Why do some tectonic hazards turn into major disasters?

A hazard is a potential threat to humans and their welfare (ie people, goods and living environment), arising from a dangerous phenomena which may have social (loss of life and injury, and economic impacts (property damage, employment prospects and community loss) and environmental impacts.

Disaster is an actual serious disruption of the functioning of a community or society involving widespread/serious socio-economic and environmental losses which exceed the ability of the community (local/national) to cope (UN/ISDR), ie exceed their capacity and resilience level. Risk is the probability of a hazardous event and its negative consequences occurring.

This can be portrayed by the Risk equation and illustrated by the Degg model.

The factors leading to disasters can be related to both the physical profile of the hazard event and the human context in which it occurs.

1. Magnitude (the size of the event) is perhaps the key physical factor but the direct correlation between magnitude and level of disaster is far from perfect.
   Earthquake magnitude is now measured by the logarithmic MM (Moment Magnitude scale), a modification of the earlier Richter scale, and the damaging effects by the Mercalli scale (useful for impacts of shaking). MMS is based on a number of parameters of an earthquake event including the area of fault rupture and the amount of fault movement involved which determines the amount of energy released.

   Table 1 summarises the relationship, eg magnitude and deaths.

Date	Region	Magnitude	Fatalities
2011 March 11	E coast of Honshu, Japan	9.0	28,050*
2010 January 12	Port au Prince, Haiti	7.0	220,000
2009 September 30	Southern Sumatra, Indonesia	7.5	1,117
2008 May 12	Eastern Sichuan, China	7.9	87,587
2006 May 26	Java, Indonesia	6.3	5,749
2005 October 8	Kashmir, E Pakistan/NW India	7.6	73,000
2004 December 26	Sumatra and Indian Ocean	9.1	227,898*
2003 December 26	Bam, SE Iran	6.6	30,000
2002 March 25	Hindu Kush, Afghanistan	6.1	1,000
2001 January 21	Gujarat, NW India	7.9	20,023

Volcano magnitude is measured by the VEI Index based on the volume and column height of ejections. This index is very closely related to the type of magma which influences type of eruption. This can be related back to the type of plate boundary the volcano is located on. Effusive eruptions of basaltic lavas with low VEI are associated with constructive boundaries or plumes whereas explosive eruptions of andesitic or rhyolitic lava are associated with destructive boundaries.

2. Frequency, ie how often an event occurs is sometimes called the recurrence level, eg 'a 1 in a 100 year event'. There is an inverse relationship between frequency and magnitude. The effect of frequency on severity of impact is difficult to gauge but theoretically areas experiencing frequent tectonic events usually have a plethora of both adaption and mitigation measures, from extensive monitoring (usually good for volcanoes), education and community awareness for what to do and various technological strategies for shock proof building design (Tokyo, San Francisco) or protection (Japanese tsunami walls). Unexpected tectonic events can be particularly devastating, eg the 1993 Killari earthquake unrelated to plate boundaries.
3. Duration is the length of time that the tectonic hazard exists. Often the initial event is followed by aftershocks (Christchurch), or a series of eruptions (Merapi). Whilst the actual individual earthquakes often last for only 30 seconds, the damage can be really extensive. Secondary hazards often prolong the duration and the damage, for example, the triple whammy of the 2011 Tohaku multi-disaster (earthquake, tsunami and nuclear accident) or the secondary hazards associated with volcanic eruptions such as lahars (eg Mount Pinatubo) or jokulhlaups (glacier bursts). In November 1985 the melting of the ice cap and snow on the Nevado del Ruiz volcano released huge mudflows which overwhelmed Armero and surrounding villages killing 23,000 people. Krakatoa 1883 generated a 35m high tsunami killing nearly 35,000 people. Gas discharge and CO^2 from Lake Nyos killed 1,700 people in 1986. Locally landslides disrupt post-event rescue and recovery.
4. Areal extent – the size of the area covered by the tectonic hazard does have a very clear impact, as is the case in the Icelandic ash clouds such as Eyjafjallajokull in 2012 which disrupted the whole of the Northern Hemisphere air transport system for a week with widespread economic losses. Chaiken 2008-9 in Chile is an interesting example to research too.
5. Spatial concentration is the areal distribution of tectonic hazards over space, obviously controlled largely by the types of plate boundary. In theory, hazardous regions are avoided for permanent settlement although the opportunities provided by fertile soils encourage agricultural settlements as on the flanks of Mt Merapi, Indonesia. Active tectonic landscapes, especially volcanic examples, encourage tourism. As the recent, unexpected Japanese eruption showed (Ontake) many of the 48 deaths were from hikers enjoying weekend trips. Generally, spatial concentration promotes sound strategies for management of the hazard and disasters are rare.
6. Speed of onset can be crucial too. Earthquakes come with very little warning, such as the Kobe earthquake, and the speed of onset of the ground shaking leads to maximum destruction. The 2004 Boxing Day Tsunami illustrates the variation very well, with little awareness possible at Aceh, but theoretically warnings and therefore evacuation possible everywhere else.

7. Regularity – the random temporal distribution of both earthquakes and volcanoes can add to their disaster potential. Whilst gap theory can increase the possible prediction of the 'big one', in reality earthquakes are very unpredictable. Volcanic eruptions can be hard to predict precisely even with close monitoring (hence discussions concerning Vesuvius or the long wait for the action of Mount Pinatubo).

However, whilst the intrinsic physical properties of a hazard's event profile can lay the foundations for the development of a disaster it is the extrinsic areal factors which impact on the vulnerability of communities and societies and cause tectonic disasters.

The PAR model (pressure and release model) helps to explain the variability of levels of vulnerability and resilience. It is this vulnerability (both human and economic) not the tectonic environment which helps to explain the differences in social and economic impacts of physically similar hazard events.

		Magnitude	Fatalities	Damage US$milions
1992	Erzican, Turkey	6.8	540	3,000
1999	Izmit, Turkey	7.4	17,225	12,000
1989	Loma Prieta, USA	7.1	68	10,000
1994	Northridge, USA	6.8	61	44,000

As the PAR model shows, certain drivers of disaster (root causes) lead to pressures which create potentially unsafe conditions. The development paradigm argues that at a macro scale the root causes of vulnerability lie in the contrasting economic and political systems of MEDC/LEDC divide. The most vulnerable people are channelled into the most hazardous environments (the result of chronic malnutrition, disease armed conflict, chaotic and ineffective governance, lack of educational empowerment).

Drivers of disaster and vulnerability include:

1. Economic factors
   Human vulnerability is closely associated with levels of absolute poverty and the economic gap between rich and poor (inequality). Disasters are exacerbated by poverty (Haiti, Kashmir etc). The poorest LDCs lack money to invest in education, social services, basic infrastructure and technology all of which help communities overcome disasters. Poor countries lack effective infrastructure. Economic growth however increases economic assets and therefore raises risk unless managed.
2. Social factors
   Overall world population is growing especially in developing nations with higher levels of urbanisation and many people living in dense concentrations of population in unsafe political settings. An increasing ageing population as in China (Sichuan) increases vulnerability with problems of emergency evacuation and survival. Housing conditions and quality of building have a major impact on the scale of deaths and injuries. Essentially, disadvantaged people are more likely to die, suffer injury and psychological trauma during the recovery and reconstruction phase.

3. Political factors
   The lack of strong central government produces a weak organisational structure. Equally a lack of financial institutions inhibits both the disaster mitigation and both emergency and post-disaster recovery (contrast Haiti and Chile). A good strong central government leads to highly efficient rescue (Chinese earthquake).
4. Geographical factors
   Increasing urbanisation especially in mega cities creates high hazard risk and exposure with poorly sited squatter settlements. These huge cities are very vulnerable to post earthquake fires (Kobe). Relief, rescue and recovery efforts are very difficult in these areas (Kashmir where isolationism, coldness and frontier position complicated the relief and recovery). Many SIDS fare badly – often multi-hazard areas, eg Comoros.
5. Technological factors
   Whilst community preparedness and education can prove absolutely vital in mitigating disasters, technological solutions can play a major role, especially in building design and prevention and protection.
6. Environmental Factors
   Destruction of rural environments can lead to disasters amongst rural populations with a loss of food supplies and livelihoods (Andean earthquake)

   However as the case study of Bam shows, it is the interplay of the intrinsic (hazard event) factors and the extrinsic factors. Petley has likened this disaster causation complexity to a model of DNA with the interlinkage of human and physical systems.

BAM EARTHQUAKE – an example of the complex inter-connectivity of physical and socio-economic factors which contribute to disaster.

A. Context
   - 26th December 2003 at 5.26am an earthquake struck Southern Iran centred on Bam. Most of the 140,000 residents were asleep at the time.
   - Magnitude was 6.6 (Moment Magnitude Scale)
   - 26,000 people died. In the ancient citadel of Bam 70% of all buildings completely collapsed. 90% of all building stock of the wider city was 60-100% destroyed.
   - The three main hospitals and the fire station were completely destroyed.

B. Physical Explanation
   - Fairly shallow earthquake – epicentre 7 km below ground surface
   - Only 1.5 seconds of shaking, but very intense and concentrated – very high peak ground acceleration. Concentrated damage zone (only 16 km^2 in area).
   - The rupture occurred at a location 5km west of the well-known Bam fault in a location where no surface evidence of faulting existed.
   - The seismic waves occurred directly under the city, very near to the fault again adding to the intensity.

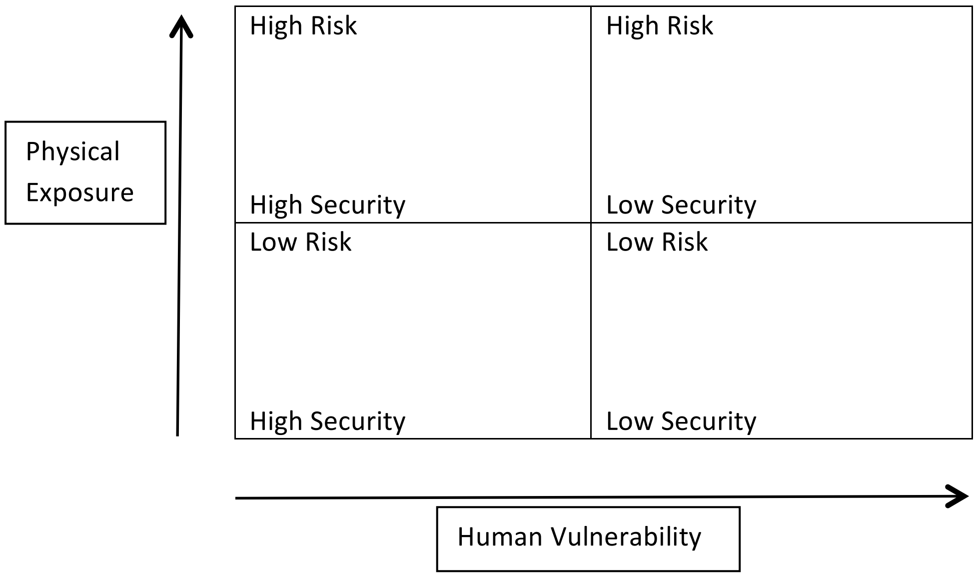
C. Social explanation
   - Poor quality building stock, especially the 2,400 year old adobe buildings in Bam Citadel (however only 3 people died here).
   - Most fatalities were in buildings fewer than 30 years old, often with heavy tiled roofs, often renovated with faulty cement and walls weakened by termite activity.
   - The Iranian building code was not implemented or enforced as the area had not suffered an earthquake in historic times, so was not considered at risk.
   - The emergency services were understaffed and poorly trained and not adequately prepared to rescue work, especially as the key facilities were destroyed (hospitals and fire station), 20% of the staff were killed by quake. The local and international teams were poorly co-ordinated and slow to arrive.
   - Temperatures were low in the Iranian winter so hypothermia killed many trapped victims.
   - There were conflicts over the supply of rescue equipment such as aircraft.

D. Conclusion

   BAM, like many events, fits Reason's Swiss Cheese Model of disaster, ie many vulnerable circumstances arise simultaneously.

<u>Case Studies of Christchurch and Haiti</u>

Frameworks



Disaster Matrix Quadrant

Haiti: a long term disaster? 25 years to recovery?

<u>Context</u>

- 12th January 2010. 7.0 (Moment Magnitude Scale) on a transform fault.
- Epicentre 25km west of coastal capital of Port au Prince (2 million people).
- Shallow depth 13km leading to unusually severe shaking.
- Direct death toll 222,570
- 188,383 buildings collapsed of which 60% were completely destroyed including 8 hospitals, UN headquarters and other government buildings
- 1.8 million people, around 20% of total population, were homeless
- At height of emergency 1.5 earthquake refugees in 1,300 spontaneous settlements and camps.
- Heavily damaged communication and transport systems, especially the port, which was so important for importing and supplies.

<u>**Issues** - 'The collapse of what was already a house of cards'</u>

- Emergency response was hampered by supply chain difficulties with confusion over lead responsibilities, failure to prioritise relief flights and delay in distribution of aid supplies.
- Long term socio-economic problems greatly amplified the disaster impact. 80% of Haitians live below the poverty line of $2 per day in an LEDC which is the poorest country in the Western Hemisphere.
- Two thirds of the workforce lacks formal employment and is engaged in subsistence agriculture and other informal work.
- HDI – 151/180 – an economically vulnerable 'fragile' state.

- Unstable political situations with many years of dictatorships and since 2006 a weak democracy.
- Much of the damage was in the capital where 75% of people lived in urban slums (rapid rural-urban migration resulting from a swine flu alert) – very high density of inadequately built concrete buildings with no real access roads – ‘a patchwork of unmarked corridors’.
- 50% of population had no access to toilets, 66% had no piped water. 60% of houses were unsafe before the quake indicative of extreme urban poverty.
- In the recovery period movements of survivors were unpredictable, further hazards such as tropical cyclones, flooding and landslides on the deforested slopes occurred, disputes over land rights and outbreaks of cholera (killed nearly 5,000) all slowed progress to recovery.
- Extensive building collapse led to 19 million m^3 of rubble in the streets which needed removing before work could start. The question is, could Haiti, with help of humanitarian aid committed (US$11.5 billion needed for reconstruction), ‘build back better and more sustainably’ restoring not just physical infrastructure but rejuvenating urban governance (poor capacity of staff and outmigration of brightest and best and weak accountability) and also improving risk reduction capability by community mobilisation and education. This needed the capital’s eight municipalities to work together to redesign Port au Prince and also at the same time to develop the rural area to end rural to urban migration.

Haiti is limping from emergency to temporary shelter to a long term reconstruction – perhaps by 2030?

Two useful sources
Geofile 672 Sept. 2013 and GeoFactsheet 285 to follow reconstruction process and explore issues such as NGO shortcomings.

Christchurch NZ – so what’s the problem?
Context
The greater Darfield earthquake, epicentre 40 km to SW of Christchurch at 4.35am on September 10th 2010 (7.1 mm scale). It caused no deaths, but caused $4 billion NZ of damage with 350,000 people experiencing 33 seconds of severe ground shaking, laterally offsetting roads, hedges and fences up to 4m with a complex movement of faults erupting at the surface.

The Christchurch earthquake on 2nd February 2011 (6.3 MM scale) regarded as an aftershock was 10 times smaller but it occurred in daytime with close proximity (5km) to Christchurch CBD on a buried fault running East-West through the city, creating a 15km surface rupture.

- 181 people died, concentrated in several clusters (2 large buildings and 1 bus)
- 50% of buildings were red-listed for demolition as a result of the enormous amount of ground shaking due to the high energy levels released along the fault and the shallow depth of the earthquakes’ focus and geology which enhances the step down effect causing a random pattern of ‘munt’.
- Liquefaction had a localised impact.
- In the immediate aftermath 70,000 residents left the city, ie 20% of the total largely to nearby suburbs such as Prebbleton.

- 50,000 people were unable to return to work 6 months later and even in 2014 unemployment remains at 5% (huge demand for builders and electricians).
- Destruction of many iconic buildings, such as the cathedral in the heart of Christchurch, now replaced by the cardboard cathedral, lowered the morale of many citizens.
- Tourist trade and the retail sector were hit very hard with the closure of most large CBD hotels and shops.
- Damage and economic costs was estimated at $120 billion NZ with figures rising all the time (eg for loss of port facilities at Lyttleton)
- It was measured as a 1 in 2500 year event, but the building regulations only budgeted for a 1 in 500 year event.

Issues

- Out of sight, out of mind – most Cantabrians thought a major earthquake would not happen in their lifetime in spite of occasional warnings from scientists and planners and anyway it would come from the very visible Alpine. There had been no major earthquake since 1888.
- The earthquakes occurred along faults hidden by 500m of superficial deposits - gravel, sand and silt (eg Greendale Fault). These faults had not been ruptured in recent history, but were an accident waiting to happen with a veritable spaghetti junction of faults beneath the city, many of which were poorly mapped and monitored.
- Whilst the death toll was low as immediate disaster rescue systems worked well with well organised and well-coordinated emergency management the only problem was a meltdown of the overloaded mobile phone systems.
- There was much concern over the slackness of the building code and this has been subsequently strengthened. There was also almost total destruction of utilities, with a need to build 100km+ of water mains, 400km of sewers and 1,000km of roads – a mammoth task.
- The traffic light classification system of buildings: red for demolition and relocation, amber for repairs and retro-fitting and green for repair grants, proved very controversial.
- It was the scale of demolition required. Christchurch is currently (for the last three years) the world capital of demolition, with the arrival of awesome machines such as Twinkletoes.
- The post-earthquake response (it began a week after the quake coordinated by CERA) was successful in rehousing the residents with 'munted' houses, and also restoring normal life with reorganisation of education and health services, and the development of the containerised CBD.
- The idea is to build a new compact CBD for the city, but the problem is that so much activity and people have migrated to the suburbs.
- The concentration of aftershocks (over 6,000) led to psychological stress for residents with many leaving for good, but mapping of aftershockdistribution has enabled the hidden faulting pattern to be mapped.
- The big issue has been the Earthquake Commission (ECQ) slowness in settling insurance claims which has caused hassle to many!

References

www.naturalhazards.org.
www.geonet.org.nz/canterbury-quakes