Summary: Reason’s Swiss Cheese Model of disaster causation
The Swiss Cheese Model of disaster causation is also known as the cumulative acts effect model (Figure 2.19) and is widely used in risk management and analysis, especially by the aviation industry. This industry in particular is very conscious of safety so there are many barriers put in place to minimise accidents—the idea of layered security or duplicate back-up systems. In the model, the layers of cheese represent these safety systems and the holes the weaknesses in each line of defence. J. Reason, the developer of the model, argued that an accident occurs when all the holes line up in a single trajectory.

So, in natural hazards science, a disaster is thought to occur as a result of a series of coincidental events and processes. It highlights the fact that a particular disaster can be linked to a single hazard event, but then there is a cascade of other events (possibly through the “holes”) that provide a context for the hazard. Generally the hazard becomes a disaster when several holes line up (a trajectory of accident opportunity), which creates the conditions for loss of life, property and livelihood.

Further research
Research data from the International Disaster Database to investigate patterns and trends, and to look for links between magnitude of events, deaths and economic damage: www.emdat.be

Use International Red Cross World Disasters Reports to compare hazard impacts (loss of life, numbers affected and so on) between hazard types and regions: www.ifrc.org/en/publications-and-reports/world-disasters-report/world-disasters-report

Find out more about the role of UNISDR and what it does: www.unisdr.org

Research the most significant earthquakes in the last 30 days using the USGS website. It possible use GIS to show their distribution and then add a layer to show vulnerability in terms of wealth: http://earthquake.usgs.gov

Maxim Re is a Swiss re-insurer. Research its connection to natural hazards online

Research different tectonic hazard events in areas of varying development and explain the ways in which the context of each disaster is different.

Management of tectonic hazards and disasters

How successful is the management of tectonic hazards and disasters?

By the end of this chapter you should:

- understand the complex trends in disasters over time and how some disasters can become mega-events and have impacts over a very wide geographical area
- recognise the hazard models and frameworks that can be used to understand the prediction, impact and management of hazards
- know how tectonic hazard impacts can be managed through a range of mitigation and adaptation strategies which have varying degrees of success

It is worth remembering that seismic tectonic and volcanic processes cannot be prevented, and it is unlikely that they ever will be. Yet we have found out that the risks seem to be increasing for many people, especially those in the middle income and poorest groups. This increase in hazard vulnerability is mostly due to human factors rather than physical factors, as the trends in tectonic hazards reveal a pattern that does not indicate a significant increase in the last 50 years. This idea is true but complex and needs additional explanation.

3.1 Understanding tectonic and other disaster trends since 1960

In comparison with other natural hazards, few tectonic hazards manifest themselves into disasters. Figure 3.1, for example, shows that in the period 2004–2014 tectonic hazards had a low occurrence compared to hydrological and meteorological hazards, and also much lower numbers of victims compared to the other three hazards (climatological, hydrological and meteorological).

A look at the overall patterns

The overall longer-term natural hazard trends, since about 1960, show a number of key points:

- The total (aggregate) number of reported hazards has increased over the last 50 years.
- The number of reported disasters seems to be falling, having peaked in the early 2000s (but that appears to be in anomaly to the longer-term trend).
- Number of deaths is also lower than in the recent past, but there are spikes with mega-events.
The total number of people affected is increasing for some hazard and disaster types, especially meteorological and hydrological (Figure 3.2). The economic costs associated with both hazards and disasters of all types have increased significantly since 1960.

But trends relating to tectonic (geophysical) hazards only show a different overall trend, one which is much more in terms of the number of events (Figure 3.3). However, somewhat hidden within that overall pattern is one that shows that the number of people affected and number of deaths does vary considerably year on year.

Spatial variation of tectonic disasters

Another important aspect of disaster geography is the spatial variation of tectonic impacts. It is wrong to assume that the location of hazard impacts always translate into simple distributions. Data from the Centre for Research on the Epidemiology of Disasters (CRED) and the International Red Cross shows that the number of disasters reveals a complex pattern when either viewed by world region or by level of development.

Figure 3.2 Natural disaster trends (all types), 1975-2011

![Graph showing natural disaster trends from 1975 to 2011.](image)

Figure 3.3 Number of hazard loss events (all types), 1980-2014

![Graph showing number of hazard loss events from 1980 to 2014.](image)

Table 3.1 Total number of reported disasters grouped by type and level of economic development, 2004-13

<table>
<thead>
<tr>
<th>Type</th>
<th>Very high human development</th>
<th>High human development</th>
<th>Medium human development</th>
<th>Low human development</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthquakes / tsunami</td>
<td>43</td>
<td>71</td>
<td>221</td>
<td>24</td>
<td>290</td>
</tr>
<tr>
<td>Volcanoes</td>
<td>5</td>
<td>12</td>
<td>30</td>
<td>10</td>
<td>57</td>
</tr>
<tr>
<td>Mass movements</td>
<td>7</td>
<td>33</td>
<td>84</td>
<td>49</td>
<td>173</td>
</tr>
<tr>
<td>Floods</td>
<td>237</td>
<td>378</td>
<td>585</td>
<td>552</td>
<td>1751</td>
</tr>
<tr>
<td>Droughts</td>
<td>14</td>
<td>25</td>
<td>57</td>
<td>129</td>
<td>225</td>
</tr>
<tr>
<td>Windstorms</td>
<td>354</td>
<td>146</td>
<td>347</td>
<td>134</td>
<td>1011</td>
</tr>
</tbody>
</table>

Table 3.2 Total number of reported disasters grouped by type and global region, 2004-13

<table>
<thead>
<tr>
<th>Type</th>
<th>Africa</th>
<th>Americas</th>
<th>Asia</th>
<th>Europe</th>
<th>Oceania</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthquakes / tsunami</td>
<td>18</td>
<td>39</td>
<td>174</td>
<td>27</td>
<td>11</td>
</tr>
<tr>
<td>Volcanoes</td>
<td>5</td>
<td>20</td>
<td>22</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Mass movements</td>
<td>12</td>
<td>34</td>
<td>119</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Floods</td>
<td>443</td>
<td>343</td>
<td>702</td>
<td>215</td>
<td>49</td>
</tr>
<tr>
<td>Droughts</td>
<td>124</td>
<td>51</td>
<td>37</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Windstorms</td>
<td>82</td>
<td>330</td>
<td>400</td>
<td>139</td>
<td>54</td>
</tr>
<tr>
<td>Total</td>
<td>684</td>
<td>823</td>
<td>1450</td>
<td>399</td>
<td>131</td>
</tr>
</tbody>
</table>

Tectonic mega-disasters

Tectonic mega-disasters have several key characteristics:

- They are usually large-scale disasters on either an aerial/spatial scale or in terms of their economic and/or human impact.
- Because of their scale, they pose serious problems for effective management to minimize the impact of the disaster (both in the short and longer term).
- The scale of their impact may mean that communities, but usually government as well, often require international support in the immediate aftermath as well as during longer-term recovery. This may be at a regional level (for example the Asian tsunami of 2004) or globally (for example Japan 2011). These events can affect more than one country either directly or indirectly.

How good are disaster statistics?

There is neither a universally agreed definition of a disaster nor a universally agreed numerical threshold for disaster designation. Reporting disaster impacts, especially deaths, is therefore controversial for a number of reasons:

- It depends on whether direct (primary) deaths or indirect (secondary) deaths from subsequent hazards or associated disasters are counted.
- Location is significant because local or regional events in remote places are often under-recorded.
- Declaration of disaster deaths and casualties may be subject to political bias. The 2004 Asian tsunami was almost completely ignored in Myanmar but perhaps initially overstated in parts of Thailand, where foreign tourists were killed, and then played down to protect the Thai tourist industry.
- Scarcity on major disasters is difficult to collect, particularly in remote rural areas of low human development countries (LHDCs), for example the earthquake in Kashmir in 2005, or in densely populated squatter settlements, for example the Caracas landslides in 2000-2004.
- Time-trend analysis (interpreting historical data to produce trends) is difficult. Much depends on the intervals selected and whether the means of data collection have remained constant. Trends (deaths, numbers affected, economic impacts) can be upset by a cluster of mega-disasters, as happened in the 2004 Asian tsunami or the 2011 Haiti earthquake, or even in the 2015 Kachinndaw earthquake.

Figure 3.4 Diagrammatic representation of the likely range of impacts following a large VEI 6 (or above) eruption

Figure 3.4 illustrates how a large volcano, for example, can have significant impacts in both time and space. Tectonic mega-events and disasters are often classified as high-impact, low-probability (HILP) events. So, one-off high-profile crises such as the 2010 Haiti earthquake and the 2011 Japanese earthquake and tsunami were all mega-disasters requiring rapid responses at a global level. But known hazards such as earthquakes and volcanoes (as well as floods and hurricanes), which, owing to the low likelihood of occurrence or the high cost of mitigating action, often remain ill- or under-prepared for in many parts of the world. These events are impossible to predict but very likely to occur over long time scales.

The globalisation of production and supply chains has increased manufacturing efficiencies, but it has also reduced resilience in the case of some events. High-value manufacturing is often most at risk because of its just-in-time (JIT) business model. The consequences of HILP events spread rapidly across both economic and geographic boundaries, creating other impacts (economists might call these negative externalities) that are difficult to plan for. The Japanese earthquake in 2011, for example, led to a five per cent reduction in the country's GDP. There were much wider knock-on impacts for global transnational corporations (TNCs) however, such as Toyota and Sony, which were forced to halt production.
The 2010 Eyjafjallajökull volcano and 2011 Japanese Tohoku tsunami

Two examples of significant tectonic events in recent years are the Iceland Eyjafjallajökull eruption in 2010 and the Japanese tsunami mega-disaster of 2011. They both had significant, but different, impacts at a global scale. Table 3.3 considers the effects on the global supply chain (Eyjafjallajökull) as well as the wider concerns about nuclear power (Tohoku).

### Table 3.3 Context and impacts of two recent high-profile tectonic events

<table>
<thead>
<tr>
<th>Event</th>
<th>Location</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyjafjallajökull, Iceland</td>
<td></td>
<td>A magnitude 5.1 earthquake in March 2010 produced a large tsunami that weakened infrastructure along the coast, leading to widespread destruction.</td>
</tr>
<tr>
<td>Tohoku tsunami, Japan</td>
<td></td>
<td>The tsunami hit the Fukushima Daiichi nuclear power plant on the coast of Japan, leading to a loss of power supply and widespread destruction.</td>
</tr>
</tbody>
</table>

### Key term

**Disaster hotspots**: A country or area that is extremely disaster-prone for a number of reasons, as shown in Figure 3.5.

### Multiple-hazard zones

Multiple-hazard zones are places where a number of physical hazards combine to create an increased level of risk for the country and its population. This is often made worse if the country’s population is vulnerable (wealth/GDP, population density, and so on) or suffers repeated events, often on an annual basis, so that there is never a time for an extended period of recovery. Such places are often seen as **disaster hotspots**.

Hazards in multiple-hazard zones are, in fact, part of a wider picture of more complex geography linked to vulnerability over both space and time. This often makes their impact greater and more challenging to manage. The magnitude of the hazard event together with the human geography of the area in which it occurs is important factors, but hazards generally form part of a much more complex web of socio-economic-environmental issues that makes the impact greater and harder to manage. Table 3.4 lists the countries that are most exposed to multiple hazards globally. Figure 3.6 is a global summary of the multiple-hazard pattern.
There may also be variation in disaster risk within smaller geographical areas. Large urban areas are often zones of multiple-hazard risk (Figure 3.7). Cities are centres of economic development (economic cores) as they represent a natural focus for investment and development. They are also frequently centres of growing population as a result of the rapid urbanisation occurring in most developing countries. Many cities have huge areas of unplanned, poor-quality housing where growing numbers of the urban poor live, often located on marginal, potentially dangerous sites such as river banks and steep slopes.

Analysis of the global distribution of these rapidly growing mega-cities shows that many of them are located in hazard-prone areas. With such high densities of people, up to 25,000 per km², hazard management in large urban areas is both expensive and complex, making disasters inevitable, both socially (high concentration of vulnerable people) and economically (for example, loss of infrastructure).

### Comparing the Philippines and California – classic multiple-hazard geography

There is a tendency to assume that all hazards occur in both places, and that the hazards may have the same root causes. In the Philippines, the main risk is typhoons with typically five or six storms a year as it lies on a major storm track. Annual deaths far exceed the long-term average for California (the last time more than 100 people died in a Californian natural disaster was the 1939 Long Beach earthquake). The Philippines has to spend around two per cent of its annual GDP cleaning up after typhoons. Table 3.5 summarises the hazard similarities and differences.

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Californian coast</th>
<th>Philippines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volcanoes</td>
<td>Rarely in northern California (Mount Shasta, Lassen Peak), which is part of the Cascades subduction zone – not really on the coast.</td>
<td>Very common; Pinatubo, Mount Mayon. Frequent and violent; andesitic magmas, ash, lahars, pyroclastic flows.</td>
</tr>
<tr>
<td>Earthquakes</td>
<td>Frequent, within the conservative plate margin that includes the San Andreas and Hayward faults; usually shallow.</td>
<td>Subduction zone; frequent but very in depth from shallow to deep.</td>
</tr>
<tr>
<td>Landslides</td>
<td>Frequent, associated with earthquakes, heavy rain, coastal erosion and wildfires.</td>
<td>Frequent; linked to typhoons and deforestation; often deadly.</td>
</tr>
<tr>
<td>Cyclones</td>
<td>Never occur here.</td>
<td>Very frequent and usually deadly.</td>
</tr>
<tr>
<td>Flood</td>
<td>Can be associated with El Niño cycles.</td>
<td>A frequent result of typhoons.</td>
</tr>
</tbody>
</table>

Table 3.5: Hazard similarities and differences (Source: International Red Cross World Disasters Report www.ifrc.org/Global/Documents/Secretariat/201410/WDR/20014.pdf)

### 3.2 Managing tectonic hazards

#### Prediction and forecasting frameworks

The ‘risk disc’ (Figure 3.8) is one model that attempts to explain the reasons for the decline in deaths in terms of disaster preparedness, disaster mitigation (hazard proofing), disaster response and disaster recovery. The next section of this book will examine these different areas, together with the associated models that help to explain their purpose.

Getting closer to earthquake forecasting and prediction?

Earthquake forecasting and prediction is an active topic of geological research. Earthquake risk can be forecast since it is based on a statistical likelihood of an event happening at a particular location. These forecasts are based on data and evidence gathered through global seismic monitoring networks, as well as from historical records. Long-term forecasts (years to decades) are currently much more reliable than short- to medium-term forecasts (days to months). Forecasting is very important as it can encourage governments to enforce better building regulations in areas of high stress, or create improved evacuation procedures in areas of highest risk.

Currently it is not possible to make accurate predictions of when and where earthquakes will happen. For this to be possible, it would be necessary to identify a ‘diagnostic precursor’ – a characteristic pattern of seismic activity or some other physical, chemical or biological change – which would indicate a high probability of an earthquake happening in a small window of space and time. So far, the search for diagnostic precursors has been unsuccessful. Some geophysicists are trying to improve prediction based on calculating the underground movement of magma. Their models try to predict where the plates are running together with the most stresses, often a tell-tale sign of where an earthquake might hit. They map underground patterns of activity in the Earth’s mantle across underground grid points. The models then predict where stress points will occur by simulating different rock mantle flows. The calculations can ascertain where, as a result of these flows, the plates are likely to run together, and automatically detect these stressed zones.

Such models are still in their infancy and need considerable refinement as the link between earthquakes and underground mantle flows is complex and hard to model. Other scientists are working on predicting earthquakes...
3.3 Hazard management: a variety of approaches

In theory, the best response to tectonic hazards is to avoid all danger. In reality, however, this is impossible because of the conflicting development pressures on land. Hazard management is, therefore, always a series of imperfect solutions. The Swiss Cheese Model (page 28) suggests that hazard and disaster risk can be reduced by:

1. reducing the number of holes in each layer (that is, the number of systemic weaknesses), or,
2. reducing the size of the holes in each layer (that is, the "gaps" in the system, or the scale of the system weaknesses).

A better understanding of the complexity of tectonic risk through systematic analysis is important. The Swiss Cheese Model, for example, provides a framework for tectonic hazard management which links a number of areas. These include where possible:

- modifying the hazard event
- modifying vulnerability and resilience (at an individual, community and country scale)
- modifying the loss (a component of resilience).

It is important to develop a number of frameworks when taking an overview of hazard events and their ability to develop into disasters so that descriptive accounts of suffering and damage are avoided. Figure 3.11, for example, provides a framework for response analysis.

Modifying the hazard event

During the 1970s and 1980s there was a general feeling that the technological capability and engineering skills to control earthquakes would soon be developed, for example by lubricating the fault planes. But it is now realised that seismic activity cannot be controlled, so efforts instead focus on science and civil engineering solutions to reduce the hazard by either minor or major protection techniques:

- Micro: strengthening individual buildings and structures against hazardous stress.
- Macro: large-scale protective measures designed to protect whole communities.

Earthquakes

Macro approaches are generally used in the case of tectonic hazards. For earthquakes, most energy has been focused on public buildings and facilities, especially those expected to remain operational during a disaster: hospitals, police stations and pipelines. Schools and factories were also strengthened so that people could shelter in them. More recently there has been a shift towards improving the planning.
Figure 3.12 Mangroves may provide an important coastal buffer both against rising sea levels and tsunamis.

Tsunamis

No technologies can prevent tectonic disturbance but some regions and communities have put engineering solutions in place, for example tsunami walls that work for a given amplitude or threshold of wave. Research shows that replanting of coasts (Figure 3.12) may be a way of affording better protection and therefore modification of the event. In the great Asian tsunami of 2004, for example, science has indicated that fewer people might have died if coasts had been protected by mangroves or other types of dense coastal forest.

Yet there is still considerable debate as to the effectiveness of these so-called buffer zones. Mangroves are known to be effective at dissipating energy from waves whipped up by the wind. Modelling studies also suggest that shore vegetation can reduce the flow speed and height of an oncoming tsunami, but there is limited field evidence to back this claim up.

Volcanoes

In some instances it may be possible to modify a volcanic event once the eruption and lava flows have started, either by diverting or chilling the flows. For example, the 1975 volcanic eruption on the island of Heimaey, off the southwest coast of Iceland, threatened to destroy a whole community (Figure 3.13). Seventy homes and farms were buried under tephra and 300 buildings were burned by fires or buried under lava flows.

The lava flow was heading towards the fishing port and harbour – the economic lifeblood of the island. Loss of the harbour would have resulted in financial ruin for the community. The Icelanders sprayed seawater on to the lava to slow its movement by chilling. More than 30 km of pipe pumped 6 million cubic metres of water on to the flows. The effort saved the port and the residents returned to rebuild their town.

Figure 3.13 The classic 1973 volcanic eruption 'timeline' on the Icelandic island of Heimaey.

Modifying vulnerability and resilience

Modification of the hazard event, as shown in Figure 3.31, can involve a number of approaches and adaptations including:

- prediction, forecasting and warnings
- improvements in community preparedness
- working with groups and individuals to change behaviours (to reduce the disaster risk), for example, better land-use planning

With the advent of better technology, prediction, forecasting and warning are becoming increasingly important parts of disaster preparation and management. For example, a tsunami warning system (TWS) is used to detect tsunamis in advance and issue warnings to prevent loss of life and damage to movable possessions. It is made up of two components: a network of sensors to detect tsunamis and a communications infrastructure to quickly issue alerts to allow evacuation of the coastal areas.

Adaptation and preparedness is essential to ensure an effective response to disaster. It usually involves the planning and testing of hazard reduction systems on timescales that may operate from seconds (for example, tsunami warnings) to years (for example, improvements in land-use planning and zoning).

One of the complexities with adaptation and increasing resilience is the fact that there are a range of interest groups that have some role to play in modification of vulnerability (Figure 3.14).

Figure 3.14 Interest groups that have roles to play in modification of vulnerability.

Governance, for example, is important but it has limitations in terms of the affordability of prediction and prevention measures, especially in the management of mega-disasters immediately after the event. This means that other factors such as poverty may hamper any top-down efforts to reduce impact and adapt.

Volcanoes: a hazard vulnerability success story?

Volcanologists have an advantage over seismologists in that volcanoes usually do not erupt without warning. The warning signs typically take the form of numerous small earthquakes and a swelling of the ground surface, which reflect the passage of magma to the surface. But it is difficult to predict exactly when activity will take place, especially the timing of a major eruption. Technology in the form of a network of sensors is now being used to help predict eruptions and allow more sophisticated modelling to be undertaken. Monitoring may give time for the area under threat to be evacuated.

Looking at data on deaths, the volcanic hazard threat seems to have been successfully mitigated: only two eruptions since 1980 have caused more than 1000 deaths. Eruptions still affect large numbers of people but prediction and evacuation have reduced the death toll enormously.

An exception to this is was the Mount Ontake eruption in Japan on 27 September 2014. It is a popular area with hikers and walkers, who became the victims. There was no warning and the VEI 3 eruption killed 56 people, the first deaths in Japan from eruptions since 1991 (Mount Unzen). It was the highest death toll from an eruption in Japan since 1902.

Science to reduce earthquake vulnerability

Following the 1995 Kobe earthquake in Japan, the National Research Institute for Earth Science and Disaster Prevention (NIED) deployed 1000 strong-motion accelerometers throughout the country. This is the Koyoshima Network, or Ki-NET. The average distance between stations is 25 km. During an earthquake, primary and secondary wave velocities are measured at each site and logged. Data is then sent to the local municipality (via the internet). The municipality can use the information for local emergency management and response.

Figure 3.15 shows how the UN World Food Programme uses a range of strategies and players to modify loss and vulnerability. Importantly, new technology and communication, for example social media such as Facebook and Twitter, are used to help people adapt and improve their resilience.

So, adaptation is really about modifying resilience, which is a measure of how well an individual, community or country might absorb or recover from a hazard. This approach to disaster reduction is seen as very important nowadays, especially in the world's poorer communities where the disaster focus had traditionally been on seeing people as vulnerable victims and therefore recipients of external support (a 'top-down' model).

Now attention is focusing on supporting affected communities to prepare and manage themselves, and strengthening this local capability before, during and after a hazard event.

Modifying the loss

Mitigation is about modification of the loss burden. Insurance to cover the cost of earthquake damage, for example, is an important part of wider earthquake protection. Seismologists work with computer risk analysts to help the insurance industry calculate premiums and risks. Computer simulations are used to estimate the probability of damage from different earthquake events, based on:

- seismicity: the raw information about how frequently earthquakes affect a particular location
- seismic hazard: the probability that a certain strength of shaking will occur
- seismic risk: the probability that a certain amount of risk will occur.
Figure 3.16 shows that, since 1980, Japan’s earthquakes (1995, 2004 and 2011) have been costly, with a total cost of over $280 billion. Other tectonic events are also shown to be expensive. Since 2000, the UNISDR estimates the total economic cost of all disasters to be approximately $1.3 trillion. Even in developed economies such as the USA and Japan, insured losses for tectonic events tend to be relatively low, at approximately 25 to 30 per cent, meaning many people are unprotected.

Most insurance policies provide cover for property loss caused by a volcanic blast, airborne shock waves, dust, lava or pyroclastic flow. Fire or explosion resulting from volcanic eruption is also usually covered, however some may not cover shock waves or tremors caused by volcanic eruption.

Disaster aid and internal governmental aid
Disaster aid is the result of humanitarian concern following severe loss. This aid is all about protecting life, health, subsistence and a person’s physical security. Table 3.7 compares disaster aid and internal governmental aid. Disaster aid is often criticized, however; there may be poor or corrupt distribution systems, and it doesn’t encourage self-help or a more bottom-up management of the disaster at a local level. In the 2010 Haiti earthquake, the Nepalese disaster relief workers were implicated in the introduction of cholera – see Chapter 2, page 22.

A complex risk environment
Despite considerable efforts to improve scientific understanding and better risk-management approaches, in general governments and businesses remain insufficiently prepared to confront many tectonic hazards and effectively manage their economic, social, political and humanitarian consequences. This is often true irrespective of a country’s level of development. In certain high-threat events, governments are the responders of last resort, but they may not have the resources or technical expertise to deal with such events.

Table 3.7 Disaster aid compared to internal governmental aid

<table>
<thead>
<tr>
<th>Disaster aid</th>
<th>Internal governmental aid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air flows to countries and victims via governments, NGOs and private donors. In the longer term aid is used for relief, rehabilitation and reconstruction. This type of aid is often targeted to middle-income countries.</td>
<td>This is typically used in emerging and developing countries where the disaster mitigation is achieved by spreading the financial load throughout the tax payers of the country. This may include a national disaster fund and release of funds may require a political declaration.</td>
</tr>
</tbody>
</table>

Figure 3.15 Response to hazards - the stages over time

Review questions
1. Summarise the main trends in tectonic natural hazards in recent decades, including deaths, numbers affected and economic costs.
2. What are the characteristics of a mega-disaster?
3. Outline the spatial variation in disasters by both region and level of economic development.
4. Explain the differences in the modification of hazard events for different tectonic hazards.
5. Compare the hazard management cycle to the Disaster Response Curve.
6. Why is there a complex risk environment?
7. Summarise the reasons why volcanoes pose a much lower disaster risk than they have historically.

This was replaced by the Sendai Framework in March 2015. It set out four priorities:
1. Understanding disaster risk.
2. Strengthening governance to manage disaster risk.
3. Investing in disaster-risk reduction for resilience and enhancing disaster preparedness for effective response.
4. ‘Build back better’ in recovery, rehabilitation and reconstruction.

Importantly the framework emphasized the need to tackle disaster risk, reduction and climate change adaptation when setting Sustainable Development Goals, particularly in light of an insufficient focus on risk reduction and resilience in the original Millennium Development Goals (MDGs). There is also a focus on emergency preparedness. In the case of international disaster relief, the framework recognizes that distribution is complex, fragmented and disorganised. This is because there are various separate institutions, mechanisms and approaches defining where the funding is directed and how it is spent.

Further research
Research and select a Creditreform relevant to tectonic disasters and develop a case study from its findings: http://cred.be/publication/field_publication_type_id=668/field_cred_staff_authors_id=All
Use this link to research and summarise the key points relating to the 2010 Haiti earthquake: www.gfdr.org/sites/default/files/publication/Haiti_August_2014_Summary.pdf

Research the most expensive tectonic hazards in the last 30 years online. How do tectonic hazards compare to hydrological, meteorological and climatological hazards? Research the differences between the Hyogo and Sendai approaches to disaster management.
Exam-style questions

AS questions

1. Define what is meant by the term disaster. [1]
2. Study Figure 1. State the mode and range of earthquake risk magnitude.
   a. Mode: [2]
   b. Range: [2]
3. Explain two reasons how a government might influence a community’s resilience. [4]
5. Assess the factors that contribute to increased impacts from some tectonic hazard events. [12]

A level questions

1. Assess the factors which influence the effectiveness of responses used by different groups of people to cope with tectonic hazards. [12]
2. Assess the physical and human factors which cause some tectonic hazards to have a more disastrous impact than others. [12]
3. Assess the different challenges tectonic activity poses for the communities who experience its effects. [12]
4. Study Table 1. Calculate the mean, median and interquartile range of property damage for the earthquake data. [4]

Figure 1. Earthquakes in the San Francisco area since 1850 (Source: Munich Re, based on USGS Earthquake Hazard Program, 2004)

Table 1. Earthquake data

<table>
<thead>
<tr>
<th>Year</th>
<th>Name</th>
<th>Magnitude</th>
<th>Property damage: Sbillion (inflation-adjusted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1923</td>
<td>Great Kanto earthquake</td>
<td>7.9</td>
<td>8</td>
</tr>
<tr>
<td>1976</td>
<td>Tengshan earthquake</td>
<td>7.8</td>
<td>42</td>
</tr>
<tr>
<td>1989</td>
<td>Loma Preita</td>
<td>7.1</td>
<td>21</td>
</tr>
<tr>
<td>1994</td>
<td>Northridge earthquake</td>
<td>6.7</td>
<td>67</td>
</tr>
<tr>
<td>1995</td>
<td>Great Hanshin earthquake</td>
<td>6.9</td>
<td>312</td>
</tr>
<tr>
<td>1998</td>
<td>Sichuan earthquake</td>
<td>8.0</td>
<td>95</td>
</tr>
<tr>
<td>1999</td>
<td>921 earthquake Taiwan</td>
<td>7.6</td>
<td>10</td>
</tr>
<tr>
<td>1999</td>
<td>Izmit earthquake</td>
<td>7.6</td>
<td>29</td>
</tr>
<tr>
<td>2010</td>
<td>Chile earthquake</td>
<td>8.8</td>
<td>30</td>
</tr>
<tr>
<td>2011</td>
<td>Japan earthquake and tsunami</td>
<td>9.0</td>
<td>249</td>
</tr>
<tr>
<td>2015</td>
<td>Nepal earthquake</td>
<td>7.8</td>
<td>11</td>
</tr>
</tbody>
</table>