PEER Decision Variable: Fatalities

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Discussion Topics

- Background on Casualty Modeling Efforts
- Current Scope of Work and the Integration of Casualty Models into PEER's PBEE Methodology
- Unresolved Issues / Future Efforts

Engineering-Based Casualty Models

- **Engineering-based** earthquake casualty models predict building damage-related casualties (and in some cases, other types of casualties).
- Typically developed by engineers from limited anecdotal, historical data (not from epidemiological studies, nor involving health-related researchers).
- Development efforts include USGS/NOAA (1970s), ATC (1980s), and HAZUS (1990s).
- Typically used for emergency response, planning and mitigation by government agencies, but are less useful for health preparedness planning.

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Example: ATC-13 Casualty Rates

ATC's expert-opinion based model relates casualty rates to damage state, defined solely by percent damage (as a percent of replacement cost) i.e., not dependent on structural type

Damage State	Range	Minor Injuries	Serious Injuries	Deaths
Slight	0-1	3/100,000	1/250,000	1/1,000,000
Light	1-10	3/10,000	1/25,000	1/100,000
Moderate	10-30	3/1,000	1/2,500	1/10,000
Heavy	30-60	3/100	1/250	1/1,000
Major	60-100	3/10	1/25	1/100
Destroyed	100	2/5	2/5	1/5
		Rate=30A	**Rate = 4A**	**Rate = A**

Note: for light steel and wood-frame construction, multiply all numerators by 0.1

HAZUS® Earthquake Loss Estimation Methodology - (HAZUS®99, SR-2)

- HAZUS building damage functions include: (1) building capacity (push-over) curves that are used to determine peak building response and (2) fragility curves (to determine the probability of reaching different damage states given peak building response).
- Damage states definitions include descriptions of physical damage mechanisms. For example, "Extensive" structural damage for Concrete MRF Structures:
  - "Some of the frame elements have reached their ultimate capacity indicated in ductile frames by large flexural cracks, spalled concrete and buckled main reinforcement; nonductile frame elements may have suffered shear failures or bond failures at reinforcement splices, or broken ties or buckled main reinforcement in columns which may result in partial collapse."

HAZUS® Earthquake Loss Estimation Methodology - Indoor Casualty Rates (HAZUS®99, SR-2)

•HAZUS includes both indoor and outdoor casualty rates, **by damage state** and **model building type**, based on ATC-13 and "limited historical data" for 4 injury severity levels:

»Injuries requiring basic medical aid
»Hospitalized
»Life threatening Injuries
»Deaths

	CASUALTY SEVERITY LEVEL			
Damage State	**Severity 1 (%)**	**Severity 2 (%)**	**Severity 3 (%)**	**Severity 4 (%)**
Slight	0.05	0	0	0
Moderate	0.2 – 0.25 (URM* = 0.35)	0.025 – 0.030 (URM = 0.40)	0 (URM = 0.001)	0 (URM = 0.001)
Extensive	1.0 (URM = 2.0)	0.1 (URM = 0.2)	0.001 (URM = 0.002)	0.001 (URM = 0.002)
Complete (No Collapse)	5.0 (URM = 10.0)	1.0 (URM = 2.0)	0.01 (URM = 0.02)	0.01 (URM = 0.02)
Complete (With Collapse)	40.0	20.0	5.0 (LRWF* = 3.0, MH* = 3.0, SLF* = 3.0)	10.0 (LRWF = 5.0, MH = 5.0, SLF = 5.0)

Notes:
URM = unreinforced masonry,
LRWF = low-rise wood frame,
HR URMI = high rise steel or concrete frame structures with URM Infill walls
MH = mobile home,
SLF = steel, light frame,
HR PC = high rise precast concrete structures

Current Research

An inter-disciplinary research team (UCLA and ABS/EQE) has been working to collect and correlate data from the Northridge and other earthquakes (currently collecting Nisqually data), including:

- building characteristics and damage data
- coroner's data, hospital admission data, ED logs
- Survey data on damage and injuries

Research goal: capitalize on the high-quality data to improve the way engineering-based models estimate building-related casualties, and make the results more meaningful to both emergency responders and health care providers.

Additional products include a **standardized classification scheme** for all aspects of earthquake-related casualties See: **http://www.ph.ucla.edu/cphdr/scheme.pdf**

Classification Scheme: Building Level Variables

Building Description:

- Structural System
- Building Height
- Building Size
- Building Year Built
- Seismic Design Quality (HAZUS)
- Debris Potential
- Occupancy Type
- Estimated Occupancy
- Actual Occupancy

Building Damage:

- Building Safety Inspection Status
- Building Safety Tag
- Dollar Damage
- Damage Percent
- Damage State
- Building Collapse

Individual Level Variables

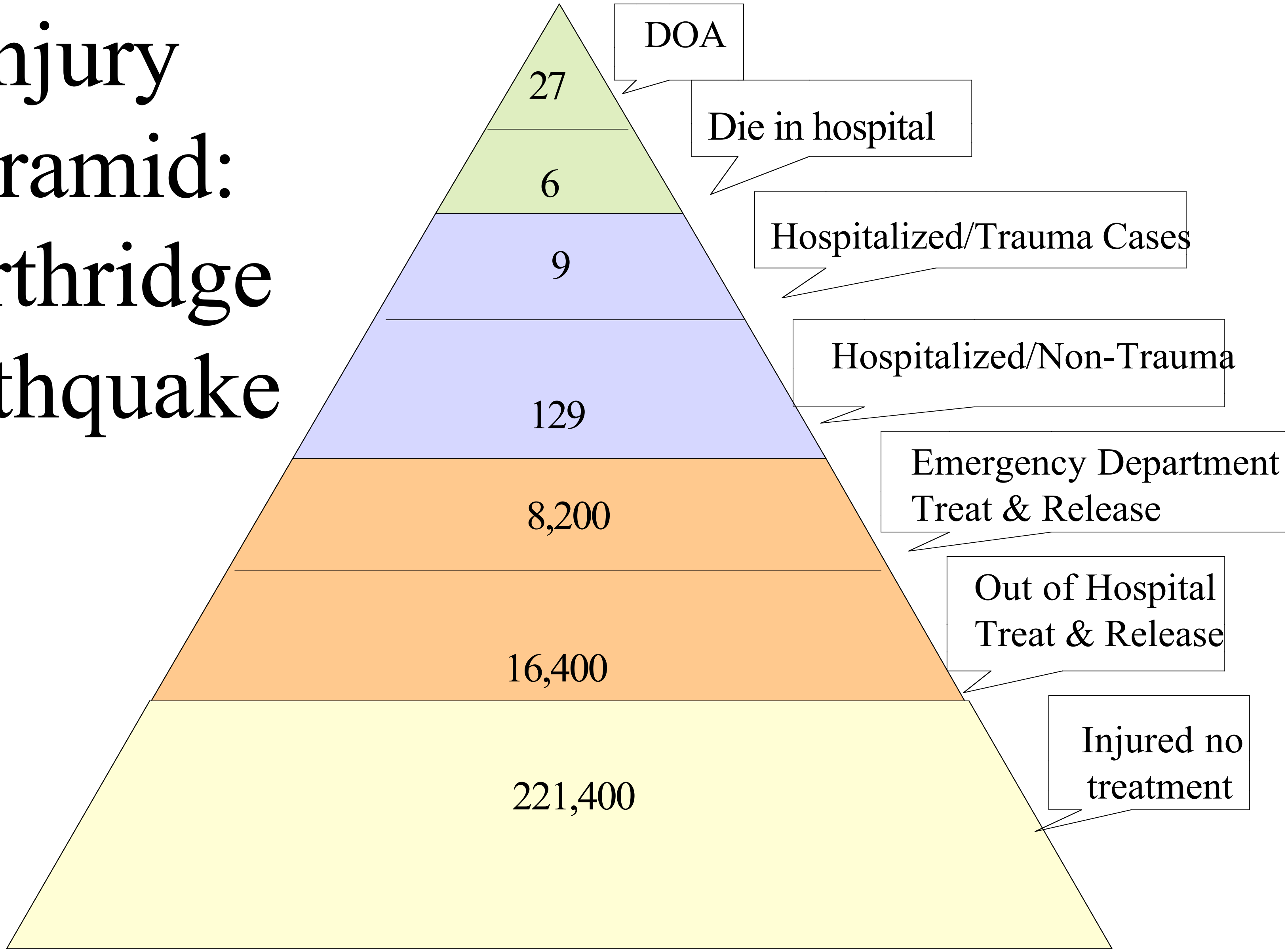
Demographics:

- Age
- Gender
- Race/Ethnicity
- Level of Education
- Occupation
- Income
- Disabilities and Pre-Existing Conditions

Injury Characteristics

- Cause of Injury
  - Relation to EQ
  - Structural Relatedness
  - Secondary Hazards
  - Injury Mechanism
- Injury Severity
- Treatment
  - Level of Treatment (see pyramid)
  - Immediacy
- Diagnoses
- Costs
  - Direct Medical Care Costs
  - Indirect Costs

Injury Pyramid: Northridge Earthquake



Current PEER Project Goals

- Develop a model framework for building-collapse related fatalities (DM = local collapse or global building collapse)
- Develop model parameters for **non-ductile concrete frame buildings** from available population-based survey data from 1999 Turkey Earthquake (Golcuk), and illustrate the application using the Van Nuys testbed.

Model Framework

- Definition of Relevant Damage Measures – working with other PEER researchers, clearly define DMs relevant to fatality models under consideration: **Local or partial collapse, global collapse, wall collapse***
  - Our concern: definition of these DMs relative to available fatality data (Golcuk survey)
  - Other PEER researchers concern: defining DMs for collapse from PEER PBEE model outputs (EDPs)

* Even though this failure mode is not relevant to VNT

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Golcuk Survey

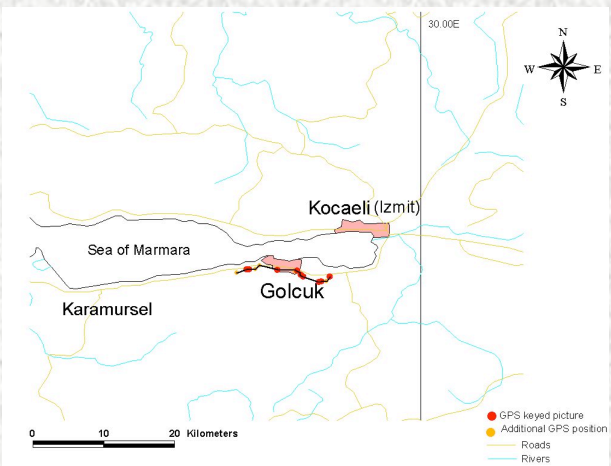
- Conducted by Marla A. Petal (now a UCLA Ph.D. candidate) and Suha Ulgen in March - June of 2001.
- 450 Households surveyed – 47% were HH in temporary housing whose homes were “damaged beyond repair” in the 1999 Kocaeli EQ, 53% were HH still occupying their homes at the time of the survey.
- Total population surveyed =1841 (238 injured, 34 killed)

Importance of Golcuk data

1999 Marmara EQ: ~17000 reported killed of 15M people in affected area
Overall Fatality rate =~1.13x10 $^{-3}$
(>300 x Northridge rate)

Golcuk: 1999 Pop = ~80,000
Fatalities = 34 of 1841 in survey
Survey Fatality rate = 1.85 x 10 $^{-2}$
> 5000 x Northridge rate.

Los Angeles Co. (4082 sq.mi.)
1994 pop = ~9.2 million
Northridge EQ bldg-related fatalities = 33 (22 bldg-related)
Fatality rate= 2.4 x 10^{-6} bldg
3.6 x 10-6 overall



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Relevance to VNTB: NDCF Building and Damage Data in Golcuk Survey

- Building parameters:
  - Building use – **Apt/condo (76%),** house (22%)
  - Construction – **Concrete (80% HH, 97% of deaths),** Brick/masonry (15%, 0%), Wood (4%, 3%)
  - Year Built
- Damage parameters:
  - Ceiling/roof damaged or collapsed, walls damaged or collapsed, floors damaged or collapsed, entire building destroyed

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Model Framework (Cont.)

- Model Co-Variates: we will identify parameters that may impact fatality risk for inclusion in the model framework:
  - Structure Type
  - Extent of damage/damage state
  - Demographics – age, gender
  - Location – floor location, ability to egress, actions taken
  - Time of day
- For NDCF model, we will review available Golcuk data, and determine which parameters may be assessed for quantification of risk variation.

Available Parameters for Injury Data in Golcuk Survey

- Demographics – age, gender, marital status, education, employment, own/rent, household size
- Location - Floor of Residence, floor location at time of EQ, Room location
- Activity - during EQ, during injury , movement type and direction
- Injury – time of occurrence, injury cause, injury type, body part, building element responsible, treatment

Components of Model Framework (Cont.)

- Form of fatality model – "probabilistic" relationship correlating fatality rate with damage measure, with co-variates. Northridge example:

Binary Logistic Regression Model where INJURED (0=N, 1=Y) is the dependent variable				
			95% CI	
Covariate	**P-value**	**Odds Ratio**	**Lower**	**Upper**
Gender (0=F, 1=M)	0.014	0.629	0.436	0.910
Moved (0=N, 1=Y)	0.058	1.378	0.990	1.919
Damaged (0=N, 1=Y)	0.000	9.701	6.203	15.172
Ages (0=under 40, 1=over 40)	0.014	0.633	0.440	0.910

Form of Model: Odds Ratio/Risk Ratio

- Odds Ratio (OR) is roughly equivalent to the Risk Ratio (RR) when the outcome is rare (generally less than 10% prevalence).
- The Risk Ratio approximates the risk of the outcome and can be used to estimate the outcome in a given population.

Application

- Application Guidelines and Limitations – We will provide guidelines that clearly document assumptions and limitations associated with the resulting model.
- In addition to developing the general framework, NDCF model parameters developed from the Golcuk survey data will be provided to allow test application to the VNT.
- Additional data on fatalities in Nishinomiya in the 1995 Kobe EQ will be reviewed to assess the model framework's applicability to other structure types.

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Future Directions in Casualty Modeling

- Continue on-going data collection and data integration efforts, including investigating recent earthquake events.
- Develop fatality models for other building types
- Develop injury models for NDCF buildings and other buildings types