Planning a Disaster Resistant University Study

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INTRODUCTION

In the wake of natural and manmade disasters that have occurred throughout the country including 9/11, Oklahoma City, Hurricane Katrina, Virginia Tech incident and the most recent flooding in the mid-west, society seems to be increasingly vulnerable. Amidst these disasters, the role of architects and planners in the protection of public and private property, and the preservation of human life, should come under increased evaluation.

Universities campuses are home to buildings that vary in function and form. Universities are research centers whose laboratory buildings contain chemicals, and often-irreplaceable specimens. Many universities are also hospitals that house incapacitated patients and expensive equipment. Universities contain valuable arts collections, books, and artifacts. Many campuses are comprised of dormitory housing, restaurants, and retail. Teaching environments at the university including classrooms and lecture halls are occupied during most of the day and often into the night. These facilities hold mass numbers of students and faculty. In addition, many university buildings are historical, meaning they were designed and built without consideration for disasters, or without regulatory codes, especially measures to protect property and life from natural hazards such as hurricanes and earthquakes.

The increase in disaster coupled with the uniqueness of the university campus suggests that universities need to make efforts to understand the planning and design of their campus in order to prepare for future events. Recovering after a disaster in the university context is difficult. After an event questions such as where shall students be taught, and how will research continue are at the top of list because they are fundamental for sustaining the survival of the university as an operational institution. Hazard mitigation planning is therefore not only critical, but necessary for universities. Consideration should be given to Architecture and Planning programs within these universities to participate in disaster planning efforts.

BACKGROUND

Around 2000, FEMA granted six universities funding to study how their institutions could become more disaster resistant. This initiative was called the Disaster-Resistant University (DRU). Among the selected institutions was UC Berkeley. The Chancellor over campus affairs at Berkeley selected an Architecture faculty member, Mary Comerio, to lead a study to determine the vulnerability of campus in the event of an earthquake. Treating the study as an academic exercise, Professor Comerio led a group of researchers in other departments, professional consultants in the community and administrators in the most robust disaster resistant university study to date. The study’s initial goal, to establish a plan for disaster mitigation and planning of the physical environment on campus, has spawned multiple mitigation programs for existing and new construction at the campus of UC Berkeley. UC Berkeley has now retrofitted over half of the identified at risk buildings as a result of this initial effort and has one of the few performance based design and construction campus codes in existence.

Building upon the UC Berkeley study, in 2004 the authors, as architecture faculty at the University of Utah, organized a group of researchers on campus and collaborated with the Department of

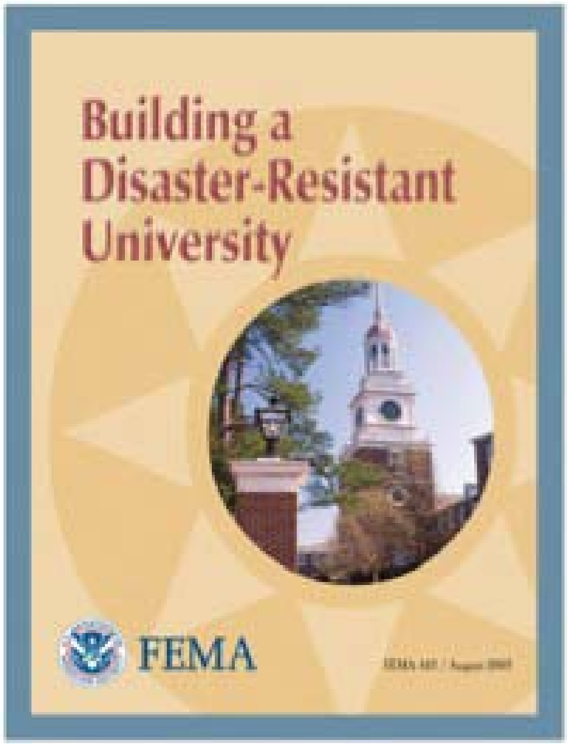

Figure 1: FEMA 443 Building a Disaster Resistant University guide.

Environmental Health and Safety (EHS) to convince the upper administration that a multi-hazard study of campus was necessary in order to prepare for a looming seismic event, hurricane, and potential flooding. Funding was sought in order to perform the study. In 2005 FEMA moved the funding for DRU studies into the larger competitive cycle of grants called FEMA Pre-disaster Mitigation Grants – Competitive (PDM-C). This made obtaining a grant for multihazard university studies much more difficult. The grant was sought after in order to perform the study with the group of researchers interested in disaster planning on campus and prepare a plan for mitigation at the university. Funding was awarded in 2006 for a three-year project, where the participants are in the 2nd year.

The following paper will outline the DRU study structure at the University of Utah, the key players, and focus on the technical aspect of the study for which the authors participated. The results of the study are confidential, but will be released as a formal report once the final phases of the project are completed next year. In addition to our experiences as architecture faculty, which are far from over, a publication by FEMA titled Disaster Resistant University helps in developing a plan of action for doing such a study, however does not give advice on what to avoid in such as study.[1] (Fig.1) As each institution is unique, this paper should be seen as representative of one case, however, the experiences can be valuable for similar studies. Therefore, this paper is intended be a support to faculty researchers in schools of architecture and planning contemplating or who are currently engaged in the process of predisaster mitigation planning.

DRU STRUCTURE

In developing plan for mitigation efforts, the team identified four phases that consist of: (I) Organize resources; (II) Hazard/risk assessment and loss estimation; (III) Development of mitigation plan; and (IV) Adoption and implementation of the plan.

Phase I. Organize Resources

To develop a comprehensive plan, the first phase of the four-phase action plan entails organizing the resources necessary to run a risk and loss assessments, develop a plan, and implement the plan campus wide. The Department of Environmental Health and Safety at the University of Utah was selected to manage the activities surrounding the development and implementation of the mitigation plan. To this end, the department, prior to the application for funding, organized an Advisory Committee comprised of representatives from various organizations, departments, and communities on and adjacent to campus, such as: Facilities and Public Works, Public Safety, Health and Safety, Telecommunications, Research Administration, Business Administration, Computing Services, Architectural Services, Academic Administration, Public Relations, Legal Council, Risk and Insurance Management. Members of the Advisory Committee assembled and met on occasion and will continue to meet throughout the study. The Advisory Committee organized a mission statement for the project and was the lead group to create a methodology for plan development.
In addition to the Advisory Committee, a Technical Work Group, comprised of faculty researchers on campus including the authors and other faculty instigators of the study, were participants in the

development of the mission statement and methodology. This was necessary in order to understand the context for work of the second phase of risk assessment and loss estimation. Beginning a study of this magnitude, a fundamental question of research versus service emerges. The study was primarily considered service to the university. The key during the process however was to unravel potential research avenues. The goal was to build on the Berkeley methodology but provide a more in depth evaluation of nonstructural and geotechnical data as well as establish a method for planning for research-oriented universities with medical schools. The goals and objectives should be clearly defined before applying for the DRU funding. For example, if the study is to perform an inventory, a professional agency perhaps is more appropriate than faculty researchers from the institution. However, an invested interest in the place of work and bettering the academic environment suggests involving faculty on campus in the study. The DRU study, in the case of Berkeley, has led to additional interdisciplinary research and more in depth evaluations of problematic buildings uncovered during the evaluation. In the case of Utah, the DRU was an opportunity for departments on campus eager to work together, but never having an initiative to do so, utilize the funding to discover the vulnerabilities on campus and develop interdepartmental research relations in the process.

Determining the goals of the project early on and who will be involved is a crucial beginning step to a DRU study. Further, an important beginning is establishing a structure of reporting and decision-making. At the University of Utah the project was adopted by the President's office as a key element in an ongoing effort to develop and update the campus master plan. The DRU grant was awarded to the university, but administered through the EHS whose job it is to monitor chemicals, OSHA practices, and maintain the general health and welfare of campus. A DRU director from within the EHS was hired to manage the elements of the project and see the project through from Phase I to IV. This individual in the case of Berkeley and Utah was an experienced individual on campus with whom faculty and staff were familiar. In addition, the director had an integral knowledge of the programs and physical characteristics of the campus environment. Having the study be top heavy with administration has lessened the burden on the working groups, specifically the technical group of which the authors are a part. (Fig.2)

Phase II. Hazard/Risk Assessment and Loss Estimation

The core working committee consisted of geoscientists, engineers, and architects. These researchers came from campus departments because of the pent up interest among the faculty in the topic specifically of seismic risk to campus. Phase II is the most important and time intensive portion of the project as the data will drive the development of the plan and ultimately the direction of mitigation efforts on campus. Therefore, a committed and generally congenial collaborative group is necessary for this phase. Not only is Phase II the most time consuming and important, it is also the portion of the DRU that has the most potential for innovation and research. The theory of the group performing the study was to push the study to yield more than service but present research and publishing opportunities.

In trying to determine what method of risk assessment and loss estimation to use, many tools came our way. The tool used during this phase is the Hazus-Multi-Hazard Advanced Engineering Building Model (HMH), first developed by Charlie Kircher, Structural Engineer in the San Francisco Bay Area, and adapted by FEMA. The tool to date has never been used on a DRU study. The tool was also selected as a standard in which the university might be able to update the inputs in the future for annual risk and loss scenario runs. More on the HMH will be discussed later.

The second phase of the four-phase action plan therefore consists of a fourstage process:

(1) Identifying hazards;
(2) Profiling hazard events;
(3) Inventory assets; and
(4) Estimate losses.

Identifying Hazards:

The State of Utah Department of Emergency Services and Homeland Security identified local hazards for the Salt Lake region including: drought, fire, flood, freezing, hurricane, severe ice storm, land subsidence, nuclear, earthquake, mud/landslide, snow, special event, severe storm, tornado,

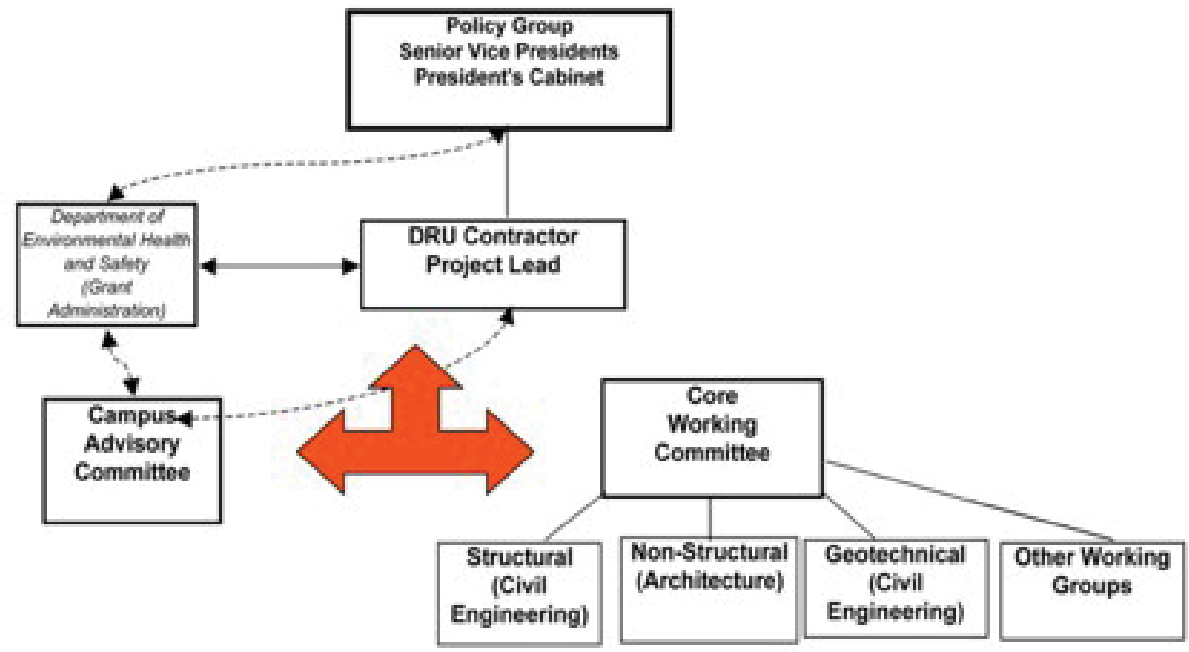

Figure 2: University of Utah disaster resistant university structure

toxic substances, and windstorms. Additional local hazards include human-caused events, such as terrorist activity and civil unrest. Due to the presence of laboratories and the

University Hospital, the Advisory Committee initially identified other hazards specific to the University of Utah, which include biological and chemical hazards. A major earthquake in the Salt Lake Valley or adjacent valleys has been identified as the most significant hazard that will impact the operations of the University, its infrastructure, hospitals, and medical and research facilities, etc. for an extended time period. Coupling the potential occurrence of a major seismic event with likely damage to biological and chemical contents of medical facilities, earthquake risks become even more threatening.

Profiling Hazard Events:

Each hazard imposes a specific demand on a system, which depending on the intensity may lead to damage. For example, a large, nearby earthquake may cause severe ground shaking which may damage of various structures and facilities. This demand can be either expressed deterministically, via a scenario event, or probabilistically. A deterministic scenario event for the University may consist of a M7.0 maximum credible earthquake occurring on the nearby Salt Lake City segment of the Wasatch fault. Given this earthquake event and the proximity of the fault, deterministic estimates of strong motion and the potential for damage can be calculated for campus facilities.

However, from a risk perspective, it may not be prudent to perform loss estimation for the "worst case scenario," using a deterministic earthquake. The "worst case scenario," or maximum credible earthquake does not occur very often, so the frequency, or return period, of the events is also an important consideration. Probabilistic methods consider both the frequency and intensity of all possible events, so that the complete seismic hazard is represented in annual probabilities. This approach was utilized for this project. The profiling of the seismic hazards for this project was done using strong motion estimates from the National Seismic Hazard Mapping Project. These estimates were modified for soil effects taken from data of soil report that were recorded as part of new building efforts on campus. This data was used in a probabilistic manner in the vulnerability and loss estimations activities within the HMH. The faculty geoscientist developed the ideology for this portion of the study in consultation with the other technical team members.

Inventory Assets:

To support the risk assessment and loss estimation, an extensive system/inventory analysis was performed to catalogue and describe the University's systems and assets. The inventory analysis was both of structures, and nonstructural contents of buildings. Ideally, the inventory would also consider infrastructure, however due to time and budget constraints was left for a later study. The data gathering efforts were as comprehensive as possible, with a prioritization according to the functional classification of each University system used when time was an issue. The functional classifications include critical functions, essential functions, important functions, and routine functions. The complied inventories were developed in GIS format for the subsequent vulnerability and loss estimation according to the format requirements of HMH.

Beginning the study, a fifteen-year-old seismic plan, written by Dr., Professor and Chair in the Department of Civil Engineering and the University of Utah, with graduate research assistants, updated the building inventory for the mapping exercise and helped to establish ranking criteria for structural stability with respect to the identified hazards. Dr. Reaveley was the structural consultant on ATC-39 Rapid Visual Screening for Seismic Vulnerability that has become FEMA 154, 155.[2] The authors, faculty in the College of Architecture + Planning, along with graduate research assistants, performed an in depth non-structural contents and components. The DRU director, and members of the Advisory Committee from the Department of Campus Facilities and Planning were and continue to be instrumental in gathering data during the process.

The non-structural evaluation of assets was arguably the most involved element of the study. Based on FEMA 74 [3] and FEMA 443, non-structural was divided into three data gathering modes: contents and component information including equipment, furnishings, hazardous materials, enclosures, built-in millwork, mechanical/electrical/plumbing and finishes; occupancy information including occupancy type and populations; and financial information including valuations and fiscal accounting. All the data for inventory was available directly on campus, however discovering where in what form the data existed was difficult.

Valuations were determined from insurance reports. These values were carefully scrutinized to ensure current dates for valuation. The University of Utah departments produce reports annually including fiscal accounting reports of income from rent, tuition, and retail as well as expenditures such as wages and overhead. Research accounting provided reports concerning research dollars generated by department. Space planning provided reports concerning space use on campus. In addition to reports, the Department of Facilities and Planning was instrumental in having an open door policy where the authors were able to investigate any building's digital and/or physical archive. For information on the physical character of the nonstructural components, the campus Fire Marshall provided data on hazardous chemicals. Assumptions were made about bracing of components of buildings based on code benchmarks from the campus code official and FEMA 454. [4]

A software program also developed by FEMA called InCast is a data capture user interface for the HMH module. This tool allowed the nonstructural researchers and their assistants continue to update the data. InCast offers an image identification function that was instrumental to the coordination of the core working committee. Photos were taken of each facility and associated with building data by the structural team. A numbering system was used as well as the name of the building, but the photograph provided a much-needed point of reference during the inventory portion of the study. In addition, the photos provided information for enclosure type data, architectural character, and evaluation of falling hazards.

Data not taken into account in the nonstructural assessment included the quantity and type of hazardous materials. This information was pertinent to scientific and medical facilities on campus, whose housing of these materials increases their vulnerability to hazard. The infrastructure backup per building is not considered, for example: a back-up generator in a hospital is necessary to it's functioning in after an event and was discovered but not captured in the HMH model. Enclosure systems of buildings are evaluated based on hurricane scenarios, but are not considered with regard to seismic. In addition, secondary effects on buildings are not considered as part of the HMH method. For example, in the scenario event of a hurricane, the glass enclosure on a building is damaged, and the effects of rainwater on the computers inside and the loss associated are not accounted for in the HMH model. Much of these omissions will be considered in an analog analysis post processing of the model scenario runs.

A major concern of the authors during the inventory phase was occupancy type and population data. For each calculation in the HMH, occupancy type and population is the base factor required for loss of life evaluation. HMH allows for only one occupancy type allocation per building. It was determined to ubiquitously apply the most prevalent occupancy type for the occupancy input field (i.e. "Assembly" for a stadium). The populations of the spaces were determined from a space planning report. HMH asks for peak day and night populations. The difficulty with this method is that the report did not show the maximum populations for large lecture classrooms and event spaces such as the performing arts center and the stadiums as they are not scheduled as regular teaching spaces. These numbers had to be obtained separately. It should also be noted that departments on campus assign many spaces within campus buildings. Departmental scheduling data could not be captured from the campus space planning macro data.

A major draw back to the utilization of HMH for nonstructural risk assessment is that the loss of life is considered only for structural damage. Although death is very low as a result of nonstructural in precedent hazard events around the world, content and components accounts for over half of reported injuries.
Estimate Losses:

"Loss" estimates the personal and economic impact to the University from the scenario event(s). Four types of scenarios were simulated: (1) loss of life; (2) loss of property by way of structures and contents; (3) loss of function or downtime, and (4) social losses. One of the requirements from FEMA is that the developed methodology should be general enough so that it can be used as a template at other universities. To this end, the natural hazard evaluation and loss estimation for earthquakes was done using the *Advanced Engineering Building Module* (AEBM) of HAZUS-MH. HAZUSMH is a powerful loss estimation/risk assessment program for analyzing potential losses from earthquakes, floods, and hurricane winds. In this program, scientific and engineering knowledge is coupled with the latest geographic information systems (GIS) technology to produce estimates of damage and losses from these hazards.

HAZUS-MH loss estimation capabilities include:

Life safety losses resulting from death and injury include determining which structures and facilities may have collapsed and estimating death resulting from collapse. This is a function of the building type and its occupancy. Nonfatal injuries can be estimated in a similar manner.

Physical damage losses to buildings include the cost of repair and reconstruction of critical facilities, infrastructure, components and contents. Physical damage losses are relatively straightforward to calculate using the expected damage obtained from the fragility curve for a given event and reasonable estimate of the repair or replacement costs. This difficulty has been in the gathering of the inventory as discussed previous.

Economic losses include costs resulting from interruptions of function and income from various University entities or enterprises (research institutes, centers, colleges, departments, retail enterprises). Economic losses are perhaps the hardest to estimate, but may be the largest component of the total loss. These losses should include loss of research assets, instructional time, damage to valuable medical, engineering and science laboratory equipment, data and information systems.
Social losses include loss of services and other valued assets. Societal losses are attributed to damage or loss of valuable library/art/historical and other collections.

Fragility is expressed as a curve that determines expected damage (i.e., loss or interruption of function) as a function of the intensity of the natural hazard. For example, in the case of a seismic event, fragility is expressed as percent damage to the structure or component versus the intensity of the ground shaking. Fragility is a function of the age, type of construction and configuration of the building; or in the case of components, their vulnerability to damage from earthquake shaking. Fragility curves are essential for vulnerability assessment and loss estimation. For seismic evaluations and the other hazards, the technical group used published fragility curves, or curves developed by expert opinion that were defaults in the HMH module to perform the subsequent damage and loss estimation. Future research is planned to develop fragilities specific to Salt Lake City events.

Phase III. Development of Mitigation Plan

After evaluating the conclusions reached by the hazard identification and risk assessment study, mitigation goals and objectives will develop. The University of Utah Hazard Mitigation Plan will address all of the hazards in prioritized order based on the university's vulnerability to specific natural and man-made hazards. After these specific hazards have been identified and prioritized, the management, with the help of the Advisory Committee and, particularly, the key participants, will determine the appropriate mitigation actions. The mitigation actions will also be prioritized based on a benefit cost analysis. An implementation strategy will be developed to determine how actions will be funded and who will be responsible for overseeing mitigation efforts.

Once the priorities are established and actions determined, the plan will be assembled. The plan will be assembled utilizing the data gathered, the evaluation of the conclusions, and FEMA 386-3 Developing the Mitigation Plan. An external board from UC Berkeley, a group that was instrumental in the initial FEMA Disaster Resistant University Initiative, will review the plan. The plan will then be reviewed on the Local, State and Federal level for changes and ultimately to be accepted as a FEMA-approved plan.

Phase IV. Adoption and Implementation

Once the plan is approved, it will be presented to the Office of the President of the University for formal adoption. Support from the President will help in disseminating the plan to other key campus and community stakeholders, including the governing body and Board of Trustees. The Advisory Committee will take the plan back to their organizations and departments to adopt and implement. Included in those targeted to endorse the plan is administration at the University and Departmental-level.

After adoption of the plan, implementation must necessarily commence. Coordinating the effort, the Advisory Committee will lead in measuring outcomes outlined in the plan. The Advisory Committee will develop an implementation strategy, including an extensive training period lead by the DHS and training officers hired by the department.

Other implementation efforts anticipated are adopting a set of design and construction regulations for facilities and planning on campus for all new buildings to be constructed to a higher disaster resistant standard. In addition, the effort will research additional sources of funding including FEMA Pre-Disaster Mitigation project grants for specific structural and non-structural retrofitting of existing buildings and building projects in design or early construction phases. The university will also work to disseminate the information of the plan to the other universities in the state through seminar workshops to train in hazard mitigation planning for the state. During the plan research and development a focus has be placed upon the processes at the university. This information will be disseminated throughout the United States as a model plan for medical laboratory universities. Therefore, in an effort to develop new information for the Disaster Resistant University Initiative, an analysis based on processes at the university will be disseminated for national benefit.

ENDNOTES

1. FEMA 443 Building a Disaster Resistant University. Federal Emergency Management Association. 2003. http://www.fema.gov/institution/dru.shtm

2. FEMA 154, 155 Rapid Visual Screening for Buildings for Potential Seismic Hazards: A Handbook. Second Edition. Federal Emergency Management Association. March 2003. http://www.fema.gov/library/viewRecord.do?id=1415

3. FEMA 74 Reducing the Risks of Nonstructural Earthquake Damage. Federal Emergency Management Association. September 1994. http://www.fema.gov/library/viewRecord.do?id=1574

4. FEMA 454 Designing for Earthquakes: Manual for Architects. Federal Emergency Management Association. December 2006. http://www.fema.gov/library/viewRecord.do?id+2418