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Managing the Risks from Natural Catastrophes: Are We Making Progress?

Robin Spence

Emeritus Professor of Architectural Engineering and Director of Cambridge University Centre for Risk in the Built Environment

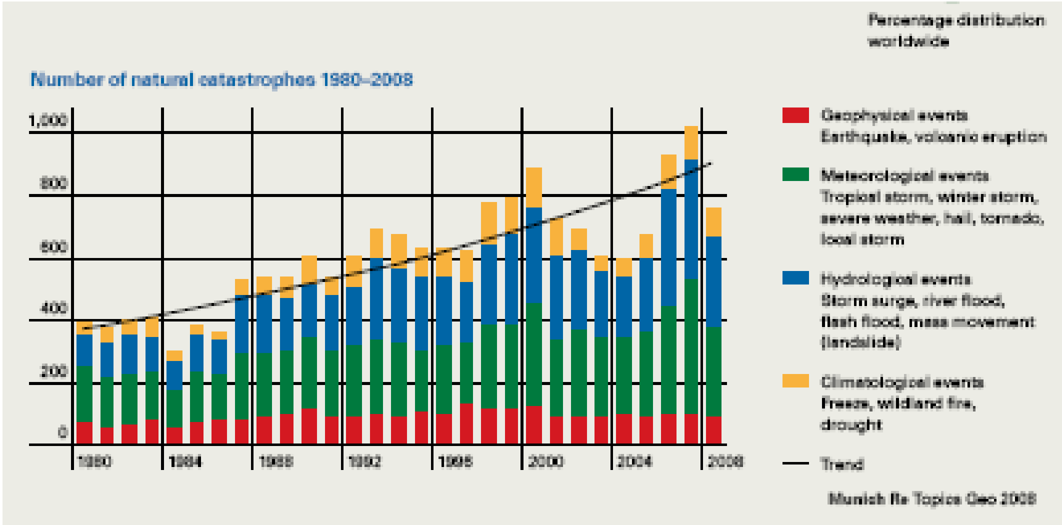
Director, Cambridge Architectural Research Ltd

Outline

- Reducing catastrophic risks- what progress?
- The causes of catastrophes
- Risk modelling- earthquakes and volcanic eruptions
- Can we do better ?

Numbers and costs of natural catastrophes – rising trend lines...

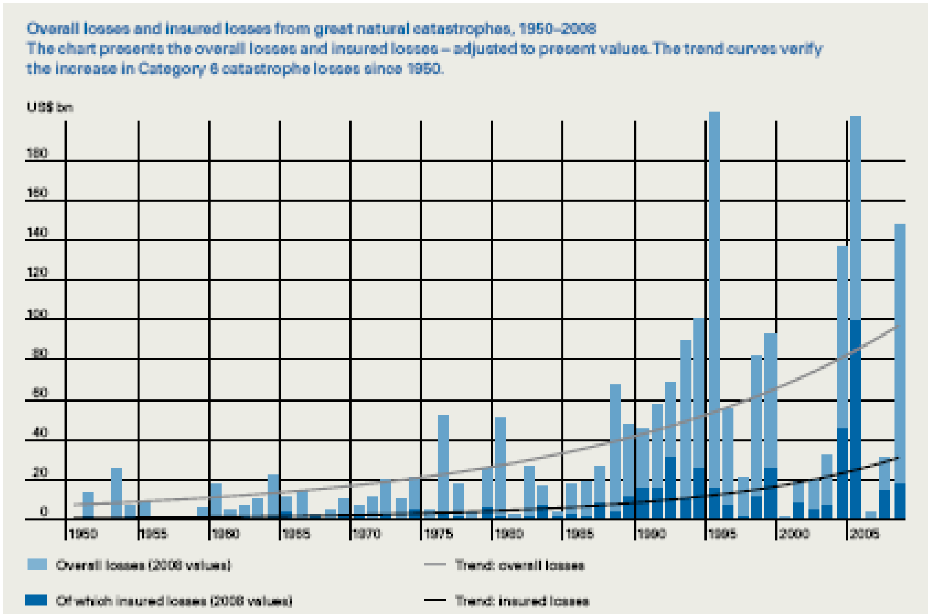
Numbers of catastrophic events have increased steadily since 1950s, with most of the growth in meteorological and hydrological events



Overall and insured losses (at constant prices) have been rising exponentially, with a doubling time of about 2-3 decades.

Reasons are rising populations, concentration of values, and climate change

Data from Munich Re Publication Natural Catastrophes, 2008

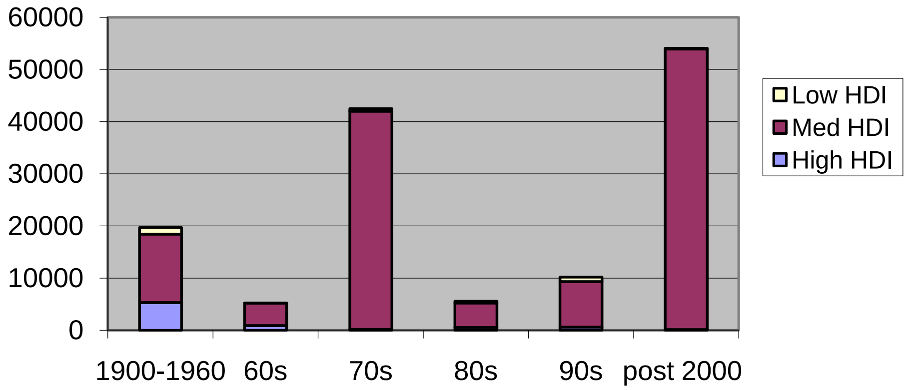


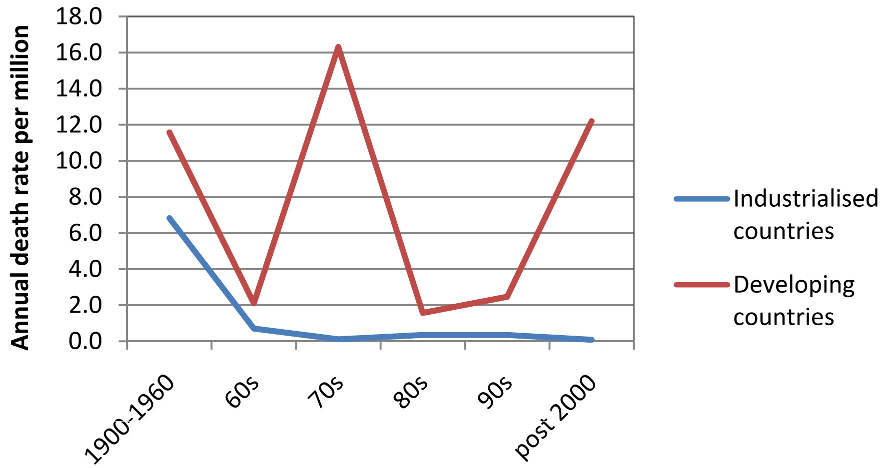
Annual death rates from earthquakes

The current decade has witnessed the highest annual death rate for the last 100 years

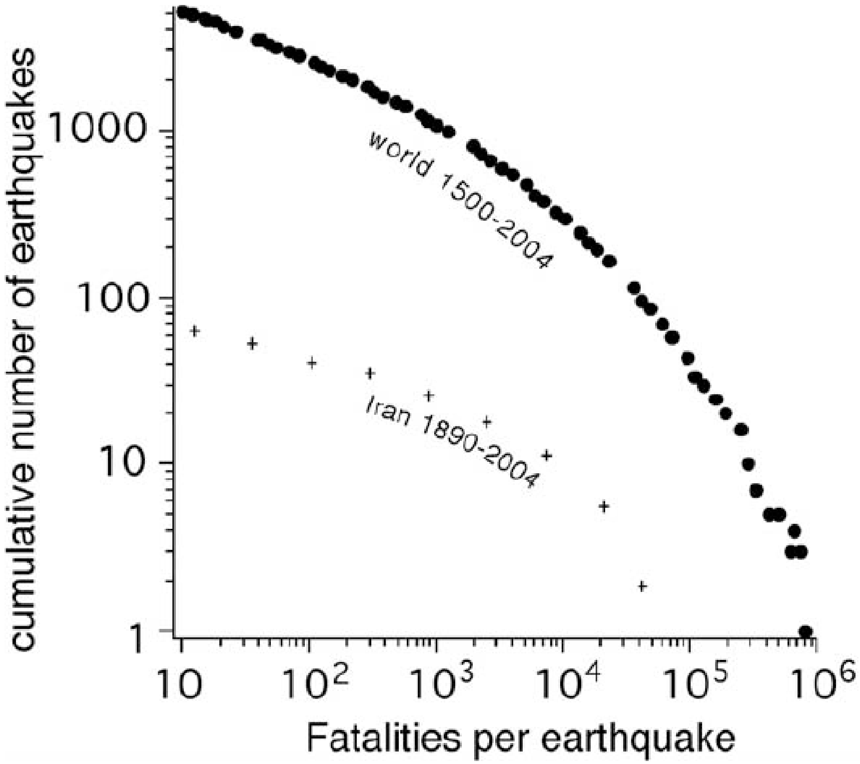
Allowing for population growth, in the richer countries the death rate has been sharply reduced

But in the poorer countries, there is no evidence of any sustained progress





Earthquake deaths – worse to come ?



Data on number of events globally causing a given number of fatalities over 5 centuries

Can be interpreted to suggest that with a global population of 10 billion we can expect a “one million fatality event “ once a century

Data from Iran show a similar trend

Cities most at risk include Tehran, Kathmandu, Lima, Xi’an

Source Roger Bilham, CIRES, University of Colorado

Risks from Volcanic Eruptions

Year	Volcano	Country	Damage in US $ million (2007)	Source
1973	Eldafjell	Iceland	93	EM-DAT
1980	Mount St.Helens	United States	3,327	EM-DAT
1982	Mount Galunggung	Indonesia	306	EM-DAT
1982	El Chichon	Mexico	224	EM-DAT
1983	Mount Gamalama	Indonesia	275	EM-DAT
1985	Nevado Del Ruiz	Colombia	1,719	EM-DAT
1991	Mount Pinatubo	Philippines	300	EM-DAT
1994	Rabaul/Tavarvur	Papua New Guinea	531	EM-DAT
1996	Grimsvotn	Iceland	21	EM-DAT
1997	Soufriere	Montserrat (UK)	10	EM-DAT
2001	Etna	Italy	4	EM-DAT
2002	Stromboli	Italy	1	NOAA
2006	Tungurahua	Ecuador	154	EM-DAT

- Financial losses from volcanic eruptions have been around $6 bn over the last 30 years, more than 50% from the 1980 Mt St Helens eruption.
- Deaths have been around 30,000 or 1000 per year.
- Human casualties have often been avoided by timely evacuation during a pre-eruption phase of unrest.
- There are many cities worldwide exposed to possible future eruptions, eg Quito, Naples
- Except in Japan, Western USA and New Zealand little has been done to prepare populations for possible future eruptions

Annual death rates: natural catastrophes compared with other risks

Cause of death	*Micromorts per year*
Smoking 10 cigarettes a day	4000
All natural causes, aged 40,UK	1176
Accidental deaths, UK	350
Traffic accident, UK	125
Earthquake, in Iran	43
Accident at home	38
Accident at work	23
Floods, in Bangladesh	**20**
Volcanic eruption, Vesuvian popn	**13**
Homicide, living in Europe	10
Floods, Northern China	**10**
Earthquake in Turkey	**9**
All natural disasters, globally	**7**
Railway accident, Europe	2
Earthquake, Globally	**2**
Earthquake, Japan	**1.1**
Earthquake California	**0.5**
Volcanic eruption, Globally	**0.5**
Hit by lightening	0.1

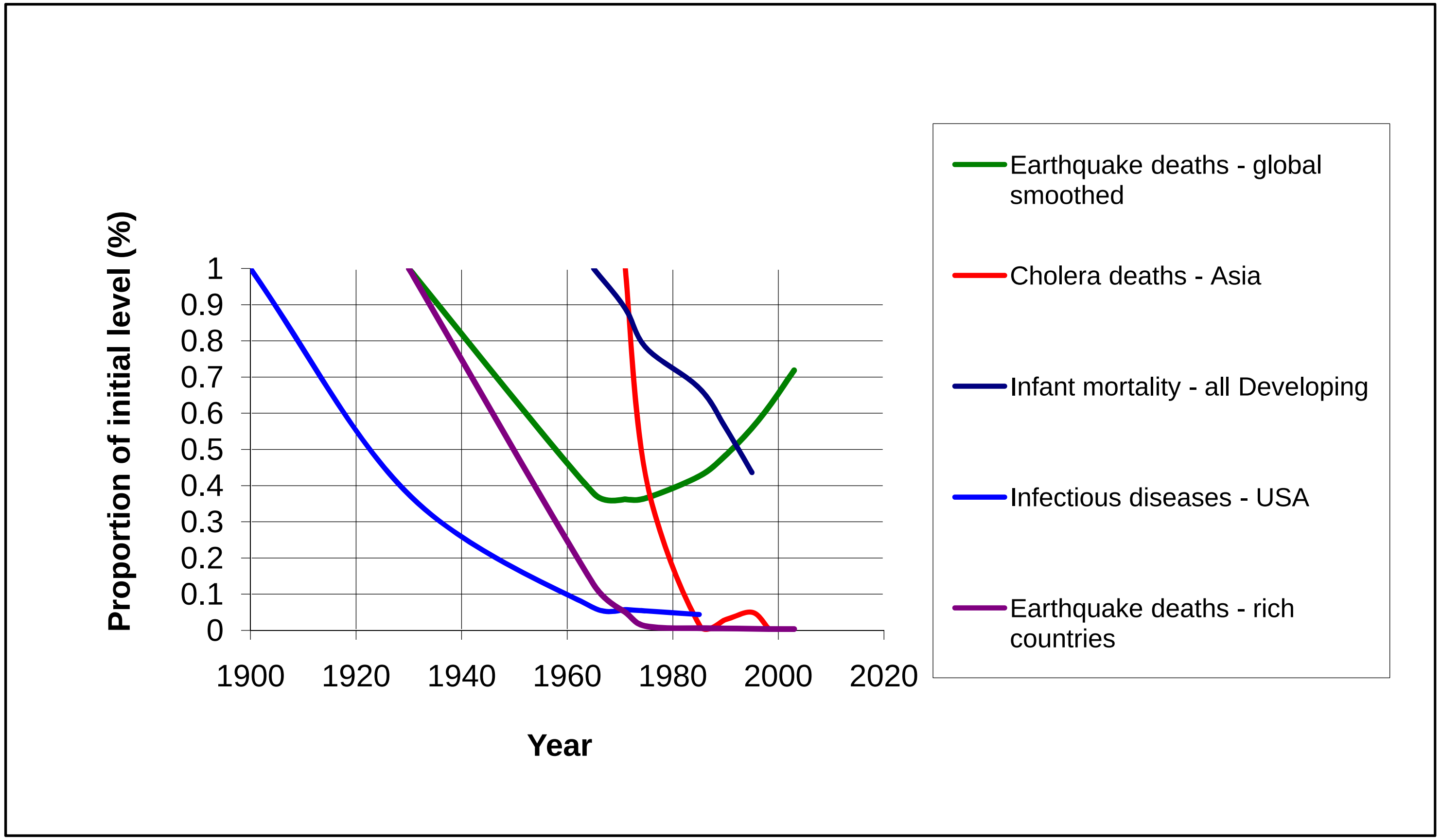
Such comparisons are often used in policy-making

They are questionable as they mix voluntary and involuntary risks

For catastrophe risks the definition of the population exposed and the time period considered make an enormous difference

Note: 1 micromort = one in a million risk of death

Earthquake risk reduction and public heath campaigns – relative achievements



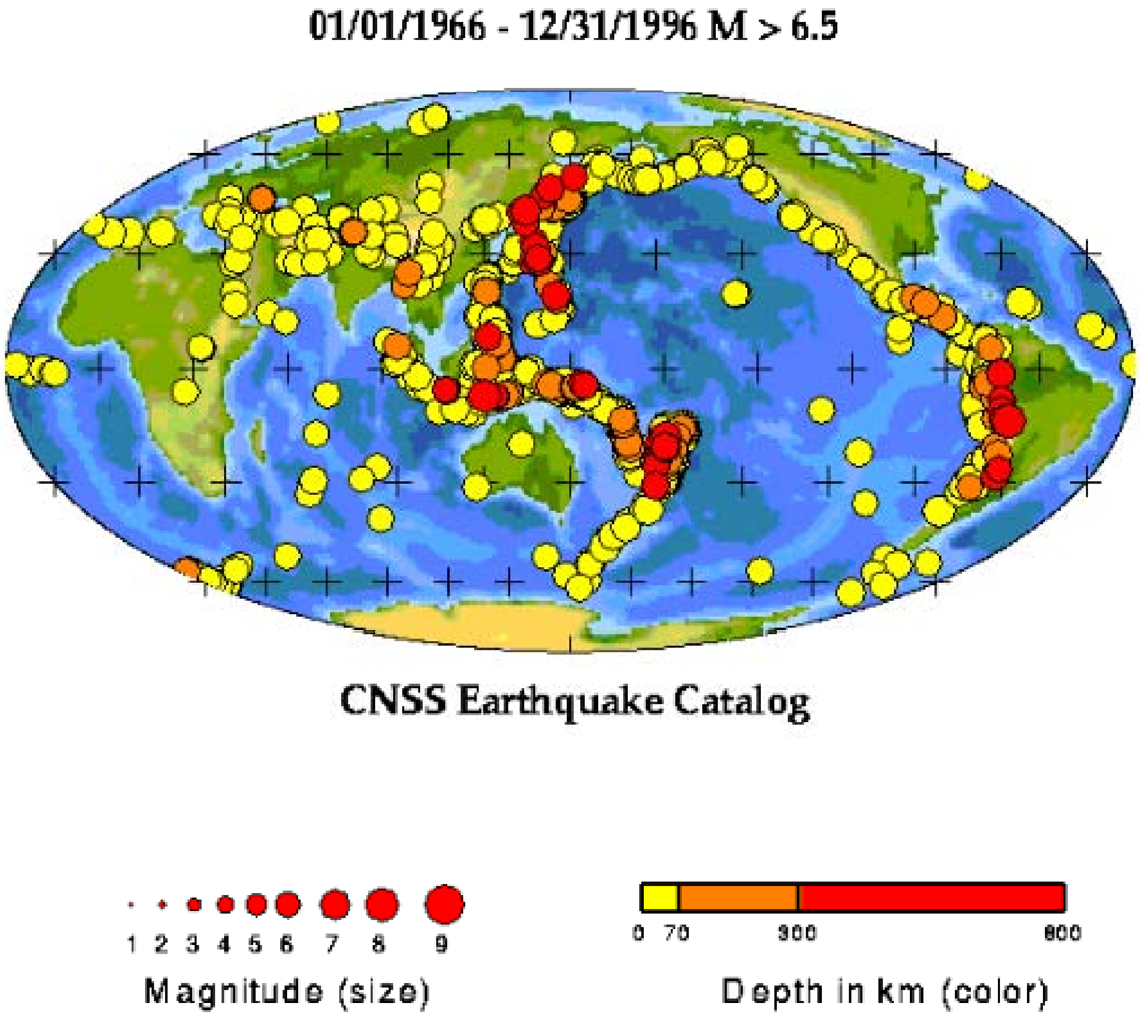
Causes of catastrophic events

- The location and magnitude of events
- The vulnerability of buildings, infrastructure and urban systems
- Human behaviour

Volcano losses depend on location, scale and type of eruption, and eruption frequency

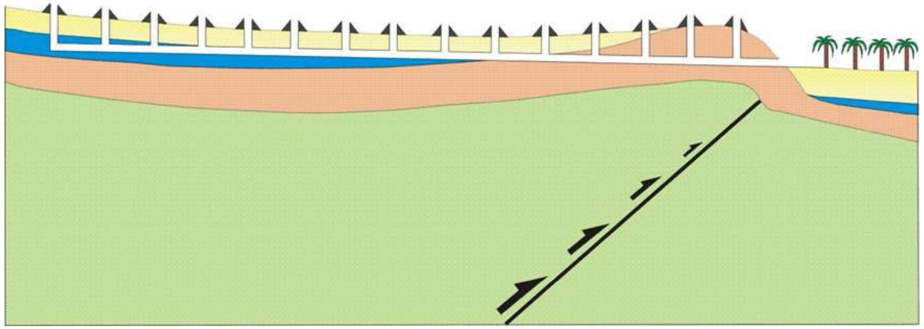
Locations of potentially hazardous volcanoes: Munich RE Globe of Natural Hazards

Earthquake losses depend on magnitude, location and frequency of large earthquakes



Locations and magnitudes of earthquakes of Mw>6.5 over 30 years

Earthquakes losses also depend on location of settlements – attracted to fault zones



Thrust faulting leads to the creation of water storage in arid regions, and accounts for the development of human settlements directly alongside fault systems (eg Bam - shown, Tabas, Tehran in Iran).

Also along the mountain margins in India, China?

Earthquake losses depend on building vulnerability

traditional forms of construction often have extreme vulnerability to ground shaking

Bhuj, India, 2001: 14,000 deaths
rubble and adobe masonry

Bam, Iran, 2003: 32,000 deaths
adobe with vaulted roofs

Earthquake losses depend on building vulnerability

In modern forms of construction requirements for earthquake resistance are frequently ignored

Building vulnerability can be reduced to a life-safe level by adopting modern codes

Western USA: earthquake-resistant buildings

Earthquake losses: secondary hazards

Landslides, tsunamis and fire following can be major sources of loss

Volcanic losses: building vulnerability

Tephra Fall: Mt Pinatubo, 1990

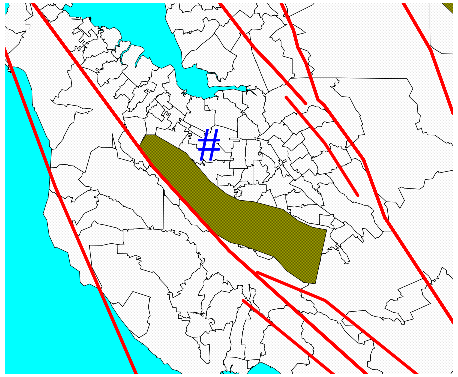
Pyroclastic density current: Montserrat, 1997

Casualties in earthquakes and volcanoes: the importance of human behaviour

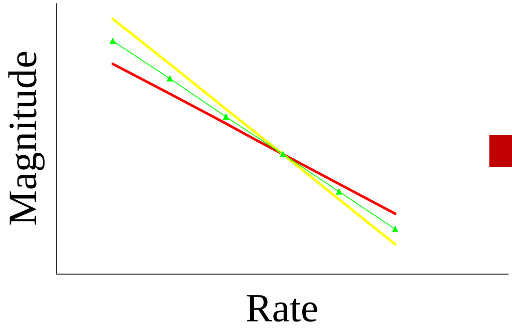
- Pre-event preparatory behaviour
- Action during the earthquake
- Post-event rescue and subsequent treatment

Earthquake Risk Modelling: Typical Structure

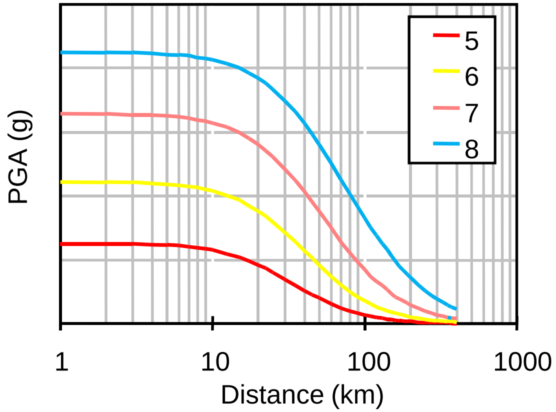
Source: Risk Management Solutions Inc.



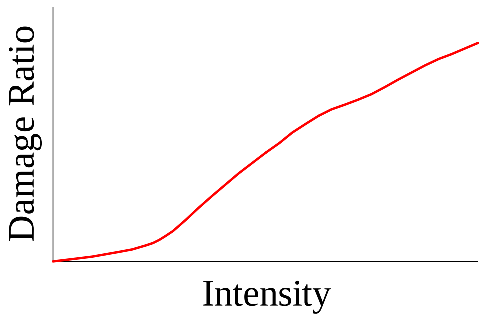
Source Definition



Event Rates



Attenuation



Vulnerability

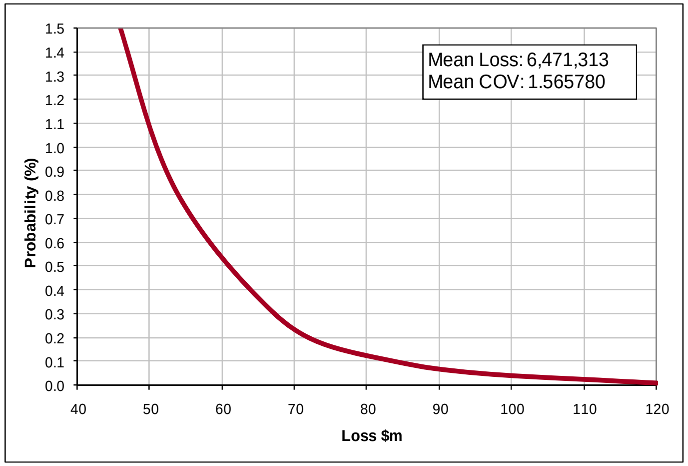
Event	Rate	Loss
1	.0001	$
2	.0002	$
3	.0001	$

Event Loss Table

EP Curve

Modelling earthquake risks for insurance

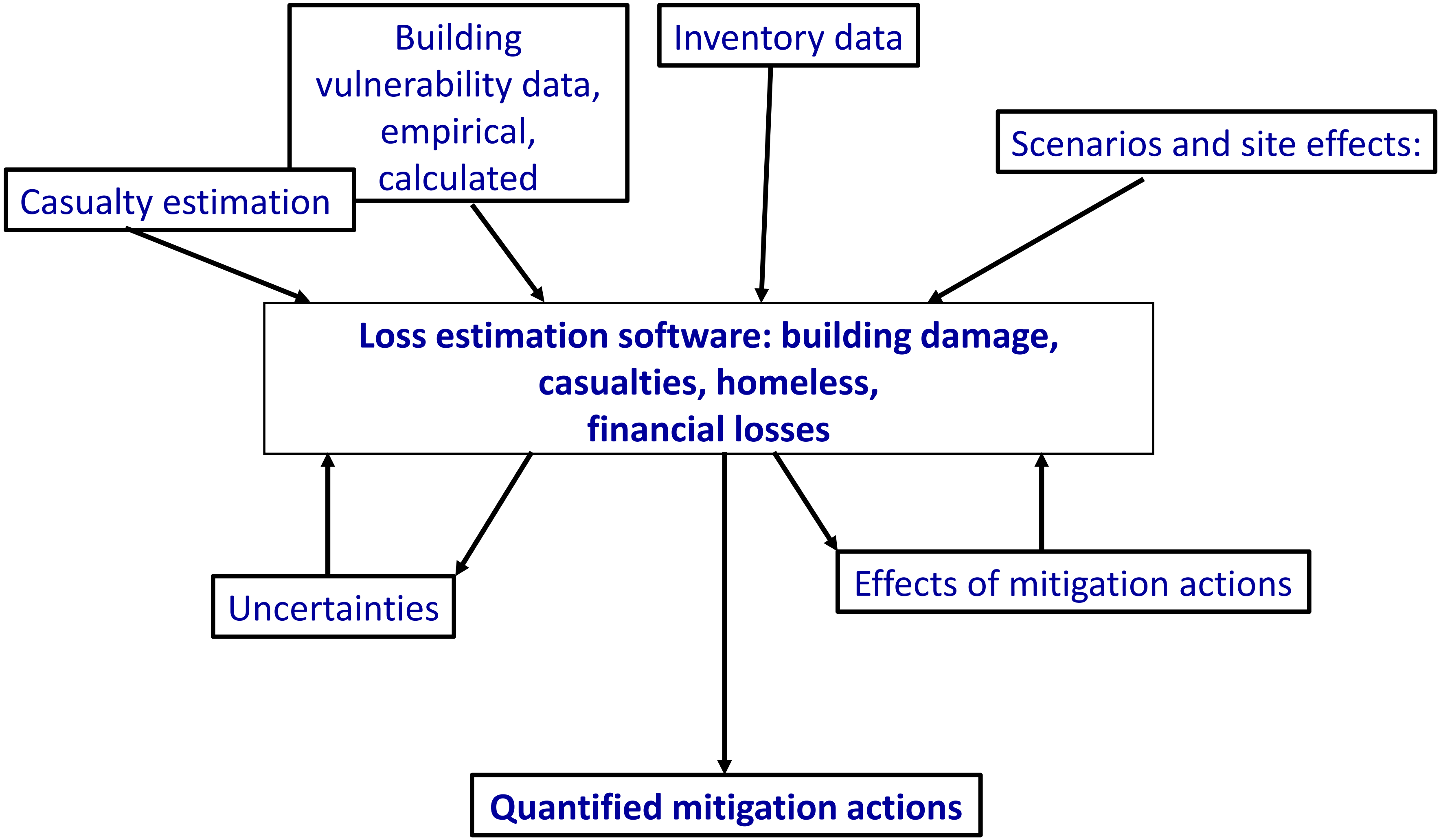
Event ID	Annual rate	Loss
1	R1	L1
..	.	..
N	Rn	Ln



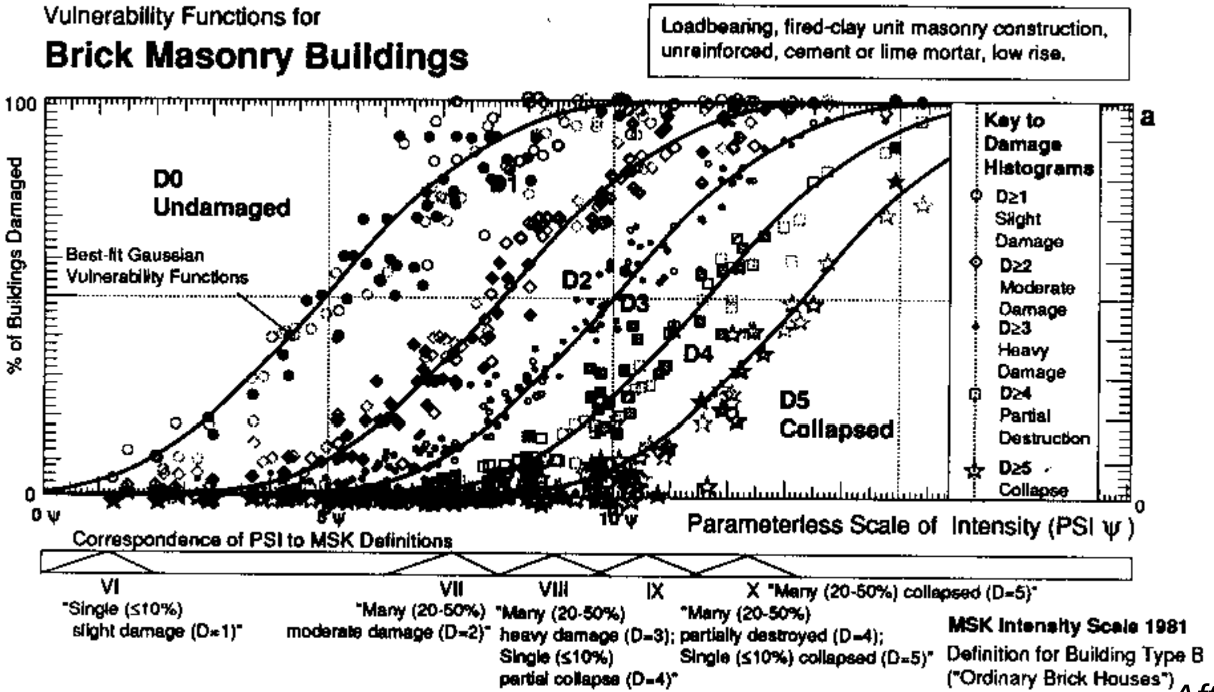
- Aim **is to produce a Loss Exceedence Probability (EP) Curve for the client's portfolio, which can be used to determine pricing and reinsurance needs**
- This is derived from an event-loss table which gives expected losses from a large number of simulated events, each assigned an annual probability
- In the last decade, commercial modelling companies (eg RMS) have developed country earthquake risk models for most countries.
- There are also flood and hurricane risk models, but no volcano risk models yet.
- These models are of great importance in insurance, and are now part of the regulation of insurance companies
- Methods and outputs are confidential to clients, so methods of treating uncertainty are unknown.

Modelling earthquake risk for urban mitigation

Aims: provide quantified statements about the benefits of possible mitigation actions, to support decision-making by urban authorities



Vulnerability estimation: observed vulnerability

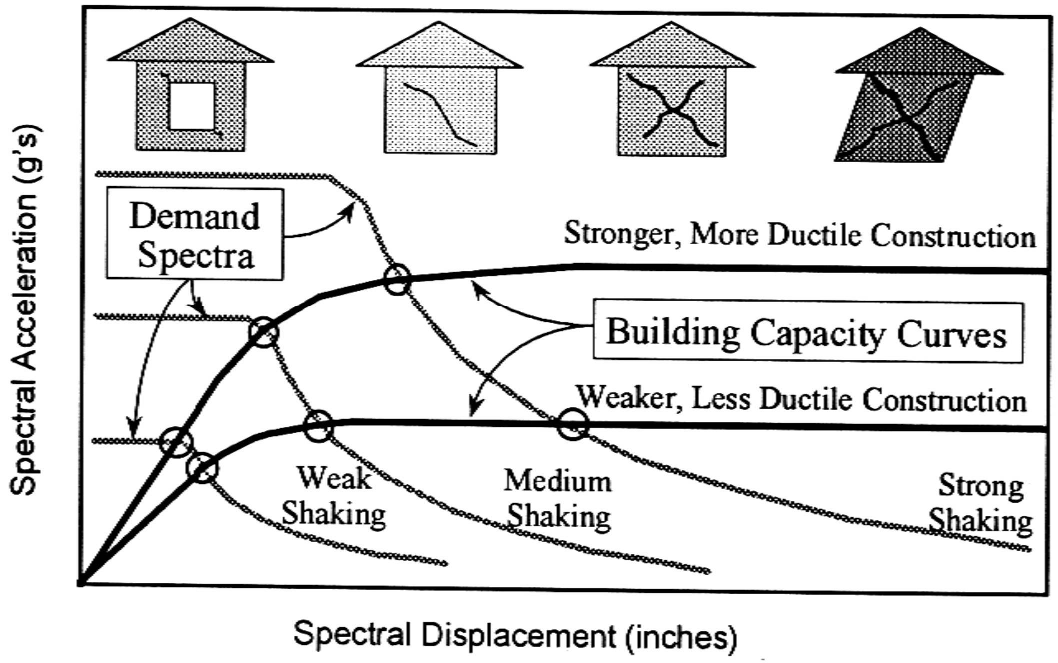


After Coburn and Spence, 1993

Limitations of observed vulnerability:

- Can’t use for (eg) newer buildings for which no damage data exists
- Single parameter of ground motion cannot capture relationship between ground motion, subsoil and structural behaviour
- Assessment of earthquake ground shaking depends of building damage

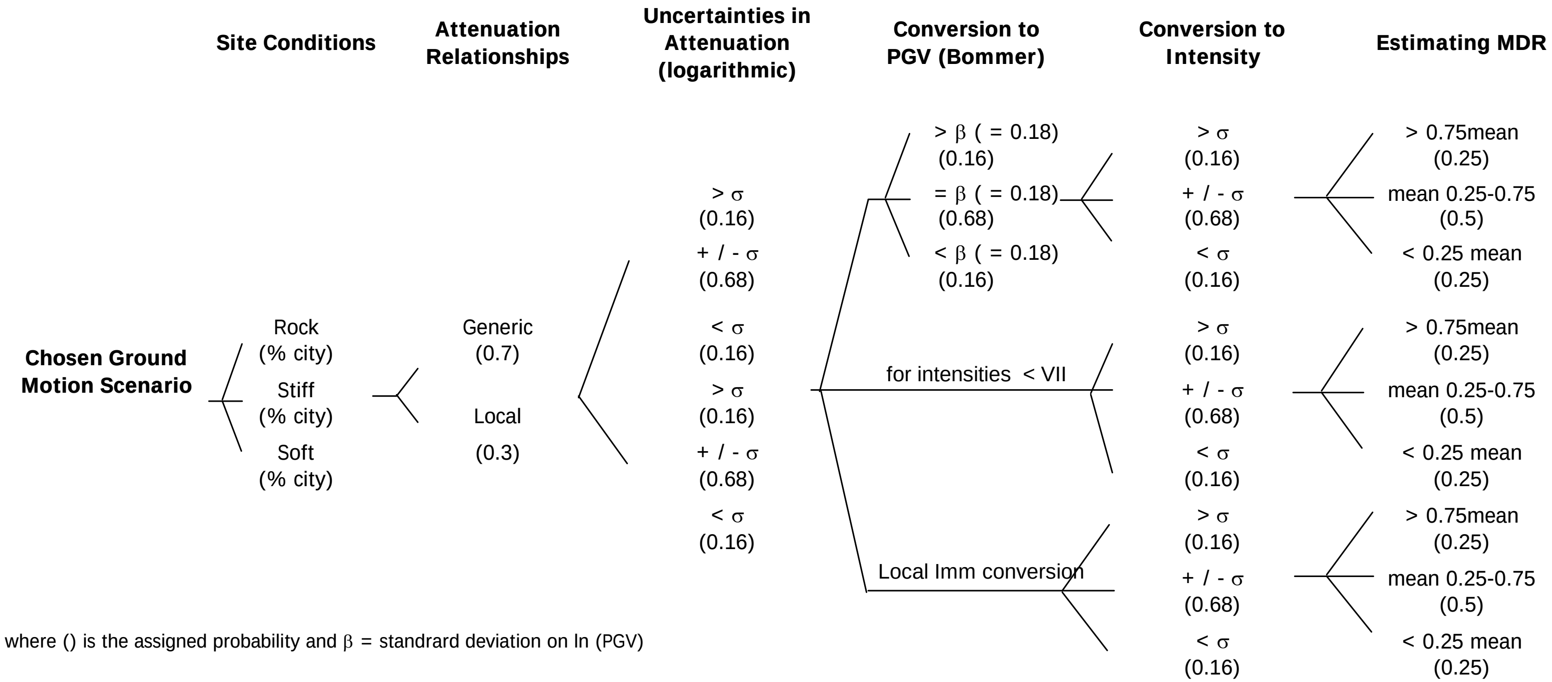
Vulnerability estimation: calculated vulnerability

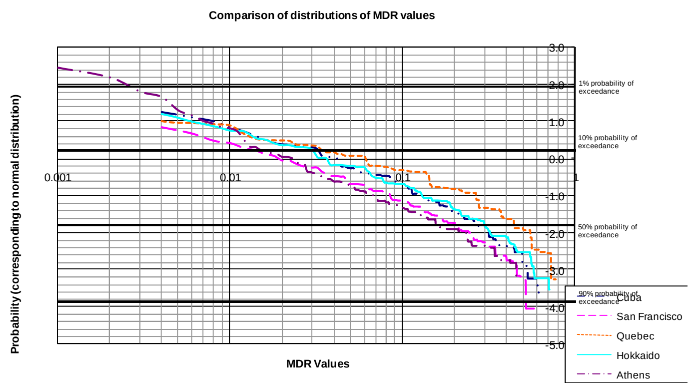


Limitations of calculated vulnerability:

- Models of building assumed do not adequately represent real structural form
- Models of structural behaviour assumed unlike real behaviour of the worst buildings
- Extension of single building model to large populations of buildings

Understanding uncertainties in loss modelling: the logic-tree approach

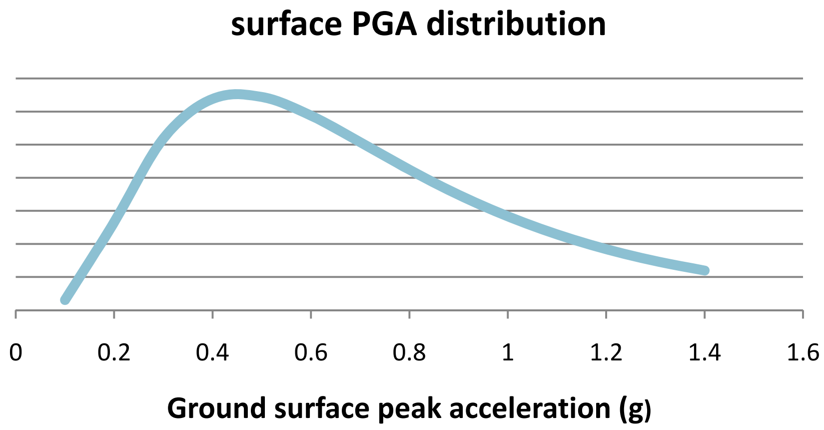


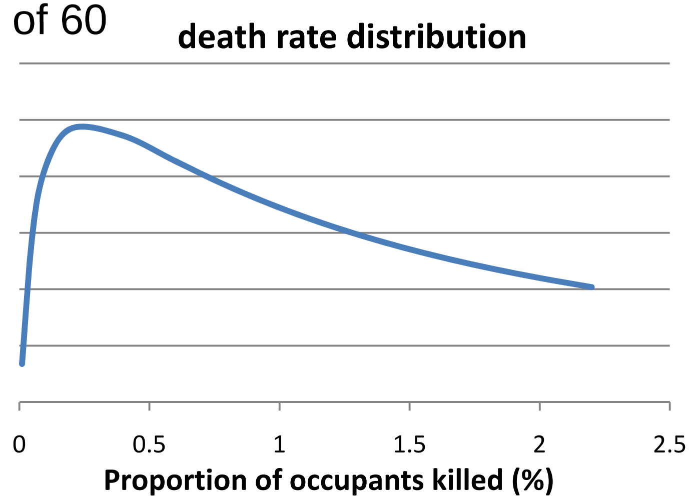


- Mean Damage Ratio to a given set of buildings (portfolio) estimated for a given earthquake.
- Typically values with10% exceedence probability were between 4 and 6 times 50% exceedence values
- Most of this MDR uncertainty results from the ground motion uncertainty

Comparison of alternative earthquake loss models: LessLoss

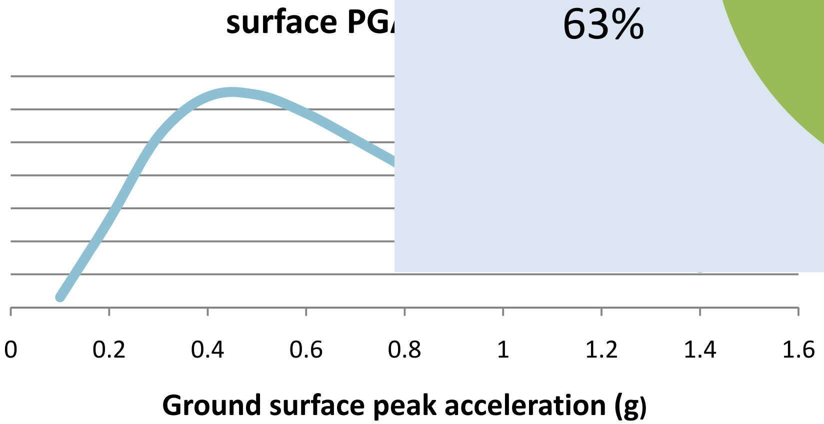
- Three leading academic European loss models were applied to a common data set:
    - o Predefined earthquake ground motion time-histories (2) and soil profiles (3)
    - o Predefined number and distribution of building classes and occupants
- Models computed:
    - o Surface ground motions
    - o Proportions of buildings damaged and collapsed
    - o Numbers of casualties
- Variations in computed results for each separate ground motion were:
    - o Surface ground motion estimate by a factor of 5
    - o Proportion of collapsed buildings by a factor of 30
    - o Proportion of occupants killed by a factor of 60

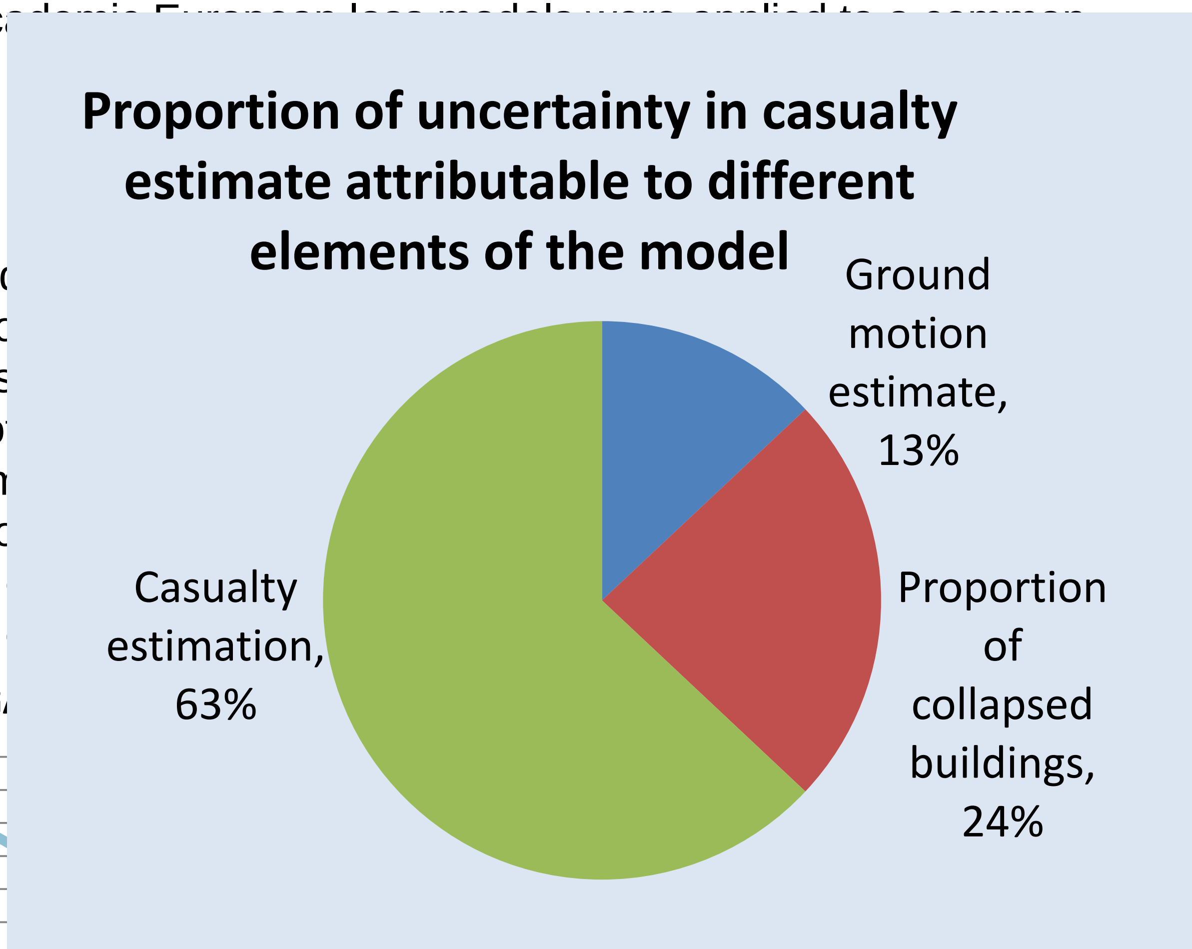


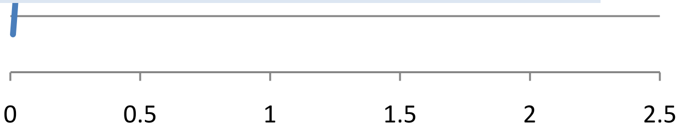


Comparison of alternative earthquake loss models: LessLoss

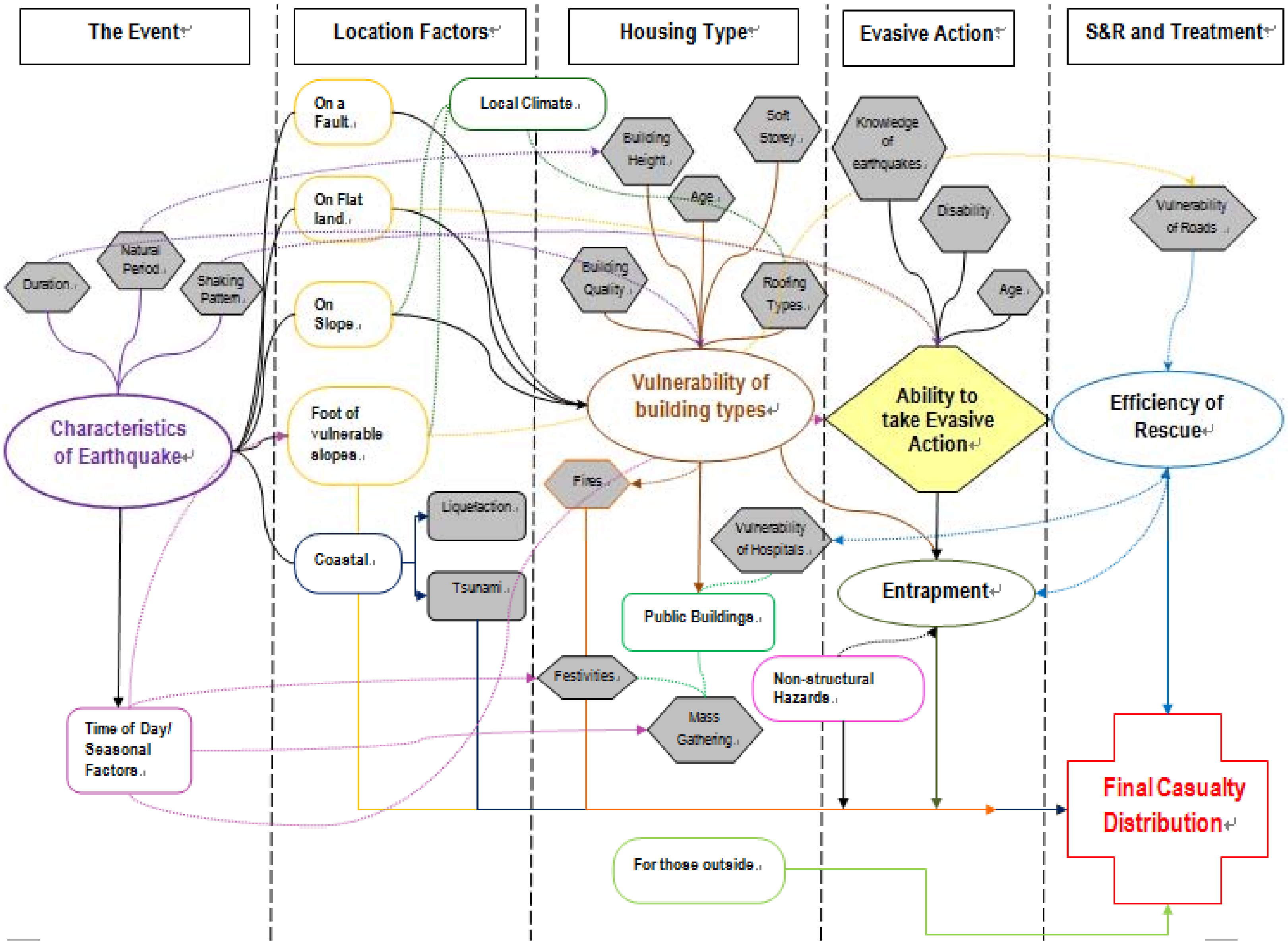
- Three leading ac... data set:
  - Predefined ... profiles (3)
  - Predefined ...
- Models compute...
  - Surface gro...
  - Proportions...
  - Numbers o...
- Variations in com...
  - Surface gro...
  - Proportion ...
  - Proportion ...







Earthquakes: modelling human casualties



Post event rapid impact assessment: the USGS PAGER system

- Alerts to emergency response and aid agencies within 30 minutes of earthquake occurrence
- Currently gives estimates of population affected at different levels of ground shaking

USGS
science for a changing world

USAID
FROM THE AMERICAN PEOPLE

PAGER
Version 1
Created: 3 hours, 10 minutes after earthquake

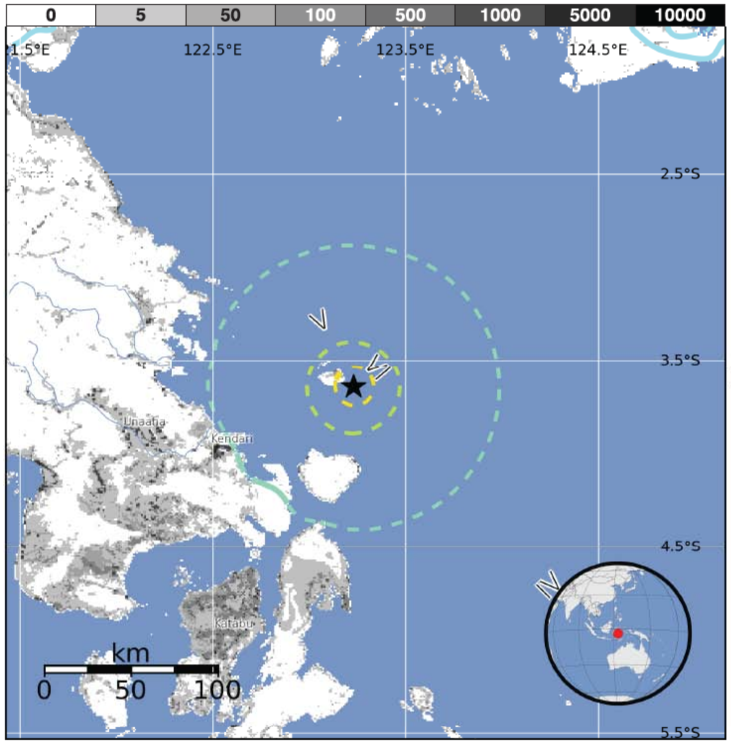
M 5.6, SULAWESI, INDONESIA
Origin Time: Sun 2009-10-18 08:23:25 UTC
Location: 3.65°S 123.23°E Depth: 17 km

Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)		- -*	4k*	2,088k	17k	6k	1k	0	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY		I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING		Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure population per ~1 sq. km from Landscan

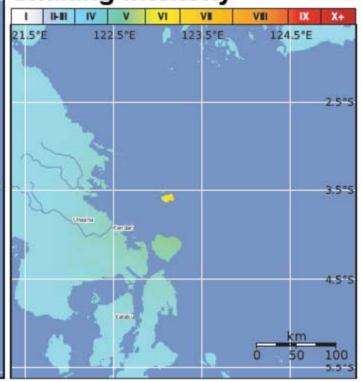


Selected City Exposure

MMI	City	Population
IV	Kendari	0
IV	Unaaha	0
III	Katabu	43k

bold cities appear on map (k = x1000)

Shaking Intensity MMI



Overall, the population in this region resides in structures that are vulnerable to earthquake shaking, though some resistant structures exist. A magnitude 5.8 earthquake 396 km West of this one struck Indonesia on September 28, 1997 (UTC), with estimated population exposures of 137,000 at intensity VIII and 196,000 at intensity VII, resulting in an estimated 17 fatalities. On November 29, 1998 (UTC), a magnitude 7.7 earthquake 259 km Northeast of this one struck Indonesia, with estimated population exposures of 5,000 at intensity VIII and 6,000 at intensity VII, resulting in an estimated 41 fatalities.

The Cambridge Bet...

World Agency of Planetary Monitoring & Earthquake Risk Reduction
2 rue de Jargonnant
1207 Geneva, +41 (0)22 700 5544

The Cambridge Bet on Accurate Fatality Estimates in Near-Real Time After M≥6.5 Earthquakes Worldwide

Report by Max Wyss, August 11, 2009

Background

On June 15th, 2009, at the conference dinner in the venerable dining hall at the Old Library at Pembroke College, Andrew Coburn challenged Max Wyss to a bet, which Max Wyss accepted. A secretary of the Architecture Department of Cambridge University recorded the text of the bet and Frederick Krimgold witnessed it.

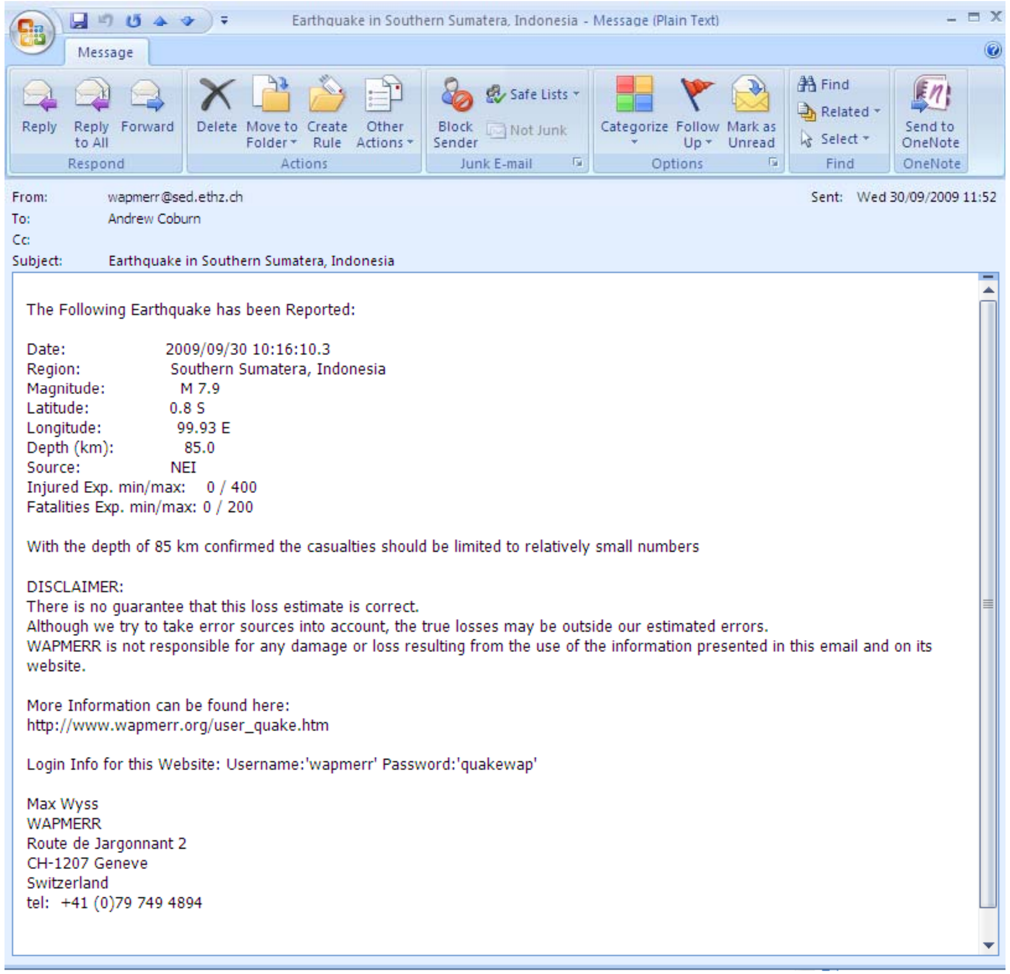
The Bet

As I remember it, the bet was as follows.

Andrew Coburn bets $1,000 that Max Wyss cannot estimate the number of fatalities to within a factor of 2, due to the next 5 consecutively occurring earthquakes worldwide, and subject to the relevance-filter of the Swiss Seismological Service (SED), with magnitudes larger and equal to 6.5, within an hour of their occurrence.

- WAPMERR claims to be able to estimate casualties within 1 hour within a factor of 2.
- At the Second Workshop on Casualties in Disasters in June, Andrew Coburn challenged WAPMERR to substantiate this claim, with a bet of $1000

… The outcome



From: wapmerr@sed.ethz.ch
To: Andrew Coburn
Cc:
Subject: Earthquake in Southern Sumatera, Indonesia
Sent: Wed 30/09/2009 11:52

The Following Earthquake has been Reported:

Date: 2009/09/30 10:16:10.3
Region: Southern Sumatera, Indonesia
Magnitude: M 7.9
Latitude: 0.8 S
Longitude: 99.93 E
Depth (km): 85.0
Source: NEI
Injured Exp. min/max: 0 / 400
Fatalities Exp. min/max: 0 / 200

With the depth of 85 km confirmed the casualties should be limited to relatively small numbers

DISCLAIMER:
There is no guarantee that this loss estimate is correct.
Although we try to take error sources into account, the true losses may be outside our estimated errors.
WAPMERR is not responsible for any damage or loss resulting from the use of the information presented in this email and on its website.

More Information can be found here:
http://www.wapmerr.org/user_quake.htm

Login Info for this Website: Username:'wapmerr' Password:'quakewap'

Max Wyss
WAPMERR
Route de Jargonnant 2
CH-1207 Geneve
Switzerland
tel: +41 (0)79 749 4894

Number of fatalities in W Sumatra quake now 1,115

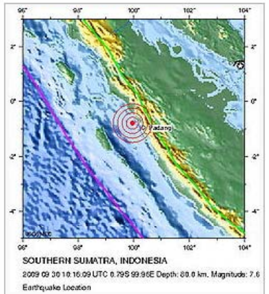
Wednesday, October 14, 2009 05:26 WIB | National | | Viewed 474 time(s)

Rescuers sees debris building in Padang, West Sumatra. (ANTARA/Ismar Patrizki/*)

Padang (ANTARA News) - The number of dead bodies found following the 7.9-magnitude earthquake in West Sumatra continued to increase, and on Tuesday night at 8 p.m local time had reached 1,115.

Most of the dead bodies, 675, were found in Padang Pariaman regency, and 313 in Padang city, the West Sumatra Disaster Response Center in Padang said Tuesday night.

2009 Sumatra earthquakes



Date	10:16:10, September 30, 2009 (UTC)
Magnitude	7.6 M_w
Depth	87 kilometres (54 mi)
Epicenter location	0.725°S 99.856°E
Countries/ regions affected	Indonesia Singapore Malaysia
Casualties	estimated to be at least 1100,[1] government reports confirmed 1,115 dead, 1,214 severely injured and 1,688 slightly injured.[2]

The following are details on the victims and damage caused by the quake:

1. Fatalities : 1,115
2. Seriously injured : 1,214
3. Lightly injured : 1,688
4. Missing : 1 (one)
5. Seriously damaged houses : 135,299
6. Lightly damaged homes : 65,306
7. Homes with minor damage : 78,591

Fatalities (official) :

1. Padang city : 313
2. Padang Pariaman regency : 675
3. Pariaman city : 37
4. Pesisir Selatan regency : 11
5. Solok city : 3
6. Agam regency : 80
7. Pasaman Barat regency : 3(*)

- The first major test was the W Sumatra earthquake of 30.9.09
- WAPMERR Initial Estimates of Fatalities at T+1 hr 36mins: 0-200 dead
- Actual Fatalities: at least 1,115 so far recorded

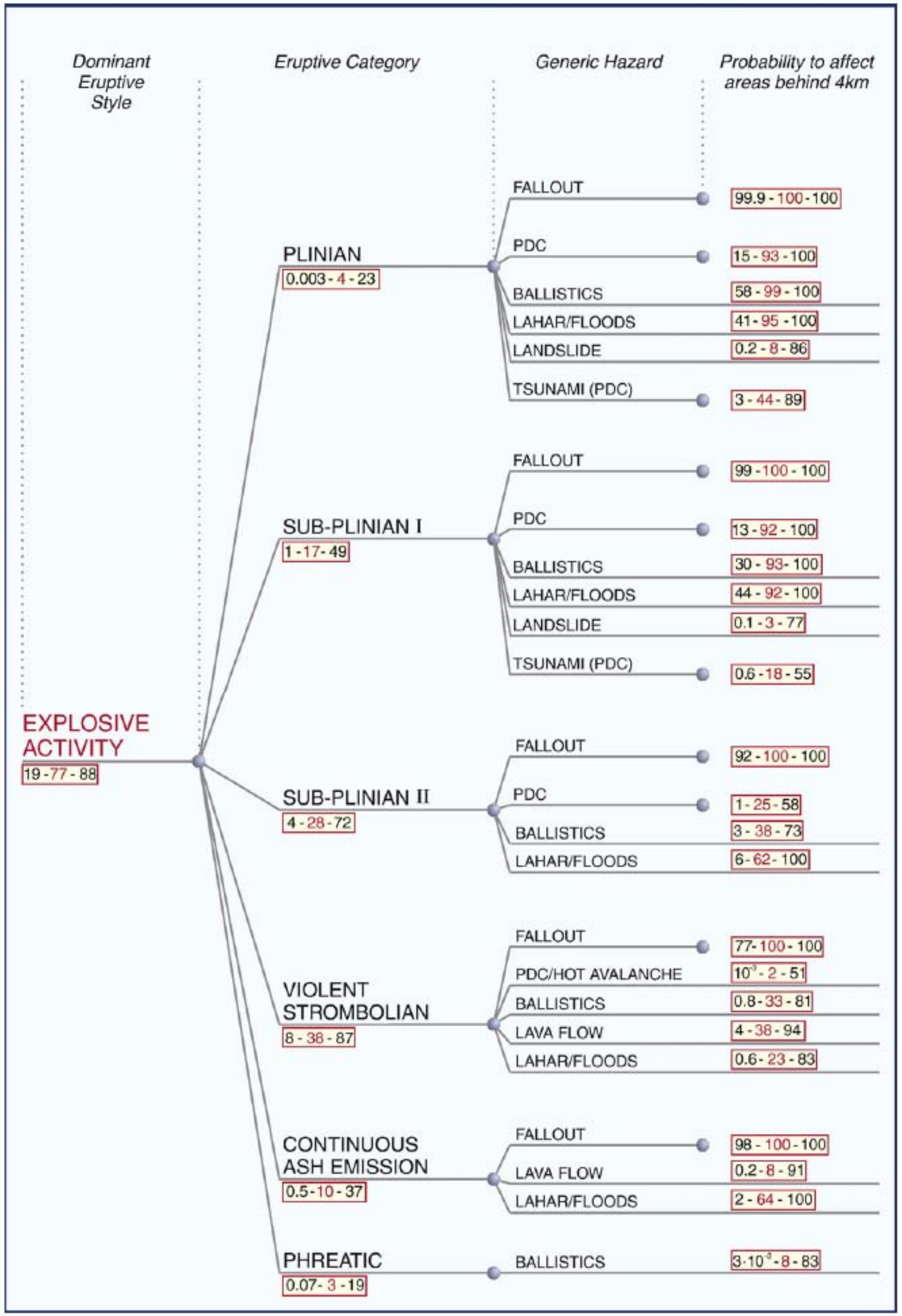
Volcano risk modelling: probabilistic event-tree for alternative scenarios at Vesuvius

Aimed at providing an assessment of possible different categories of eruption and the probability that the next eruption will be of each type.

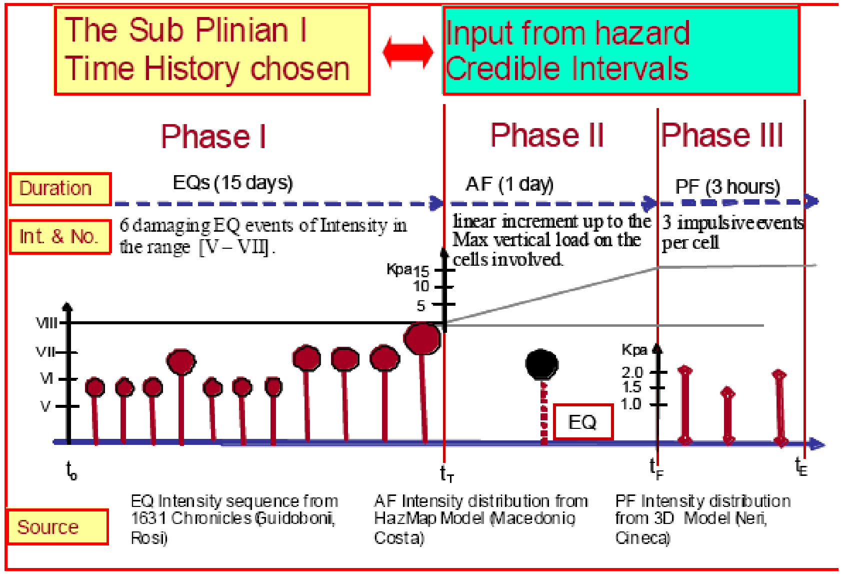
Probabilities estimated by a formal elicitation process among professional volcanologists, and presented as ranges 5%,50%, 95%

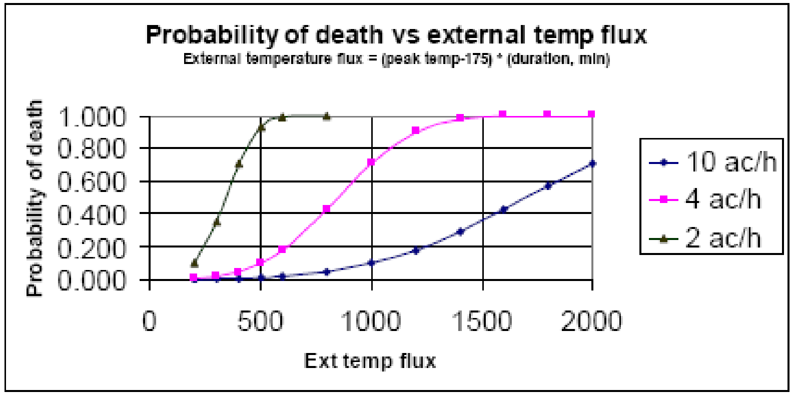
Each eruption category is associated with probable consequent hazards.

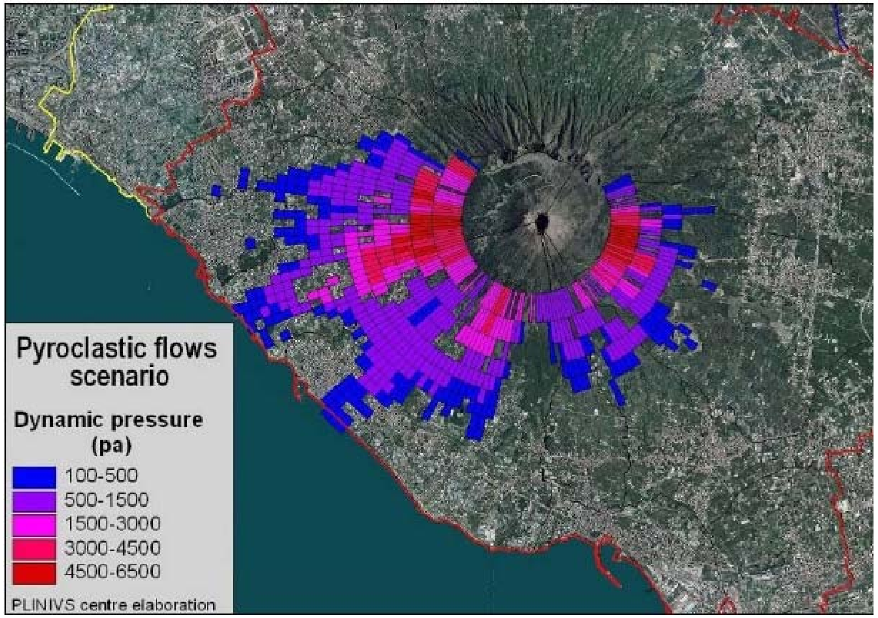
Wide range of expert opinion a problem for Civil Protection

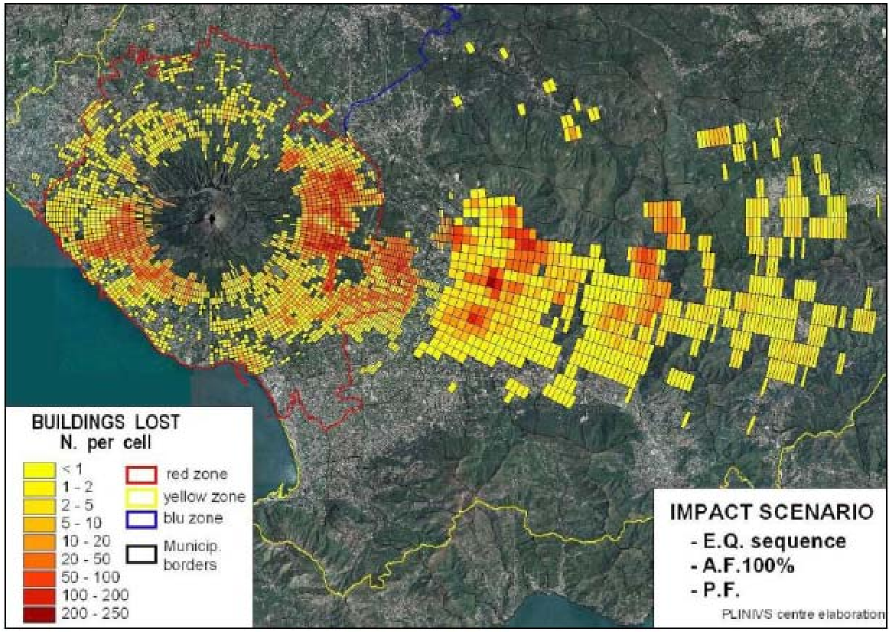


Modelling impacts of volcanic scenarios

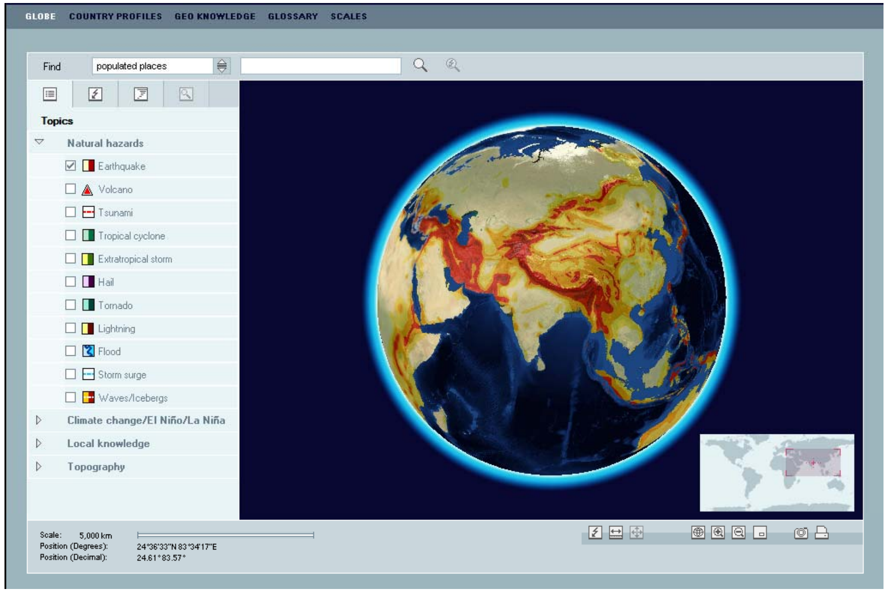








How can we do better ?



Munich Re's Hazard Globe, 2009

- Improve understanding of active faults and global seismicity
- Collect and organise impact data post event
- Improve understanding of "at risk" buildings and infrastructure
- Improve global collaboration
- Improve understanding of uncertainty
- Connect with business processes

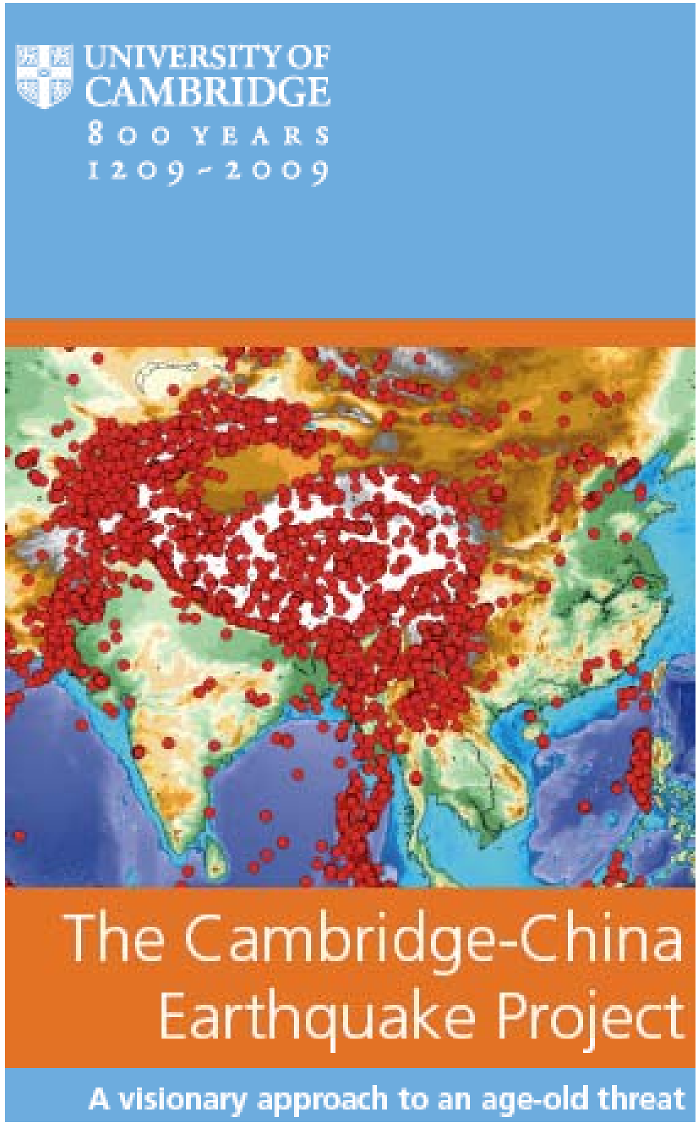
Mapping active faults

Many large and growing cities lie close to active faults which have been affected by destructive earthquakes in the past. In many cases the responsible fault is not known.

New forensic techniques developed at the Bullard Lab will enable the recently active faults to be identified.

This knowledge could have a profound effect on urban development over the next 20 years

The Cambridge China project joins the Depts of Earth Sciences and Architecture at Cambridge with Chinese Partner institutions to develop this potential.



Improving post-earthquake reconnaissance methods, using remote sensing

- EEFIT has been active in data collection since 1982 with increasing sophistication
- Damage Case-Study: YingXiu Township, Wenchuan earthquake

Archiving earthquake consequence data

UNIVERSITY OF CAMBRIDGE

Cambridge University Earthquake Damage Database

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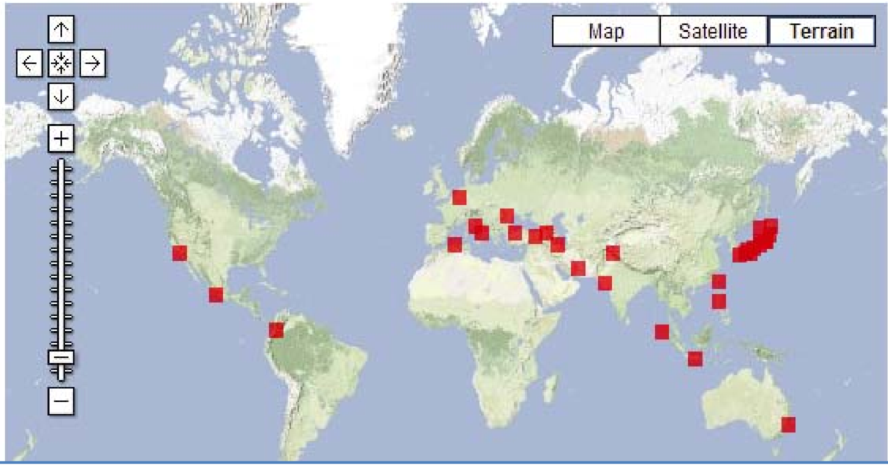
Reducing the impact of earthquake catastrophes requires a good understanding of the destruction they cause and the vulnerability of different types of buildings.

Damage survey data from destructive earthquakes is compiled here as a reference resource for use in vulnerability assessment and seismic risk analysis.

Data has been contributed by ma… ac… su… res… Ce… Ar… Ca… fu… ea… da…



Key: Earthquakes

Indonesia	2006
Pakistan	2005
Japan	2005
Indonesia	2004
Japan	2004
Iran	2003
Japan	2003
Algeria	2003
Japan	2001
India	2001
Japan	2000
Taiwan	1999
Turkey	1999
Columbia	1999
Italy	1997
Japan	1995
Japan	1994
Italy	[illegible]
Japan	1978
Japan	1964
Japan	1948

FREE web-accessible source of building typology/damage data on >1m buildings from 32 earthquakes since the 1960s. Plus casualty data

Use to create vulnerability curves

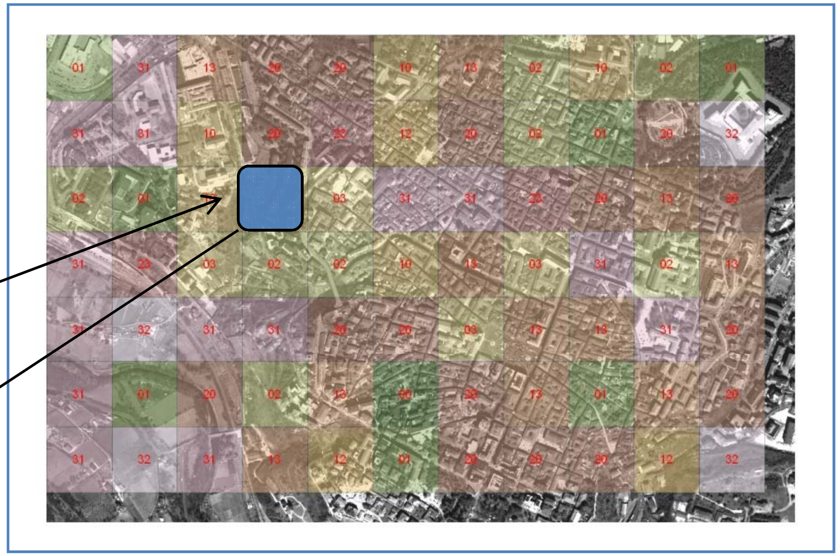
www.arct.cam.ac.uk/eq

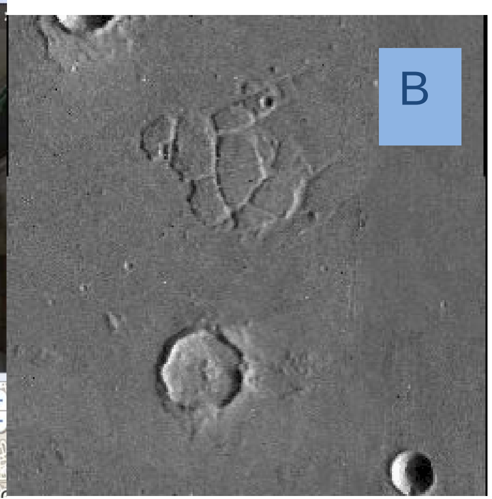
Usage is free, but please credit the Cambridge University Earthquake Damage Database.

We welcome feedback and suggestions.

Understanding global exposures: application of remote sensing and "mass observation"

Unsupervised segmentation using Gabor filters and Self Organising Maps (SOM) to segment image (urban area) into clusters where building type distribution is similar. Selection of sampling area





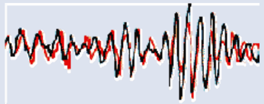
A: Google Street View

B: "Mass observation" (example from NASA's moon crater mapping project)

Collaboration: The Global Earthquake Model (GEM) Project

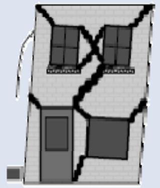
GEM integrates developments at the forefront of seismological and engineering knowledge in three interconnected modules

HAZARD



- *Probability of earthquake occurrence*
- *Probability of ground motion*

RISK



- *Building inventories*
- *Vulnerabilities*
- *Probability of damage*
- *Probability of loss of lives*

SOCIO-ECONOMIC IMPACT €

- *Probability of direct financial loss*
- *Probability of indirect financial loss*

Earthquake probabilities
Building Code input

Earthquake impact
User awareness of risk

Financial tools
Cost-Benefit Analysis

Engaging with uncertainty

Uncertainty needs to be acknowledged in:

- Specific future events
- Quantities/parameters in a model
- Assumptions underlying the 'best' model (both internal and external)
- Inadequacies of our 'best' model

David Spiegelhalter, Risk Centre Talk, Oct 22 2009

Connecting with business processes

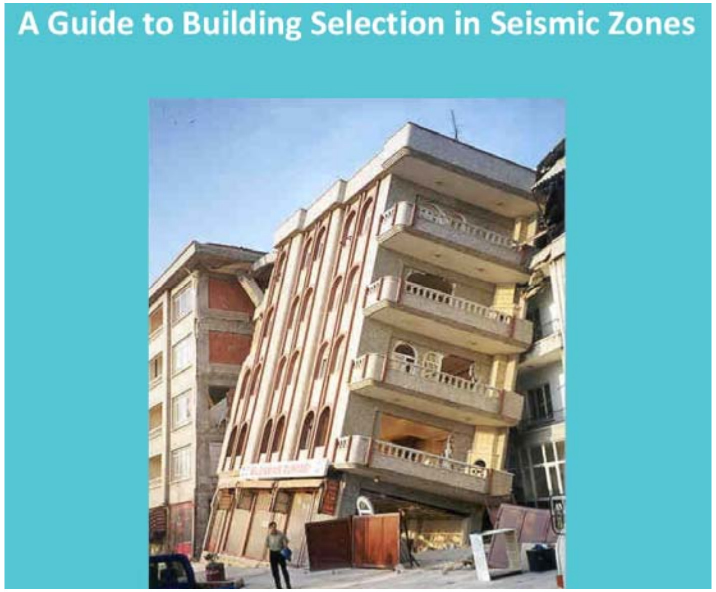
Risk modelling can:

- Help owners of global building estates identify and modify or avoid high-risk premises

- Help the insurance industry model its likely losses and avoid insolvency

- Help improve codes of practice for new buildings

- Help urban authorities identify zones for future expansion



Study for British Council by CAR Ltd

Tehran to be replaced as Iranian capital amid quake fears

The Guardian, 2.11.2009

Conclusions

- Losses from natural hazards including earthquakes and volcanic eruptions have been increasing as human populations and their activities and investments grow into hazardous areas
- We have a very incomplete knowledge of the hazards and the vulnerability of people and buildings to them
- Risk modelling has and can have important contributions to improving decision-making for government, businesses, and individuals
- Risk modelling for earthquakes and volcanic eruptions is still in its infancy, and uncertainties in estimates are very large
- There is much that research can contribute to make it a more effective tool, but large uncertainties will remain.
- Research is also needed on how best to communicate those uncertainties to decision-makers.