looked at analyzing the threats and case studies.

The first and second phases have been discussed with data collection methodology. A comprehensive literature review has been done to develop a better understanding about the hospital building evacuation process and to establish the significance of the study. The study has considered the relevant research, as well as the codes and standards and the rules and regulations of hospital building evacuation design and process. The study has also considered the functional purpose and requirements of research parameters for the evacuation process.

2.1 Relevant Research

The review of existing literature reveals that in the context of hospital evacuation, researchers have mostly focused on emergency planning and preparedness of hospital evacuation (Pollak, 2004; Talebi et. al, 1985 and Jaffari, 2005). Some have addressed the decision-making problems of evacuation (Tufekci, 1995; Iakovou, et. al, 2001; Sorensen, et. al, 2004 and Schultz, 2007) and a few researchers have concentrated on an evacuation model and simulation drill (Gildea, et. al, 2005; Taaffe, et. al, 2006; Taaffe, et. al, 2007; Gretenkort, et. al, 2002 and Kaji, et. al, 2007). Additionally, one researcher addressed the benchmarking of a hospital data collection tool (Schultz, et. al, 2005), another addressed the counting crisis of hospital evacuation (Sternberg, et. al, 2004), and several others addressed the lessons learned from evacuation experiences (Perrin, 2006; Distefano et al, 2006; Hamm, 2006; Lopez, 2006; Augustine, et. al, 2005; Schultz, et. al, 2003; Cocanour et al, 2002; Joseph, 2004 and Biumhagen, 1987). Only one addressed the issues and complexities of hospital evacuation (Taffee et al, 2005). There is no study found on the design strategies of hospital evacuation.

Most of the research addressed the issues related to hospital evacuation planning and operation, which are not considered in this study scope. Only those studies that have relevancy with this study's research objectives are discussed below.

A study by Taaffe, Kohl, and Kimbler (2005) has well described the 'issues and complexities' of hospital evacuation to construct appropriate models for emergency preparedness and evacuation. According to them the most important issues for hospital evacuation are as follows:

a) Nature of Threats: Evacuation process depends on the threat's severity, urgency of evacuation required, and ability to function during the evacuation. Among them, the evacuation warning time is the most important factor. For example, hurricanes and floods present threats that may allow some time for evacuation, but tsunamis allowing less time and earthquakes, tornados, and building fires almost none at all.

b) Risk to Patients and Staff: Several risk factors for patients and staff:

- Risk due to threats, such as hazardous materials varies widely depending on the material.

- Risk level vary with patients acuity, such as, ICU patients may have severe condition for evacuation, tend to be shelter-in-place.
- Staff injury and fatigue due to patients' transfer during disaster.

c) **Threat Probabilities and Timing:** Evacuation timing depends on threat probabilities. The amount of notice before evacuation is an important factor in the evacuation's success. Also some threats continue to grow, so during evacuation the patients' may become target by the threat. Such as, during hurricane Katrina, the New Orleans people took shelter some places, which also became affected by hurricane Rita.

d) **Continuing Care:** Hospital should provide continuous care for patients', whom they cannot discharge during evacuation. But to provide continuous care outside the hospital building, requires resources, such as, emergency supplies, medical professionals, equipments, medicines, etc. In some cases the continuing care may required at certain limit, but in others it may span full range of patient acuity.

e) **Resource Demand:** Evacuation requires resources, such as, lots of people to transfer critically ill patients, transportation, medical professionals, emergency supplies. But hospital does not possess these amounts of resources for routine operations. So, during evacuation the crisis of resources is an important issue.

The discussion of this study is very organized and supportive to be aware of the present situation. All the issues are very important considerations for designing. The factors need to identify are as follows:

- Threats, its frequency, urgency, and evacuation pattern.

- Evacuation mode according to threats.
- Resources require for evacuation process and continuing care.
- Factors that increase patients and staff risk.

A research study by Gretenkort, Harke and Blazejak, Pache and Leledakis (2002) focused on the practical methods of immobile patients' evacuation. The study planned and performed a hospital evacuation exercise to get experiences and to calculate the transport times of elevator independent patient. The effectiveness and efficiency of carrying teams with five persons each were compared to those with a rescue drag sheet employed by a single person. The study found that incident leadership of the fire authorities can be supported effectively by hospital pre-defined and trained executives in the management of mass casualties and for elevator-independent patient transport, the rescue drag sheet was superior to conventional carrying measures because of a reduced number of transport personnel required to move each patient. With this method, patient transport times averaged 54 m/min. flat and 18 seconds for one floor descent. The study provides two significant information; hospital staff and fire fighter both can work together and the evacuation travel time with a specific method. For the designing of evacuation system the calculation of evacuation travel time is very important.

Gildea and Etengoff (2005) had studied a vertical evacuation of critically ill patients in a Hospital by simulation. The research conducted vertical evacuation of 12 simulated critically ill patients from the fourth floor of a newly constructed and vacant critical care unit by local fire fighters, on-staff nursing, residents, and ancillary staff, all under the direction of the hospital Emergency Management Committee. The study result shows that a four firefighter extraction team and accompanying nurse and respiratory therapist would be able to evacuate one patient at a rate of 3.75 minutes per floor. For the designing of evacuation system the calculation of evacuation travel time is very important. The outcomes of these above research can be used to calculate the evacuation duration of a hospital building during planning and designing.

Schultz, Koenig and Heide (2005) developed a standardized data collection tool to record hospital evacuation information in a systematic manner so that comparable data can be accumulated, evacuation research methods can be improved, and consensus on methods can be reached. The study's principal subjects include: (1) hospital demographics; (2) description of existing disaster response plans; (3) an event's impacts on hospital operations; (4) decision-making and incident command; (5) movement of patients within the facility; (6) movement of patients to off-site institutions; and (7) hospital recovery. This data collection tool provides information to develop better understanding for case analysis with previous evacuation experience.

2.2 Relevant Codes and Standards

'Hospitals are among the most regulated of all building types' (WBDG, 2008). As Hospitals provides healthcare, they must meet the federal standards to be accredited, as well as the local and/or state general building codes to become licensed.

- **Federal**

The Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) and the federal government refer to the National Fire Protection Association

(NFPA) model fire codes, including Standards for Health Care Facilities (NFPA, 2005) and the Life Safety Code (NFPA, 2006) for hospitals. Hospital design must comply with the Americans with Disabilities Act (ADA) for its general and specific accessibility requirements. The Uniform Federal Accessibility Standards (UFAS) apply to federal and federally-funded facilities, not greatly different from ADA requirements. Hospital design must follow the regulations of the Occupational Safety and Health Administration (OSHA) particularly in laboratory areas (WBDG, 2008).

- **Local and/or state**

The hospital design must comply with the individual state licensing regulations to be licensed by the state. Many states adopt the *AIA Guidelines for Design and Construction of Hospitals and Health Care Facilities* (WBDG, 2008).

2.2.1 Codes and Standards for Hospital Evacuation Design

Evacuation of any building is a part of Building Fire Protection System. The *AIA Guidelines for Design and Construction of Hospitals and Health Care Facilities* and JCAHO referred the hospital fire safety to NFPA-101standards. So, the Hospital Building Evacuation Code and Standard basically depends on the National Fire Protection Association NFPA-101, Life safety code for Healthcare Occupancies.

a) Hospital Building Evacuation Design Standards by AIA

The *AIA Guidelines* mentioned about ‘Fire prevention/protection measures’ in Chapter-1.1-7 under Construction Requirements. Compartmentation, exits, fire alarms, automatic extinguishing systems, and other fire prevention and fire protection measures, including those within existing facilities, shall comply with NFPA *101*, with the following stipulation. The Fire-Safety Evaluation System (FSES) is permitted in new construction and renovation projects (AIA-2006).

b) Hospital Building Evacuation Design Standards by NFPA-*101*

Full building evacuation is the last resort for hospital facilities. A significant percentage of occupants in hospitals and nursing homes are incapable of self-evacuation or are ambulatory but incapable of perceiving a fire threat and choosing a rational response. Therefore, fire protection is based on a **"**defend-in-place**"** principle and cannot depend on any one safeguard. Depends on the disaster threat hospital evacuation planning should consider the following steps one after another (NFPA *101*, 2006).

- 1st – Defend-in-place,
- 2nd – Horizontal Evacuation, and
- 3rd – Vertical Evacuation.

The rules and standards of evacuation exit route will be discussed with research parameters on Section 2.2.

c) State Guidelines for Hospital Evacuation Protocol

In US many states have their own guidelines for hospital evacuation protocol, such as, New York State. The *Hospital Evacuation Protocol* for New York State has developed by the Center for Bioterrorism Preparedness Planning (CBPP) and the New York Center for Terrorism Preparedness and Planning (NYCTP), to provide a plan of action during a response to an emergency where partial or full patient evacuation may be required, to New York City Hospital personnel. It outlines responsibilities of individuals and departments, prioritizes evacuation requirements and conceptually establishes how the evacuation should take place (NYCTP, 2006). This type of evacuation protocol can be a good example for other state hospitals to follow.

2.2.2 Rules and Regulations for Hospital Evacuation

a) JCAHO's Rules for Hospital Evacuation

The Standards of the Joint Commission on Accreditation of Healthcare Organizations in the United States require that hospitals have a plan to evacuate their facilities as part of overall emergency management strategy (JCAHO, 2005).

b) State Rules and Regulations for Evacuation Preparedness and Planning

Different States have different rules and regulations for disaster preparedness and planning. After 9/11, the State of New York has developed lots of rules and regulations on disaster protection and preparedness (NYSDOH, 2005). Also the State of Texas has developed some rules and regulations after hurricane Katrina and Rita (TDSHS, 2006). As an example the state rules and regulation of the State of Texas are discussed below;

- **Texas**

The Texas Department of State Health Services (TDSHS, 2006) published a letter to the Texas Hospital Administrator on September 15, 2006. As the hurricanes Katrina and Rita have changed the face of disaster planning/management in Texas, the letter mentions about three significant projects at the state level, which have an impact on hospital facility. These projects include:

i. Development of a state Hurricane Evacuation and Mass Care Plan by the Governor's Division of Emergency Management (GDEM),

ii. Drafting of rules related to All-Hazards Disaster Planning for licensed hospitals by the Department of State Health Services (DSHS), and

iii. Surveying of coastal hospitals regarding the status of their disaster and evacuation planning.

From the above statement of the TDSHS (2006) it is clear that every hospital should have the disaster management planning and also the preparedness for evacuation.

According to the *Hurricane Evacuation and Mass Care Plan* by the State of Texas (2006), the following regulations for evacuation published:

i. "Evacuees from specialized care facilities such as hospitals have the legal responsibility to evacuate individuals in their care to equivalent care facilities inland. Evacuating special needs facilities must bring specialized equipment, staffing, and caregivers. Evacuating caregivers may bring their families with them." (4-IV-G-1-b).

ii. "All medical facilities, hospitals, nursing homes, assisted living centers, state schools, state mental health facilities, will have in place plans and means to transport and care for persons in their facilities during an evacuation event." (Medical special needs-III-B-2).

iii. "Medical Special Needs Sheltering-Level 5 will be a facility-to-facility transfer (i.e. hospital to hospital, long term care to long term care, assisted living to assisted living, etc)." (Medical special needs-IV-B-2-d).

iv. “Transportation of Medical Special Needs evacuees: ground or air ambulance, mass transit or accessible buses” (Medical special needs-IV-B-3-e).

From the above study, evacuation design guidelines by NFPA *101* show that horizontal evacuation should be considered during hospital design. The complete evacuation is the last resort. So, the current hospital designs are mainly considering the standards for the horizontal evacuation by NFPA *101*. But, according to JCAHO (2005) the complete evacuation planning for a hospital is mandatory requirement for all US hospitals. The planning and preparedness for complete evacuation are also compulsory by some States.

As a result, all the licensed hospitals in US have planning for complete evacuation, though the building systems did not design with this consideration. So, it is difficult to incorporate the complete evacuation with the buildings; such as, evacuation of ICU patients from 20th floor of a hospital building during fire hazard.

2.2 Functions and Requirements of Research Parameters

The functional purpose and requirements of research parameters for evacuation process are discussed below:

a) Evacuation Exit Route

Function: ‘An exit route is a continuous and unobstructed path of exit travel from any point within a workplace to a place of safety’ (OSHA, 2008). For any kind of evacuation the exit route is the primary consideration. An exit route consists of three parts; exit access, exit and exit discharge (NFPA *101*, 2006, AIA, 2006 and JCAHO, 2008).

Requirements: The exit access routes should be protected against fire effects. Also the exit routes should not be obstructed by any kind of furnishings, decorations, and other objects. Also As a significant percentage of occupants in hospitals are incapable of self-evacuation, vertical evacuation is difficult and time consuming. So that horizontal movement of patients is of primary importance in healthcare facilities (NFPA *101*, 2006).

Horizontal Exits: Hospital should have at least two smoke free areas on each floor for horizontal exit. Each floor should have compartmentations for horizontal evacuation using fire resistance separation for 2 hours and 1 hour respectively. 'Exit capacity for healthcare facilities was set conservatively to offset slow travel rates and to create space within exit enclosures for "storing" patients on litters and in wheelchairs' (NFPA *101*, 2006).

Compartmentation: The size of compartment area depends on two limitations; related to area and travel distance from any point to a door in a smoke barrier (NFPA *101*, 2006).

- The area of smoke compartment cannot exceed 22,500 sq ft (2100 m2).
- The travel distance from any part of a smoke compartment to the door in a smoke barrier cannot exceed 200 ft (60 m).

Vertical Exits: Vertical exits used to evacuate patients to another part of the building or outside the building. Usually patients are vertically evacuated using stairs, elevators or ramp. The fire resistance criteria for vertical openings are as follows (NFPA *101*, 2006):

- Minimum 1-hr fire resistance rating should be provided for vertical openings not connecting more than three floors.
- 2-hour fire resistance ratings should be provided for vertical openings connecting more than three floors.

Exit Discharge: ‘Exit discharge is a part of the exit route that leads directly outside or to a street, walkway, refuge area, public way, or open space with access to the outside’ (OSHA, 2008). Each exit discharge in healthcare facilities should be limited to doors leading directly outside of the building, interior stairs and smoke proof enclosures, ramps, horizontal exits, outside stairs, and exit passageways (NFPA *101*, 2006).

Number of Exits: It depends on the number of employees, the size of the building, its occupancy, or the arrangement of the workplace is such that all employees would not be able to evacuate safely during an emergency (NFPA *101*, 2006, AIA, 2006, OSHA, 2008, and JCAHO, 2008).

b) Site Access

Function: Hospital site should have distinguished and proper access for outside transportations. Usually hospitals have two types of transportations to evacuate patients outside the facilities; ground transportation and air transportation. Ground transportation includes Ambulance, bus, van, truck or boats, and air transportation includes mainly helicopter (Burgun, 1994, Kobus et al, 2000, Miller et al, 2002, and AIA, 2006).

Requirements: Hospital may require lots of transportation during emergency evacuation to other facilities or other town. During disaster the access route can be blocked. Flood, earthquake, windstorm, or hurricane can cause obstacles of access roads, cutting off normal evacuation routes ((Burgun, 1994, Kobus et al, 2000, Miller et al, 2002, AIA, 2006, and FEMA, 2007).

Parking and Ambulance Entrance: Hospitals should have adequate parking space for patients, personnel, and the public. For service delivery vehicles and vehicles utilized for emergency patients (ambulance), hospital should have separate and additional space (AIA, 2006). The ambulance entrance should be covered. The size of parking lots and ambulance entrance depends on location, type and size of hospital facilities. For large facilities, a garage type ambulance entrance should be considered (Burgun, 1994, Kobus et al, 2000, and Miller et al, 2002).

Helicopter Access: All hospitals with emergency facilities should have access for helicopter. The landing facility should be located to provide direct access to the emergency department (Burgun, 1994, and Miller et al, 2002). Helipad is a place for helicopters to land and take off. Hospital use helipad during air evacuation of patients to other facilities. So, the access of helicopter is essential during disaster situation. Usually the helipad can be located on ground, roof, elevated platform or others. According to FEMA (2007), during hurricane Katrina the air evacuation was impaired because many ground level helicopter landing pads were under water. ‘Helipads physically connected to the hospital were most useful, because patients could be transported directly and very rapidly from the upper levels of the hospital to the helipad without interference from other hospital functions.'

c) Vertical Transportation

Function: Vertically transport patients from one floor to another. Hospital may have three types of vertical transportation; elevator, stair or ramp.

Elevator: 'All hospitals having patient facilities (such as bedrooms, dining rooms, or recreation areas) or critical services (such as operating, delivery, diagnostic, or therapeutic areas) located on other than the grade-level entrance floor shall have electric or hydraulic elevators' (AIA, 2006).

Elevators are not recommended to use as a vertical transport during fire, because it possess numerous shortcomings. But in the cases of critically ill patients, patients in body casts and others who would be difficult to move, elevators provide the only practical vertical evacuation method. Fire fighters can inspect and use the elevators during fire to evacuate patients. If separate cluster of elevators are located in separate smoke compartments, it may be possible to use elevators safely (NFPA *101*, 2006).

According to AIA (2006), hospital should apply an engineered traffic study to calculate the number of elevators. In absence of an engineered traffic study, the following guidelines for number of elevators shall apply:

- At least two hospital-type elevators shall be installed where 1 to 59 patient beds are located on any floor other than the main entrance floor (AIA- 9.2.2.1).

- At least two hospital-type elevators shall be installed where 60 to 200 patient beds are located on floors other than the main entrance floor, or where the major inpatient services are located on a floor other than those containing patient beds (AIA- 9.2.2.2).
- At least three hospital-type elevators shall be installed where 201 to 350 patient beds are located on floors other than the main entrance floor, or where the major inpatient services are located on a floor other than those containing patient beds (AIA-9.2.2.3).
- For hospitals with more than 350 beds, the number of elevators shall be determined from a study of the hospital plan and the expected vertical transportation requirements (AIA -9.2.2.4).

Stair: For healthcare facilities, the evacuation exit stairs should be designed to satisfy the criteria for interior stairs. Stairs must be enclosed with fire resistive materials with proper protection properly protected from the effects of fire. ‘It is presumed that evacuation over stairs will involve only staff, visitors, and ambulatory patients. Nonambulatory occupants are expected to remain in the building under the defend-in-place concept, with those patients on the floor of fire origin being moved horizontally to an area of refuge’ (NFPA *101*, 2006). But in case of complete evacuation, if the elevators are rendered inoperable, the patients must be carried up or down by using stairs (FEMA *577*, 2007).

Ramp: According to the Americans with Disabilities Act (ADA, 1990), healthcare facilities should have ramps where it required to access building by wheelchair users. Usually ramp was used in hospital buildings to transfer patients floor to floor instead of stairs. In recent year ramp are only used to access the buildings, not using instead of stairs from floor to floor (Burgun, 1994 and Miller et al, 2002). 'If a raised platform is used for ambulance discharge, a ramp shall be provided for pedestrian and wheelchair access' (AIA, 2006).

d) Emergency Assembly Area

Function: Emergency assembly area is a safe location away from the hazards where all occupants of the building can meet after an evacuation (NYCTP, 2006). It can be located inside the building or outside the building.

Requirements: According to OSHA (2008), for evacuation planning any institute should have designate assembly areas, both inside and outside the buildings. Assembly areas should have sufficient space to accommodate all of the occupants of the building. Exterior assembly areas, used when the building must be partially or completely evacuated, are typically located in parking lots or other open areas away from busy streets (Burgun, 1994, Kobus et al, 2000, Vogt, 1990, Lewis et al, 2003, NFPA *101*, 2006, NYCTP, 2006).

Inside Assembly Area: A safe area inside hospital building where all patients, staff, or visitors can bring together for shelter before evacuation. It can work as staging areas; locations at which resources are kept while temporarily awaiting incident assignment. Most large incidents will have separate Staging Areas for non-clinical hospital staff, volunteers, supplies and other resources (Burgun, 1994, Kobus et al, 2000, Vogt, 1990, Lewis et al, 2003, NFPA *101*, 2006, NYCTP, 2006).

Outside Assembly Area: A safe open area outside the building where all the patients, staff, or visitors can meet. It should be out of the way of responding emergency personnel. A hospital may have more than one assembly point depending on the size of the building (Lewis et al, 2003, Drabek, 1999, Vogt et al, 1990, and NYTCP, 2006, and Burgun, 1994).

e) Emergency Operation System

Hospital must have emergency electrical services. Emergency power shall be provided to hospital facilities in accordance with NFPA *99*, NFPA *101*, and NFPA *110*. The storage capacity shall permit continuous operation for at least 24 hours (AIA-10.3.4.1). The engine and appropriate accessories (i.e., batteries) of generators should be enclosed in a weatherproof housing (AIA, 2006-6.7.2.2).

f) Zoning of Function

Hospitals are designed with lots of important functions. The architects and planners always try to organize all the functions with the most effective way to achieve maximum benefits (Burgun, 1994). The zoning of hospital functions should consider the building evacuation system to reduce the patients travel time during evacuation. Also, the planning should consider the protection of facilities from any kind of disaster hazards (Kobus et al, 2000, Miller et al, 2002, NFPA *101*, 2006, FEMA, 2007).

2.3 Conclusions

From the above study of all relevant research, codes, standards, rules, regulations and parameters, it shows that the design considerations for full building evacuation are very limited. Also, it is clear that there is a gap between the design standards and evacuation process. For instance, according to NFPA *101*, to evacuate immobile patients, hospitals need to use elevators, but during fire the elevators are vulnerable to use. It proves that the whole evacuation process has great challenges and difficulties.

Though there are lots of rules and regulations developed by the federal and state authorities after the 9/11 terror attack and 2005 Hurricane Katrina, they are mostly on evacuation planning and operations. Also, the issues related with evacuation design have not been properly addressed by the relevant organizations and researchers.

An in-depth study is required to develop adequate guidelines for design considerations to make the hospital evacuation process smooth and easy.

3. METHODOLOGY

3.1. Types of Research

To fulfill the requirement of the study, the qualitative research approach is chosen to gather, review, and understand the survey data. The qualitative research method is suitable for analysis, as the research is trying to gain a better understanding of the complexities of hospital evacuation, and based on that understanding, trying to develop the design strategies for betterment (Marshall & Rossman, 1999).

The qualitative research method is designed with Case-Based Reasoning (CBR) to achieve the desired objectives of the study. Slade (1991) used the following to describe the Cased-Based Reasoning:

"Expertise comprises experience. In solving a new problem, we rely on past episodes. We need to remember what plans succeed and what plans fail. We need to know how to modify an old plan to fit a new situation. Case-Based Reasoning is a general paradigm for reasoning from experience. It assumes a memory model for representing, indexing and organizing past cases and a process model for retrieving and modifying old cases and assimilating new ones. Case-Based Reasoning provides a scientific cognitive model."

Since the designers use their experiences of previous design to develop new design solutions, the reasoning method of CBR, which organizes previous experiences as cases, is well suited to develop strategies for design problem solutions (Aamodt & Plaza, 1994). Borner (1993) provides an example of CBR as a methodology for industrial building design with two prototypical implementations. As the research considers the fundamental design issues of hospital evacuation, by using CBR, the study should consider the previous experiences to identify the pattern and requirements of the threats, to identify the consequences and complexities, and to form design strategies (Watson & Marir, 1994).

3.1.1. Importance of Qualitative Research for This Study

This study is focused on hospital evacuation complexities and probable design considerations. Qualitative research benefits the study by the following implications: (a) consider different threats, which are subjective with pattern and frequency, for hospital buildings, (b) consider guidelines that state current considerations for hospital evacuation for multiple organizations, (c) identify the relevant consequences of threats in greater depth, (c) based on study objective, provide measures with conservative and subjective approaches towards the conclusion, and (d) based on the study, guide the architect and planner in their considerations for a hospital evacuation system through exploratory recommendations.

3.1.2. Importance of Case-Based Reasoning for This Study

“A case is a contextualized piece of knowledge representing an experience,” (Watson & Marir, 1994). This study considers the cases that contain a past experience with hospital evacuation and offer lessons to be learned. The CBR used the following implications: (a) understand the evacuation pattern and mode according to the threats, (b) compile the singles-incident lessons learned and the design considerations, and (c) to assess the concerns by the experience based expertise.

3.2. Methods of the Research

The methods of this study are simple and objective based. To fulfill the requirement of the objectives, the following steps are considered (Figure-1).

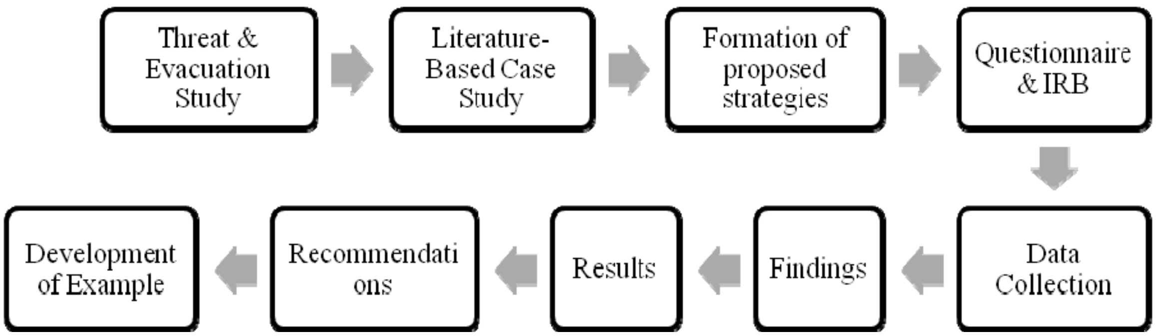

Figure-1. Methods of Research.

3.2.1. Identification of Evacuation Methods Based on Threats

1. **Identification of Threats:** As stated earlier, the data set of threats that cause evacuation of hospital facilities are for the most part not organized. The threats are selected from two sources: (a) Federal Emergency Management Association (FEMA) and (b) the study by Sternberg, Lee and Huard (2004).

2. **Identification of Evacuation Methods According to Threats**: Every individual threat has been analyzed by its pattern and frequency. Based on that, evacuation possibilities and probable methods for each threat are identified. Some cases with previous evacuation experiences are also analyzed, which gives more strong evidences of evacuation methods for specific threats.

3. **Development of Matrix:** A table of matrix has been developed based on evacuation methods according to threats.

3.2.2. Development of Proposed Strategies

The proposed strategies are developed from literature-based case analyses. The cases are selected from several articles that have been published on evacuation experience on single disaster event. Most of them address the issues and lessons related with evacuation planning, designing and operating level. The study has only concentrated on the issues that are related with research parameters. The issues are analyzed to understand the requirements of design and to form the proposed considerations. Table-1 is showing the cases with causes of evacuations and sources.

Table 1. List of Literature Base Case Study.

No	Name	Cause	Date
Case -1	Children Hospital, New Orleans	Hurricane -Katrina	2005
Case -2	Texas Children’s Hospital, New Orleans	Hurricane -Katrina	2005
Case -3	Tulane University Hospital, New Orleans	Hurricane -Katrina	2005
Case -4	Charity Hospital, New Orleans	Hurricane -Katrina	2005
Case -5	Rural Community Hospital	Bomb Threat	1999
Case -6	12 hospital, Northridge, California	Earthquake	1994
Case -7	Memorial Hermann, Houston, Texas	Tropical Storm	2001
Case -8	General Hospital of Everett, Washington	Fire	1987

3.2.3. Development of Questionnaire and IRB Approval

There are two sets of open-ended questionnaires developed for data collection. Set-A was developed to study the hospital cases that have experiences of evacuation, and Set-B was developed to interview the experts of hospital design. Set-A was developed to interview the hospital administrator or representative to gather the information about the cause of evacuation, the problems faced during evacuation and suggestions for improvement. Set-B was developed to interview the architects who have experience with hospital design and to gather their views on the proposed design considerations and further suggestions. The Set-A Questionnaire and Set-B Questionnaire are enclosed in Appendix A.

An Institutional Review Board (IRB) approval from Texas A&M University has been obtained since there was an involvement of human subjects in the research. The approval announcement is enclosed in Appendix B.

3.2.4. Survey and Data Collection

a) Selection of Cases: Four hospitals were selected that have a previous experience of complete evacuation. One has experience with a hurricane, one has experience with a flood and two have experiences with a storm that caused flood.

b) Selection of Experts: Four architecture consulting firms were selected among the top 10 firms in the US. Depending on the experience, six healthcare architects were selected from those four consulting firms. Among those six architects, three of them have the professional affiliation of FAIA and more than 20 years experience with healthcare design, and three have experiences of working with hospital post recovery situations after a disaster and evacuation.

c) Data Collection Process: The survey data was collected by three processes of interview: by email, or phone, or person-to-person contact.

3.2.5. Results of the Study

The data collected from the case studies is compiled and cross checked with proposed design considerations: only the additional suggestions of design considerations are taken from the case study. The experts' views and suggestions are compiled and discussed in depth for each proposed design considerations. Finally, the results of every proposed design considerations are discussed with explanations.

3.2.6. Recommendations

The recommendations are summarized from the discussion of results. The recommended strategies are listed in a chart to provide the hospital designer, planner and administrator a checklist for design and assessment. Figure-2 is showing the methods for developing recommendations.

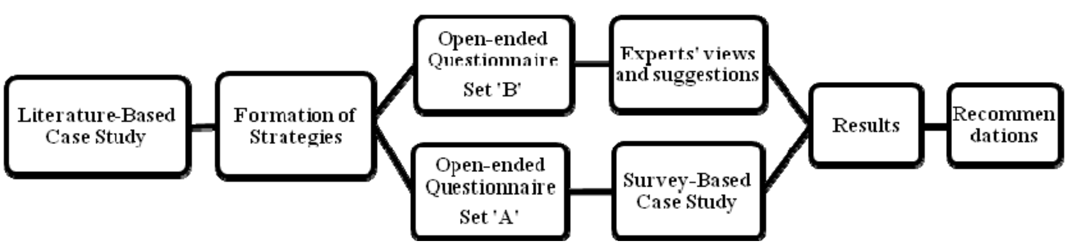

Figure 2. Methods for Developing Recommendations.

3.2.7. 3-D Model Example Based on Recommendations

The strategies are listed in to a chart to provide the hospital designer, planner and administrator a checklist for design considerations. Also, a 3-D model of conceptual hospital building had been developed with the recommended strategies for better understanding of the implementation.

4. DATA COLLECTION

4.1 Literature Based Data Collection

4.1.1. Identification of Evacuation Methods Based on Threats

To develop a better understanding about hospital evacuation causes and methods, the identification of threats and their patterns and frequency with evacuation methods is necessary. The following steps are considered to identify the evacuation methods based on threats.

4.1.1.1. Identification of Threats

In the United States, the hospitals are exposed to varied hazards capable of causing crisis for evacuation. The data sets of hospital evacuation causes are very limited and, for the most part, are not organized. A study by Sternberg, Lee and Huard (2004) had addressed the issues of the ‘counting crises’ of hospitals evacuations in US. The study investigated various sources to develop the relative distribution of hazards causing hospital evacuation. A study used academic and newspaper databases, and the national data set of hospital evacuations due to fire, which was available by the US Fire Administration. The study developed the reasons for hospital evacuation incidents and percentage. Table-2 shows the results from this study on evacuation causes and percentages.

Table 2. Causes of Partial or Complete Evacuation with Percentage.

(Sternberg et. al, 2004)	
Causes of Partial or Complete Evacuation	**Percentage**
Internal Fire	23%
Internal Hazardous Materials	18%
Hurricane	14%
Human Threat	13%
Earthquake	9%
External Fire	6%
Flood	6%
Utility Failure	5%
External Hazardous Material	4%

The above study shows that more than 50% of the hospital evacuations occurred because of hazards originating in the hospital facility itself or from human intruders. Natural disasters were not the preponderant causes of evacuations. But this study was published in 2004, after that United States faced lots of hospital evacuation cases during hurricane Katrina (2005), Rita (2005), Gustavo (2008) and Ike (2008). Any kind of disaster may cause the internal or external crisis for a hospital to drive for evacuation. To identify the threats for hospital in US, this study considered the major disasters addressed by FEMA (2008), are listed below in Table-3:

Table 3. Major Disasters in US: Type and Hazards for a Building.

MAJOR DISASTERS (FEMA, 2007, FEMA, 2008 and USGS, 2008)		
Type	**Disaster**	**Hazards for a Building**
Manmade	Terrorism	May create internal, or external, or both type of hazards.
	Internal Fire	Initially create internal hazards, then create external.
	Internal Hazards	Initially create internal hazards, then create external.
Natural	Hurricane	Initially create external hazards, then create internal.
	Earthquake	Create both types of hazards at a time.
	Flood	Initially cause external, then cause internal damage.
	Wildfire	Create both types of hazards at a time.
	Tsunami	Can create both at a time or only external, then internal.
	Tornado	Initially create external hazards, then create internal.
	Volcanic Eruption	Create both types of hazards at a time.
	Thunderstorm	Initially create external hazards, then create internal.
	Winter Strom	Initially create external hazards, then create internal.
Natural or Manmade	Landslide	Create both types of hazards at a time or only external.
	Heat	May create internal, or external, or both type of hazards.
	Dam Failure	Initially create external hazards, then create internal.

4.1.1.2 Identification of Evacuation Methods

Evacuation can be happen in different ways and in different patterns depending on threat events. Several studies had categorized the evacuation methods in many ways. This study had compiled and summarized the evacuation methods for hospital facilities from different sources (Lewis et al, 2003; Drabek, 1999; Vogt et al, 1990; NYCTP, 2006; Taffee et al, 2005; DHSH, 2007; FEMA, 2007; JACHO, 2005 and NFPA *101*, 2006). Evacuation method mainly depends on four major factors; destination, duration, mode (timing) and pattern (population). These four categories of evacuation are discussed below:

a) Evacuation Destination: Destination depends on distance; how far the safe area is? The safe distances are considered based on threat's severity. This study had classified the evacuation destination in four types:

i. Within Hospital: When there is an internal condition posing an immediate threat to patients or staff in one part of building that requires evacuation of the unit to another part of the building (Lewis et al, 2003; Drabek, 1999; Vogt et al, 1990; NYTCP, 2006, and NFPA *101*, 2006).

ii. Outside Hospital: When there is an internal disaster posing an immediate threat to patients or staff in major or whole part of building that requires evacuation to outside of the building (Lewis et al, 2003; Drabek, 1999; Vogt et al, 1990; NYTCP, 2006, and NFPA *101*, 2006).

iii. Another Facility: When there is an internal or external disaster cause major damage of the building and unable for quick recovery for patients care that requires evacuation to another facility (Lewis et al, 2003; Vogt et al, 1990; NYCTP, 2006; Taffee et al, 2005; DHSH, 2007; FEMA, 2007 and JACHO, 2005).

iv. **Another City/Town:** When there is an external disaster posing threats to a large amount of population in a community, or city that requires evacuation to another city or town. Generally this type of mass evacuation requires for massive disaster threats (Lewis et al, 2003; Vogt et al, 1990; NYCTP, 2006; Taffee et al, 2005; DHSH, 2007; FEMA, 2007 and JACHO, 2005).

b) **Evacuation Duration:** Evacuation always require due to emergency situation created by any kind of disaster. Depends on disaster warning time, the preparedness and process of evacuation duration determined. It can be categorized in two types; Regular and Rapid.

i. **Regular:** When occupants have adequate time for preparation and evacuation. This type of evacuation is often initiated through recommendations or orders of a local or state authority (Lewis et al, 2003; Vogt et al, 1990; NYCTP, 2006; Taffee et al, 2005; DHSH, 2007; FEMA, 2007 and JACHO, 2005).

ii. **Rapid:** When occupants have very little time for evacuation or occupants are in contact with threats, need to evacuate quickly (Lewis et al, 2003; Drabek, 1999; Vogt et al, 1990; NYTCP, 2006, and NFPA *101*, 2006).

c) **Evacuation Mode:** Evacuation mode depends on timing of evacuation with disaster. It can be categorized in three types; before, during and after.

i. **Before Disaster:** When disaster gives adequate warning for evacuation. Usually natural disasters, such as, hurricane, cause this type of evacuation. Usually, evacuation before disaster initiated through recommendations or orders of an organization, or local or state authority. This type of evacuation mostly requires mandatory evacuation of a mass population from a large threaten area (Lewis et al, 2003; Vogt et al, 1990; NYCTP, 2006; Taffee et al, 2005; DHSH, 2007; FEMA, 2007 and JACHO, 2005).

ii. **During Disaster or Threat:** When occupants are in contact with disaster threats and need to relocate a safe area away from hazards. This type of evacuation mostly requires for any kind of internal disaster, such as, fire, need rapid evacuation (Lewis et al, 2003; Drabek, 1999; Vogt et al, 1990; NYTCP, 2006, and NFPA *101*, 2006).

iii. **After Disaster:** When disaster is over, but occupants are in contact with threats that caused by disaster aftereffects, such as, hurricane causes flood, earthquake causes structural or nonstructural damages, flood impaired power supply, etc (Vogt et al, 1990; NYCTP, 2006; Taffee et al, 2005; DHSH, 2007; FEMA, 2007; JACHO, 2005; Lopez, 2006; Schultz, 2003 and Joseph, 2004).

4.1.1.3 Evacuation Methods According to Threats

Evacuation pattern depends on threats pattern. To develop an effective evacuation plan for a hospital, a better understanding about threats is important. In this section every individual threat had analyzed with its pattern and frequency. Based on that, evacuation possibilities and probable methods for each threat are identified. Some cases with previous evacuation experiences are also analyzed, that give more strong evidences of evacuation methods for specific threat. The study only considered the hospital evacuation cases from US.

1) Terrorism

Threats: Terrorism include several types of threats; Explosions, Biological Threats, Chemical Threats, Nuclear Blast, Radiological Dispersion Device (FEMA, 2008).

Warning: It is critical, because it varies with threats' type and pattern. Some give warning with few times for preparedness, some give short warning and some give none.

Frequency: Recent technological advances and ongoing international political unrest are components of the increased risk to national security" (FEMA, 2008). A large number of International Affairs Experts are predicting that the world would face more serious threats related to terrorism in near future (Foreign Policy, 2008).

Hospital Evacuation: Any kind of terrorism may cause partial or complete.

Evacuation Destination: All types of destination.

Evacuation Duration: Regular or Rapid.

Case Analysis-1: (Augustine, 2005)

Name & Date: Galion Community Hospital, October 13, 1999.

Cause: A credible bomb threat.

Evacuation Pattern: Complete evacuation, 46 patients.

Evacuation Mode: Before any kind of hazards.

Evacuation Destination: Another facility.

Evacuation Duration: Rapid evacuation.

2) Earthquake

Threats: A severe earthquake and its terrible aftereffects is one of the most frightening and destructive phenomena of nature. There are no guarantees of safety during an earthquake. If an earthquake occurs in a populated area, it may cause many deaths and injuries and extensive property damage (FEMA, 2008).

Hospital Evacuation: A severe earthquake causes evacuation for any kind of facilities. Depends on warning and severity evacuation can be before, during or after earthquake. Mass level evacuation may require before earthquake.

Warning: Earthquakes strike suddenly, violently, and without warning at any time.

Evacuation Destination: All, but within hospital building.

Evacuation Duration: Regular or Rapid.

Case Analysis: In 1994, there are 33 hospital reported partial or complete evacuation due Northridge Earthquake, California (Sternberg, Lee and Huard, 2004). In high magnitude earthquakes (like 6.7) hospitals have lost functionality for critical time periods and have had to evacuate existing patients, either due to structural damage or non-structural damage that shuts down essential systems (Schultz et. al, 2003).

Evacuation Pattern: Six evacuated within 24 hours, four completely and two partially. One hospital evacuated patients after 3 days and another after 14 days (Schultz et. al, 2003).

Evacuation Mode: After disaster.

Evacuation Destination: Another facility and another town.

Evacuation Duration: 6 hospitals evacuated rapidly.

3) Flood

Threats: In the United States one of the most common hazards is Flood. Every state is at risk from this hazard. It can be in small or large scale. Floods can be destructive, specially the flash floods often have a dangerous wall of roaring water that carries rocks, mud, and other debris and can sweep away most things in its path.

Warning: Some develop slowly, over a period of days, but some, like flash floods can develop quickly, just a few minutes and without any visible signs of rain.

Hospital Evacuation: Usually flood occurs in flood plain, so the hospital buildings may have flood protection system. If not, flood can cause hospitals' external and internal damage that may cause evacuation. Most of the cases of hospital evacuation are happed during or after flooding.

Evacuation Destination: All, but outside the hospital.

Evacuation Duration: Regular or Rapid.

Case Analysis-1: (Cocanour et al, 2002 and Joseph, 2004)

Name & Date: Memorial Hermann Hospital, Houston, Texas, June 2001.

Cause: The tropical storm Allison caused severe rainfall of 3 feet which caused catastrophic flood in Houston, Texas. It lost electrical power, communications systems, running water, and internal transportation. Also the life-saving equipments such as ventilators, infusion pumps, and monitors, all became useless.

Evacuation Pattern: complete evacuation, all 575 patients were either discharged from the hospital (169 patients) or evacuated (406 patients).

Evacuation Mode: After the disaster.

Evacuation Destination: Another facility.

Evacuation Duration: Rapid

Case Analysis-2: (Saulny et. al, 2008)

Name & Date: Mercy Medical Center hospital, Cedar Rapids, June 12, 2008.

Cause: The feared to lose power was the main cause of evacuation.

Evacuation Pattern: Complete, 176 patients, including babies in ICU.

Evacuation Mode: Before hazards; the hospital had switched to backup generators, which were threatened by floodwaters hours later.

Evacuation Destination: Another facility.

Evacuation Duration: Rapid

Case Analysis-3: (Topix, 2008)

Name & Date: Columbus Regional Hospital, IN, June, 2008.

Cause: Columbus Indiana Flood.

Evacuation Pattern: The hospital had a safe evacuation of 157 patients.

Evacuation Mode: After effects of disaster, the basement was completely flooded and the first floor of the building had 6”-8” of water which incapacitate laboratory, radiology, and pharmacy services. There is no power, no access to medical records, no internet and no phones other than a single main phone line.

Evacuation Destination: Another facility.

Evacuation Duration: Regular

4) Hurricane

Threats: In recent year Hurricane is one of the most destructive natural disasters in US. It can wreak havoc over thousands of square miles on costal and island area. Hurricane hazards include intense wind, high waves, strong currents, flooding, storm surge (can exceed 20 feet in height and extend along shore for 100 miles), tornadoes, landslides, and coastal erosion. Sometimes hurricanes leave an area more vulnerable then storms (USGS, 2008).

Frequency: More than half of the U.S. population lives within 50 miles of a coast, and this number are increasing. Many of these areas, especially the Atlantic and Gulf coasts, will be in the direct path of future hurricanes. Hawaii is also vulnerable to hurricanes (USGS, 2008).

Warning: The advance technologies give early warning for emergency planning and response. But still have no accurate way to predict exactly which storms will spawn tornadoes or where they will touch down, the new systems gives warning before 30 minutes, so, preparedness is critical for hurricane tornados (USGS, 2008 and FEMA, 2008).

Hospital Evacuation: A mass level of evacuation requires which include hospital evacuation of a hurricane threatens area, but there are some cases of evacuation due to aftereffects of hurricane.

Evacuation Destination: Another city/town.

Evacuation Duration: Regular (Mass evacuation).

Case Analysis: There are several hospitals evacuated during hurricane Katrina, Rita, Gustav and lastly during Ike. Most of them evacuated before the hurricane, especially those are located on mandatory evacuation area. During Katrina some hospitals evacuated after hurricane due to its aftereffects; Charity hospital, Tulane University hospital and others in New Orleans. According to THA (2008), there are 14 hospital reported about evacuation for hurricane Ike.

5) Dam Failure

Threats: Dam failure cause severe flood of forced water. **‘**According to National Inventory of Dams (update 2005), approximately one third of 79,500 dams in the United States pose a "high" or "significant" hazard to life and property if any failure occurs’ (FEMA, 2008).

Warning: Dam failure or levee breeches can occur with little warning may be an hour of first signs of breaching. Some failures and breeches can take much longer to occur, from days to weeks (FEMA, 2008).

Hospital Evacuation: Mass level of evacuation may require from the upstream locations, which may include hospital evacuation too.

Evacuation Destination: Another city/town.

Evacuation Duration: Rapid.

Case Example: Not available.

6) Internal Fire

Threats: Fire occurs from various sources and in various scales; small or large. In U.S., each year more than 4,000 Americans die and more than 25,000 are injured in fires (FEMA, 2008). It can cause of death, injury and damage by producing flame, heat, smoke and poisonous gases. Asphyxiation is the leading cause of fire deaths

Warning: 'Fire spreads quickly; there is no time to gather valuables or make a phone call. In just two minutes, a fire can become life-threatening. In five minutes, a residence can be engulfed in flames' (FEMA, 2008).

Hospital Evacuation: Depends on size and effects; complete or partial.

Example: There are several cases of hospital fire. Here only one discussed.

Evacuation Destination: All buy another city/town.

Evacuation Duration: Rapid.

Case Analysis: (NYTimes, 1993)

Name & Date: Maimonides Medical Center in Brooklyn, September, 1993.

Cause: A faulty respirator supplying oxygen exploded and caused fire.

Evacuation Pattern: Complete, 120 patients, most of them elderly and infirm.

Evacuation Mode: A fearful evacuation, as nurses and other hospital workers, using sheets as stretchers, frantically dragged patients through smoky corridors and then carried them down six flights of stairs.

Evacuation Destination: Outside the building.

Evacuation Duration: Rapid.

Casualties: A 76-year-old patient across the hall died of smoke inhalation.

7) Wildfire

Threats: 'Dry conditions at various times of the year and in various parts of the United States greatly increase the potential for wildland fires' (FEMA, 2008). The hospital near wildland areas has the threat of wildland fires.

Hospital Evacuation: Mass level of evacuation requires.

Evacuation Destination: Another city/town.

Evacuation Duration: Rapid or Regular (Mass evacuation).

Case Example: Not available.

8) Thunderstorms and Lightning

Threats: Thunderstorms are dangerous and produce lightning. On average every year 300 people are injured and 80 people are killed by lightning in the United States. Thunderstorms may include tornadoes, strong winds, hail, and flash flooding. During dry thunderstorms, lightning can cause wildfires.

Warning: Thunderstorms may strike quickly, with little or no warning.

Hospital Evacuation: Complete or partial evacuation may require.

Evacuation Destination: Another facility or another city/town.

Evacuation Duration: Rapid.

Case Analysis: (NWS, 2003)

Name & Date: Sheppard Pratt Hospital in Towson, August 27, 2003.

Cause: A lightning struck but the aftereffects are unknown.

Evacuation Pattern: Complete, 60 people had to evacuate.

Evacuation Mode: After disaster due to its effects.

Evacuation Destination: Another facility.

Evacuation Duration: Rapid.

9) Winter Storms and Extreme Cold

Threats: Heavy snowfall and extreme cold can immobilize an entire region. Even areas that normally experience mild winters can be hit with a major snowstorm or extreme cold. The results of winter storms can be flooding, storm surge, closed highways, blocked roads, downed power lines and hypothermia.

Hospital Evacuation: Mass level of evacuation may require.

Evacuation Destination: Another city/town.

Evacuation Duration: Regular.

Case Example: Not available.

10) Tornado

Threats: Tornadoes are most violent storms that can cause fatalities and devastate a neighborhood in seconds. ‘A tornado appears as a rotating, funnel-shaped cloud that can reach 300 miles per hour with one mile wide and 50 miles long damage path. Every state is at some risk from this hazard. Tornadoes can accompany tropical storms and hurricanes as they move onto land (FEMA, 2008).

Warning: Tornado may strike quickly, with little or no warning.

Hospital Evacuation: Complete or partial evacuation may require.

Evacuation Destination: All but outside the building.

Evacuation Duration: Rapid.

Case Example: Not available.

11) Volcanic Eruption

Threats: Volcano eruptions can be quiet or explosive; there may be lava flows, flattened landscapes, poisonous gases, and flying rock and ash. Lava flows destroy everything in their path. Volcanic ash can affects people hundreds of miles away. Other accompanied natural hazards include earthquakes, mudflows and flash floods, rock falls and landslides, acid rain, fire, and tsunamis (FEMA, 2008).

Warning: Most move slowly enough that people can move out of the way.

Hospital Evacuation: Mass evacuation may necessary for the danger area around a volcano. The radius of the danger area around a volcano covers approximately 20-mile radius, sometimes may exist 100 miles or more (FEMA, 2008).

Evacuation Destination: Another city/town.

Evacuation Duration: Regular.

Case Example: Not available.

12) Tsunami

Threats: Tsunamis are a series of enormous waves created by an underwater disturbance such as an earthquake, landslide, and volcanic eruption. It can move

100m/hr in Ocean and can have 100 feet or more high waves (FEMA, 2008). Five Pacific States are especially vulnerable for tsunami; Hawaii, Alaska, Washington, Oregon, and California, and also the U.S. Caribbean islands (USGS & FEMA, 2008).

Warning: 'In case of major earthquake or landslide close to shore, the first wave could reach the beach in a few minutes, before a warning is issued' (FEMA, 2008).

Hospital Evacuation: Mass evacuation requires in the threaten area.

Evacuation Destination: Another city/town.

Evacuation Duration: Rapid.

Case Example: Not available.

13) Internal Hazards

Threats: The study considered this threat as all kind of internal hazards except internal fire. There are no significant reasons for internal hazards, it can occur in various ways; chemical hazard, building supportive mechanical or electrical system hazards, etc. But any kind of internal hazards can cause death, serious injury, or long-lasting health effects (FEMA, 2008).

Warning: Various with situation, some give enough time and some are not.

Hospital Evacuation: Complete or partial hospital evacuation may require.

Evacuation Destination: All but another city/town.

Evacuation Duration: Regular **or** Rapid.

Case Analysis -1: A study by Burgess (1999) stated that 12 Washington State Hospital reports evacuations due to hazardous material incidents.

Evacuation Pattern: Complete or partial.

Evacuation Mode: After and during disaster.

Evacuation Destination: Within building and another facility.

Evacuation Duration: Rapid or regular.

Case Analysis-2: (NYTimes, 2006)

Name & Date: St. Mary's Hospital in Passaic, New Jersey, July 15, 2006.

Cause: The boiler exploded and the blast force to split in two parts and flew about 30 feet. Evacuation happened due to cutting off the air-conditioning and hot water.

Evacuation Pattern: Complete

Evacuation Mode: After the blast, during cut off situation.

Evacuation Destination: Another facility.

Evacuation Duration: Rapid.

14) Landslide and Debris Flow (Mudslide)

Threats: In a landslide masses of rock, earth, or debris move down a slope. Landslides may occur from several reasons; storms, earthquakes, volcanic eruptions, fires, alternate freezing or thawing, and steepening of slopes by erosion or human modification. It can be in small scale or in large scale. Sometimes the large scale landslides are destructive (FEMA, 2008).

Warning: It can happen very slowly or suddenly (FEMA, 2008).

Hospital Evacuation: Partial or complete evacuation may require**.**

Evacuation Destination: Another city/town.

Evacuation Duration: Regular **or** Rapid.

Case Example: Not available.

15) Extreme Heat

Threats: Stagnant atmospheric conditions, poor air quality or heat wave can cause heat-related illnesses. 'Heat kills by pushing the human body beyond its limits. In extreme heat and high humidity, evaporation is slowed and the body must work extra hard to maintain a normal temperature' (FEMA, 2008).

Warning: Very few warning time for preparation and evacuation.

Hospital Evacuation: Partial or complete evacuation may require**.**

Evacuation Destination: All but outside the building.

Evacuation Duration: Regular or Rapid.

Case Example: Not available.

- **Findings:** From the above study the following results are come out;

a) Short Warning Threats: Internal Fire, Flood, tornado, terrorism, Tsunami, Thunderstorm, and Dam Failure and Internal Hazards are the disasters that may start with little or no warning. So that, evacuation process become challenging for a hospital facilities.

b) Threats Cause Most Evacuation Cases: maximum numbers of evacuation cases are caused by the disaster Hurricane, earthquake, flood, fire, thunderstorm, hazardous material, terrorism and internal hazard.

c) Evacuation Mode: The above cases show that evacuation can be happen for any kind of disaster in three modes; before threat, during threat, and after disaster. Usually, evacuation before disaster requires for the natural disaster with regular warning time for evacuation. Among these types of natural disaster, some require mass evacuation, such as, hurricane, volcano, wildfire, tsunami, and earthquake. Evacuation during threats require mostly for any kind of internal hazards created by natural or manmade disaster, such as, fire, bomb threat, blast, bioterrorist attack or earthquake. Evacuation after threats require mostly for any kind of internal hazards caused by disaster aftereffects, such as, hurricane causes flood, earthquake causes structural or nonstructural damages, flood impaired power supply, etc.

d) Evacuation Frequency: The natural disaster and the man-made disaster, both types are increasing in the world for various reasons. Natural disaster is increasing for many reasons, “The rise in sea level, global climate change, and weather patterns change, which influence the impact and occurrence of hurricanes, floods, and tornadoes. Changes in plate motion and strain accumulation can similarly alter the pattern of earthquakes” (AGU, 2008). According to the FEMA (2008) website “Recent technological advances and ongoing international political unrest are components of the increased risk to national security”. So, we can conclude that the threats are increasing day by day in the world as well as in United States.

- **Development of Matrix: Threat vs. Evacuation Methods.**

A matrix has developed on evacuation methods according to threats from the above study showing in the Table-4. The matrix also shows the possible use of design parameters for every threat based on following findings from literature review.

a) **Evacuation Way Inside the Buildings:** Elevator use is restricted only for fire. The fire fighter can examine and use the elevator for evacuation (NFPA *101*).

b) **Evacuation Way Outside the buildings:** Flood water can impair the ground evacuation (FEMA, 2007).

c) **Evacuation Assemble Area:** Inside assembly area requires for all type of disaster. Outside assembly area are hazardous during natural disaster (FEMA, 2007).

Table 4. Matrix of Threat and Evacuation Pattern.

MATRIX OF THREAT AND EVACUATION PATTERN																	
			THREATS														
	Evacuation Methods and Parameters		Internal Fire	Hurricane	Terrorism	Flood	Earthquake	Tornado	Wildfire	Tsunami	Thunderstorm	Volcanic Eruption	Extreme Heat	Winter Strom	Landslide	Dam Failure	Internal Hazards
METHODS	Destination	Within Hospital															
		Outside Hospital															
		Another Facility															
		Another City/Town															
PARAMETER	Duration	Regular															
		Rapid															
	Way- Out	Air/ Others															
		Ground															
	Way-In	Elevator															
		Stair															
	Assembly	Assembly Outside															
		Assembly Inside															

Explanation of Matrix: There are 15 types of threats analyzed with its evacuation pattern; destination and duration.

a) **Evacuation Destination:** Evacuation destination depends on threats' severity and pattern.

   1) **Within Hospital:** Require for Internal Fire, Terrorism, Flood, Tornado, Extreme Heat and Internal Hazards.

   2) **Outside Hospital:** Require for Internal Fire, Terrorism, Earthquake, and Internal Hazards.

   3) **Another Facility:** Require for Internal Fire, Terrorism, Flood, Earthquake, Tornado, Thunderstorm, Extreme Heat, and Internal Hazards.

   4) **Another City/Town:** All but Internal fir and hazards.

b) **Evacuation Duration:** Regular evacuation require for those disaster that have warning for mass evacuation.

   1) **Regular:** Hurricane, Terrorism, Earthquake, Wildfire, Volcanic Eruption, Extreme Heat, Winter Strom, Landslide, and Internal Hazards.

   2) **Rapid:** Internal Fire, Terrorism, Flood, Earthquake, Tornado, Wildfire, Tsunami, Thunderstorm, Extreme Heat, Landslide, Dam Failure and Internal Hazards.

c) **Evacuation Way Inside the Buildings:** Elevator use is restricted only for fire. The fire fighter can examine and use the elevator for evacuation (NFPA *101*).

d) **Evacuation Way Outside the Buildings:** Flood water can impair the ground evacuation (FEMA, 2007).

e) **Evacuation Assemble Area:** Inside assembly area requires for all type of disaster. Outside assembly area are hazardous during natural disaster (FEMA, 2007).

4.1.2 Development of Proposed Strategies

There are several articles describing the evacuation experience. In most cases numerous responders and planners have written articles about their experiences and the lessons learned. Most of them address the issues related to the planning and operations (Scultz, et. al, 2005). But very few articles address the issues related to building design layout and strategy. One of the basic reasons is that the hospital building designers and planners were not present at the events. Some of the articles mentioned the lessons they learned from the experience, some just describe the consequences of the events, and some address the suggestions for design and operations.

4.1.2.1 Case Analysis

A total of eight cases were selected for study to develop the possible design considerations for hospital design to support an evacuation process. The following Tables 5 through 12 contain the list of lessons learned and the design considerations that developed from the lessons. The tables also contain one column that expresses the short form of parameters. There are seven types of short forms: six for the six parameters and one for general considerations that fall under all parameters.

Table 5. Analysis of CASE-1 from Literature Review.

CASE-1			
Texas Children's Hospital, New Orleans (Perrin, 2006).			
Hurricane Katrina, 2005			
	Lessons Learned	**Design Considerations**	**Parameter**
1.	Complete evacuation should be considered in the disaster plans.	Design should consider the complete evacuation of the facility.	All
2.	'There was no uniform method for evacuating patients, particularly for the critically ill ones.'	Design should consider uniform method for evacuating patients, specifically the critical ones.	All
3.	Usually transports are overwhelmed during mass evacuation; need to reduce time and efforts.	Multiple accesses to the site with adequate space for transportation required for mass evacuation.	SA
4.	'Management of patient's family members, children of staff, and pets became problems.'	During massive disaster the hospital evacuation procedure should include the external and internal visitors.	All

Table 5. Continued.			
5.	‘Architectural design for a hospital in a flood area needs to include a power plant well above the category5 storm–predicted water level.’	The zoning of important functions should consider the threats and vulnerability; such as, power plant should be above the flood level.	ZF
7.	‘Backup generators to run all essential equipment and fuel for at least 2 weeks required.’	Hospital should have emergency power supply at least for two weeks.	EOS
8.	‘An alternative water supply such as a well should be included so that there is an alternative supply of potable water and water for plumbing services.’	Alternative water supply system requires for drinking and plumbing services.	EOS
9.	As communication is crucial during a catastrophic event, backup system should be provided.	Battery-operated communication systems required for internal and external use.	EOS

Table 6. Analysis of CASE-2 from Literature Review.

CASE-2			
Children's Hospital of New Orleans, New Orleans. (Distefano et al, 2006)			
Hurricane Katrina, 2005			
	Lesson Learned	**Design Considerations**	**Parameter**
1.	Physical plant should be secured from disaster threat.	The zoning of important functions should consider the threats and vulnerability; such as, power plant should be above the flood level.	ZF
2.	An effective communication strategy require during disaster.	Battery-operated communication systems required for internal and external use.	EOS
3.	Patients' evacuation and transportation were challenging.	Design should consider easy and smooth solution for Patient transfer.	All
4.	'Because of flooding and impassable roads, the only evacuation route by the end of that day was rotorcraft from helipads.'	Hospital should have both types of evacuation route, ground and air.	EER
		Helipads should not be affected by flooding to provide air evacuation.	SA

Table 7. Analysis of CASE-3 from Literature Review.

CASE-3			
Tulane University Hospital, New Orleans (Hamm, 2006).			
Hurricane Katrina, 2005			
	Lesson Learned	**Design Considerations**	**Parameter**
1.	As hospital was surrounded by flood water, patients had to transfer via boats or helicopters.	Multiple evacuation routes should be designed according to threats.	EER
2.	Consistent communication system requires for external & internal use.	Battery-operated communication systems required for internal and external use.	EOS
3.	Emergency supply like water, fuel or diesel fuel, food, medicines, portable oxygen is required.	Protection from threats and preservation (storage space) require for emergency supplies.	EOS
4.	Excellent Security is necessary during sheltering for evacuation.	Assembly Area (shelter for evacuation) should be protected from external and internal man-made hazards.	EAA

Table 8. Analysis of CASE-4 from Literature Review.

CASE-4			
Charity Hospital, New Orleans (Lopez, 2006).			
Hurricane Katrina, 2005			
	Lesson Learned	**Design Considerations**	**Parameter**
1.	'Basement flooded where thousands of medical records and the morgue were located.'	The zoning of important functions should consider the threats and vulnerability; medical records.	ZF
2.	50 patients were moved from first-floor to the second floor Auditorium, an area of regular hospital staff meetings.	Auditorium or meeting space can become Assembly Area.	EAA
3.	A patient with possible tuberculosis was placed next to window, away from others during sheltering in assembly area.	Provision for separation of contagious patients requires in Assembly Area.	EAA
4.	Patients' survivals become threatened without continuous cares that need hemodialysis, peritoneal dialysis & surgery.	Necessary medical equipments and supplies require for continuing care during evacuation.	ALL

Table 8. Continued.			
5.	During sheltering for evacuation, security requires to make situation calm. Especially when people are frustrated, communication broke down and people are shouting loudly.	Assembly Area (shelter for evacuation) should be protected from internal man-made hazards.	EAA
6.	Due to power outage all the clocks on the walls had stopped.	Battery operated clock required.	EOS
7.	‘Human forces necessary to carry patients who could not walk safely down as many as 12 flights of dark, fetid, and stiflingly hot stairs.’	Stairwells require emergency lighting system. Alternative solution requires transferring patients vertically to reduce extensive efforts and number of people.	VT
8.	The hospital was surrounded by flood water, boats and trucks ferried many patients to the nearby helicopter pad.	In flood plain, hospital should have helicopter pad above flood level for air evacuation.	SA

Table 9. Analysis of CASE-5 from Literature Review.

	CASE- 5		
	Galion Community Hospital, Galion, Ohio (Augustine, 2005)		
	Terrorism: Bomb threats, 1999		
	Lesson learned	**Design considerations**	**Parameters**
1.	'The Emergency Department is a good place to stabilize more acute patients prior to transfer, and keeping charts and medications with patients during an evacuation situation helped to maintain ongoing care.'	Emergency Department is a good place as an Inside Assembly Area.	EAA
2.	'Ambulatory patients were sent to a holding area in the hospital lobby.'	Hospital lobby can work as an inside Assembly Area.	EAA

Table 10. Analysis of CASE-6 from Literature Review.

CASE-6			
12 Hospitals of Northridge, California (Schultz, 2003)			
Earthquake, 1994			
	Lesson Learned	**Design Considerations**	**Parameter**
1.	Elevators may become inoperable after a massive disaster.	Alternative solution required to transfer patients' vertically.	VT
2.	'Limited electric power made situation more complicated.'	Hospital should have adequate emergency power supply.	EOS
3.	Evacuation planning should consider available time and resources to transfer patients. . During limited time, healthiest patients first and during limited resources, critically ill patients first may be an effective strategy.	Limited use of time and resources required during evacuation.	All
4.	EM communication system necessary.	Battery-operated communication systems required for internal and external use.	EOS

Table 10. Continued.			
5.	'Initially, supervisors moved patients to safer areas of the hospital or outdoors,'	Hospital inside and outside safe area can work as Assembly Area to move patients.	EAA
6.	One institution moved all 334 patients to open areas adjacent to the buildings in two hours, including patients in a six-story structure containing the intensive care unit.	Open areas adjacent to the buildings can be an outside Assembly Area to transfer patients immediately.	EAA
7.	'Specialized devices like stair chair, infant carriers and earthquake slides may not necessary.'	Specialized devices may not necessary to transfer patients by stairwell.	VT

Table 11. Analysis of CASE-7 from Literature Review.

CASE- 7			
Memorial Hermann Hospital, Houston (Cocanour et al, 2002) and (Joseph, 2004)			
Tropical Storm Allison, 2001			
	Lesson Learned	**Design Considerations**	**Parameter**
1.	"Flooding will occur in a flood plain." Identification of disaster threats is important.	Hospital design including evacuation system, should consider the disaster threats.	All
2.	Emergency evacuation requires extensive effort for a large hospital.	Evacuation procedure should be more smooth and easy, to reduce the extensive efforts.	All
3.	Patient transfer is challenging and critical.	Design should consider easy and smooth solution for Patient transfer.	All
4.	Electric power outage is one of the main issues for hospital evacuation.	Protection and preservation require for electrical power supply all the times.	EOS
5.	In-house communication system not dependent on telephone lines or electricity is required.	Battery-operated communication systems required for internal and external use.	EOS

Table 11. Continued.			
6.	Flashlights should be available on all units during emergency.	All units should have flashlights option.	EOS
7.	Battery-operated exit signs and stairway lights require.	Signage system and lighting system should have battery-operated option.	EOS
8.	'Critical services such as pharmacy, laboratories, blood bank, and central supply rooms should be located at sites more secure than the ground floors.'	The zoning of important functions should consider the threats and vulnerability; such as, pharmacy, laboratories, blood bank, and central supply rooms should be above the flood level.	ZF
9.	The Critical services should be prepared for more extensive performances during massive disaster.	Critical functions should have the options and flexibility to accommodate extensive services during disaster situation.	ZF
10.	'Contingency plans to maintain protected water supplies.'	Water supply system should be protected from contingency.	EOS
11.	Flood can impair the ground evacuation that requires alternative route and exits.	Evacuation route and exits should be threat specific.	EER

Table 11. Continued.			
12.	Patients' vertical transportation was difficult using stairs as many as 10 flights, without overhead lights and air conditioning.	Alternative solutions require avoiding stairs as a vertical transportation.	VT
13.	'Patients were brought to the ambulance bay of the emergency center which was used as a staging area.'	Ambulance bay can be used as an Outside Assembly Area to transport patients.	EAA

Table 12. Analysis of CASE-8 from Literature Review.

Case-8			
General Hospital Of Everett, Everett, Washington (Biumhagen, 1987)			
Fire, 1982			
	Lesson Learned	**Design Considerations**	**Parameter**
1.	A small fire can produce enough smoke and smoke travels rapidly which may require the evacuation of hospital building.	Design should consider the complete evacuation of the facility.	All
2.	‘Safe elevator operation can be maintained for evacuation during a fire.’	Safe elevator operation requires during fire.	VT
3.	‘Their electrical supply should be similarly safeguarded.’	Emergency power supply necessary for elevator.	EOS
4.	Multiple evacuation route is preferable than one central evacuation route for rapid evacuation during fire hazards.	Multiple evacuation exit route facilitate rapid evacuation.	EER
5.	‘If possible, patients receiving intensive care should be evacuated to a place within the hospital, where they can be stabilized prior to transport.’	Inside Assembly Area is necessary with provision to transfer patients outside.	EAA

4.1.2.2 Findings

All cases had addressed the multiple issues that are related with research parameters. The following Table-13 developed to show that which parameter has addressed by which cases.

Table 13. Matrix of Parameters Addressed by Cases.

<table>
<tr><th></th><th></th><th></th><th colspan="8">Case No</th></tr>
<tr><th></th><th>Parameters</th><th>Short Form</th><th>Case -1</th><th>Case -2</th><th>Case -3</th><th>Case -4</th><th>Case -5</th><th>Case -6</th><th>Case -7</th><th>Case -8</th></tr>
<tr><td>1.</td><td>Evacuation Exit Route</td><td>EER</td><td></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td><td></td><td></td><td></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td></tr>
<tr><td>2.</td><td>Site Access</td><td>SA</td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td><td></td><td bgcolor="#a9a9a9"></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3.</td><td>Vertical Transportation</td><td>VT</td><td></td><td></td><td></td><td bgcolor="#a9a9a9"></td><td></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td></tr>
<tr><td>4.</td><td>Emer. Assembly Area</td><td>EAA</td><td></td><td></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td></tr>
<tr><td>5.</td><td>Emer. Operation System</td><td>EOS</td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td><td></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td></tr>
<tr><td>6.</td><td>Zoning of Function</td><td>ZF</td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td><td></td><td bgcolor="#a9a9a9"></td><td></td><td></td><td bgcolor="#a9a9a9"></td><td></td></tr>
<tr><td>7.</td><td>General Considerations</td><td>All</td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td><td></td><td bgcolor="#a9a9a9"></td><td></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td><td bgcolor="#a9a9a9"></td></tr>
</table>

The findings of design considerations and the proposed design strategies developed from the findings are compiled below (Perrin, 2006; Distefano et al, 2006; Hamm, 2006; Lopez, 2006; Augustine, et. al, 2005; Schultz, et. al, 2003; Cocanour et al, 2002; Joseph, 2004 and Biumhagen, 1987):

1) General Considerations (All)

Findings:

- Design should consider the complete evacuation of the facility.
- Hospital evacuation system design should consider the disaster threats.
- Design should consider easy and smooth solution to transfer patients, specifically the critical ones.
- Design should consider limited use of time and resources required during evacuation.

Proposed Strategies:

- Evacuation procedure should be smooth and easy, to reduce travel time and extensive efforts for patients' transfer, especially the critical ones.
- Evacuation systems need to be designed based on nature of threats and hazards.

2) Evacuation Exit Route (EER)

Findings:

- Evacuation route and exits should be threat specific.
- Multiple evacuation routes should be designed according to threats.
- Hospital should have both types of evacuation route, ground and air.

Proposed Strategies:

- Multiple evacuation exit points facilitate rapid and threat specific evacuation.

3) Site Access (SA)

Findings: Air

- In flood plain, hospital should have helicopter pad above flood level for air evacuation.
- Helipads should not be affected by flooding to provide air evacuation.

Findings: Ground

- Multiple accesses to the site with adequate space for transportation required for mass evacuation.

Proposed Strategies:

- Elevated helipads on roof tops or on elevated structure will be useful for air evacuation.
- Multiple accesses to the site with adequate space for transportation required for mass evacuation.
- During adverse weather (storming heavily), the evacuation exit point should have facilities to protect patients transportation.

4) Vertical Transportation (VT)

Findings: Elevator

- Safe elevator operation requires during fire.
- Alternative solution required to transfer patients' vertically.

Findings: Stairwell

- Stairwells require emergency lighting system.

- Alternative solutions require avoiding stairs as a vertical transportation to reduce extensive efforts and number of people.

Proposed Strategies:

- Ramp can be a suitable alternative solution for patients' vertical evacuation to reduce extensive efforts and number of people.
- The number and size of elevators need to evaluate based on evacuation requirements.

5) Emergency Assembly Area (EAA)

Findings: Inside

- The Emergency Department can be a good place for patients' Assembly Area.
- Depends on threats assembly area should be inside and outside of a hospital.
- Necessary equipment and supplies required for continuous care, especially for critically ill patients.

Findings: Outside

- Separation require for contagious patients' during Evacuation.
- Air and water supply should be protected from contingency.
- Internal and external Security systems require during massive disaster.

Proposed Strategies:

Assembly Area should be located inside and outside of the hospital building to support the evacuation process. All necessary medical supplies should accommodate in the Assembly Area.

6) Emergency Operation System (EOS)

- Hospital should have adequate (2 weeks) emergency power supply, especially for elevator to evacuate patient.
- Battery-operated communication systems, signage system, lighting system and clock required for internal and external use.
- All units should have flashlights option.
- Emergency supplies and storage space requires protection from threats.
- Alternative water supply system requires for drinking and plumbing services.

Proposed Strategies:

Hospital should have the adequate facility for emergency power, lighting, communication and a signage system.

7) Zoning of Function (ZF)

- The zoning of important functions should consider the threats and vulnerability; such as, power plant, medical records, pharmacy, laboratories, blood bank, and central supply should be above the flood level.
- Critical functions should have the options and flexibility to accommodate extensive services during disaster situation.

Proposed Strategies:

- The zoning of patients’ accommodation should be arranged to limit the travel distance of evacuate.
- Zoning of important functions should consider the evacuation procedure.

4.1.2.3 List of Proposed Strategies

1. Evacuation procedure should be smooth and easy, to reduce travel time and extensive efforts for patients' transfer, especially the critical ones. (ALL)
2. Evacuation systems need to be designed based on nature of threats and hazards. (ALL)
3. Multiple evacuation exit points facilitate rapid and threat specific evacuation.(EER)
4. Elevated helipads on roof tops or on elevated structure will be useful for air evacuation. (SA)
5. Multiple accesses to the site with adequate space for transportation required for mass evacuation.(SA)
6. During adverse weather (storming heavily), the evacuation exit point should have facilities to protect patients transportation.(SA)
7. Ramp can be a suitable alternative solution for patients' vertical evacuation to reduce extensive efforts and number of people.(VT)
8. The number and size of elevators need to evaluate based on evacuation requirements.(VT)
9. Assembly Area should be located inside and outside of the hospital building to support the evacuation process. All necessary medical supplies should accommodate in the Assembly Area.(AA)
10. Hospital should have the adequate facility for emergency power, lighting, communication and a signage system. (EOS)

11. The zoning of patients' accommodation should be arranged to limit the travel distance of evacuate.(ZF)
12. Zoning of important functions should consider the evacuation procedure.(ZF)

4.2 Survey Based Data Collection

The collected from survey based case study discussed below:

4.2.1 Case Study Findings

The findings from the four hospital case studies are discussed below:

Case A: Tropical Storm Allison, June 2001.

Cause of Evacuation: Due to power failure.

Problem Faced during Evacuation: During evacuation it was difficult in going down stairs without lights and the specialized devices to evacuate patients' vertically were limited.

Findings:

- Hospital should have more specialized devices, such as, Stair Chairs.
- Adequate elevator system required to transfer patients vertically. (Already considered in proposed strategies)
- Hospital building connection with other buildings in different levels, help to evacuate patients horizontally.
- The evacuation of Non-patient areas, such as, pharmacy, should be considered.

- The switch gear of generators should be above flood level. (Already considered in proposed strategies)
- More than one place to evacuate is suitable. (Already considered in proposed strategies)
- Assembly Area can be conference room, or where the supportive outlets are present.
- There should be primary and secondary patients' evacuation area.
- The stairwell corners need to consider the vertical evacuation of patients by stretcher, or evacuation board.

Case B: Columbus Indiana Flood, June 2008.

Cause of Evacuation: The basement was completely flooded and the first floor of the building had 6”-8” of water which incapacitate laboratory, radiology, and pharmacy services. There is no power, no access to medical records, no internet and no phones other than a single main phone line. The hospital had a safe evacuation of 157 patients.

Problem Faced during Evacuation: Patients' evacuation was challenging and stressful without electric power and supply.

Findings:

- The important functions of hospital should consider the flood level. (Already considered in proposed strategies)
- Emergency electrical power supply is necessary to evacuate the patients. (Already considered in proposed strategies)

Case C: Tropical Storm Allison, June 2001.

Cause of Evacuation: Flood water enters from two sides to the hospital complex. Broke the glass walls and doors, and also entered into the basement, ground floor and central core of the hospital caused power failure.

Problem Faced during Evacuation: Transferring patients' to other facilities was troublesome without electrical power, water, or telephone service.

Findings:

- Emergency electrical power supply, emergency communication system, lighting system are necessary to evacuate the patients. (Already considered in proposed strategies)
- Make sure the elevators are able to transfer patients' for vertical evacuation. (Already considered in proposed strategies)
- Lots of volunteer and staff required for the evacuation. (Already considered in proposed strategies)
- In building design the switchgear and generators should be located on above flood level. (Already considered in proposed strategies)

Case D: Hurricane Ike, September 2008.

Cause of Evacuation: Hurricane Ike and predicted loss of power and infrastructural support cause the evacuation.

Problem Faced during Evacuation: Faced problems coordinating with transportation vehicles in front of the hospital at the same time the patient arrived to load on the ambulance.

Findings: For mass evacuation, adequate space for transportation requires to transfer patients'. (Already considered in proposed strategies)

Most of the findings from the survey based case study have similarities with literature based case study findings. After the cross check of this findings with proposed strategies, the additional design considerations are listed below;

- Hospital building connection with other buildings in different levels, help to evacuate patients horizontally.
- The stairwell corners need to consider the vertical evacuation of patients by stretcher, or evacuation board.
- Assembly Area can be conference room, or where the supportive outlets are present.
- There should be primary and secondary patients' evacuation area.
- The evacuation of Non-patient areas, such as, pharmacy, should be considered.

4.2.2 Experts' Views on Proposed Strategies and Suggestions

As stated earlier, all the experts were asked to give their views and suggestions on proposed strategies. Their views came out for the strategies can be categorized in three ways; supportive, partially supportive and not-supportive.

a) Supportive: When most of the experts gave positive remarks and identified the advantages of one strategy, then it considered as a Supportive View.

b) Partially Supportive: When some experts gave identified the disadvantages of one strategy, then it considered as Partially Supportive View.

c) Not Supportive: When most of the experts mentioned about the disadvantages of one strategy, then it considered as Not Supportive View.

For the partial and not supportive views, the experts gave suggestions for alternative solutions. All the views and suggestions made by the experts about the proposed strategies are compiled below:

1. Evacuation procedure should be smooth and easy, to reduce travel time and extensive efforts for patients' transfer, especially the critical ones.

Views: Supportive

2. Evacuation systems need to be designed based on nature of threats and hazards.

Views: Supportive

3. Multiple evacuation exit points facilitate rapid and threat specific evacuation.

Views: Supportive

Suggestions: Depends on the building size and type, the exits should be distributed horizontally and vertically. Tall building should have multiple vertical exits.

4. Elevated helipads on roof tops or on elevated structure will be useful for air evacuation.

Views: Partially Supportive.

Cause: Sometimes the location of helipad on roof top is the only choice, such as, a hospital in urban dense area. But, if possible, it should be avoided, because any kind of accident or crash can make massive disaster for the hospital facilities.

Suggestions: Depends on hospital type and site, the location of helipad should be considered. In flood plain, it is wise to place the helipad on elevated platform, garage, and make connection with the hospital buildings. But in earthquake zone, a ground helipad with safe distance from the building is beneficiary.

5. Multiple accesses to the site with adequate space for transportation required for mass evacuation.

Views: Supportive

Suggestions: Multiple accesses also increase the safe entrance and exit to the site during disaster.

6. During adverse weather (storming heavily), the evacuation exit point should have facilities to protect patients transportation.

Views: Partially Supportive

Cause: It's better to have the protection in the evacuation exit points to move patients' into transportation. But it's difficult to provide shading for lots of transportations (10-15 Ambulance) during mass evacuation.

7. Ramp can be a suitable alternative solution for patients' vertical evacuation to reduce extensive efforts and number of people.

Views: Not Supportive

Cause: Hospital building should have ramp inside or outside, where it required according to ADA standards. But, as an alternative solution of inoperable elevator, ramp is not suitable. Because ramp is not frequently used in regular operation, as it requires extra effort to use, and also it takes lots of space to build.

Suggestions: In the flood affected area, hospital may have one outside ramp to access the boat or other facilities, but this consideration need more experiments. Stairwell is the practically alternative solution of elevators. Stairwell design should consider the turning radius of various specialized devices, such as Backboard, Stretcher, or Scoop Stretchers.

8. The number and size of elevators need to evaluate based on evacuation requirements.

Views: Supportive

Suggestions: Usually the hospitals are designed with minimum number of elevators (big one) considering the construction cost and life-cycle cost. To support the evacuation process, this number needs to increase. The addition of elevator can increase the overall life safety of the hospital by reducing the travel time and efforts of staff/nurses. The supportive value engineering needs to focus on this issue. The last stoppage of elevator should be above the flood level.

9. Assembly Area should be located inside and outside of the hospital building to support the evacuation process. All necessary medical supplies should accommodate in the Assembly Area.

Views: Supportive

Suggestions: Inside Assembly Area

Inside Assembly Area is more preferable for the patients' care than outside. It can be any space inside the hospital; emergency department, conference room, or lounge, need to design with adequate supportive facilities for continuous care to the patients. Also should have provision to separate the contagious patients. In high-rise building, multiple Assembly Areas should be designed in different vertical location.

Suggestions: Outside Assembly Area

Location should be threat specific, such as, for fire or explosion, the location should have safe distance from the building. It can be parking lot, terrace top, roof top or any elevated platform. It can be designed with shading device to protect them from sun or rain. Both types of Assembly Areas should have the provisions to transfer patients to other facilities.

10. Hospital should have the adequate facility for emergency power, lighting, communication and a signage system.

Views: Supportive

Suggestions: Flash lights should be located in every units of a hospital and should have a hanging system on the wall to reduce the efforts to hold that.

11. The zoning of patients' accommodation should be arranged to limit the travel distance of evacuate.

Views: Partially Supportive

Cause: Some hospitals may have to evacuate frequently due to their location and threats, such as, hospitals in New Orleans; for those, patients' travel distance can be an important consideration. But in most cases, evacuation is a rare process; the zoning of patients' accommodation can consider the evacuation travel distance without hampering other important concerns.

Suggestions: In hospital complex, it is wise to connect one building with others in different level, specifically, where the critically ill patients are located to avoid the vertical evacuation.

12. Zoning of important functions should consider the evacuation procedure.

Views: Supportive

Suggestions: The zoning of important functions should consider the threats and vulnerability, such as, pharmacy, laboratory, supply storage, physical plant, switch gear or generators. Critical functions should have the options and flexibility to accommodate extensive services during disaster situation.

5. DISCUSSION

The overall results from the literature review, case studies and experts' review are summarized and discussed below:

The hospital design needs to consider the full building evacuation. The design should incorporate the strategies to make the procedure smooth and easy and to reduce the duration and extensive efforts for evacuation. Identification of threats and evacuation pattern is necessary to design the evacuation system properly.

The literature review recognized that a hospital can have multiple threats according to its location, building type, facilities and geography. So evacuation routes and exits should be multiple and threat specific. The experts suggested that depending on the building size and type, the evacuation exits should be distributed horizontally and vertically. For instance, tall buildings should have multiple vertical exits. From the threats analysis, it is clear that evacuation travel time is a very important factor for rapid evacuation. So, without hampering other design considerations, the zoning of patients' accommodations should consider the evacuation duration and accessibility to exit. From the literature and survey based case study, it reveals again that the location of important functions should consider the threats and vulnerability; for example, the switch gear or generators should be located above the flood level.

In hospital complex design, it is beneficiary to connect one building with others in different levels, specifically where the critically ill patients are located to avoid a vertical evacuation. During mass evacuation hospital may have external visitors, staff or patients' family members, so that hospital facilities should have flexibility to accommodate extensive services. Though the study only focuses on patient evacuation, design should consider the non-patient area evacuation, such as a pharmacy, laboratory, medical supplies areas, etc.

Multiple accesses to the site with adequate space for the transportation required for mass evacuation should also be considered. This also increases the safe access to the site. As access depends on hospital location and site, for dense urban areas, accesses may be limited. The location of helipads should be considered in the threat pattern, as well as a hospital's type and size. Roof top helipads need to be avoided due to accidental hazards. In a flood plain, it is wise to place the helipad on an elevated platform or garage and to make a connection with the hospital building. In an earthquake zone, a ground helipad with a safe distance from the building is beneficiary.

Most of the experts suggest increasing the number of elevators (big one), because they can be designed with minimum configurations considering the construction cost and life-cycle cost. The addition of elevators can increase the overall life safety of the hospital by reducing the travel time and efforts of staff/nurses. Value engineering needs to focus on this issue. Elevators are the most practical method of vertical evacuation for all threats except fire. Therefore, a continuous power supply is mandatory for elevator use during evacuation. Also, elevators need to be designed according to threat; for instance, in flood plains the last stoppage of elevators should be above the flood level.

Ramps could be an alternative solution, but most of the experts suggest avoiding ramps because they take lots of space to build, but are rarely used in regular time. Also the staff must exert more effort to push a patient's wheelchair or bed down a long ramp pathway. In a flood-affected area, a hospital may have one outside ramp to access the boat, but this consideration need more experiments. A stairwell is the practical alternative to elevators. Stairwell design should consider the turning radius of various specialized devices, such as backboard, stretcher, or scoop stretchers.

An inside assembly area is more preferable for the patients' care than an outside area. It can be any space inside the hospital, such as the emergency department, conference room, or lounge, and it needs to be designed with adequate support facilities for continuous care to the patients. Also, ith should have provisions to separate the contagious patients. In high-rise buildings, multiple assembly areas should be designed in different vertical locations. For any kind of internal hazards, hospitals should have assembly areas outside the building to gather patients. This area can be a parking lot, terrace top, rooftop or any elevated platform, but it needs to be threat specific. For fire, explosion or earthquake, it should be at a safe distance from the building. It can be designed with a shading device to protect patients from sun or rain. Both types of assembly areas should have provisions to transfer patients outside.

Most of the findings from case studies are about emergency operation systems. During evacuation the emergency power supply is mandatory for hospital facilities. This system should be located in a secure place; for instance, the switch gear or generators should be located above the flood level. Also, the internal communication system or signage system should have the option of an emergency power supply or the ability to become battery operated. Flashlights should be located in every unit of a hospital and should have a hanging system on the wall to reduce efforts to hold the light.

6. CONCLUSIONS

6.1 Recommendations

1. Evacuation procedure should be smooth and easy, to reduce travel time and extensive efforts for patients' transfer, especially the critical ones.
2. Evacuation systems need to be designed based on nature of threats and hazards.
3. Multiple evacuation exits should provide to a building, and should distribute the exits horizontally and vertically.
4. The zoning of important functions should consider the threats and vulnerability, such as, pharmacy, laboratory, supply storage, physical plant, switch gear or generators.
5. Critical functions of a hospital should have the options and flexibility to accommodate extensive services during massive disaster.
6. In hospital complex design, it is wise to connect one building with others in different levels, specifically, where the critically ill patients are located to avoid the vertical evacuation.
7. Multiple accesses to the site with adequate space for transportation required for mass evacuation.
8. Location of helipad should threat specific.
   a. Ground helipad should be avoided for flood.
   b. For earthquake, ground helipad with a safe distance from the building is better.

c. Sometimes the hospital roof top is the only choice, but if possible the garage top can be a better option which can be connected with the hospital building in upper level.

9. A hospital should have two types of assembly areas; inside the building and one outside the building.

   a. Inside the building:

      - Any function can be considered as an assembly area during disaster.
      - Should have adequate outlets and supply to provide continuous care.
      - Emergency department can be a good choice for assembly area.
      - Should have the provision of separation for contagious patients.
      - Should be located near to the exit point, to transfer patients quickly.
      - For high-rise building, multiple assembly areas in different vertical location increase safety and reduce travel time.

   b. Outside the building:

      - Location should be threat specific, such as, for fire or explosion, the location should have safe distance from the building.
      - It can be parking lot, terrace top, roof top or any elevated platform.
      - May have provision for transport patients from there to other facilities.
      - May have shading device to protect from sun or rain.

10. The elevator is the practical way to transfer patients vertically, it should considered the followings;

    a. The operation of elevator should be protected from any kind of hazards.

b. The last stoppage of elevator should be above the flood level.

c. The number of elevator (big one) should be more than the minimum number mentioned in standards.

11. Stairwell design should consider the turning radius of various specialized devices, such as Backboard, Stretcher, or Scoop Stretchers.

12. Emergency power supply should be protected from any kind of hazards to provide continuous support for evacuation, especially for elevator.

13. Facilities, such as, communication system, lighting, signage, or clock should be designed with two types of operating system; electricity and battery.

14. Flash lights should be located in all units and stairwells with proper hanging system.

6.2 Example of 3-D Model

The strategies are listed in to a chart to provide the hospital designer, planner and administrator a checklist for design considerations. Also, a 3-D model of conceptual hospital building had been developed with the recommended strategies for better understanding of the implementation.

An example of a conceptual hospital building was designed based on the recommended design strategies. Also, a 3-D model of that example was developed using Google Sketch-up software to provide a better understanding. The model was simulated with three scenarios:

1) **Before Disaster:** Mandatory evacuation with regular duration for a hurricane.
2) **During Disaster:** A rapid evacuation for fire.
3) **After Disaster:** Evacuation due to flood.

The design 2-D perspective views for each scenario are enclosed in Appendix C.

6.3 Significance of the Study

Basically, the study looks into those design considerations that are related to evacuation of a full hospital building. The study focuses on patients' vertical evacuation and transportation during any kind of disaster. Until now, no exclusive study or recommendations with respect to design strategies for hospital building evacuation design have been identified. Hence, this study provides strategies for design considerations that can be implemented by healthcare architects and planners to reduce the evacuation difficulties and efforts. The paper also presents a matrix of hospital evacuation methods according to threats that can be used by architects to design a threat-specific evacuation route. Most of the design strategies that are recommended can be effectively implemented to a hospital building to improve the evacuation process.

Moreover, AIA and NFPA, which look over hospital building evacuation design standards, still have not considered full hospital building evacuation. Therefore, this study will be a supportive resource for the relevant organizations, researchers and designers to develop the design guidelines for full hospital building evacuation. The findings of this study also help the hospital emergency management facility managers or administrators to assess their facility and develop plans to improve the building layout for complete evacuation.

6.4 Future Directions

With the threat analysis and interventions of new technologies, the continuous modification and improvement of current rules and standards is necessary. This study will help to update some standards related to hospital building evacuation design. Further study could be done on specific threats with evacuation methods. This study has developed a matrix of threats and evacuation methods, which could be a good resource to have as a preliminary understanding. Further study could concentrate on cost analysis of recommended strategies for construction in a new hospital building.

A rapid evacuation within a limited amount of time is challenging for large hospital facilities, especially for the patients who are critically ill and who have medical life-support equipment. Further research could focus on the evacuation travel time for different types of patients with the location of evacuation exits.

The number and size of hospital elevators is an important consideration for evacuation. A study could be done on the effective number of elevators for a hospital facility to evacuate patients vertically within a limited amount of time. Also, research can be focused on patients’ vertical evacuation with building height and size, which would help healthcare architects for zoning of patients’ accommodations considering vertical evacuation.

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APPENDIX A

QUESTIONNAIRE – SET ‘A’

A. DEMOGRAPHIC INFORMATION

Please provide the following information,

1. Name of the hospital:
2. Number of storey tall:
3. How many helipads does the hospital have?
4. Where is the location of the helipad?

B. VIEWS AND EXPERIENCE

The hospital building design concept is mostly “defend-in-place”. The patients’ evacuation primarily depends upon Horizontal evacuation. The vertical or full building evacuation is the last resort. Recently several natural and manmade disasters have happened that forced evacuating patients’ from a hospital building. Some disasters give very short warning, like explosions, fire, nuclear blast, tsunami, etc.

1. What types of patient evacuation does the hospital disaster plan addressed?
    a. generic (“all-hazards”), or
    b. specific to a particular threat
1. What is the procedure to evacuate the patients in ICU, CCU, and PICU or with difficult mobility?
2. Does the evacuation route need to use the elevator?
3. Does the Hospital have any emergency lighting system, emergency signage system or battery operated signage system?
4. Did you estimate time to evacuate patients?
5. Does the hospital practice any kind of drill for patients’ evacuation?
6. What type of problems did the hospital face or accepting to face during the evacuation?
7. Recommendations for changes in building or utility system to facilitate the evacuation procedure. Specially, when to evacuate patients’ within a limited amount of time.

QUESTIONNAIRE – SET 'B'

The hospital building design concept is mostly "defend-in-place". The patients' evacuation primarily depends upon Horizontal evacuation. The vertical or full building evacuation is the last resort. Recently several natural and manmade disasters have happened that forced evacuating patients' from a hospital building. Some disasters give very short warning, like explosions, fire, nuclear blast, tsunami, etc.

C. Please provide your valuable recommendations for design strategies for hospital building to facilitate the evacuation procedure. Specially, when to evacuate patients within a limited amount of time.

D. Please provide your comments about the following suggestions.

1) Evacuation systems need to be design based on nature of the hazard.
2) Facilities should be arranged to limit the travel distance of patients to evacuate.
3) Multiple evacuation exit points facilitate quick evacuation.
4) Based on the evacuation travel time the number and size of elevators should be evaluated.
5) Zoning of patients' accommodation should consider the evacuation travel time.
6) Multiple accesses to the site will be advantageous for evacuation transportation.
7) Assembly Area outside the hospital building will be supportive for the evacuation.
8) For continuous care, providing medical supplies in the Assembly Area will be beneficial.
9) During adverse weather (storming heavily) the evacuation exit point needs to protect patients from hospital to transportation.
10) Emergency lighting and a signage system are essential for evacuation during power shortage.
11) If all the elevators become inoperable, use of ramp makes the evacuation procedure more suitable for the patients with limited mobility.
12) During Hurricane Katrina, air evacuation was impaired because many ground level helicopter landing pads were under water. Elevated helipads on roof tops or on elevated structure will be useful for air evacuation.

APPENDIX B

TEXAS A&M UNIVERSITY
DIVISION OF RESEARCH AND GRADUATE STUDIES - OFFICE OF RESEARCH COMPLIANCE

1186 TAMU, General Services Complex | 979.458.1467
College Station, TX 77843-1186 | FAX 979.862.3176
750 Agronomy Road, #3500 | http://researchcompliance.tamu.edu

Institutional Biosafety Committee | Institutional Animal Care and Use Committee | Institutional Review Board

DATE: 11-Sep-2008

MEMORANDUM

TO: KADER, SHARMIN
77843-3578

FROM: Office of Research Compliance
Institutional Review Board

SUBJECT: Initial Review

Protocol Number:	2008-0520
Title:	Hospital Building Evaluation System Design
Review Category:	Exempt from IRB Review

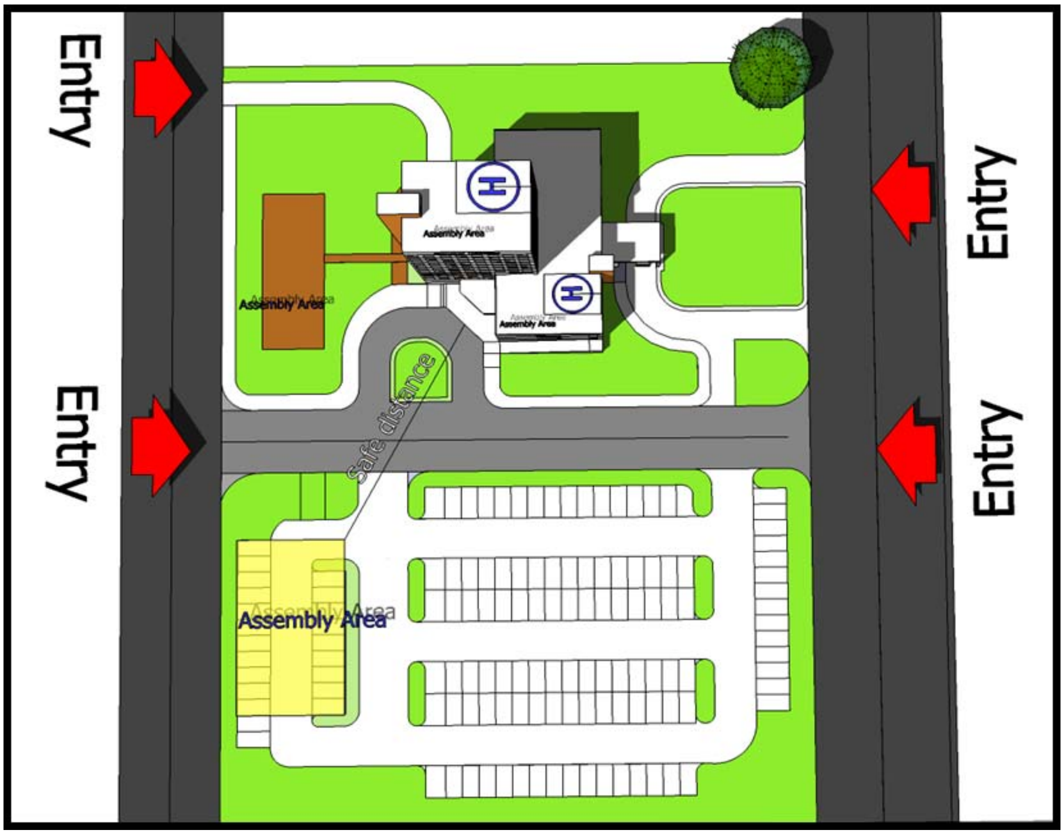
It has been determined that the referenced protocol application meets the criteria for exemption and no further review is required. However, any amendment or modification to the protocol must be reported to the IRB and reviewed before being implemented to ensure the protocol still meets the criteria for exemption.

This determination was based on the following Code of Federal Regulations:
(http://www.hhs.gov/ohrp/humansubjects/guidance/45cfr46.htm)

45 CFR 46.101(b)(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior, unless: (a) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (b) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

APPENDIX C

A Conceptual Hospital Project: Site Plan



There are four ground accesses to the site with two helipads for air evacuation. Two Emergency Assembly Area; one is located with a safe distance from the building and other is within immediate distance.

A Conceptual Hospital Project: Perspective View 1.

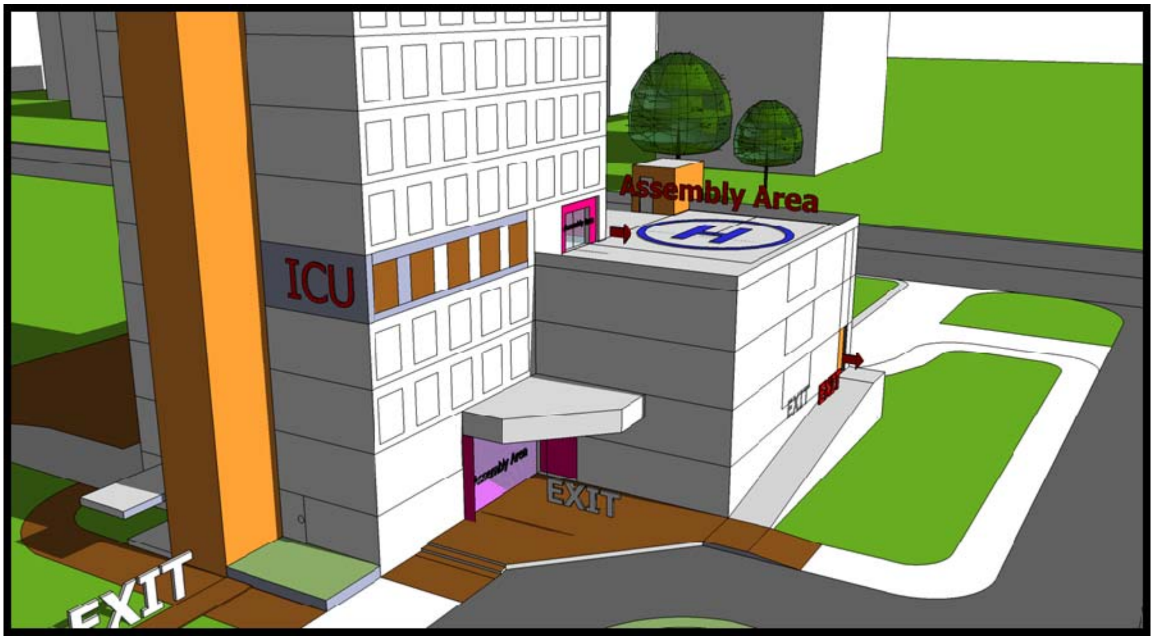
There are two helipads in the building.

One is located on top of the roof and other is located on top of the portico.

ICU located at fourth floor, adjacent with portico. Portico also has access to transfer patients by air or ground transportations.

On the left side the outside adjacent Emergency Assembly Area.

A Conceptual Hospital Project: Perspective View 2.



There are two Emergency Assembly Areas in this perspective.

One is located on fourth floor, near the ICU patients, to support patients transfer during evacuation.

Another one is located on ground floor, near the entrance lobby, to support patients transfer during evacuation.

A Conceptual Hospital Project: Perspective View 3.

Evacuation of the complete facilities before a hurricane threat.

Emergency Department can become one Assembly Areas, to support patients transfer during evacuation.

There is a ramp going down from the second floor of Emergency Department.

During Hurricane threat: Mass evacuation of an area.

Hospital is evacuating all patients by using multiple transportations.

During Hurricane threat: Mass evacuation of an area.

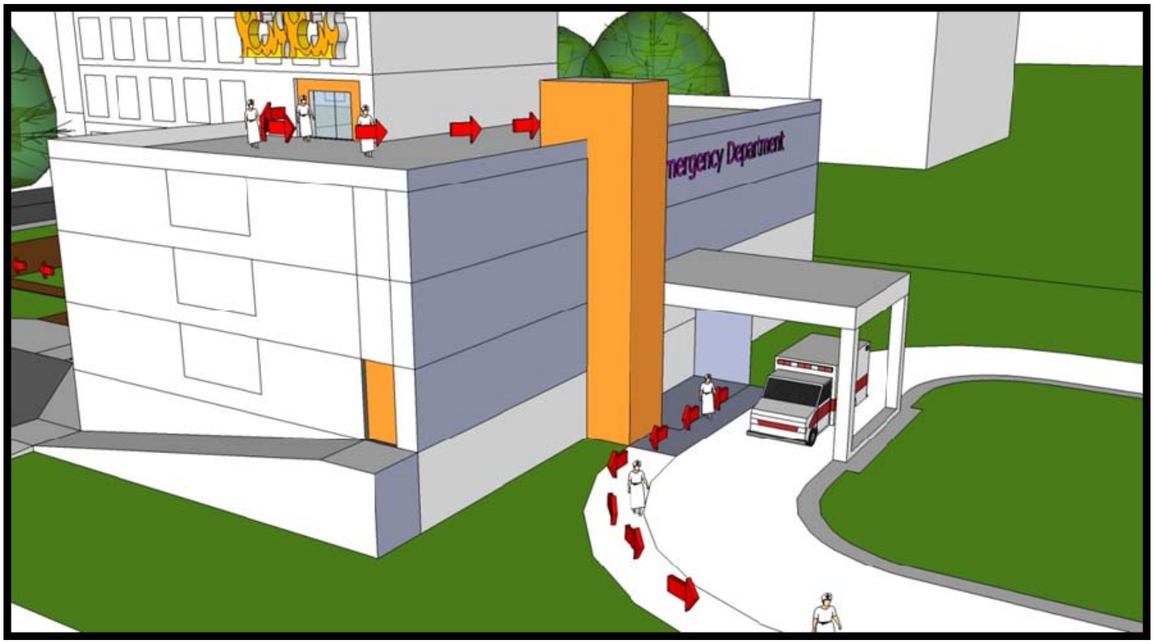
Multiple access of the side with transportation space are using for evacuation.

During Hurricane threat: Mass evacuation of an area.

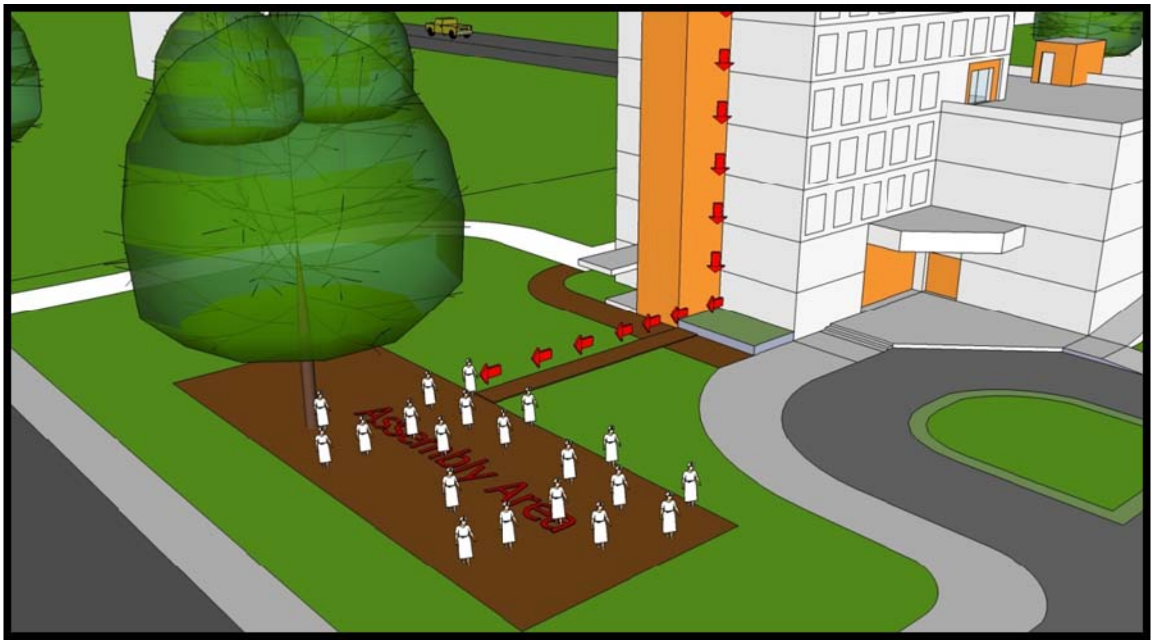
Hospital is evacuating all patients by using multiple transportations.

Evacuation of the complete facilities during a fire hazards.

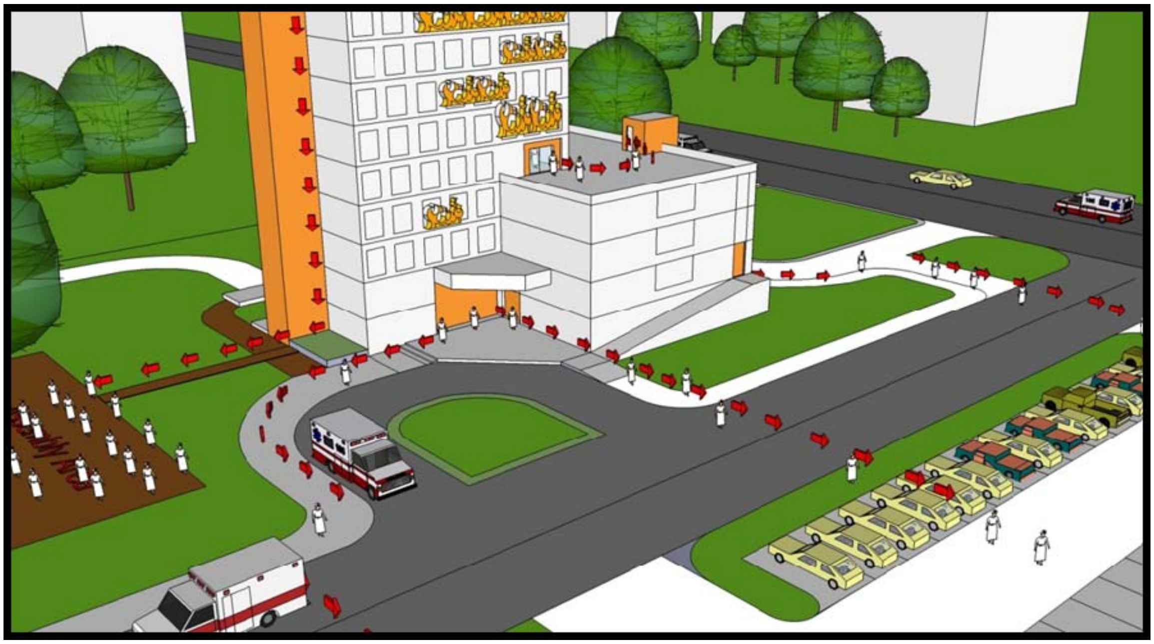
A fire hazard: Rapid Evacuation



ICU patients can be transfer quickly to avoid the smoke of the building by using portico.

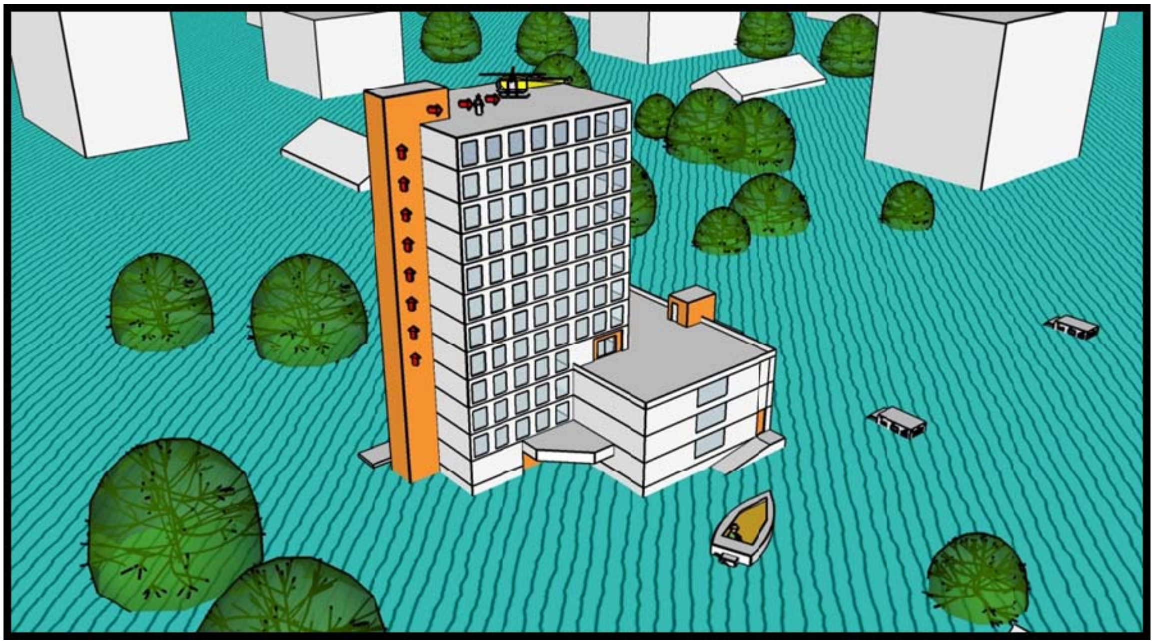


People are coming out to the outside Assemble Area.

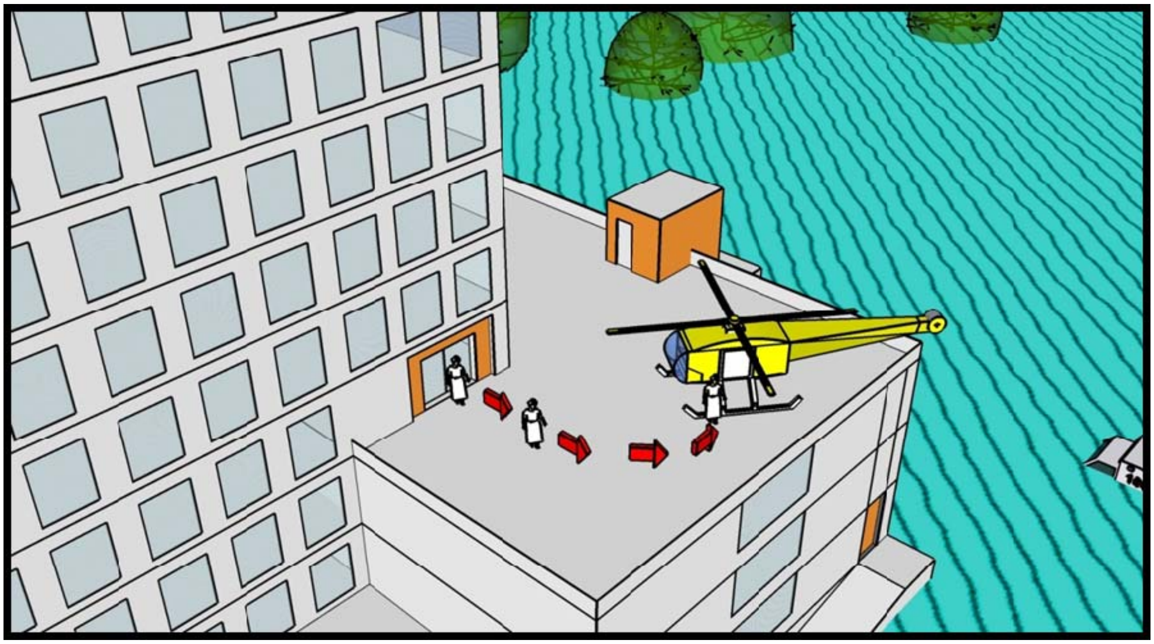


People are coming out to the outside Assemble Area by using multiple exit.

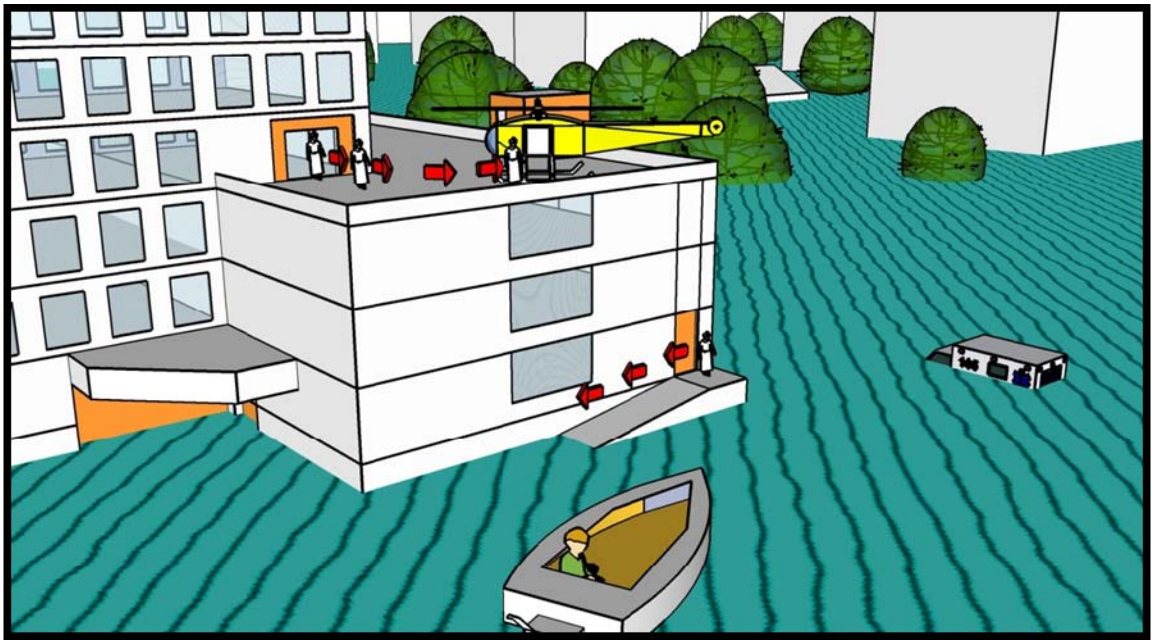
Evacuation of the complete facilities due to power shortage after a flood.



During surrounded by flood water: Air evacuation using roof top helipad



During surrounded by flood water: In case of roof top, air evacuation can be possible using portico top helipad



During surrounded by flood water: Boat evacuation using ramp.

VITA

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