2 Risks and Disasters

2.1 Introduction

Generally data about historical events strongly influence the awareness of risks. It is especially through disasters that the basis for risk estimation has been developed. This chapter classifies disasters based on their primary cause and gives examples of natural, technical, health and social disasters. The terms risk and disaster are interchangeably used here since historical disasters can indicate future risks.

2.2 Classes of Risks and Disasters

The classification of disasters based on their primary cause is an often-used technique, but presents major drawbacks as well. As disasters are considered to cause harm and damage to humans and their properties, there are always some human or technical preventive actions possible. Therefore, even disasters that are commonly accepted as natural disasters include, to a certain extent, some social or technical failures. Figure 2-1 shows that people consider there to be a human component for virtually all types of disasters. What is interesting, however, is the fact that people also consider social disasters, for example insurrection, to be not entirely human-made, but including some natural components as well.

Therefore, the classification of risks into distinct categories, such as ones shown below, is never really possible:

- Natural
- Natech (natural hazards triggering technical disasters)
- Man-made and
• Deliberate acts
  or
• Natural (volcano, earthquake, flood, storm)
• Technical (dam failure, airplane crash, car accident)
• Health (AIDS, heart attack, black death…) and
• Social (suicide, poverty, war, manslaughter)

Already the Natech risks – a technical disaster caused by a natural disaster, show the interaction and overlap between different categories of risk. Furthermore, risks to humans can be classified according to the exposure paths: inhalation risks, ingestion risks, contamination risks, violence risks and temperature risks, including fire. Another way of classifying risks is shown in Fig. 2-2, which classifies disasters and risks not only according to natural and man-made influence but also according to the voluntariness and intensity of the disaster.

Although other classifications of risks are possible, the system distinguishing natural, technical, health and social risks is used for the presentation of disasters within this chapter.

Fig. 2-1. Perception of causes of disasters (Karger 1996)
2.3 Natural Risks

2.3.1 Introduction

Natural hazards are caused by natural processes independent from the existence of the humans. Natural risks cause natural hazards when humans are exposed to them. Such hazards can be snow storms, hail, drought, flooding, hurricanes, cyclones, typhoons, volcanic eruptions, earthquakes, climate change, bites from animals or meteorites (ICLR 2008, IRR 2008). Natural hazards contribute substantially to the threat to humans. Table 2-1 lists the 40 most deadly disasters between 1970 and 2001 and Table 2-2 lists the most costly disasters for the same time period. Obviously natural disasters dominate this list. The development of the frequency of natural risks is shown in Fig. 2-3. The overall cost in the past decade attributed to these natural disasters exceeds 50 billion dollars. Of course, one has to keep in mind that over this time period the population and the number of goods on earth has increased substantially, and finally the quality of recording data has improved as well.

In the 20th century, an estimated 60 million fatalities were caused by natural disasters. At the end of the 20th century, on average about 80,000 fatalities per year were caused by natural hazards (Fig. 2-4), although in 2004 the major Tsunami event killed probably up to 250,000 people.
| Date         | Country                  | Event                        | Fatalities |
|--------------|--------------------------|------------------------------|------------|
| 14.11.1970   | Bangladesh               | Storm surge                  | 300,000    |
| 28.07.1976   | China, Tangshan          | Earthquake 8.2 ¹             | 250,000    |
| 29.04.1991   | Bangladesh               | Tropical cyclone in Gorky    | 138,000    |
| 31.05.1970   | Peru                     | Earthquake 7.7               | 60,000     |
| 21.06.1990   | Iran                     | Earthquake in Gilan          | 50,000     |
| 07.12.1988   | Armenia, UDSSR           | Earthquake                   | 25,000     |
| 16.09.1978   | Iran                     | Earthquake in Tabas          | 25,000     |
| 13.11.1985   | Columbia, UDSSR          | Volcano eruption Nevado del Ruiz | 23,000 |
| 04.02.1976   | Guatemala                | Earthquake 7.4               | 22,000     |
| 17.08.1999   | Turkey                   | Earthquake in Izmit          | 19,118     |
| 26.01.2001   | India, Pakistan          | Earthquake 7.7 in Gujarat    | 15,000     |
| 29.10.1999   | India, Bangladesh        | Cyclone 05B hits federal state Orissa | 15,000 |
| 01.09.1978   | India                    | Flooding after monsoon       | 15,000     |
| 19.09.1985   | Mexico                   | Earthquake 8.1               | 15,000     |
| 11.08.1979   | India                    | Dam failure in Morvi         | 15,000     |
| 31.10.1971   | India                    | Flooding in the Bay of Bengal | 10,800 |
| 15.12.1999   | Venezuela, Columbia      | Flooding, landslides         | 10,000     |
| 25.05.1985   | Bangladesh               | Cyclone in Bay of Bengal     | 10,000     |
| 20.11.1977   | India                    | Cyclone in Andra Pradesh/Bay of Bengal | 10,000 |
| 30.09.1993   | India                    | Earthquake 6.4 in Maharashtra | 9,500     |
| 22.10.1998   | Honduras, Nicaragua      | Hurricane Mitch in Central America | 9,000     |
| 16.08.1976   | Philippines              | Earthquake in Mindanao       | 8,000      |
| 17.01.1995   | Japan                    | Great-Hanshin- Earthquake in Kobe | 6,425     |
| 05.11.1991   | Philippines              | Typhoon Linda and Uring      | 6,304      |
| 28.12.1976   | Pakistan                 | Earthquake 6.3               | 5,300      |
| 05.03.1987   | Ecuador                  | Earthquake                   | 5,000      |
| 23.12.1972   | Nicaragua                | Earthquake in Managua        | 5,000      |
| 30.06.1976   | Indonesia                | Earthquake in West-Irian     | 5,000      |
| 10.04.1972   | Iran                     | Earthquake in Fars           | 5,000      |
| 10.10.1980   | Algeria                  | Earthquake in El Asnam       | 4,500      |
| 21.12.1987   | Philippines              | Ferry Dona Paz collides with tanker | 4,375 |
| 30.05.1998   | Afghanistan              | Earthquake in Takhar         | 4,000      |
| 15.02.1972   | Iran                     | Storm and snow in Ardekan    | 4,000      |
| 24.11.1976   | Turkey                   | Earthquake in Van            | 4,000      |
| 02.12.1984   | India                    | Accident in a chemical plant in Bhopal | 4,000 |
| 01.11.1997   | Vietnam and others       | Typhoon Linda                | 3,840      |
| 08.09.1992   | India, Pakistan          | Flooding in Punjab           | 3,800      |
| 01.07.1998   | China                    | Flooding at Jangtse          | 3,656      |
| 21.09.1999   | Taiwan                   | Earthquake in Nantou         | 3,400      |
| 16.04.1978   | Réunion                  | Hurricane                    | 3,200      |

¹ Richter scale.
### Table 2-2. The 40 most costly disasters 1970–2001 (Swiss Re 2002)

| Insured damage<sup>1</sup> | Date         | Event                        | Country                    |
|--------------------------|--------------|------------------------------|----------------------------|
| 20.185                   | 23.08.1992   | Hurricane Andrew            | USA, Bahamas               |
| 19.000                   | 11.09.2001   | Assault on WTC and Pentagon | USA                        |
| 16.720                   | 17.01.1994   | Northridge-Earthquake       | USA                        |
| 7.338                    | 27.09.1991   | Typhoon Mireille           | Japan                      |
| 6.221                    | 25.01.1990   | Winter storm Daria          | France, UK                 |
| 6.164                    | 25.12.1999   | Winter storm Lothar         | France, CH                 |
| 5.990                    | 15.09.1989   | Hurricane Hugo              | Puerto Rico, USA           |
| 4.674                    | 15.10.1987   | Storm and flooding in Europe| France, UK                 |
| 4.323                    | 25.02.1990   | Winter storm Vivian         | West/Central Europe        |
| 4.293                    | 22.09.1999   | Typhoon Bart                | South Japan                |
| 3.833                    | 20.09.1998   | Hurricane Georges           | USA, Caribbean             |
| 3.150                    | 05.06.2001   | Tropical cyclone Allison    | USA                        |
| 2.994                    | 06.07.1988   | Explosion of Piper Alpha    | Great Britain              |
| 2.872                    | 17.01.1995   | Great-Hanshin Earthquake    | Japan, Kobe                |
| 2.551                    | 27.12.1999   | Winter storm Martin         | France, Spain              |
| 2.508                    | 10.09.1999   | Hurricane Floyd, rains       | USA, Bahamas               |
| 2.440                    | 01.10.1995   | Hurricane Opal              | USA and others             |
| 2.144                    | 10.03.1993   | Blizzard, Tornado           | USA, Mexico, Canada        |
| 2.019                    | 11.09.1992   | Hurricane Iniki             | USA, North Pacific         |
| 1.900                    | 06.04.2001   | Hail, flooding and tornados | USA                        |
| 1.892                    | 23.10.1989   | Explosion in a petrochemical plant | USA |
| 1.834                    | 12.09.1979   | Hurricane Frederic          | USA                        |
| 1.806                    | 05.09.1996   | Hurricane Fran              | USA                        |
| 1.795                    | 18.09.1974   | Tropical cyclone Fifi       | Honduras                   |
| 1.743                    | 03.09.1995   | Hurricane Luis              | Caribbean                  |
| 1.665                    | 10.09.1988   | Hurricane Gilbert           | Jamaica and others         |
| 1.594                    | 03.12.1999   | Winter storm Anatol         | West/Northern Europe       |
| 1.578                    | 03.05.1999   | > 70 tornados in the middle west | USA |
| 1.564                    | 17.12.1983   | Blizzard, cold wave         | USA, Canada, Mexico        |
| 1.560                    | 20.10.1991   | Forest fire, city fire, drought | USA |
| 1.546                    | 02.04.1974   | Tornados in 14 states       | USA                        |
| 1.475                    | 25.04.1973   | Flooding of Mississippi     | USA                        |
| 1.461                    | 15.05.1998   | Wind, hail and tornados     | USA                        |
| 1.428                    | 17.10.1989   | Loma-Prieta Earthquake      | USA                        |
| 1.413                    | 04.08.1970   | Hurricane Celia             | USA, Cuba                  |
| 1.386                    | 19.09.1998   | Typhoon Vicki               | Japan, Philippines         |
| 1.357                    | 21.09.2001   | Explosion at a fertilizer plant | France |
| 1.337                    | 05.01.1998   | Cold wave and ice disaster  | Canada, USA                |
| 1.319                    | 05.05.1995   | Wind, hail and flooding     | USA                        |
| 1.300                    | 29.10.1991   | Hurricane Grace             | USA                        |

<sup>1</sup> In million US dollars, 2001.
In addition to their development over time, natural risks also show some geographical correlation. In Fig. 2-5, the distribution of natural hazards for the territory of the US is shown. Dilley et al. (2005) presented the geographical distribution of natural hazards on a worldwide scale.

Since the earliest appearance of civilization, the humans have described natural disasters, such as the big flooding in The Bible. Probably one of the earliest natural risks were astronomical risks.

![Fig. 2-3. Number of recorded natural disasters since 1900 (EM-DAT 2004)](image1)

![Fig. 2-4. Number of fatalities by disasters worldwide 1900–2000 (Mechler 2003)](image2)
2.3 Astronomical Risks

2.3.2 Solar System

If one looks into the sky on a clear night, the number of stars seems to be innumerable. The stars visible to the naked eye mainly belong to the Milky Way galaxy, which contains up to 200 billion stars (Lanius 1988, NGS 1999). With a little bit of luck, one can see the Andromeda galaxy that is two million light years away. In general, if one observes the astronomical systems, worlds with other time scales become visible. By extending the power of the human eye through sophisticated telescopes, objects at greatest distance from earth, which are essentially the physical borders of our space, may become visible. Such objects reach distances of up to 13 billion light years from the earth. Actually, one has seen only some historical objects, since when dealing with such distances, the speed of light becomes important. Within this distance of 13 billion light years, mankind, so far, has found approximately 100 billion galaxies (NGS 1999). Considering such a huge number of objects, there might, of course, be objects that pose a hazard to humans. The question is, are we sufficiently far enough to be not at risk. If events like supernovas happen in the neighbourhood of the solar system, this might result in the extinction of mankind. Evidence has also been found of huge collisions between galaxies (NASA 2003). It seems, however, that such events have happened at a sufficiently large
distance from the earth. As already mentioned, Andromeda is at a distance of about two million light years from earth. The closest galaxies to the earth, the irregular Magellanic cloud, are still a 150,000 light years away. Therefore, in the case of risk assessment, one can mainly focus on our galaxy and the stars in the neighbourhood of our sun.

The adjacent stars of our solar system behave comparably to our sun. The closest star, Proxima centaury, is at a distance of 4.25 light years. The relative speed of stars is rather slow although they move rather quickly around the centre of the Milky Way. The stars have rotated about 20 times around the centre of the galaxy. The average rotation time is 225 million years. Whether there exists a black hole in the centre of the galaxy and what that means in terms of risk seems to be currently unknown.

Mankind, however, can focus on our own fixed star. According to different computations, the sun is 4.5 billion years old (Lanius 1988). This value corresponds very well to the age of stones from the moon or from meteorite stones. It has been estimated that the fuel of the sun, hydrogen, will exhaust in about five billion years (Fig. 2-6). Then, the core of the sun will consist of helium, and a fusion of helium, to carbon will occur. The sun will evolve through fusions from hydrogen to helium, then to carbon, neon, oxygen, silicon and at the end iron. The probable death of the sun will be a supernova, leaving a neutron star. Examples of supernovas can be found in historical documents. Japanese and Chinese sources around the year 1054 describe the sudden flash of a star from Taurus (Lanius 1988). Pictures taken in that region today show a cloud. This fact supports the supernova theory. Such a huge energy release in the neighbourhood of our solar system would probably destroy all types of life in the system.

Coming back to the sun, although the sun will exist five billion more years, in about three billion years, the sun will already be a red giant causing unfavourable conditions. It will be 100 times as big as its current size. The drop in surface temperature from 5,800°C to 4,000°C will probably not help much. Considering such conditions as a disaster, one has to investigate how precise are our models about the development of stars. Fortunately, for such models, not only theoretical considerations but also observations can be used. Very old structures in the universe, especially, can give hints about the possible development of stars. In some globular clusters, different age clusters of stars were observable. In general, however, the rule of thumb is valid – that the stars of a region have the same age. Therefore, the chance of risk of a sudden explosion of stars in our neighbourhood or the explosion of our sun in a few decades or centuries should be extremely low.
2.3 Natural Risks

Fig. 2-6. Development of the sun in a Hertzsprung–Russel diagram (Lanius 1988)

Probably the earth will change extensively over the lifetime of the sun, because the earth is not a static, solidified mass. This becomes clear during events such as volcanic eruptions or earthquakes. The earth itself belongs to a group of planets. A simple tabulation of the distance of the planets from the sun is the Titus Bode rule (Table 2-3). Here, the distance is given as a factor of the Astronomical unit. The Astronomical unit represents eight light minutes or about 150 million kilometers (Gellert et al. 1983). The observed distances show rather high values, and therefore collisions or other negative impacts from these planets seem currently neglectable, although Pluto crosses the orbit of Neptune. Here, the latest developments, for example excluding Pluto from the group of planets, are not considered.

Table 2-3. Distance of planets from the sun according to the Titius–Bode rule (Gellert et al. 1983)

| Planet  | $N$ | $a_n$ | $a$  |
|---------|-----|-------|------|
| Mercury | $-\infty$ | 0.4   | 0.39 |
| Venus   | 0   | 0.7   | 0.72 |
| Earth   | 1   | 1.0   | 1.00 |
| Mars    | 2   | 1.6   | 1.52 |
| Small planets | 3 | 2.8   | 2.78 |
| Jupiter | 4   | 5.2   | 5.20 |
| Saturn  | 5   | 10.0  | 9.55 |
| Uranus  | 6   | 19.6  | 19.20|
| Neptune | $-\infty$ | $-$   | 30.09|
| Pluto   | 7   | 38.8  | 39.5 |

Titius–Bode rule: $a_n = 0.4 + 0.3 \times 2^n$; where $a_n$ is planet-sun distance in Astronomical units and $a$ is observed planet-sun distance.
However, the great distances in our solar system might not be sufficient to provide safety. According to the Milankovich theory, astronomic conditions influence the climate on earth. The main engine for the climate on earth is solar radiation. This depends on at least some rotation properties of the system earth-sun (Williams et al. 1998, Allen 1997):

- Eccentricity is the difference between the earth’s orbit around the sun and a circle. It changes in a cycle with a period of 100,000 years.
- The earth is lopsided. It changes with a period of 41,000 years.
- Gyration has a period of 19,000–23,000 years to complete a cycle.

These might have an effect on humans and might impose risks. Space weather, also called space hurricane season, has only recently been recognized as a risk. Especially since the occurrence of a power failure in 1989 in Canada and one historical event earlier in 1859, it was thought that there might be an interaction between the solar wind and the earth’s magnetic field. Such interactions might endanger astronauts during missions as well as affect electric and electronic equipment on earth (Plate 2003, Romeike 2005). Currently, the NASA installs satellites to improve prediction of such events, and there are some Aurora forecast reports available (Geophysical Institute 2007). Additionally, man’s activities on the planet might lead to consequences of astronomical risks, like the damage of the ozone layer.

### 2.3.2.2 Meteorites

The great distances between the planets might create an illusion that direct hits between astronomical bodies virtually do not exist in the solar system.

Observing, however, the common topography of most moons, planets or asteroids with solid surfaces proves this theory wrong: short-time and high-energy impacts are the main and, in many cases, the only geological surface modelling processes known so fast (Koeberl 2007).

An example of a large impact structure is the Mare Orientale on the moon with a diameter of 930 km (Langenhorst 2002). Figure 2-7 shows the number of craters on the moon related to the age of moon. In the year 1999, an impact on the moon was observed. On Jupiter, the impacts of pieces from the comet Shoemaker-Levy-9 attracted worldwide attention. The planet Mercury must also have experienced a major impact in its history, as not only the impact side of the planet changed but also the reverse side of it changed shape.

The earth is also exposed to such bombardment from space. Currently, there are about 170 known impact structures worldwide (Fig. 2-8). The size of such craters varies from 300 km to less than 100 m (Koeberl 2007). Historically, there have been much bigger impact events, creating, for example, the moon (Langenhorst 2002). On average, the earth is hit by
20,000 meteors per year. Some sources estimate even higher values, but the estimation remains difficult. The overall mass of meteors has been estimated as $4 \times 10^5$ per year (Langenhorst 2002). The speed of meteors ranges from 10 to 70 km/s (Gellert et al. 1983). Twenty percent of meteors are particles from comets. Some meteor showers occur regularly at certain times of the year; examples are listed in Table 2-4.

The October-Draconids is a good example of a regular meteor shower. The shower dates back to the Giacobini–Zinner comet, which appeared for the first time on 9 October 1926. The following years of 1933 and 1946 were extremely rich in meteor showers. On 9 October 1933, an average of 14,000 falling stars were detected. Falling stars are meteorids that break up at nearly 70–120 km before reaching earth. The contribution of falling stars to the meteorite volume that reaches earth is only about 0.05%. 

Fig. 2-7. Number of craters on the moon related to the age of the moon (Langenhorst 2002)

Fig. 2-8. Number of identified craters per million years (Langenhorst 2002)
Ninty-nine percent of the meteorite material reaching the earth comes from micrometeorites. That explains why the estimation of the overall volume of meteorites hitting the earth is so difficult. On the other hand, however, the 170 known impact structures prove that bigger impacts are possible. Tables 2-5 and 2-6 give an overview about historical meteorite impacts. The listing of only major impacts from pre-historical times is owed to the fact that other surface-forming processes are active on earth, such as wind, water, ice and so on. Additionally, small craters are much more difficult to identify than bigger ones. For example, the Barringer crater in the US with a diameter of 1 km is much easier to identify than a crater of over a 100 m diameter in a forest.

Although Table 2-6 finishes with the year 1969, there were many meteorite events afterwards. For example, in 2000, a meteorite impact occurred in Canada/Alaska (Deiters 2001). In April 2002, a meteorite was found in Bavaria, Germany. The so-called Neuschwanstein meteorite had a mass of 1.75 kg, but it probably belonged to another body of mass more than 600 kg (Deiters 2002). One recent example is the Pennsylvania Bolide. This meteor was observed on 31 July 2001 at around 6 p.m. The meteor was visible in daylight from Canada to the state of Virginia; houses were shaken by the explosion.

One speaks of meteorites if the body hits the earth surface; otherwise, one speaks of meteors. Both can yield major destruction since the explosion of meteors might cause damages as severe like a direct hit.

In general, the human experience with heavy meteorite impacts is rather low since the beginning of human civilization. It seems to be a rare event with a low probability of occurrence, but the consequences could be disastrous. Table 2-7 shows the relationship between the return periods of impacts versus the damage potential in terms of explosion power. For example, the explosion power during an impact of a body with a diameter of 10–20 km, such as the Chicxulub Asteroid in Mexico, is about $10^8 – 10^9$ megatons TNT (NASA 1999). For comparison purposes: the current explosion power of all atom bombs is about $10^{5.5}$ megatons TNT. It has been estimated that the so-called nuclear winter needs approximately $10^4$ megatons TNT, and the Hiroshima bomb had about $10^2$ megatons TNT (NASA 1999).

An explosion power of $10^8$ megatons TNT would probably leave the entire civilization and biosphere heavily shattered. A hit by a body with a diameter of several kilometers would presumably kill all life on that side of the planet. The explosion wave of temperature over 500°C and a speed of 2,000–2,500 km/h would move around the world (NN 2003). If the ocean would be hit, there would be Tsunamis with a height of several kilometers. Additionally, the impact would yield to earthquakes and volcanic eruptions. Since the impact would bring huge masses of dust into the atmosphere, the
temperature would drop rapidly. This is observed to a lesser degree for some volcanic eruptions. In general, under such situations, there is a possibility that mankind would become extinct. Quite some studies have investigated such conditions mainly based on the assumption that such conditions could exist as an aftermath of a World War (Chapmann et al. 2001).

Table 2-4. Yearly returning meteore showers (Gellert et al. 1983)

| Season          | Name                      | Origin        | Classification |
|-----------------|---------------------------|---------------|----------------|
| 3 January       | Bootiden (Quadrattiden)   | Unknown       | Rich flow      |
| 12 March–5 April| Hydraiden                 | Part Virginiden| Weak flow      |
| 1 March–10 May  | Virginiden                | Ecliptically  | Strong flow    |
| 12–24 April     | Lyriden                   | Comet 1861 I  | Moderate flow  |
| 29 April–21 May | Mai-Aquariden             | Comet Halley  | Rich flow      |
| 20 April–30 July| Scorpius-Sagittariiden    | Ecliptically  | Weak flow      |
| 25 July–10 August| Juli-Aquariden            | Ecliptically  | Intensive flow |
| 20 July–19 August| Perseiden                 | Comet 1862 III| Strongest flow |
| 11–30 October  | Orioniden                 | Comet Halley  | Intensive flow |
| 24 September–10 December | Tauriden      | Ecliptically  | Moderate flow  |
| 10–20 November | Leoniden                  | Comet 1866 I  | Moderate flow  |
| 5–19 December  | Geminiden                 | Elliptical    | Intensive flow |

Table 2-5. Examples of meteorite impacts according to Gellert et al. (1983), Munich Re (2000), Koeberl & Virgil (2007), Pilkington & Grieve (1992), Langenhorst (2002) and Woronzow-Weljaminow (1978)

| Name and country | Age (years) | Diameter (km) |
|------------------|-------------|----------------|
| Vredefort structure, South Africa | 2,023 million | 300 |
| Sudbury structure, Canada | 1,850 million | 250 |
| Clearwater lakes, Canada | 290 million | 32/22 |
| Manicouagan, Canada | 212 million | 100 |
| Aorounga, Chad | 200 million | 17 |
| Gosses Bluff, Australia | 142 million | 22 |
| Deep Bay, Canada | 100 million | 13 |
| Chicxulub, Mexico | 65 million | 170 |
| Mistastin Lake, Canada | 38 million | 28 |
| Nördlinger Ries crater, Germany | 15 million | |
| Steinheimer Becken, Germany | 15 million | |
| Kara-Kul, Tajikistan | 10 million | 45 |
| Roter Kamm, Namibia | 5 million | 2.5 |
| Bosumtwi, Ghana | 1.3 million | 10.5 |
| Wolfe Creek, Australia | 300,000 | 0.87 |
| Barringer Crater, Arizona, USA | 50,000 | 1.2 |
| Chubkrater, Canada | 3.2 | |
Table 2-6. Examples of meteorite impacts according to Gellert et al. (1983), Munich Re (2000), Koeberl & Virgil (2007), Pilkington & Grieve (1992), Langenhorst (2002) and Woronzow-Weljaminow (1978)

| Location and country     | Date     | Comments                                                                 |
|--------------------------|----------|---------------------------------------------------------------------------|
| Naples, Roman Empire     | 79 A.D.  |                                                                           |
| Ensisheim, Germany       | 1492     |                                                                           |
| Cape York, Greenland     | 1895     | 33 tonnes iron meteorite                                                  |
| Kanyahiny, CSSR          | 09.06.1866 |                                                           |
| Pultusk, Poland          | 30.01.1868 | Rain of about 100,000 stones                                              |
| Long Island, Kansas, USA | 1891     | 564 kg                                                                    |
| Tunguska Meteorite, Russia | 30.06.1908 | About 1,000 km hearable, 7 million tonnes heavy, 1,200–1,600 km\(^2\) forest area destroyed |
| Hoba, South-West Africa  | 1920     | 60 tonnes iron meteorite                                                  |
| Sikhote-Alin Meteorite, USSR | 12.02.1947 | 200 craters, biggest 27 m in diameter, 70 tonnes overall material       |
| Furnas Co, Nebraska, USA | 18.02.1948 | About 1,000 stone meteorites, one of them 1,074 kg                        |
| Allende Meteorite, Mexico | 08.02.1969 | Overall 4 tonne of particles                                              |

Table 2-7. Return period of meteorite impacts (NASA 1999)

| Size     | Return period | Explosion power | Example                        |
|----------|---------------|-----------------|---------------------------------|
| 10 km    | 50–100,000,000 years | 10\(^{8}\) megaton TNT | Chixculub, Mexico               |
| 1 km     | 1,000,000 years | 10\(^{5}\) megaton TNT | Mistastin Lake, Canada          |
| 100 m    | 10,000 years | 10\(^{2}\) megaton TNT | Barringer Krater, USA           |
| 10 m     | 1,000 years | 10\(^{-1}\) megaton TNT | Tunguska Meteorite, Russia      |
| 1 m      | 1 year       | 10\(^{-2}\) megaton TNT |                                |
| 1 mm     | 30 s         | 10\(^{-10}\) megaton TNT |                                |

However, it is not that only natural elements are causing such hazards. About 11,000 large man-made objects in space are currently observed. It has been estimated that 100,000 smaller objects exist and the number of objects of size 0.1–1 cm is over one million (McDougall & Riedl 2005, NRC–Committee on Space Debris 1995). Of course, these objects are rather a risk to space ships but might also re-entry earth’s atmosphere.

2.3.2.3 Mass Extinctions

Meteorite impacts might be one possible cause for the so-called mass extinctions during prehistoric times. An example of this was the Cretaceous–Tertiary boundary extinction event, probably caused by the impact of the Chicxulub Asteroid in the area of Mexico. As a consequence of this impact, about 17% of all biological families, including the dinosaurs, became
extinct. Whether the asteroid was the one and only cause of extinction is still debated.

The idea of a major asteroid impact is found in some work by Alvarez in the 1970s. Alvarez investigated the quantity of Iridium in the maritime mud. In general, the results of the investigation, which used some material from Italy (Gubbio), showed the expected value of 0.3 ppb (parts per billion) Iridium. Some soil layers, however, showed dramatically higher values of Iridium in the order of 10 ppb. Afterwards, a material from Denmark (Stevn’s Klint) was tested. Here, the Iridium values were even higher, reaching up to 65 ppb. This Iridium peak was found worldwide in layers representing the time of the Cretaceous–Tertiary boundary, which is now sometimes called the Cretaceous–Paleogene boundary. Iridium itself is a noble earth element. It mainly comes from meteorites or partly from volcanic eruptions. This yields to the hypothesis that, probably during the Cretaceous–Tertiary boundary, a huge meteorite impacted the earth. Based on this consideration, the impact body should have had a size of about 10 km and hit the earth approximately 65 million years ago (Alvarez et al. 1980).

The next step in the validation of this theory would be the identification of a crater. Unfortunately, terrestrial processes like sedimentation, erosion or plate tectonics might cover or erase the typical surface expression of an impact event. An important witness of an impact, however, which is not so easily altered over time, is the affected rocks. Craters are filled with melted, shocked or brecciated rocks. Some parts of the rocks have been transported during the impact from the crater to the surroundings. This transported material is called ejecta. Most parts are found in the surroundings within a distance of less than five times the diameter of the crater (Montanari & Koeberl 2000, Melosh 1989). Therefore, it is thought that the increase in Iridium was due to abundant impact debris. The identification of the local crater was done using microtektites. These are small tektites, not more than 1 mm in diameter, generated during high pressures. Such high pressures might be shock waves caused by a meteorite impact.

Summarizing the results, it shows that there was a possibility of a major meteorite impact 65 million years ago. Other explanations are also possible. Some explain the increase in Iridium by heavy volcanic eruptions. About 65 million years ago, there was an extremely active volcanic region at the Deccan Traps. The amount of lava released could have covered half the area of modern India. Due to the possible huge releases of gases, there was an average temperature increase of up to 8°C around half million years before the meteorite impact. Iridium can also be found abundant, as mentioned before, in volcanic material (NGS 1998a,b).
Paleontologists also refute the fact that the extinction of the entire classes of animals was based solely on one disastrous event. There seems to be some current discussion, however, on whether some species survived, for example some dinosaurs. There are indications that, for example, some hadrosaurids might have survived the event for some time. But, under such conditions, it might be that the animal class cannot recover (Jablonski 2002). Additionally, it is not clear if the fossils might have been moved to later sediment. Although paleontologists do not like the idea of sudden extinction events, such phenomena have occurred several times in the history of the earth as shown in Table 2-8.

Table 2-8. Mass extinctions in the history of the earth (Morell 1999)

| Age      | Before (million years) | Percentage of extinct biologic families |
|----------|------------------------|----------------------------------------|
| Ordovician | 440                    | 25%                                    |
| Devon    | 370                    | 19%                                    |
| Perm     | 250                    | 54%<sup>1</sup>                         |
| Trias    | 210                    | 23%                                    |
| Cretaceous | 65                     | 17% (C/T boundary extinction event)    |
| Average  | 88                     | Probability of $1.14 \times 10^{-8}$ per year |

<sup>1</sup> During Perm, about 90% of all marine families became extinct (Hoffmann 2000).

Figure 2-9 is a graphical visualisation of the diversity of marine families that have existed throughout time. The first interesting fact is the diversity of marine life at present. There have never been so many different families at one time. The data, however, have not yet considered the influence of humans, which is, of course, decreasing the diversity of marine life. The second interesting fact is the repeated occurrence of mass extinction events. Probably the most significant event was the Perm extinction. Some references state that, around 100,000 years back, 50% of all biological families and 90% of all marine families became extinct (Morell 1999, Newson 2001). Other references give lower percentages (NGS 1998a,b). The oldest event was the Ordovician extinction. During this event, about 25% of all biologic families disappeared (Morell 1999). Other references, however, mention that up to 75% of all animal families became extinct (NGS 1998a,b). During the Devonian event, the number of extinctions was about the same.
The current number of species has been estimated at about 1.5 million. However, since the human population has shown a rapid growth over time, many species have become endangered. In 1980, the overall biomass was estimated to be about $2,000 \times 10^6$ tonnes. Assuming that the human biomass was about 2.5% of the overall biomass and farm stocks was approximately $325 \times 10^6$ tonnes, then about $1,625 \times 10^6$ tonnes were left for the 1.5 million species. Furthermore, it should be assumed that the amount of biomass remains constant, and mankind and farm stock constantly grow between 1.7 and 2.1%; then in the year 2020, only about $1,370 \times 10^6$ tonnes will be left for all other species. One can easily imagine that this will yield to a decrease in the number of species. Furthermore, since the decrease is at a very fast pace, it could be considered a mass extinction (Füller 1980).

Many examples can be given for the extinction of species. For example, the wild pigeon, Extopistes Migratorius, was very common at the end of the 19th century in the eastern states of the US. According to different estimations, the overall number of this bird species must have been several billions. However, due to the good taste and the good preservability of the meat, the birds were hunted since about 1870. In 1879, in Michigan alone, more than one billion birds were captured. The last brooding nest was seen in 1894, the last wild pigeon was seen in 1907, and in 1914 the last pigeon captured died. Nowadays, only a few primed specimens remain, for example in Jena, Germany (Füller 1980).
A further example was the Quagga. This was a type of zebra living in southern Africa. Because the Boers thought it was a competitor for their own farm stocks, Quaggas were killed. In 1870, only three Quaggas were left in zoos, and in 1883, the last one died (Bürger et al. 1980). Further examples of extinct species are listed in NGS (1998a,b) and Sedlag (1978).

2.3.3 Geological Risks

While the causes of disasters considered so far were either extra-terrestrial or unknown, the following disasters are connected to the composition of the earth. These disasters show that the earth is not a static, unchangeable planet but rather something that develops over time. Such developments might release huge amounts of energy or materials and, therefore, heavily influence life on the planet (Coch 1995, Zebrowski 1997).

2.3.3.1 Volcano

The earth is built up on different chemical layers. The layers include the upper silicate solid crust, a viscous mantle, a liquid outer core and a solid inner core. Even though most rocks are only around several hundred million years old, some rocks have been found to be more than 4.4 billion years old, indicating the age of the crust.

The thickness of the crust lies between 5 and 70 km deep, depending on whether it is an oceanic or continental crust. The crust permanently moves, mainly driven by the circulation of viscous and liquid materials in the layers beneath. If the crust opens or ruptures, the fluid, hot rock and also gases and ash might escape, creating volcanism. The maximum depth of the volcanic material is the border of the outer core and the lower mantle, which is between 2,500 and 3,000 km deep. Volcanism is a geologic, earth surface-forming process. The number of volcanos is estimated at several thousands; however, only a few hundreds are active (Fig. 2-10 and Table 2-9). In general, the number of small eruptions is about 50 per year and the number of major events is about one in 10 years. (DKKV 2002)
Fig. 2-10. Development of the number of active volcanos per year. Notice the drop in active volcanos during the World Wars (Smith 1996)

Table 2-9. Strongest volcanic eruptions in the last 250 years according to Graf (2001)

| Volcano                  | Year | Explosivity | Opacity | SO₂ (Mt) |
|--------------------------|------|-------------|---------|----------|
| Laki, Island             | 1783 | 4           | 2,300   | 100¹     |
| Tambora, Indonesia       | 1815 | 7           | 3,000   | 130¹     |
| Cosiguina, Nicaragua     | 1835 | 5           | 4,000   |          |
| Askja, Island            | 1875 | 5           | 1,000   |          |
| Krakatoa, Indonesia      | 1883 | 6           | 1,000   | 32¹      |
| Tarawera, New Zealand    | 1886 | 5           | 800     |          |
| Santa Maria, Guatemala   | 1902 | 6           | 600     | 13¹      |
| Ksudach, Kamtschatka     | 1907 | 5           | 500     |          |
| Katmai, Alaska           | 1912 | 6           | 500     | 12¹      |
| Agung, Indonesia         | 1963 | 4           | 800     | 5 ± 13¹  |
| Mount St. Helens, USA    | 1980 | 5           | 500     | 1        |
| El Chichón, Mexico       | 1982 | 5           | 800     | 7        |
| Pinatubo, Philippines    | 1991 | 6           | 1,000   | 16 ± 20  |

¹ Estimated.
Mt = mega tonnes

The intensity of volcanic features can be described by different measures. The volcanic explosivity index (VEI) has been introduced by Newhall & Self (1982). It is a measure comparable to the Richter scale, which is used to measure the intensity of earthquakes. The VEI is based on the volcanic volume released and the height of the smoke pillar (Table 2-10). Critic against the VEI is, for example, mentioned in Smolka (2007). Another volcanic intensity measure is the Tsuya-index. Additionally, for many volcanic eruptions, the opacity is given, which is a measure that describes the influence of the volcanic eruption on global climate.
Table 2-10. Volcanic explosivity index (Newhall & Self 1982, USGS 2008)

| Category | Volume erected in m$^3$ | Column height in km | Examples                  |
|----------|-------------------------|---------------------|---------------------------|
| 0        | $<10^4$                 | $<0.1$              | Nyiragongo, Tanzania (1977)|
| 1        | $10^4$--$10^6$          | 0.1--1              | Unzen, Japan (1991)       |
| 2        | $10^6$--$10^7$          | 1--5                | Nevado del Ruiz, Colombia (1985)|
| 3        | $10^7$--$10^8$          | 3--15               | El Chicon, Mexico (1982)  |
| 4        | $10^8$--$10^9$          | 10--25              | Mount St. Helens, US (1980)|
| 5        | $10^9$--$10^{10}$       | $>25$               | Krakatoa, Indonesia (1883)|
| 6        | $10^{10}$--$10^{11}$    | $>25$               | Tambora, Indonesia (1815) |
| 7        | $10^{11}$--$10^{12}$    | $>25$               | Taupo, New Zealand        |
| 8        | $>10^{12}$              | $>25$               |                           |

In the last 100,000 years, there were probably two volcanic eruptions with a VEI of 8: the Taupo eruption in New Zealand approximately 25,000 years ago with 1,200 km$^3$ of released material, and the Toba eruption in Sumatra, Indonesia, about 75,000 years ago with about 2,800 km$^3$ of released material. Additionally, in Yellowstone, there were probably volcanic eruptions with a VEI of 8 (Newhall & Self 1982). For comparative purposes, the released material of Mount St. Helens explosion was of the order of 0.6 km$^3$. Statistics about extreme volcanic eruptions are given in Mason et al. (2004).

However, even volcanic eruptions of lower intensity can have severe impacts on humans (Sparks & Self 2005). For example, the eruption of Mont Pelé in 1902 on the French Caribbean island Martinique claimed about 30,000 lives (Newson 2001). Only two citizens of the town St. Pierre survived the eruption, which included one prisoner. Lacroix investigated the Mont Pelé eruption and published a famous work about volcanic explosions. However, already in the 18th century, researchers like Hutton started to develop theories about the changing and evolving earth (Daniels 1982). In 1815, the Tambora eruption in Sumbawa, Indonesia, claimed about 10,000 lives. Afterwards, an additional 82,000 fatalities occurred in the region due to famine and disease. Furthermore, the weather worldwide was affected, and in the summer of 1816 the coldest temperatures ever were recorded. In combination with the Napoleon wars, the harvest loss was a heavy burden on the European population. In the New England states in North America, freezing temperatures were observed in summer this year. The Krakatoa eruption yielded to an average worldwide temperature drop of about 0.3°C. On average, volcanic eruptions can affect climate by the same magnitude as anthropogenic effects.

For some volcanoes, there exists quite a strong historical record with eruptions occurring sporadically over the last 2,000 years. For example,
the “Vesuvius” volcano in Italy erupted in the years 79 (perish of Pompeii), 203, 472, 512, 685, 787, five times between 968 and 1037, 1631 (about 4,000 fatalities), nine times between 1766 and 1794, 1872, 1906 and 1944. Malladra said that “the Vesuvian is sleeping, but his heart beats” (Daniels 1982).

There are different types of volcanic eruptions: effusive eruption; steam explosion, submarine eruption, Stromboly-like eruption, Plinian eruption, glow eruption, paroxysmal explosion, flooding of basalt and ash stream (Daniels 1982). Additionally, models of the eruption potential of magma are related to the concentration of silicic acid and water within the magma. Depending on the composition of these substances, the magma is either more fluid or more viscous. In combination with high steam pressure, viscous magma can enable heavy eruptions.

2.3.3.2 Earthquakes

Based on the theory of plate tectonics (Wegener 1915), the small-width asthenosphere layer moves on the approximately 100-km-thick lithosphere layer. The lithosphere – a layer of solid earth is broken into several plates (Fig. 2-11). The internal thermal engine of the earth drives the motion of the plates (Sornette 2006). The borders of the plates are not sharp boundaries, but instead they are complex systems, sometimes reaching several hundred kilometers long. Therefore, the estimated number of plates has changed over the last few decades, since microplates have been found in boundary areas. While previously only 14 plates were known, newer works suggest that 42–52 plates exist. The plate size follows a “power law”. The limitation of the earth surfaces limits the size of the plates. Furthermore the size of the convection cells in the upper mantle also influences the size of the plates. (Sornette 2006).

Not only geometrical reasons, e.g. the size of the plates, but also energy consumption limit the seismic moments. Therefore, the well-known Gutenberg-Richter law (Gutenberg & Richter 1954) for earthquake seismic moment releases was modified for large earthquakes (Hosser et al. 1991). It is thus concluded that the maximum earthquake energy realised can be found, if external events like meteorite, impact are not considered. The two strongest earthquakes in the 20th century (Chile 22 May 1960, $1.1 \times 10^{26}$ erg energy released, and Alaska, 28 March 1964, $4 \times 10^{25}$ erg energy released) nearly reached that maximum value. It is quite interesting to note that the average yearly seismic energy of all other earthquakes is about $3 \times 10^{24}$ erg. The recurrence time of a typical maximum earthquake is less than 100 years (Sornette 2006). Table 2-11 lists the magnitudes of some earthquakes in the previous century. The magnitude is related to the energy released,
and is described on the Richter scale as the logarithm of the maximum amplitude of 0.05 Hz measured with a standard Wood-Anderson seismograph on a solid ground 100 km away from the epicenter. Scales for the effects of earthquakes on buildings are the MSK-Scale (Medvedev-Sponheuer-Karnik), the Mercalli-Scale and the EMS-Scale.

Table 2-11. The largest earthquakes from 1900 to 2004 (Munich Re 2004a)

| Date          | Magnitude | Region            |
|---------------|-----------|-------------------|
| 22.5.1960     | 9.5       | Chile             |
| 28.3.1964     | 9.2       | USA, Alaska       |
| 9.3.1957      | 9.1       | USA, Aleutian     |
| 4.11.1952     | 9.0       | Russia, Kamchatka |
| 26.12.2004    | 9.0       | Indonesia         |
| 31.1.1906     | 8.8       | Ecuador           |
| 4.2.1965      | 8.7       | USA, Aleutian     |
| 15.8.1950     | 8.6       | India, Assam      |
| 3.2.1923      | 8.5       | Russia, Kamchatka |
| 1.2.1938      | 8.5       | Indonesia, Banda Sea |
| 13.10.1963    | 8.5       | Russia, Kuril Islands |

Table 2-12. The 15 deadliest earthquakes from 1900 to 2004 (Munich Re 2004a)

| Date          | Event             | Mag. | Region              | Fatalities | Economic losses in million US-dollars |
|---------------|-------------------|------|---------------------|------------|---------------------------------------|
| 27/28.7.1976  | Earthquake        | 7.8  | China, Tangshan     | 242,800    | 5,600                                 |
| 16.12.1920    | Earthquake, landslide | 8.5  | China, Gansu        | 235,000    | 25                                    |
| 1.9.1923      | Earthquake        | 7.8  | Japan, Tokyo        | 142,800    | 2,800                                 |
| 8.10.2005     | Earthquake        | 7.2  | Italy, Messina      | 88,000     | 5,200                                 |
| 28.12.1908    | Earthquake        | 7.6  | China, Kansu        | 77,000     |                                        |
| 25.12.1932    | Earthquake        | 7.9  | Peru, Chimbote      | 67,000     | 550                                   |
| 31.5.1970     | Earthquake, landslide | 7.5  | Pakistan, Quetta    | 50,000     | 25                                    |
| 30.5.1935     | Earthquake        | 7.4  | Iran, Gilan         | 40,000     | 7,100                                 |
| 23.5.1927     | Earthquake        | 8.0  | China, Gansu        | 40,000     | 25                                    |
| 26.12.1939    | Earthquake        | 7.9  | Turkey, Erzincan    | 32,900     | 20                                    |
| 13.1.1915     | Earthquake        | 7.5  | Italy, Avezzano     | 32,600     | 25                                    |
| 25.1.1939     | Earthquake        | 8.3  | Chile, Concepción   | 28,000     | 100                                   |
| 26.12.2003    | Earthquake        | 6.6  | Iran, Bam           | 26,200     | 500                                   |
| 7.12.1988     | Earthquake        | 6.7  | Armenia, Spitak     | 25,000     | 14,000                                |
Fig. 2-11. World map of tectonic plates and volcano and earthquake prone areas according to Diercke (2002)
Table 2-13. The 20 deadliest earthquakes of all times (USGS 2001)

| Year     | Country, region          | Fatalities |
|----------|--------------------------|------------|
| 23.01.1556 | China, Shansi            | 830,000    |
| 27.07.1976 | China, Tangshan          | 255,000    |
| 09.08.1138 | Syrien, Aleppo           | 230,000    |
| 22.05.1927 | China, Xining            | 200,000    |
| 22.12.856  | Iran, Damghan            | 200,000    |
| 16.12.1920 | China, Gansu             | 200,000    |
| 23.03.893  | Iran, Ardabil            | 150,000    |
| 01.09.1923 | Japan, Kwanto            | 143,000    |
| 05.10.1948 | USSR, Turkmenistan, Ashgabat | 110,000 |
| September 1290 | China, Chihli         | 100,000    |
| 28.12.1908 | Italia, Messina          | 70,000–100,000 |
| 8.10.2005 | Pakistan, India          | 88,000     |
| Nov. 1667  | Kaukasus, Shemakha       | 80,000     |
| 18.11.1727 | Iran, Tabriz             | 77,000     |
| 01.11.1755 | Portugal, Lisabon        | 70,000     |
| 25.12.1932 | China, Gansu             | 70,000     |
| 31.05.1970 | Peru                     | 66,000     |
| 1268       | Italia, Asia Minor, Sicily | 60,000    |
| 11.01.1693 | Italia, Sicily           | 60,000     |
| 30.05.1935 | Pakistan, Quetta         | 30,000–60,000 |

Based on our understanding of the mechanism of earthquakes, it becomes clear that earthquakes are connected to some regions: the borders of the tectonic plates. In these regions, about 3 billion humans live (DKKV 2002). Tables 2-12 and 2-13 show a list of deadliest earthquakes. In some areas, earthquake activities can be dated back over thousands of years. The city of Antioch in Turkey was hit by severe earthquakes in the years 115, 458, 526, 588, 1097, 1169 and 1872. It was estimated that the earthquake of 458 resulted in 300,000 victims (Gore 2000).

However, not all earthquakes yield such dreadful disasters. In fact, the current developments in engineering have significantly decreased the number of fatalities. Research has been focused on strengthening the structures for the load case earthquake in California for at least 50 years. Many risk analysis studies on earthquakes have been conducted, for example Lomnitz & Rosenblueth (1976), PELEM (1989), Grünthal et al. (1998), FEMA-NIBS (1999) and Tyagunov et al. (2006). In the previous decades in the US, severe earthquakes have caused relatively low number of 130 fatalities. To achieve this result, about 25 billion dollars were spent for protection actions (Parfit 1998). The progress becomes even more visible when the damage consequences of two earthquakes are compared as
shown in Table 2-14. The topography of the hit regions in Armenia as well as California is comparable: the ratio of lowlands to mountains, the distribution of the population, or the ratio of new civil structures to the overall number of structures (Bachmann 1997). However, the consequences of earthquakes show great differences.

Since the damage to property for Armenia was unknown, two further examples of damage should be given for developed countries. In 1994, the Northridge earthquake in California caused an estimated damage of 44 billion US dollars. Even more damaging was the Kobe earthquake in 1995, with about 6,300 fatalities and an economic loss of 100 billion US dollars (Mechler 2003).

Table 2-14. Casualty and damages from two earthquakes (Bachmann 1997, Newson 2001)

|                        | Spitak earthquake | Loma-Prieta earthquake |
|------------------------|-------------------|------------------------|
| Date                   | 7 December 1988   | 17 October 1989        |
| Magnitude              | 6.9               | 7.1                    |
| Region                 | Armenia           | Northern California    |
| Fatalities             | >25,000           | 67                     |
| Injured                | 31,000            | 2,435                  |
| Homeless               | 514,000           | 7,362                  |
| Damage of property     | Unknown           | ~7.8 billion US dollars |

2.3.4 Climatic Risks

2.3.4.1 Climate Change

In general, geological changes do not only threaten on a short-term scale, like earthquakes, but also over the long-term as they may affect climate and create changes to the weather. It is now very well known that the climate on earth has changed permanently. For example, 65 million years ago, the average climate on earth was much warmer than today, and within 55 million years, a maximum average temperature value was reached. Figure 2-12 shows the development of average earth surface temperature with a logarithmic time scale over 65 million years. At the peak value, the polar ice was completely molten and tropical forests reached up to the Arctic region (NGS 1998a,b). The ancestors of crocodiles lived up to Greenland, and the ground temperature of the oceans, which is now about 4°C, reached 17°C. The temperature gradient between equator and polar regions was nearly neglectable. Of course, geographic land distribution has heavily influenced such climatic conditions. Approximately 60 million years ago, Australia and Antarctica got separated. This created a new ocean, which
cooled Antarctica. At the same time, Africa bounded into Europe and India bounded into Asia. In these regions, new mountains were created, which changed the climate conditions, for example lowering the average sea-level and increasing the size of land. Since land has lower heat-storage capabilities, this could therefore have contributed to a drop in temperature. Additionally, it is assumed that the formation of coal and oil might have deprived the atmosphere of global warming gases. Therefore, from about 55 to 35 million years ago, earth climate experienced a cooling phase yielding polar ice caps. Following this, a warming phase occurred in the next 14 million years, and then a cooling phase started again a few thousand years ago. The polar ice caps reached three times a size than nowadays.

Based on the measurement of tree rings, coral reefs, ice drillings or other sources of historical information, one can well estimate the climate changes on earth over the last 20,000 years (Wilson et al. 1999). Compared to such climatic changes, the fluctuations are rather low. However, fluctuations do occur, as one may make out from the size of glaciers, for example. Figures 2-13 and 2-14 show the Aletsch glacier in Switzerland. This glacier has lost about 100 m of its in height at the Konkordia place over the last 100 years. Moreover, the overall ice volume on earth has decreased by about 10% since 1960.

The development of the average temperature in the northern hemisphere over the last 2,000 years is shown in Fig. 2-15. However, this curve has been heavily debated by the scientific community due to uncertain data. Therefore, the figure includes not only the average data but also the confidence interval (grey area). The figure shows the well-known warm temperatures over the medieval times as well as the small ice age. During the warm time, settlements from the Vikings existed in Greenland, which had to be abandoned during the ice age later (NGS 1998a,b, Baladin 1988).

However, Fig. 2-15 also shows the increase of average temperatures over the last 50 years. Based on these data, such a rapid change has never been observed before. The 1990s were probably the warmest decade over the last 1,000 years. The average surface temperature of the earth has increased over the last century by approximately $0.6\degree C \pm 0.2\degree C$ (IPCC 2001).

Considering the temperatures based on seasonal data for Europe, values might be even more alarming. The summer of the year 2003 was about 2\degree higher than average. This was probably the hottest summer in the last 500 years, followed by the summer of 1747. However, since 1750, there were rather warm summers, whereas the 20th century started rather cool. From 1923 to 1947, a first warming period occurred, which was followed by a cooling period until 1977. Since then, an increase of the average temperature has been observed. (NZZ 2004a,b).
Fig. 2-12. Development of mean earth surface temperatures according to NGS (1998a,b)
Fig. 2-13. The Aletsch glacier from the Konkordia place. The Aletsch glacier is the longest in the Alps

Fig. 2-14. The Konkordia lodge at Grünegg firn. Here, the Altesch glacier lost about 100 m thickness from 1877
For the winter, an increase of the average temperatures in Europe has been identified. The period from 1973 to 2002 has been considered the warmest over the last 500 years. The increase of the winter temperatures is especially interesting for risk considerations, since the loss of temperature yields to less snow and less long-term high-pressure areas in Central Europe. These high-pressure areas originally anticipated the movement of stormy low-pressure regions from the Atlantic to Central Europe. Besides, the coldest winter in Europe, based on some measurement occurred in 1708/1709.

However, not only the measurement of temperature but also the observations of other climatic effects, such as the appearance of storm or the appearance of El Nino, seem to indicate a temperature increase. Nevertheless,
the proof that a systematic climate change is currently under way is difficult to obtain. The climate system of the earth is extremely complex and related to many other systems, such as social systems, astronomical systems, maritime systems and so on. Mankind is currently influencing the climate system by the massive burning of fossil fuels.

If the trend continues as shown in Fig. 2-16 (left), then temperature increase will not only directly influence living conditions and agriculture, but also that the sea level will rise. The consequences of a sea level rise of about 0.5 m is shown in Table 2-15. About 1/5th of the world’s population lives within a distance of 30 km from the sea, and the majority of Mega cities are coastal cities or are located closest to the sea (Geipel 2001).

Table 2-15. Estimated loss of area caused by an increase of sea level of 0.5 m for North America and Japan, 0.6 m for Indonesia and 1 m for all other countries according to Abramovitz (2001)

|                | Loss of area | Affected population |
|----------------|--------------|---------------------|
|                | km²          | %                   |
|                | Million      | %                   |
| Egypt          | 2,000        | < 1                 | 8       | 11.7    |
| Senegal        | 6,000        | 3.1                 | 0.2     | 2.3     |
| Nigeria        | 600          | < 1                 | > 3.7   | 3       |
| Tanzania       | 2,117        | < 1                 | –       | –       |
| Belize         | 1,900        | 8.4                 | 0.07    | 35      |
| Guyana         | –            | –                   | 0.6     | 80      |
| Venezuela      | 5,700        | 0.6                 | 0.06    | < 1     |
| North America  | 19,000       | < 1                 | –       | –       |
| Bangladesh     | 29,846       | 20.7                | 14.8    | 13.5    |
| India          | 5,763        | 0.4                 | 7.1     | 0.8     |
| Indonesia      | 34,000       | 1.9                 | 2.0     | 1.1     |
| Japan          | 1,412        | 0.4                 | 2.9     | 2.3     |
| Malaysia       | 7,000        | 2.1                 | > 0.05  | > 0.3   |
| Vietnam        | 40,000       | 12.1                | 17.1    | 23.1    |
| Netherlands    | 2,165        | 6.7                 | 10      | 67      |
| Germany        | –            | –                   | 3.1     | 4       |

Climate change might not only cause flood risks or storm risks; it might also yield to additional gravitational risks. For example, when the temperature of permafrost ground increases, it might lose strength yielding to failure. Historical data of mass movement events in the Alps show a peak at the end of the 19th century, which is related to the end of the small ice age (Totschnig & Hübl 2008). The failures of permafrost might also cause glacier lake dam failure yielding to floods (Kääb et al. 2006).
2.3.4.2 Temperature Extremes – Heat and Cold

Of course, direct temperature changes also affect people. In August 2003, not only France but also many European countries were hit by a heat wave. From the 4th to 12th of August 2003 in Paris, all measured temperature values (minimum, highest and average values) were higher than ever recorded since 1873. The heat wave in connection with high air pollution resulted in an increase in mortality. Already on the 4th of August, about 300 people died, which was more than statistically expected. On the 12th of August, 2,200 more people died. Over the entire period, about 14,802 people died—a number much greater than the statistical average. Mainly the elderly, 75 years of age and greater, contributed to the mortality rate (70%). The highest incidence in the rate of mortalities was found in nursing homes. Also, people between the age of 45 and 75 were hit with higher mortality rates (30%) (VMKUG 2004).

Additionally, the mortality increase was regionally dependent. While in some rural areas only a slight increase was found, in Paris and in the suburbs, a dramatic increase (more than 130%) was observed. Other countries were also affected, such as Italy and Portugal (VMKUG 2004). Figure 2-17 shows a relation between mortality and maximum daily air temperatures. It is clear that high temperatures increase the mortality rate. However, these consequences do not consider a shortage of water supply.

![Fig. 2-17. Relation between daily mortality and maximum daily temperatures in a city (Munich Re 2003)](image-url)
2.3.4.3 Drought and Forest Fire

High temperatures can cause shortage of water with dramatic consequences, including droughts. Since droughts are chronic conditions in many countries or regions, they are often not considered as natural disasters or risks. However, within this book, they are assumed as a special climatic condition and, therefore, classified as a natural risk. For example, in some parts of Africa, droughts happen regularly within a cycle of several years. Drought contributes 98% to the fatality distribution by disaster origin in Ethiopia (Tadele 2005). Table 2-16 lists heavy droughts in combination with famines.

There is a general discrepancy between the amount of water flowing into the region and the amount of water flowing out. If more water flows out, then the region is arid. Approximately 40% of the human population lives in areas with water shortages. It has been estimated that, by the year 2025, only half the amount of drinking water will be available per capita worldwide (Fig. 2-18). This will create major problems for millions of people living in arid regions. Nevertheless, if a region is arid, there are still some techniques to provide a sufficient amount of water to the public. For example, in the Middle East, water desalination devices are used, and closed water circuits is another technique. Quite often, however, safety measures against droughts are either not carried out or are carried out insufficiently.

Famines might be caused not only by droughts but also by combinations of droughts and heavy fires destroying agricultural lands or forests. The heavy forest fires in October/November 2003 and 2007 in California are a good example of this. In 2003, about 20 people were killed by the fire and 2,200 houses destroyed, although 13,000 fire fighters tried to extinguish the fire. The financial damages were enormous. Damage information is also available for the Oakland Hill fire storm in October 1991. It resulted in insurance claims totaling approximately 2.3 billion US dollars. Two fires in 1993 caused a loss of about 1 billion dollars. Further examples are a fire in Arizona (Rodea-Chediski) with a loss of 125 million dollars and in New Mexico (Cerro Grande) for about 150 million dollars (Munich Re 2004b).

Forest fires are no more a local problem but a worldwide problem. For example, the forest fires in Indonesia in the first decade of the 21st century became known worldwide due to its resulting pollution in the air. In December 2001 in Sydney, the so-called black Christmas fire occurred with more than 15,000 fire fighters in action. The name black Christmas came into use since Sydney was covered by thick smoke clouds from that fire. Other big historical fires connected to droughts in Australia were the Tasmanian fire in 1967 and the Victorian fire in 1939 (Fig. 2-19). Data about forest and wildland fires in Europe can be found in Plate (2003).
Even though droughts provide the required conditions for massive fires, quite often arson can be the cause (McAneney 2005). Drought is, in many cases, related to anthropogenic hazards like civil conflicts, which then trigger the famines (Tadele 2005).

**Table 2-16. Heavy droughts with famine (NN 2004)**

| Year       | Location          | Consequences                                                                 |
|------------|-------------------|------------------------------------------------------------------------------|
| 1064–1072  | Cairo, Egypt      | Non-appearance of Nile floods causing famine where probably 4,000 people starved to death |
| 1069       | Durham, England   | Probably 50,000 people starved to death                                        |
| 1199–1202  | Cairo, Egypt      | Non-appearance of Nile floods causing famine where probably 100,000 people starved to death |
| 1669–70    | Surat, India      | Probably three million people starved to death                                |
| 1769–70    | Delhi, India      | 18 months of drought, an estimated three million people starved to death       |
| 1790–91    | Bombay, India     | Famine in India, probably several thousand people starved to death, cannibalism occurred |
| 1833       | Guntur, India     | Drought and famine with about 20,000 victims                                  |
| 1866       | Raipur, India     | Drought in Bengal, Orissa and Bihar, probably 1.5 million people starved to death or have died by diseases |
| 1868       | Bhopal, India     | Supposedly the most severe famine with about three million people starving to death and another three million dying from cholera |
| 1876–77    | Madras, India     | Drought over several years caused famine in northern and middle China with about 1.3 million victims |
| 1877–78    | Tschangtschun, Manchuria, China | Drought over several years caused famine in northern and middle China with about 1.3 million victims |
| 1898       | Punjab, India     | Prolonged drought causes famine, several million people affected              |
| 1921–22    | Nischni Nowgorod, Wolga region, Russia | Prolonged drought causes famine, several million people affected |
| 1932–33    | Kiev, Russia-Ukraine | Economic rearrangement and drought yielded to famine, several million people were affected |
| 1932–1940  | Dodge City, Kansas, USA | Drought in middle west of the USA, 350,000 people left the region |
| 1962       | Parana, Brazil    | Drought for several months yielded to severe fires in the coffee production regions |
| 1967–1970  | Biafra            | Drought and war yielded to famine, about eight million people affected       |
| 1969–1974  | Gao Mali, Sahel zone, Africa | Drought and political difficulties yielded to famine and disease |
| 1972       | Nagpur, India     | Heat wave of more than 40°C for several months, heavy damage to agriculture |
| 1984–1985  | Mekele, Ethiopia  | Prolonged drought and war yielded to famine in several African countries. Ethiopia was the most severely hit |

(Continued)
Table 2-16. (Continued)

| Year | Location                   | Consequences                                      |
|------|----------------------------|---------------------------------------------------|
| 1992 | Bulawayo, Zimbabwe         | Drought and famine hit 30 million people           |
| 1994 | Grafton, New South Wales,  | 90% of the wheat harvest was lost due to drought  |
|      | Australia                  |                                                   |

Fig. 2-18. Prognosed regions of water deficiency in 2025 (Geipel 2001)

Fig. 2-19. Major forest fires in Australia based on the number of houses destroyed according to McAneney (2005)
2.3.4.4 Famine

Famines are temporally limited situations where there is perceptible lack of food for major parts of the population. Famines have occurred recently in Zimbabwe and North Korea. The chronic lack of food for single social layers is not understood as famine. Nevertheless, the latter can be found worldwide in many regions (Figs. 2-20 and Fig. 2-21). For example in Brazil, it has been estimated that about 1/4th of the population is unable to obtain a sufficient amount of food (NZZ 2004). In Ghana, for example, 1/3rd of the population is considered malnourished (Jelenik 2004). The Food and Agriculture Organization of the United Nations estimated the number of malnourished people to be approximately 840 million. Many of them are children. Undernourishment in the year 2000 caused about 3.7 million deaths worldwide. In Africa, 50% of the deaths of children of age less than 5 are related to malnutrition. It has been estimated that undernourishment is responsible for about 10% of the global burden of disease (FAO 2003).

Fig. 2-20. Geographical distribution of undernourished people worldwide according to FAO (2003)
The nutritional conditions are identified based on different anthropometrical parameters adjusted to the type of undernourishment. Acute undernourishment, also called wasting, is mainly identified by a ratio of weight to height measurements. Here, values less than 70% or an age-dependent diameter of the upper arm indicate undernourishment. To determine chronic undernourishment, a ratio of height to age is mainly used. Again, diameter of the arm can be used for identification. Last but not least, pathogenic signs such as edemas or starvation dystrophy can be used to identify undernourishment. Such edemas occur on the arms, legs and in the face. The skin becomes fragile and hairs can be pulled out without pain. With a heavy loss of fatty tissue and muscular tissue, the ribs, spine and scapula become visible. Generally, severely malnourished children get the expression of old people. Another epidemiological measure for undernourishment is the amount of energy provided. In general, an energy amount between 2,000 and 2,600 kcal is required per capita per day.

There are records of famines in Switzerland in 1438, 1530, 1571–1574, 1635–1636, 1690–1694, 1770–1771 and 1816–1817 (Mattmüller 1987, Kurmann 2004). Famines probably occurred more frequently than the records can show (Abel 1974, Labrousse 1944). This is because records for many regions became only available since medieval times, and many famines were probably limited in spatial terms. Famines were considered one of the major threats to societies before industrialisation. Nevertheless, famines occurred even at the end of the 19th and at the beginning of the 20th
2.3 Natural Risks

century. One very well-known famine was the Irish potato famine. Probably more than one million people died and several hundred thousand people emigrated.

The question of whether famines are a natural or a social risk remains. Historically, usually a crop failure or harvest failure triggered a famine. But, this does not have to necessarily yield to a famine. Mostly after such harvest failures, the heavy prices for food can cause an economic crisis. Therefore, economic reactions to harvest failures heavily influence the development of famines. This fact becomes visible now with better means of transportation. With the increase in shipping especially around the end of the medieval times, the number of famines dropped since ships were used excessively to bring food, which positively acted in the market, at least in coastal regions.

Examples of famine as a social risk were the famines in Switzerland in 1770–1771 (Mattmüller 1982) and 1816–1817. Here, an economic crisis occurred in the textile industry. The unemployed people were unable to pay for the rising prices of food, and therefore a famine resulted for most of the unemployed. This fact is also valid for some African countries, where the per capita food production would be just sufficient to avoid undernourishment, but the portion of malnourished children remains constant. A good indicator here is the percentage of income spend on food (Ziervogel 2005).

Generally, not only reducing undernourishment but also increasing the safety of food is a major goal. This means that people have access to sufficient, harmless and nutritious food, which fulfills the psychological requirements and permits an active and healthy life. Undernourishment does not necessarily mean a lack of food – diseases might also be a cause. The general term for undernourishment is negative energy balance in the human body. The minimum energy required by a human is composed of energy necessary to maintain the body temperature, permit active work and fight diseases.

2.3.5 Aeolian Risks

After discussing some climatic risks and their consequences to humans in terms of famines, further climatic risks like aeolian and hyraulic risks are introduced here.

Winds are moving air masses in relation to the earth surface (Bachmann 2003, Hößner et al. 2005). They are powered by the energy supply from the sun. Storms can be considered a type of severe wind condition found in all continents (Munich Re 2005a). Storms are classified into barocline, tropical and convective storms. Additionally, storms of the same type
might have different names in different parts of the world: hurricanes, typhoons and cyclones are all tropical cyclones (DKKV 2002). Figure 2-22 shows the structure of a tropical cyclone.

The frequency of storms is geographically not equally distributed. Some regions have a high storm frequency as compared to others. Figure 2-23 shows the distribution of tornados worldwide. In the US, about 1,000 storms are recorded per year. In general, the number of fatalities is rather low. In 2002, storms caused 55 deaths in the US.

In general, intensive research has been carried out on the investigation of wind and its forces, as it is important for sailing and structures. Figure 2-24 shows the spectral density of wind speed indicating some micrometeorological and macrometeorological conditions.

![A model of the arial and vertical structure of a tropical cyclone taken from Smith (1996)](image)

**Fig. 2-22.** A model of the arial and vertical structure of a tropical cyclone taken from Smith (1996)
Depending on the type of storm, different storm intensity measures have been introduced. The Fujita scale describes tornado intensity by wind speeds and damages (Table 2-17). Another intensity measure is the Saffir–Simpson scale, which was developed in the 1970s (Table 2-18). This scale is used to measure hurricane intensity based on wind speeds and atmospheric pressure. Further measures are also known or under development, for example the Torro scale, the Hurricane Intensity Index or the Australian-Tropical-Cyclone-Severity Scala (Munich Re 2006b). The Beaufort scale is widely used for winds that are less intense than hurricanes (Table 2-19), and is the oldest intensity measure originating around the beginning of the 19th century.
Table 2-17. Fujita-scale (Vesilind 2004)

| Fujita-scale | Description          | Wind speed in km/h |
|--------------|----------------------|--------------------|
| F 6          | Inconceivable        | >512               |
| F 5          | Incredible           | 420–512            |
| F 4          | Devastating          | 333–419            |
| F 3          | Severe               | 254–332            |
| F 2          | Significant          | 182–253            |
| F 1          | Moderate             | 117–181            |
| F 0          | Gale tornado         | 64–116             |

Table 2-18. Saffir–Simpson scale (Kantha 2006)

| Category | Maximum wind speed (m/s) | Surface pressure (mb) | Storm surge (m) |
|----------|--------------------------|-----------------------|-----------------|
| 1        | 33–42                    | >980                  | 1.0–1.7         |
| 2        | 43–49                    | 979–965               | 1.8–2.6         |
| 3        | 50–58                    | 964–945               | 2.7–3.8         |
| 4        | 59–69                    | 944–920               | 3.9–5.6         |
| 5        | 70+                      | <920                  | 5.7+            |

Table 2-19. Beaufort scale (Lieberwirth 2003)

| #  | Description       | m/s   | km/h   | Land conditions                          |
|----|-------------------|-------|--------|------------------------------------------|
| 0  | Calm              | 0–0.2 | 0      | Smoke rises vertically                   |
| 1  | Light air         | 0.3–1.5 | 1–5   | Wind motion visible in smoke             |
| 2  | Light breeze      | 1.6–3.3 | 6–11  | Wind felt on exposed skin                |
| 3  | Gentle breeze     | 3.4–5.4 | 12–19 | Leaves in constant motion                |
| 4  | Moderate breeze   | 5.5–7.9 | 20–28 | Small branches begin to move             |
| 5  | Fresh breeze      | 8.0–10.7 | 29–38 | Smaller trees sway                       |
| 6  | Strong breeze     | 10.8–13.8 | 39–49 | Umbrella use becomes difficult           |
| 7  | Moderate gale     | 13.9–17.1 | 50–61 | Effort needed to walk against the wind   |
| 8  | Fresh gale        | 17.2–20.7 | 62–74 | Twigs break from trees                   |
| 9  | Strong gale       | 20.8–24.4 | 75–88 | Light structure damage                   |
| 10 | Storm             | 24.5–28.4 | 89–102 | Considerable structural damage           |
| 11 | Violent storm     | 28.5–32.6 | 103–117 | Widespread structural damage            |
| 12 | Hurricane         | >32.7 | >118   | Considerable and widespread damage       |

Webster et al. (2005) have described the possible changes in storm intensity in a warmer climate. Already the effects of winterstorms in Europe have been discussed in Sect. 2.3.4.1 (Lieberwirth 2003, Munich Re 2006a). Even under the current climatic conditions, storms represent a major hazard. In 1970, a storm in Bangladesh together with a water storm surge killed about 300,000 people. This was probably one of the biggest natural disasters in the 20th century (O’Neill 1998). In October 1998, Hurricane Mitch reached Central America and killed 5,700 people in Honduras.
alone. More than 600,000 people were affected by the hurricane. The damages reached up to 80% of the gross domestic product. In Peru, about 300 bridges were heavily damaged (Williams 1999). Another severe storm reached southern Africa in the year 2000. In February and March, the cyclone Eline crossed Mozambique, South Africa, Botswana, Swaziland, Zimbabwe, Malawi and Zambia, causing more than 1,000 fatalities and more than 660 million US dollars in loss of property (Munich Re 2001). In 1992, Hurricane Andrew in the US caused a financial damage of 15 billion US dollars. Also, the winterstorms in Europe in 1990 costed about 15 billion US dollars (Mechler 2003).

Major hurricanes in the US in terms of fatalities occurred in Galveston with 8,000 fatalities in 1900, on the Lake Okeechobee in 1928 with 2,500 fatalities, Savannah, Georgia in 1893 with 1,500 fatalities and in Cheniere Caminada with 1,250 fatalities in 1893 (Munich Re 2006b). This numbers show the enormous damage capacity of storms. Therefore, many risk assessment studies for storms or strong winds were carried out in the last decades. Examples are works by Leicester et al. (1976), Petak & Atkisson (1992), Khanduri & Morrow (2003) and Heneka & Ruck (2004).

2.3.6 Hydraulic Risks

Besides earthquakes, floods are the biggest natural hazard in terms of fatalities. Probably the biggest natural disaster ever was the Henan Flood in China in 1887 with between 900,000 and 1.5 million victims. The biggest natural disaster in Europe was probably the “Gross Manndränke” in the year 1362. Here, between 30,000 and 100,000 victims were counted. And, the flood in summer 2002 in Central Europe was probably the costliest European natural disaster ever (Mechler 2003). First estimations ranged from 20 to 100 billion Euros (Kunz 2002). Figure 2-25 shows the Dresden railway station, Germany, during a flood in 2002. The station is usually more than 1 km from the river. About 300,000 people were affected in Germany alone. However, a flood in China in 1991 affected about 220 million people (Newson 2001).

An incomplete list of severe floods is given in Table 2-20. A cyclone in Bangladesh in 1970, which caused about 300,000 victims, was already mentioned (Mechler 2003). However, the flood in the 1950s in the Netherlands with about 2,000 fatalities should be mentioned. The flood resulted in an intensive program to avoid floods in this country where about 40% of the population live behind dams and below sea-level. An intensive study about the loss of life in floods has been carried out by Jonkman (2007).
Historical data of floods in Europe have shown that floods are correlated. In fact, so called “time clusters” could be found. There exist several theories to describe such effects, for example climate cycles or the fatigue of the water storage capability of a landscape after a flood. Therefore, the next flood can occur even with a lower water supply. An example of a cluster could be shown for the French rivers Ter, Segre and Llobregat. There are data available since the year 1300. Peaks of floods were observed between 1582 and 1632, with maximum values in 1592 and 1606. Moreover, in the period from 1768 to 1800 and between 1833 and 1868, clusters of floods could be found (Huet & Baumont 2004, Baladin 1988).

Historical data for the river Elbe are shown in Table 2-21. Figure 2-26 shows flood marks on a house in Bad Schandau, Germany. More data can be found in NaDiNe (2007). Interestingly, floods show not only a temporal correlation but also a geographic correlation, as shown in Jorigny et al. (2002).

Fig. 2-25. Dresden central railway station in summer during the 2002 flood
### Table 2-20. List of severe floods at the German North Sea coast and worldwide (NN 2004, Schröder 2004).

| Date         | Location                  | Number of victims         |
|--------------|---------------------------|---------------------------|
| 2200 B.C.    | Hyderabad, India          |                           |
| 26.12.838    | East Frisian coast        | 2,437                     |
| 1099         | Boston, England           | Thousands                 |
| 17.02.1164   | East Frisian coast        | 20,000                    |
| 16.01.1219   | Jütland, Denmark          | Thousands – 36,000        |
| 14.12.1287   | East Frisian coast        | Thousands                 |
| 1287         | Dunwich, East Anglia, England | < 500                  |
| 1332–1333    | Peking, China             | Several millions          |
| 16.01.1362   | Schleswig, Germany        | 30,000–100,000            |
| 09.10.1374   | East Frisian coast        | –                         |
| 1421         | Dort, The Netherlands     | 100,000                   |
| 26.12.1509   | East Frisian coast        | –                         |
| 31.10.1532   | East Frisian coast        |                           |
| 1.11.1570    | East Frisian coast        | < 4,000                   |
| 1606         | Gloucester, England       | > 2,000                   |
| 1634         | Cuxhaven, Germany         | > 6,000–8,000             |
| 1717         | Den Haag, Netherlands     | 11,000                    |
| 1824         | St. Petersburg, Russia    | 10,000                    |
| 3.-4.2.1825  | East Frisian coast        | 200                       |
| 1851–1866    | Shanghai, China           | Several millions          |
| 1887         | Henan, China              | 900,000–1.5 millions      |
| 1890         | New Orleans, Louisiana, USA |                       |
| 1911         | Shanghai, China           | 20,000                    |
| 1927         | Cairo, Illinois, USA      | 300                       |
| 1931         | Nanking, China            | 130,000–several millions  |
| 1935         | Jérémie, Haiti            | 2,000                     |
| 31.1-1.2.1953| Hollandflut               | 2,000                     |
| 1954         | Wuhan, China              | 40,000                    |
| 1955         | Cuttack, India            | 1,700                     |
| 16.2.1962    | East Frisian coast        | 330                       |
| 1999         | Ovesso Monsun Flood, India| 10,000                    |
| 1999         | Venezuela                 | 25,000–50,000             |
The floods mentioned so far were storm surges, sea floods caused by storm and tides, or river floods caused by the heavy release of water either through snow or ice melting or heavy rain. Both types cause the so-called “surface waves”. Another type of sea surface waves is “freak waves”. They are explained by spatial and temporal interference, and are defined as being at least three times the size of an average storm wave (Rosenthal 2004).

In contrast to such surface waves, tsunamis are deep-sea waves caused by under-sea earthquakes. They have a great wave length and wave speed, and usually are not noticeable at sea. However, at coastal regions, they can cause great damages as the event in December 2004. In fact, it was not the first tsunami wave to cause severe damages (Table 2-22). Many tsunami events were known in the Pacific region, for example in Hawaii (1960 and 1974) or in Papua New Guinea (PTM 2004, Synolakis et al. 2002, Synolakis 2007, Yeh et al. 1995). Tsunamis are also common in Norway. For example, events that occurred in 1905, 1934 and 1936 killed about 174 people. It was assumed that in Holocene times, slides at the Norwegian Continental Slope caused huge tsunamis in the North Sea regions (NGI 2007).

### Table 2-21. Historical maximum water levels of the river Elbe at Dresden (Fischer 2003)

| #  | Date               | Water level (m) | Volume m$^3$/s |
|----|--------------------|-----------------|----------------|
| 1  | 17 August 2002     | 9.40            | 4,700          |
| 2  | 31 March 1845      | 8.77            | 5,700          |
| 3  | 1 March 1784       | 8.57            | 5,200          |
| 4  | 16 August 1501     | 8.57            | 5,000          |
| 5  | 7 February 1862    | 8.24            | 4,493          |
| 6  | 3 February 1830    | 7.96            | 3,950          |
| 7  | 24 February 1799   | 8.24            | 4,400          |
| 8  | 17 March 1940      | 7.78            | 3,360          |
| 10 | 20 February 1876   | 7.76            | 3,286          |

$^1$Further major floods occurred in 1015, 1318 and 1432, however detailed information about the water level and volume is missing.
Fig. 2-26. Flooding marks on a house in Bad Schandau, Germany
Table 2-22. Major tsunamis (Munich Re 2004a, Smolka & Spranger 2005, Schenk et al. 2005)

| Date          | Magnitude | Region                              | Fatalities |
|---------------|-----------|-------------------------------------|------------|
| 26.12.2004    | 9.0       | Indonesia, Sri Lanka, India, Thailand | >223,000   |
| 1883          |           | Krakatau, Indonesia                 | 36,400     |
| 1.11.1755     |           | Portugal, Marocco                   | >30,000    |
| 15.6.1896     |           | Japan, Sanriku                      | 27,000     |
| 1815          |           | Indonesia                           | >10,000    |
| 17.8.1976     | 8.0       | Philippines                         | 4,000      |
| 2.3.1933      | 8.3       | Japan, Sanriku                      | 3,060      |
| 21.5.1960     | 9.5       | Chile, Hawaii, Japan                | 3,000      |
| 28.3.1964     |           | USA, Alaska, Hawaii, Japan, Chile    | 3,000      |
| 12.12.1992    | 7.5       | Indonesia, Flores                   | 2,500      |
| 17.7.1998     | 7.1       | Papua New Guinea                    | 2,400      |
| 20.12.1946    | 8.1       | Japan, Nankaido                     | 2,000      |
| 5.11.1952     |           | Russia, Paramushir Island           | 1,300      |
| 7.12.1944     | 8.0       | Japan, Honshu                       | 1,000      |
| 31.1.1906     | 8.2       | Ecuador, Colombia                   | 500        |

2.3.7 Gravitational Risks

2.3.7.1 Introduction

The Alpine regions are heavily exposed not only to climatic hazards but also to gravitational risks. Such risks consider mass movements driven by gravitation. Examples are landslides, debris flow, torrents and avalanches. Figure 2-27 shows a system of such different processes depending on the amount of water and the distribution of solid materials. Table 2-23 gives time estimation of the processes and the warning time.

Table 2-23. Types of processes and their properties (Holub 2007)

| Process                  | Speed      | Warning time       |
|--------------------------|------------|--------------------|
| Flood                    | 20 km/h    | Minutes to hours   |
| Debris flow              | 40 km/h    | Minutes            |
| Spontaneous slope failure| 4 km/h     | Seconds to minutes |
| Permanent slope failure  | 0.0001–1 m/year | Months to years |
| Rock fall                | 110–140 km/h | Seconds         |
| Flowing avalanche        | 40–140 km/h | Seconds to minutes |
| Powder avalanche         | 110–250 km/h | Seconds         |
2.3 Natural Risks

### 2.3.7.2 Rock Fall

A rock fall is a fast downward movement of rocks or an unconstrained coarse material reaching a certain total volume and where partial loss of ground occurs. When the contact between the falling rocks remains, it is called a rock slump or a rock slide (Fig. 2-28). Additionally, it is important to note that the water content is negligible. The negligible water content yields to a lower travelling distance as compared to debris flow (Abele 1974, Selby 1993).

In the German language, in particular, a variety of terms are used in dealing with the processes of rock falls. The different terms are separated according to the volume, the block size, the area covered or the released energy. The classification of rock falls is shown in Table 2-24 (Poisel 1997, Abele 1974).

**Table 2-24. Classification of rock falls according to Poisel (1997)**

|                     | Volume (m$^3$) | Block size | Area covered (ha) |
|---------------------|---------------|------------|-------------------|
| Pebble and block fall (Steinschlag) | 0.01          | 20 cm      | < 10              |
| Rock fall           | 0.1           | 50 cm      | < 10              |
| Block fall          | 2             | 150 cm     | < 10              |
| Cliff fall (Felssturz) | 10,000       | 25 m       | < 10              |
| Rock slide (Bersturz) | > 10,000     |            | > 10              |
There are many causes for rock falls, including postglacial load removal, mechanical stress changes caused by disturbances, stress changes caused by sliding, temperature changes, earthquakes, hydrostatic or hydrodynamic pressures, load by trees, ice loads or anthropogenic changes. If the rock elements have started to move, there are different kinds of movements. Usually the rock fall starts with sliding, free-fall, bouncing and rolling. The difference between bouncing and rolling is that bouncing constitutes one full rotation of a stone block without ground contact. The first ground contact after free fall is very important, because during that contact up to 85% of the kinetic energy can be assimilated by the ground. Of course, this depends very much on the type of ground, for example rock or scree.

Some computer programs were developed in the last decades to model rock falls, such as “Rockfall”, “CRSP” or “Stone”. Using these programs, the kinetic energy of a rock at a certain location can be determined and mitigation measures can be designed. Active mitigation measures might be fences, nets, walls, dams, galleries and also forests. Such active measures can be used for rock falls, but not for heavy rock slides. For severe rock slides, passive mitigation measures, for example regulating the use of areas, have to be implemented.

Some major historical rock avalanches occurred in 6000 B.C. at Köfelsberg, in 1248 at Mont Granier causing 2,000 fatalities, in 1348 in Dobratsch, caused by an earthquake, killing 7,000 people and in 1618 at Piuro, caused by illegal quarrying, killing 2,500 people (Erismann & Abele 2001).

2.3.7.3 Debris Flow

Debris flows are extremely mobile, highly concentrated mixtures of poorly sorted sediments in water (Pierson 1986). The materials incorporated in debris flows vary from clay-sized solids to boulders of several meters in diameter (Fig. 2-29). Debris flows can exceed the density of water by more
than a factor of two. The front of a debris flow can reach velocities up to 30 m/s (e.g. Costa 1984, Rickenmann 1999), and peak discharges can be tens of times greater than for floods occurring in the same catchment (e.g. Pierson 1986, Hungr et al. 2001). It is difficult to quantify annual economic losses due to such phenomenon; however, in the year 2005, more than 80 million Euros were spent in Austria for protection measures against torrential hazards (including floods, bed load transport and debris flow) (WLV 2006).

In debris flow research, the flowing mixture is mostly divided into the liquid “matrix”, composed of water and fine sediment in suspension, and the solid phase, consisting of coarse particles dispersed in the fluid. Depending on the relative concentration of fine and coarse sediments, the prefix “viscous” or “granular” is often used. Since the early 1970s, research increasingly focussed on the topic of debris flow behaviour (Johnson 1970, Costa 1984). Mud flows and debris flows consisting of a considerable amount of fine sediments are often regarded as homogeneous fluids, where the bulk flow behaviour is controlled by the “rheologic” properties of the material mixture (e.g. Julien & O’Brien 1997, Coussot et al. 1998, Cui et al. 2005). For debris flows mainly consisting of coarse particles and water, this simple rheological approach has limitations. In the last decades, geotechnical models have been employed to describe the motion of (granular) debris flows (e.g. Savage & Hutter 1989, Iverson 1997, Iverson & Denlinger 2001).

![Debris flow surge](Image)

**Fig. 2-29.** Debris flow surge (Pierson 1986)

The behaviour of debris flows can be very variable, strongly depending on sediment composition and water content. Moreover, debris flow volume and bulk flow behaviour may change during travelling through a channel,
for example by the entrainment of loose sediment and/or incorporation of water from a tributary. For this reason until now, no general applicable model used in praxis was able to cover the range of all possible material mixtures and event scenarios.

There were some rules of thumb developed to estimate return periods as well as intensities, including volumes and duration (Figs. 2-30 and 2-31). Table 2-25 shows some examples of extreme volumes. Due to their high density and fast movement, debris flows can jeopardize humans and residential areas. Table 2-26 mentions some calamities caused by debris flows.

Fig. 2-30. Different types of erosion scars (Weber 1964)

Fig. 2-31. Types of debris flow depending on the erosion scar (Hübl 2006)
### Table 2-25. List of major debris flows, rock avalanches or landslides (Bolt et al. 1975)

| Location                              | Time                        | Volume in billion cubic metres | Comments                      |
|---------------------------------------|-----------------------------|--------------------------------|-------------------------------|
| Blackhawk Landslide, Mojave Desert    | Several thousand years ago | 320                            | 8 km length                   |
| Vajont Dam, Italy                     | 1963                        | 250                            |                               |
| Axmouth, Devon, England               | 1839                        | 40                             | No fatalities                 |
| Madison Canyon, Montana               | 1959                        | 27                             | 26 fatalities                 |
| Sherman Glacier Slide, Alaska         | 1964                        | 23                             | Air-crushing mechanism        |
| Iran, Saidmarreh                       | Prehistoric times           | 20                             |                               |
| Flims, Switzerland                    | Prehistoric times           | 15                             |                               |
| Rossberg or Goldau, Switzerland       | 1806                        | 14                             | 457 fatalities, 4 villages    |
| Tsiolkovsky crater, Moon              |                             | 3                              | 100 km length (based on the lower mass, the volume of the moon was decreased by a factor of 216) |
| Usoy, Pamir, USSR                     | 1911                        | 2.5                            | 54 fatalities                 |

### Table 2-26. Historical debris flow events with fatalities (Kolymbas 2001, Stone 2007, Pudasaini & Hutter 2007)

| Year | Place                      | Fatalities  |
|------|----------------------------|-------------|
| 1596 | Schwaz, Austria            | 140         |
| 1596 | Hofgastein, Austria        | 147         |
| 1669 | Salzburg, Austria          | 250         |
| 1808 | Rossberg/Goldau, Switzerland| 450        |
| 1881 | Elm, Switzerland           | 115         |
| 1893 | Verdalen, Norway           | 112         |
| 1916 | Italy/Austria              | 10,000      |
| 1920 | Kansu Province, China      | 100,000–200,000 |
| 1949 | USSR                       | 20,000      |
| 1962 | Huascaran, Peru            | 5,000       |
| 1963 | Vajont-Reservoir, Italy    | 2,043       |
| 1996 | Aberfan, South Wales       | 144         |
| 1970 | Huascaran, Peru            | 18,000      |
| 1974 | Mayunmarca, Peru           | 451         |
| 1985 | Stava, Italy               | 269         |
| 1985 | Nevado del Ruiz, Peru      | 31,000      |
| 1987 | Val Pola, Italy            | 30          |
| 2006 | Leyte, Philippines         | 1,400       |
In view of the severe damage capabilities of debris flows, there have been some mitigation measures introduced. For example, torrential barriers have been employed in the former Austrian empire since the middle of the 19th century. Figure 2-32 shows a possible classification of such torrential barriers, and Figs. 2-33 and 2-34 show two examples.

![Types of torrential barriers](image1)

**Fig. 2-32.** Types of torrential barriers (Bergmeister et al. 2007)

![Example of the Christmas tree barrier](image2)

**Fig. 2-33.** Example of the Christmas tree barrier
2.3 Natural Risks

2.3.7.4 Landslides

Landslides belong, like rock falls or avalanches, to the group of gravitation-initiated hazards. In contrast to debris flow, landslides are non-channel processes. Landslides of slopes and hillsides are mass movements by sliding or flowing under wet conditions. The soil is usually fine-grained and is able to absorb water. The mass moves or flows on a slide face. Very often the process changes over time. For example, a mass movement might start as a landslide, but then trigger a debris flow. A torrent might initiate a debris flow. There were many different attempts to define landslides or debris flows (Table 2-27). However, as explained in the first chapter, it seems to be questionable to reach an ultimate state of such definitions (DIN 19663, DKKV 2002, Crozier 1998, Cruden & Varnes 1996).
Another landslide in combination with debris flow and volcanic eruption occurred at the Colombian volcano Nevado del Ruiz Armero on 13th November 1985. The event killed about 30,000 people (Newson 2001). However, several smaller tragedies have been caused by landslides as well. For example in Sweden, many smaller landslides have happened in the last centuries (Table 2-28). In Table 2-28, an event on 1st October 1918 is mentioned, which shows only a small volume of moved area (0.2 ha), but the number of victims is rather high. In this case, a train crashed into the moving slope and started to burn (Alén et al. 1999, Fréden 1994, SGU 2004).

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### Table 2-27. Types of landslides (Cruden & Varnes 1996, Bell 2007)

| Velocity class | Description | Velocity (mm/sec) | Typical velocity | Damage |
|----------------|-------------|-------------------|------------------|--------|
| 7              | Extremely fast | $5 \times 10^3$ | 5 m per sec | Disaster, many fatalities |
| 6              | Very fast    | $5 \times 10^1$ | 3 m per min | Some fatalities |
| 5              | Fast         | $5 \times 10^{-1}$ | 1.8 m per hour | Evacuation possible |
| 4              | Moderate fast | $5 \times 10^{-3}$ | 13 m per month | Impassible structures resist |
| 3              | Slow         | $5 \times 10^{-5}$ | 1.6 m per year | Mitigation measures |
| 2              | Very slow    | $5 \times 10^{-7}$ | 16 mm per year | Some structures can resist |
| 1              | Extremely slow | $5 \times 10^{-7}$ | Movement not perceptible |

In contrast to avalanches or rock falls, landslides, also sometimes in combination with other processes like rock avalanches, have caused some major accidents with enormous numbers of fatalities. For example, in December 1999, a terrific landslide killed about 30,000 people in Venezuela. The landslide occurred after two weeks of permanent rain. The water volume corresponded with the two years, average rain volume of this region (Abramovitz 2001).

### Table 2-28. Examples of historical landslides in Sweden (Alén et al. 1999, Fréden 1994, SGU 2004)

| Year | Location                | Size (ha) | Number of fatalities |
|------|-------------------------|-----------|----------------------|
| 1150 | Bohus, River Göta älv  | 37        |                      |
| 1648 | Intagan, River Göta älv | 27        | $> 85$               |
| 1730 | Gunnilse, River Lärjeån| 30        |                      |
| 1759 | Bondeström, River Göta älv   | 11        |                      |
| 1918 | Getå, Bråviken Bay       | 0.2       | 41                   |
| 1950 | Surte, River Göta älv    | 22        | 1                    |
| 1957 | Göta, River Göta älv    | 15        | 3                    |
| 1977 | Tuve, Hisingen Island, Göteborg | 27 | 9 |
Landslides occur in many countries. For example, landslides killed 73 people in Australia from 1842 to 1997 (QG 2004). In the USA, landslides cause an average yearly damage between 1.2 to 1.5 billion US dollars (1985) (Fernández-Steeger 2002). Damages and numbers of fatalities for Hong Kong are given by Shiu & Cheung (2003). In recent years, severe accidents have happened, for example, in Philippines due to landslides, killing up to 200 people.

Risk evaluation of landslides has found wide application, and might be further applied to avoid severe events in the future (Fell & Hartford 1997, Shiu & Cheung 2003). This is especially of importance since many victims could easily have been saved by sufficient land-use planning. More sophisticated are the methods where the indirect consequences of landslides, for example tsunamis, are considered (Minoura et al. 2005).

### 2.3.7.5 Avalanches

Avalanches are moving masses of snow. The movement depends on the type of the avalanche (Fig. 2-35). Flowing avalanches are sliding or flowing, whereas in powder avalanches, the material is suspended (flying). Usually a flowing avalanche starts by breaking and releasing snow slabs. These snow slabs accelerate by sliding. When the slabs break into pieces through tumbling and bounding, the movement of snow becomes a flow. The density of flowing avalanches is comparable with the density of normal snow (Table 2-29). The flowing avalanches might slide either on the ground itself or on another layer of snow. These are called ground avalanches or upper (top) avalanches. Additionally, ground avalanches might consist of non-snow materials. In contrast, powder avalanches have a density much lower than snow. However, they either develop from a flowing avalanche or, in most cases, are combined with flowing avalanches. Pure powder avalanches exist only if, through certain conditions, the powder avalanche part separates from the flowing avalanche part. The speed of a powder avalanche reaches up to 90 m/s, whereas flowing avalanches might reach a velocity of up to 40 m/s. Worldwide about $10 \times 10^5$ avalanches fall per year (Egli 2005, Mears 2006, Pudasaini & Hutter 2007). The impact

| Avalanche type        | Flow density (kg/m³) | Concentration of solid material (%) | Typical deposit density (kg/m³) |
|-----------------------|----------------------|------------------------------------|---------------------------------|
| Powder avalanche       | 1–10                 | 0–1                                | 100–200                         |
| Wet avalanche          | 150–200              | 30–50                              | 500–1,000                       |
| Dry snow avalanche     | 100–150              | 30–50                              | 200–500                         |
of the avalanches depends not only on the type of the avalanche, but also of the size. The Canadian Avalanche Size Classification is one example to describe the size (McClung & Schaerer 1993). Currently intensive research work is carried out to develop models for avalanche impact forces (Gauer et al. 2008, Sovilla et al. 2008). For such investigations real size avalanche test sites are used, where impact forces are measured (Issler et al. 1998).

The origin of the word avalanche is still under discussion. Some researchers suggest that it came into use after a Spanish bishop, Isidorus, in the 6th century who mentioned of avalanches. He used the terms “lavina” and “labina”. Therefore, the origin seems to be the Latin word “labi”, which means sliding, slither or drift. There exist some dialects with “lavina” or “lavigna”. Other theories consider the German word “lawen” as the origin. This word describes thaw, and might have been applied to moving snow masses caused by thaw (Schild 1982).

Roman writers were the first to mention avalanches. Livius noted the human loss caused by avalanches when Hannibal crossed the Alps in 218 B.C. After the fall of the Roman Empire, there were rare documentations about avalanches, for example the mentioned work by Isidorus. From the beginning of the 12th century, the number of avalanche documentations increased (Schild 1982).

The first known reports on avalanches were from Iceland in 1118 (Pudasaini & Hutter 2007) and from the European Alpine region in 1128 and earlier (Ammann et al. 1997). Totschnig & Hübl (2008) have collected data about more than 13,000 events of natural hazards for Austria, many of them avalanches. The data start with the year 325 and runs until 2005. Table 2-30 lists reports of damages by avalanches for Switzerland for a period of 500 years (Fig. 2-36).

The worst years in Norwegian avalanche history were 1679 when up to 600 people were killed, and 1755 when approximately 200 people were killed. Even in countries like Turkey avalanches can cause high number of fatalities like in 1992 with more than 200 victims (Newson 2001). However, the highest number of fatalities caused by avalanches happened in the wars. Fraser (1966, 1978) has estimated that avalanches killed about 40,000–80,000 soldiers during the times of the World Wars as avalanches were used as weapons. Avalanches on 13th December 1916 alone killed around 10,000 soldiers.
2.3 Natural Risks

Fig. 2-35. Classification of avalanches (Munter 1999)

Table 2-30. Examples of avalanches and accidents in Switzerland (Ammann et al. 1997)

| Date       | Location                                | Number of fatalities and damages                                      |
|------------|-----------------------------------------|-----------------------------------------------------------------------|
| January 1459 | Trun, Disentis (Surselva/GR)         | 25 fatalities, church, some houses and stables destroyed               |
| 1518        | Leukenbad (VS)                         | 61 fatalities, many buildings destroyed                               |
| February 1598 | Graubünden (Engadin) Livigno          | 50 fatalities, damage on buildings and livestock                       |
|            | Campodolcino (Italy)                  | 68 fatalities                                                        |
| January 1667 | Anzonico (II) Fusio-Mogno (II)        | 88 fatalities, village mainly destroyed (event not certain)           |
| January 1687 | Meiental, Gurtnellen (UR)             | 23 fatalities, 9 houses and 22 stables destroyed, cattle killed, many avalanches |
|            | Glamerland                             |                                                                       |
| February 1689 | St. Antönien, Saas im Prättigau, Davos (CR) | 80 fatalities, 37 houses and many other structures destroyed, damage on forest and cattle killed |

(Continued)
| Date          | Location                                                                 | Number of fatalities and damages                                                                 |
|---------------|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| February 1695 | Vorarlberg, Tirol (Austria)                                              | 149 fatalities, about 1,000 houses and many other structures destroyed, great loss of livestock and forest |
| January 1719  | Leukerbad (VS)                                                           | 55 fatalities, 50 houses and many other buildings destroyed                                      |
| February 1720 | Bosco Gurin (TI), Villa/Bedretto (TI)                                    | 34 fatalities, 11 houses and many stables destroyed, 1 fatality, church and some houses destroyed |
| February 1749 | Ffan, St. Antönien, Davos (GR)                                           | 40 fatalities, many buildings destroyed, 7 fatalities, 4 buildings destroyed                     |
|               | Ennenda, Engi (GL), Obergesteln (Goms/VS)                               | many fatalities (between 48 and 88 depending on the source), about 120 buildings destroyed        |
|               | Brig, Randa, St. Bernhard (VS)                                          | 75 fatalities                                                                                   |
| March 1741    | Saastal (VS)                                                             | 18 fatalities and about 25 buildings destroyed                                                  |
| December 1808 | Obermad/Gadmental (BE)                                                   | entire village destroyed, 23 fatalities, major damages on buildings, further 19 avalanches in Berner Oberland |
|               | Zentralschweiz (mainly Uri)                                             | 20 fatalities and major damages parts of a village completely destroyed                          |
|               | Selva (Surselva/GR)                                                     |                                                                                                |
| March 1817    | Andereggl, Gadmental (BE), Elm (CL), Saastal (VS), Tessin und Engadin (GR) | village destroyed, 15 fatalities, many avalanches with fatalities and damages                    |
| 1827          | Biel, Selkingen (Goms, NS)                                               | 51 fatalities and 46 houses destroyed                                                            |
| January 1844  | Göschenertal (UR), Guttannen, Grindelwald and Saxeten (BE)               | 13 fatalities and damages on buildings                                                            |
| April 1849    | Saas Grund (VS)                                                          | 19 fatalities, 6 houses and 30 other buildings destroyed                                         |
| March 1851    | Ghirone-Gozzera (II)                                                     | 23 fatalities and 9 buildings destroyed                                                           |
Table 2-30. (Continued)

| Date       | Location                                                                 | Number of fatalities and damages                          |
|------------|---------------------------------------------------------------------------|----------------------------------------------------------|
| January 1863 | Bedretto (II)                                                            | 29 fatalities and 5 houses and stables destroyed          |
| Winter 1887/88 | Three avalanche periods, main areas: North and Mittelbünden, Tessin, Goms | 1,094 recorded avalanches claim 49 fatalities and 850 buildings destroyed |
| December 1923 | Northern Alps, Gotthard, Wallis, Nord- and Mittelbünden                   | major avalanche damages in many parts of the Swiss Alps  |
| Winter 1950/51 | Two avalanche periods, main areas: Graubünden, Uri, Oberwallis, Berner Oberland, Southern Alps (Tessin, Simplon) | 1,421 recorded avalanches claim 98 victims and 1,527 buildings destroyed |
| January 1954 | Northern Alps, NordbündenVorarlberg (Austria)                            | 258 recorded avalanches claim 20 fatalities and 608 houses destroyed, 125 fatalities and 55 houses destroyed or damaged |
| January 1968 | Northern Alps and Graubünden, Davos                                     | 211 recorded avalanches claim, 24 fatalities and 296 houses destroyed |
| April 1975   | Southern Alps                                                            | 510 recorded avalanches claim, 14 fatalities and 405 houses destroyed |
| February 1984 | Northern Alps, mainly Gotthard area, Samnaun                              | 322 recorded avalanches claim, 12 fatalities and 424 houses destroyed |

Fig. 2-36. After a heavy snow fall with up to 350 cm of fresh snow within one week in February 1999, the bottom of the Lötschen valley in Switzerland was filled by avalanches up to 10 m in height
As with other gravitational hazards, there are possibilities to employ mitigation measures against avalanches. Such mitigation measures might range from nets to dams. In addition, avalanche warning using infrasound or laserscanning is possible (Prokop 2007). Currently, in most Alpine regions, avalanche reports are available to inform people entering mountains during snow times (EAS 2008). However, if people are hit by an avalanche, the chance of survival depends very strongly on the time entombed, as shown in Fig. 2-37.

**2.3.8 Biological Risks**

Humans are exposed not only to hazards caused by the non-living environment, but also to hazards caused by the living environment. Such hazards include poisonous plants or animals, predators and viruses. The last one will be dealt with more in Sect. 2.5. In this section, predators such as bears are of interest.

Great predators, such as bears, lions, tigers and wolves, are able to kill humans. However, in general, the number of fatalities is rather low. It is different though for polar bears. For example, in Spitzbergen where we find many polar bears, people have to carry weapons if they move out of human settlements (Fig. 2-38). In the last 10 years, polar bears have killed two people in Spitzbergen having an overall population of less than 2,000
people. Those killed, however, were mainly tourists. In general, polar bears are extremely aggressive. On the other hand, the number for killings by brown bears in Europe shows rather lower values (Table 2-31). The high number of fatal accidents caused by bears in Romania is mainly due to the artificial overpopulation for hunting, and is therefore not representative.

The great predators in Europe became extinct during the middle of the 19th century. Actually, in earlier times, lions lived in Europe; however, they were very early on hunted and wiped out by the Greeks and the Persians. Currently, there are talks about re-introducing the great predators into densely populated areas, such as the Alps. Whether this would result in an increase in the number of accidents is heavily discussed.

![Polar bear warning sign at Svalbard](image)

**Fig. 2-38.** Polar bear warning sign at Svalbard

Not only wild animals but also domestic animals too attack people. In Germany, an average of nearly two persons are killed per year by dogs. For the German population, this results in an individual risk of $2 \times 10^{-8}$ per year. Table 2-32 gives examples of such killings in Germany for about 40 years.

Furthermore, people might be attacked by snakes, scorpions or other creatures. Even small insects can kill people. On average in Austria, about five people per year are killed by such accidents. This value is higher than the number of persons being killed by dogs.

Moreover, many people world over fall a victim to poisonous plants, mushrooms and bacteria.
### Table 2-31. Statistics of killings by bears in Europe (Riegler 2007)

| Country                  | Population in million | Bear population | Fatal accidents |
|--------------------------|-----------------------|-----------------|-----------------|
| Norway                   | 4                     | 230             | 1               |
| Sweden                   | 9                     | 700             | 1               |
| Finland                  | 5.2                   | 400             | 0               |
| Russia European part     | 106                   | 2,300           | 6               |
| Albania                  | 3.1                   | 130             | 0               |
| Poland                   | 38.6                  | 300             | 0               |
| Slovakia                 | 5.3                   | 400             | 0               |
| Romania                  | 22.3                  | 6,800           | 24              |
| Yugoslavia               | 23.5                  | 2,300           | 4               |
| Italy                    | 57.7                  | 110             | 0               |
| France                   | 59.5                  | 8               | 0               |
| Austria                  | 8                     | 25              | 0               |
| Greece                   | 10.6                  | 200             | 0               |
| Spain                    | 40.1                  | 300             | 0               |
| **Total**                | **492.2**             | **14,203**      | **36**          |

### Table 2-32. Statistics of killings by dogs in Germany since 1968 according to Bieseke (1986, 1988) and Breitsamer (1987)

| Date                     | Location                  | Accident                                                                 |
|--------------------------|---------------------------|---------------------------------------------------------------------------|
| 18 November 1968         | Landau, Pfalz             | Dog kills a baby (14 days old)                                            |
| 18 March 1971            | Wunsiedel                 | Dog kills a child (4 years old)                                           |
| 2 January 1972           | Frankfurt/Main            | Dog kills a man (73 years old)                                            |
| 23 August 1972           |                           | Dog kills a child (6 years old)                                           |
| 25 April 1973            | Waiblingen                | Two dogs kills a pupil (12 years old)                                    |
| 23 March 1974            | Saarland                  | Dog kills a child (6 years old)                                           |
| 30 September 1974        | Herne                     | Dogs kill a boy (12 years old)                                            |
| 6 October 1974           | Dinslaken                  | Dog kills a child (8 years old)                                           |
| 1976                     | Schwarzwald               | Dogs kill a demented woman                                                |
| 1976                     |                           | Dog kills a drunken man                                                   |
| December 1977            | Rödental bei Coburg       | Dogs hurt and kill a child (6 years old)                                  |
| January 1977             | Karlsruhe                 | Dogs kill a child (5 years old)                                           |
| 5 April 1977             | Berlin-Frohnau            | Dog kills a child (3 years old)                                           |
| August 1977              | Delmenhorst               | Dog or wolf kills a child (7 years old)                                   |
| 10 September 1979        | Rothenburg o.d.T          | Dog kills a woman (82 years old)                                          |
| 1982                     | Berlin                    | Two dogs kill a child (6 years old)                                       |
| March 1983               | Düsseldorf                | Two dogs kill a 34-year-old woman                                         |
| 1983                     | Munich                    | Dog kills a baby (10 days old)                                            |
| August 1984              | Straubing                 | Two dogs kill a 79-year-old woman                                         |
| 16 January 1985          | Hannover                  | Dogs kill an old woman                                                    |
| Date            | Location          | Accident                                                                 |
|-----------------|-------------------|---------------------------------------------------------------------------|
| January 1985    | Nuremberg         | Dog kills a young woman                                                   |
| 28 January 1985 | Giessen           | Two dogs kill a young girl (10 years old)                                 |
| 8 February 1985 | Straubing         | Dogs kill a pensioner                                                     |
| 18 March 1985   | Flensburg         | Two dogs kill a girl (11 years old)                                       |
| 2 August 1985   | Bamberg           | Dog kills girl a (3 years old)                                            |
| 6 August 1985   | Berlin            | Dog kills man a (48 years old)                                            |
| January 1986    | Gosier            | Dog kills a pensioner                                                     |
| 6 February 1986 | Frankfurt/Main    | Two dogs kill an man (61 years old)                                       |
| February 1988   | Bavaria           | Dog kills a old woman                                                     |
| 5 November 1988 | Odenwald          | Dogs kill a man                                                           |
| November 1989   | Buchholz          | Dog kills a baby                                                          |
| 20 March 1989   | Karlsruhe         | Three dogs kill a child (4 years old)                                     |
| 19 May 1989     | Ofterdingen       | Dog kills a child (7 years old)                                           |
| September 1990  | Berlin            | Dog kills a boy (11 years old)                                            |
| October 1990    | Rottal-Inn        | Three dogs kill an old woman                                              |
| 12 July 1993    | Hannover          | Dog kills a girl                                                           |
| 27 June 1994    | Bad Dürkheim      | Dog kills a taxi driver                                                   |
| 3 November 1994 | Halberstadt       | Dogs kills a drunken man                                                  |
| June 1995       | Frankfurt/Main    | Dog kills a woman (86 years old)                                          |
| 9 April 1996    | Arnsberg          | Dog kills a child (5 years old)                                           |
| 10 June 1996    | Berlin            | Dog kills a woman (86 years old)                                          |
| 10 June 1996    | Mörfeld-Waidorf   | Dog kills a woman (63 years old)                                          |
| 26 June 1996    | Frankfurt/Main    | Dog kills a woman (86 years old)                                          |
| 23 July 1996    | Bamberg           | Dog kills a child (3 years old)                                           |
| 15 February 1997| Zwickau           | Dog kills a baby (7 months old)                                           |
| 28 April 1998   | Büttzow           | Dogs kill a child (6 years old)                                           |
| 11 May 1998     | Uckermark         | Dog kills a woman                                                          |
| 14 February 1999| Stralsund         | Dogs kill a two children                                                  |
| 2 February 2000 | Frankfurt/Main    | Dogs kill a woman (51 years old)                                         |
| 4 March 2000    | Gladbeck          | Dog kills a woman (86 years old)                                          |
| March 2000      | Untergruppenbach  | Dog kills a man (24 years old)                                            |
| June 2000       | Hamburg           | Dog kills a child (6 years old)                                           |
| 8 August 2001   | Pinneberg         | Dog kills a girl (11 years old)                                           |
| 28 March 2002   | Zweibrücken       | Dogs kill a child (6 years old)                                           |
| 3 April 2002    | Neuental          | Dogs kill a man (54 years old)                                            |
| 16 November 2002| Pforzheim         | Dog kills a baby                                                          |
| 1 September 2004| Bremen            | Dog kills a man (drug addict)                                             |
2.4 Technical Risks

2.4.1 Introduction

The term technology here describes procedures and methods of the practical application of the laws of nature. Therefore, by definition, technical and natural risks cannot be completely separated since technology is based on natural laws. Nevertheless, there is a common understanding of technology that permits a separation from natural processes. Such understanding of technology includes industries, such as the construction industry, transport industry, chemical industry, food industry, energy sector, information technology and so on. The risks connected with such sectors will be looked at in detail.

2.4.2 Means of Transportation

2.4.2.1 Introduction

Motion is a general need of humans. The first things that humans learn are actions that permit movement. While economic considerations assume that an increased capacity of transport and motion means more wealth, other works such as Knoflacher (2001) suggest that more transport capabilities does not necessarily improve wealth. At a certain level of transport capacity, transport decreases wealth. In general, however, if one looks at the development of different means of transportation, such as road traffic, railway traffic, ship traffic, air traffic or space traffic, one finds a constant increase in transport volume. Figure 2-39 illustrates this statement for Germany in terms of the domestic transport volume in billion-tonne-kilometer within the last few decades. As seen in the figure, there is a strong competition between the different means of transportation. Very often the choice of transportation depends not only on the competitiveness but also on some general properties, such as distance.

Figure 2-40 shows the choices of mode of transport taken from a survey in 1999 in the German city of Heidelberg. Clearly, walking and biking are mainly chosen for short distances, whereas the individual car traffic is chosen for activities within a radius of about 10 km. Public transport reaches two peaks, one for very short distances – which is probably bus transport, and the second – most likely railway transport, for longer distances, say 50 km. It is interesting to note that, during the medieval ages, most humans and goods did not have a larger transport radius than about 100 km. Nowadays, however, more or less the entire surface of the earth is reachable by transport means.
Fig. 2-39. Contribution of different means of transport in the development of internal transport in Germany from 1960 to 1997 (Proske 2003)

Fig. 2-40. Means of traffic versus distance after a survey in the year 1999 for the German city of Heidelberg (Heidelberg 1999)
2.4.2.2 Road traffic

Road transport is obviously older than motorcars. It has been assumed that since the invention of the wheel about 5,000–6,000 years ago, there was some form of road transport, even if those roads might not be comparable to what we see nowadays. However, the risk of travelling in old coaches will not be discussed here.

Modern road transport can be clarified in several ways. One possibility is the division according to the means of transport, such as bicycle traffic, motorcar traffic and so on. A second division considers public transport, individual transport, scheduled services and occasional traffic. Additionally, one can distinguish among the goals of transport, such as holiday transport, job transport, transport during spare time, transport for shopping and business transport. Figure 2-41 gives the portions and the development over one year for Germany based on the latter classification.

Table 2-33 shows that, over the last decades, the number of trips per person as well as the distance and time travelled have increased. Only within the last few years in Germany, there has been a small drop in individual travel due to the high unemployment rate and the increase in fuel prices. Additionally, the cold winter in 2005/2006 decreased the traffic volume.

By neglecting these short time variations, the development of car traffic over the last century gives an impressive picture about the success and growth of that means of transport. Figure 2-42 shows the development of passenger cars in millions in Germany from 1914 up to 2003.
Table 2-33. Mobility indicators for Germany according to Chlond et al. (1998)

| Indicator                                      | 1976   | 1982   | 1989   | 1992   | 1994   | 1995   | 1996   | 1997   |
|------------------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Participation of population in traffic in %   | 90.0   | 82.2   | 85.0   | 91.9   | 93.9   | 92.9   | 92.0   |        |
| Number of trips per person per day            | 3.09   | 3.04   | 2.75   | 3.13   | 3.32   | 3.39   | 3.46   | 3.52   |
| Number of trips per mobile person per day     | 3.43   | 3.70   | 3.24   | 3.61   | 3.61   | 3.73   | 3.82   |        |
| Number of motorcars per inhabitant            | 0.508  | 0.502  | 0.467  | 0.511  | 0.518  |        |        |        |
| Travel time per day in hours:minutes          | 1:08   | 1:12   | 1:01   | 1:19   | 1:20   | 1:21   | 1:22   |        |
| Kilometer per person per day                  | 26.9   | 30.5   | 26.9   | 33.8   | 39.3   | 39.2   | 39.6   | 40.4   |
| Average way length in km                      | 8.7    | 10.0   | 9.80   | 10.8   | 11.8   | 11.5   | 11.5   | 11.5   |

Fig. 2-42. Development of the number of passenger cars in Germany from 1914 to 2003 (KBA 2003)

The temporal development of road traffic fatalities for Europe, Poland, US, Japan and Germany is shown in Figs. 2-43, 2-44, 2-45 and 2-46. While Figs. 2-43 and 2-44 use a timescale of two decades, Fig. 2-45 shows the monthly development of fatality numbers in Poland. Highest values are usually reached in fall and lowest values are reached in spring. Figure 2-46 shows the fatality numbers for young drivers on a daily basis. As seen from the figure, the maximum fatality numbers occur on Saturday nights.
Fig. 2-43. Development of road traffic fatalities in Europe including goal values

Fig. 2-44. Development of road traffic fatalities in Poland, USA and Japan according to Krystek & Zukowska (2005)
Fig. 2-45. Development of monthly numbers of road fatalities in Poland according to Krystek & Zukowska (2005)

Fig. 2-46. Number of road fatalities involving people of age between 18 and 24 years over a week in Germany according to the SBA (2006)
About 1.2 million people worldwide are killed per year (over recent years) by road traffic – particularly in low-and middle-income countries (90%) and involving a significant number of young people (Peden et al. 2004). About 1,000 people under the age of 25 are killed per day worldwide in road accidents. Road accidents is the main cause of death on a global scale of children of age between 15 and 19. For the ages 10–14 years and 20–24 years, it is the second leading cause of death. Most young fatalities are vulnerable participants of the traffic. They are pedestrians, motor cyclists or passengers of public transport (Toroyan & Peden 2007).

Weather conditions also play an important role in traffic risks. Figure 2-47 shows the distribution of road surface temperatures related to some environmental conditions. The relationships between weather conditions and accidents has been investigated by Andrey & Mills (2003) and Andrey et al. (2001).

![Pattern of minimum road surface temperature according to Smith (1996)](image)

However, traffic itself can cause a risk structure as shown by two bridge collapses by lorry impact against bridges in Germany (Scheer 2000). Figure 2-48 shows force–time functions for different means of transport and debris flow impacts. On 28th June 1997, an overpass bridge collapsed over a motor highway in France, caused by a truck impact against a pier, resulting in three fatalities. In general, in France, the number of impacts of cars against piers or other parts of bridges is about 30 per year and about 20 for trucks. But, only in 1973, 1977, 1990, 1997 and 1998, collapses caused by impacts have occurred (as far as the data reach). The probability of impact per bridge per year has been estimated at 0.0085 for cars and 0.006 for trucks. Considering the amount of traffic, the probability of an impact of a truck per passage is about $4 \times 10^{-9}$ per year. The probability that a bridge
collapses during an event is about $10^{-4}$, not considering bridges that are designed for an impact. First design rules for impacts were introduced in 1966 and updated in 1977 and 1993 (Trouillet 2001, Holicky & Markova 2003).

![Graphs showing possible time impact–force functions by means of transport and natural processes (Zhang 1993, Rackwitz 1997, Proske 2003)](image)

**Fig. 2-48.** Possible time impact–force functions by means of transport and natural processes (Zhang 1993, Rackwitz 1997, Proske 2003)

### 2.4.2.3 Railway Traffic

Trains are considered the safest way to travel as shown in Table 2-35, giving mortalities and accident rates for different means of transport. Following World War II, there were several years where no train passenger was killed. For example in Great Britain, for a period of 12 years after the World War II, no passenger was killed, excluding those who were killed jumping onto a moving train or those killed at crossings. However, the train operator was not responsible for these accidents. Since railway traffic started over 150 years ago in Great Britain, about 3,000 passengers were
killed. Figure 2-49 shows the development of railway accidents for U.K. in recent years.

Table 2-34. Mortalities and accident frequencies for different means of transport according to Kafka (1999) and Kröger & Høj (2000)

| Means of transport                | Mortality or accident frequency |
|-----------------------------------|---------------------------------|
| Railway (Japan)                   | 7.69×10\(^{-13}\) passenger kilometer |
| Railway (goods traffic Germany)   | 5.00×10\(^{-7}\) goods kilometer |
| Road traffic (Japan)              | 6.67×10\(^{-11}\) passenger kilometer |
| Road traffic                      | 4.67×10\(^{-6}\) car kilometer |
| Railway                           | 2.13×10\(^{-5}\) train kilometer |
| Airplanes (scheduled flights)     | 4.19×10\(^{-9}\) flight kilometer |

The soundness of railway traffic is due to the use of track chains, which mainly control the direction of the train. Along with this, the signal technology used nowadays is mainly automatic, providing a high level of safety.

However, in Europe, about 100 train passengers and about 800–900 people are killed per year (European Commission 2002). The latter number corresponds to fatalities at railroad crossings and suicides. Unfortunately in Germany, there have been some major accidents, strongly influencing the perception of the safety of railways. One such event was the the accident in Eschede, Germany, in 1998 with about 100 fatalities. This accident was the combination of two disasters: firstly the train derailed, and secondly
a bridge was hit and collapsed. Another impact of a train against a bridge happened in 1977 in Australia, which claimed about 90 fatalities (Schlatter et al. 2001). Table 2-35 lists several major train accidents.

**Table 2-35.** List of several major accidents involving the railway according to Kichenside (1998), Preuß (1997) and DNN (2005)

| Country, Location          | Date            | Number of fatalities | Remarks                                                                 |
|----------------------------|-----------------|----------------------|-------------------------------------------------------------------------|
| Sri Lanka, Seenigama       | 26.12.2004      | 1,300                | Tsunami hit a train.                                                    |
| France, Saint Michel      | 12.12.1917      | 660                  | A train with approximately 1,100 soldiers derailed due to overload and defect brakes. |
| Soviet Union, Tscheljabinsk| 3.6.1989        | 645                  | A gas pipeline close to a train line explodes and hits two trains.    |
| Italy, Balvana            | 2.3.1944        | 521                  | Due to overload of the steam engine, the train came to a standstill in a tunnel; people suffocated by the steam of the locomotive. |
| Ethiopia, Schibuti-Addis-Abeba | 13.1.1985      | 428 fatalities, 370 injured | Train derailed due to high speed on a bridge, four railway carriages fell from the bridge. |
| Indonesia, Sumatra        | 8.3.1947        | 400                  | Train stopped in a tunnel.                                             |
| Spain, Leon               | 16.1.1944       | 400                  | Train stopped in a tunnel.                                             |

**2.4.2.4 Ship Traffic**

The construction of ships is known since at least 10,000 years (Mann 1991). Such a long time of existence, however, does not mean that ships have been a safe form of transport during the last centuries. As a rough measure, it has been estimated that about 250,000 ships were lost on the coast of Great Britain (Wilson 1998). In the year 1852 alone, 1,115 ships were lost on this coast, claiming about 900 lives. One January storm lasting over five days took 257 ships, and 486 seamen lost their lives. The yearly maximum of lost ships was reached 1864 with 1,741 ships and 516 fatalities. But, the history of lost ships goes back to the beginning of this technology. In 255 B.C., a Roman fleet was returning from a battle in Cartago. The fleet came into a storm and about 280 ships were lost with 100,000 men (Eastlake 1998). In addition, the fall of the Spanish Armada in 1588 with the sinking of 90 ships and the loss of 20,000 men could be mentioned; however, this was not only due to natural hazards (Wilson...
A detailed description about the battle of the Spanish Armada can be found in Hintermeyer (1998).

In addition to these two famous events, there are many others, which are usually not considered. To create awareness about the risks of this technology, a few accidents are mentioned, which have been chosen based on the number of fatalities taken from Wilson (1998) and Eastlake (1998):

- In 1545, the “Mary Rose” was lost with 665 men.
- On 22nd October 1707, four ships run aground after they lost orientation due to a storm. About 1,650 men were lost.
- In 1852, the “Birkenhead” run aground claiming 445 fatalities.
- In 1853, the “Annie Jane” was lost with 348 fatalities.
- In 1854, the steam ship “City of Glasgow” was lost with 480 passengers.
- In 1857, the “Central America” was lost with 426 passengers.
- In 1858, the “Austria” was lost with 471 passengers.
- In 1859, the “Royal Charter” was lost with 459 fatalities.
- In 1865, on the “Sultana” the steam boiler exploded, killing approximately 1,600 people.
- In 1870, the “Captain” sunk due to a gust with a loss of 483 seamen.
- In 1873, the “Atlantic” was lost with 560 men.
- In 1874, the “Cosapaticock” was lost with 472 fatalities.
- On 3rd September 1878, the passenger ship “Princess Alice” was hit by a carbon steam ship, killing about 645 people.
- In 1898, the “La Bourgogne” and the “Cromartyshire” collided and 546 people were drowned.
- In 1904, one of the biggest ship disasters in New York was the fire of the “General Slocum”, killing about 955 people, mainly women and children.
- In 1912, the “Titanic” was lost with 1,503 fatalities.
- In 1914, the “Empress of Ireland” and the “Storstad” were lost with 1,078 men.
- 1917, the “Vanguard” was lost due to an explosion on the Orkney Islands, claiming nearly 670 fatalities.
- On 30th January 1945, probably, the biggest ship disaster happened. The “Wilhelm Gustloff” carrying German refugees was attacked by a submarine, claiming about 9,000 fatalities.
- In 1957, one of the biggest sailing ships built, the “Pamir”, was lost with 80 men.
• In 1987, the biggest ship disaster in peace times was the tragedy with the “Dona Paz” on the Philippines. The “Dona Paz” was a passenger ferry designed for about 1,500 people, but was occupied by about 4,400 people. The ship was involved in a crash with the oil tanker “Vector”. Unfortunately, the oil exploded, claiming nearly 4,400 fatalities.

• In 1994, the “Estonia” was lost claiming 757 fatalities.

Due to the high frequency of ship losses, especially during the middle of the 19th century, some safety measures were implemented. For example, on 29th May 1865, an organisation for the rescue of shipwreck survivors was established in Germany. Since then, the organisation has saved approximately 62,000 people (Hintermeyer 1998). Even nowadays, heavy accidents involving ships still occur. In 2006, a ferry sunk in Egypt with about 1,600 passengers. Figure 2-50 shows the loss of ship tonnage in the last years.

Much work has been carried out to develop models indicating the possible accident risk of ships (Gucma 2005, 2006 a, b, Gucma & Przywarty 2007). This becomes especially important if ships are used for the transportation of hazardous materials. A list of ship accidents during the transportation of LNG (Liquefied Natural Gas) is given in Table 2-36.

Fig. 2-50. Loss of death weight tonnage (dwt) of ships for several years (ISL 2007)
| Year | Ship | Description of event | Personal Injuries | Damage to ship | LNG release |
|------|------|----------------------|------------------|---------------|-------------|
| 1965 | Jules Verne (now Cinderella) | Overfilling | None | Fractures in tank cover and deck | Yes |
| 1965 | Methane Princess | Valve leakage | None | Fractures in deck | Yes |
| 1971 | Esso Brega (now LNG Palmaria) | Pressure increase | None | Damage to the top of cargo tank | Yes |
| 1974 | Massachusetts (barge) | Valve leakage | None | Fractures in deck | Yes |
| 1974 | Methane Progress | Touched bottom | None | None | No |
| 1977 | LNG Delta | Valve failure | None | None | Yes |
| 1977 | LNG Aquarius | Overfilling | None | None | Yes |
| 1979 | Mostefa Ben Boulaïd | Valve leakage | None | Fractures in tank cover and deck | Yes |
| 1979 | Pollenger (now Hoegh Galleon) | Valve leakage | None | Severe damage to hull and cargo tanks | No |
| 1979 | El Paso Paul Keyser | Stranded | None | | |
| 1980 | LNG Libra | Shaft moved against rudder | None | Fracture to tailshaft | No |
| 1980 | LNG Taurus | Stranded | None | Hull damage | No |
| 1985 | Gadinia (now Bebatik) | Steering gear failed | None | None | No |
| 1985 | Isabella | Valve failed | None | Fractures in deck | Yes |
| 1989 | Tellier | Broken moorings | None | Hull damage | Yes |
| 1990 | Bachir Chihani | Hull fatigue | None | Structural cracks | No |
| 1996 | LNG Portovenere | Firefighting system malfunction | Six dead | | No |
| 2002 | Norman Lady | Collision with submarine | None | Minor hull damage | No |
| 2003 | Century | Engine breakdown | None | Minor repairs | No |
| 2003 | Hoegh Galleon | Engine breakdown | None | Minor repairs | No |
| 2004 | Tenaga Lima | Damage to stern seal | None | Minor repairs | No |
| 2004 | British Trader | Fire in transformer | None | Minor repairs | No |
| 2005 | Laieta | Engine breakdown | None | Minor repairs | No |
### 2.4 Technical Risks

| Year | Ship Description of event | Personal Injuries | Damage to ship | LNG release |
|------|----------------------------|-------------------|----------------|-------------|
| 2005 | LNG Edo Gearbox vibration | None              | Replacement gearbox | No          |
| 2005 | Methane Kari Elin Leaks in cargo tanks | None | Extensive repairs | No          |
| 2006 | Catalunya Spirit Damaged insulation | None | Extensive repairs | No          |

#### 2.4.2.5 Air Traffic

Firstly, the air traffic risk for the uninvolved public shall be considered. This risk seems to be rather low. Table 2-37 mentions some incidents where airplanes hit uninvolved people on the ground. Figure 2-48 also includes the design impact–force function for an airplane impact. Between 1954 and 1983, about 5,000 airplanes crashed worldwide (not involving data from China and the Soviet Union). If one estimates that 1% of the entire world is habituated, then the probability of being hit by a crashing airplane is about $10^{-8}$ per year (van Breugel 2001).

From 1953 to 1986 in the Western world, about 8,300 jet aircrafts were built. In 1986, about 6,200 were in operation. The worst accident happened in 1977, when two Boeing 747 collided at the airport of the Canary Islands with nearly 600 fatalities (Gero 1996). However, in general, the number of airplane accidents has dropped since the beginning of the 1990s, as shown in Fig. 2-51. This statement has to be seen in the general context of air traffic development as shown in Fig. 2-52.

Statistical data about airplane crashes are given in Tables 2-38, 2-39, 2-40, 2-41, 2-42, 2-43. While Table 2-38 gives some general frequencies of airplane loss, Tables 2-39 and 2-40 give data based on flight stages. Table 2-41 gives accident data subject to the airplane type, not including passenger airplanes of the 4th generation. Tables 2-42 and 2-43 give data for some German airports. Figure 2-53 gives further information for Table 2-42. It should be mentioned here, however, that in Germany before the unification in 1990, helicopter crashes on the German border heavily contributed to the number of flight accidents (Weidl & Klein 2004).

The comparison of the risks of different means of transport depends very strongly on the parameter chosen. While in Table 2-34, airplanes showed a low risk by distance-dependent fatalities, in Fig. 2-54, air transport includes a higher risk by trip-based risk parameters.
**Table 2-37.** Examples of airplanes hitting ground structures (van Breugel 2001)

| Year | Description and location | Fatalities |
|------|--------------------------|------------|
| 1987 | Small airplane crashed into a restaurant in Munich, Germany | 6          |
| 1987 | A-7 Corsair crashed into a hotel in Indianapolis, USA       | 14         |
| 1987 | Harrier Jump-Jet crashed into a farm near Detmold, Germany  | 1          |
| 1988 | A-10 Thunderbolt II hit 12 houses near Remscheid, Germany  | 6          |
| 1988 | Boeing 747 exploded over Lockerby, Scotland; airplane parts hit petrol station and houses | 280        |
| 1989 | Boeing 707 crashed into a shanty town near Sao Paulo, Brasil | 17         |
| 1990 | Military airplane hit a school in, Italy                    | 12         |
| 1992 | Hercules Transporter crashed into a motel in Evanswille, USA | 16         |
| 1992 | Boeing 747 crashed into 10-floor house in Netherlands       | 43         |
| 1992 | C-130 crashed into a house in West Virginia, USA            | 6          |
| 1996 | Fokker-100 crashed into houses in Sao Paulo, Brasil         | 98         |
| 2000 | Military airplane crashed into a house in Greece            | 4          |
| 2000 | Boeing 737-200 crashed into house near Patna, India         | 57         |
| 2000 | Concorde crashed into a hotel near Paris, France            | 113        |

**Fig. 2-51.** Development of flight movements in Europe and Germany over the last decades (Konersmann 2006)
Table 2-38. Frequency of airplane crashes according to Weidl & Klein (2004)

| Source                                      | Frequency                              |
|---------------------------------------------|----------------------------------------|
| German risk study nuclear power plants (part 4) | $2.5 \times 10^{-12}$ per flight and km |
| German risk study nuclear power plants (phase B) | $6.0 \times 10^{-7}$ per flight         |
| Bureau of Transportation Statistics – >20 tonnes | $3.84 \times 10^{-10}$ per flight and km |
| Bureau of Transportation Statistics – <20 tonnes | $1.11 \times 10^{-8}$ per flight and km  |
| German Federal Bureau of Aircraft Accidents Investigation, Report 2001 | $6.5 \times 10^{-7}$ per flight         |
| International Air Transport Association – Ranking | $4.24 \times 10^{-10}$ per flight and km  |

Table 2-39. Distribution of flight accidents to flight stages based on data for the years 1959–1985 (Moser 1987)

| Stage of flight | Share on flight time in % | Share on accidents in % | Trend |
|-----------------|---------------------------|-------------------------|-------|
| Take off        | 1                         | 21.8                    | Falling |
| Climb           | 19                        | 7.2                     | Growing |
| En route        | 37                        | 5.5                     | Falling |
| Initial approach| 14                        | 6.1                     | Constant |
| Final approach  | 10                        | 32.4                    | Constant |
| Landing         | 1                         | 24.5                    | Falling |
| Rolling         | 18                        | 2.5                     | Growing |
Table 2-40. Number of air traffic accidents related to different traffic types using data from the year 1985

| Accidents involving different types of flights                                      | Number |
|-----------------------------------------------------------------------------------|--------|
| Fatal accidents in passenger schedule air traffic                                | 16     |
| Fatal accidents in passenger non-schedule air traffic                            | 5      |
| Fatal accidents in passenger regional and shuttle air traffic                     | 10     |
| Fatal accidents in cargo traffic                                                  | 9      |
| Non-fatal accidents in passenger schedule air traffic                             | 115    |
| Non-fatal accidents in passenger non-schedule air traffic                        | 5      |
| Non-fatal accidents in cargo traffic                                              | 16     |

Table 2-41. Failure rates of different airplanes. However, be aware that some of the airplanes were operating under difficult conditions, such as the Fokker F.28 (Moser 1987)

| Model                                    | Percentage of airplanes involved in accidents from all produced airplanes | Number of fatal accidents per million flights |
|------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------|
| 1. Generation I                          |                                                                           |                                             |
| Aérospatiale Caravelle                   | 11.8                                                                      |                                             |
| DeHavilland Comet                        | 9.8                                                                       |                                             |
| Convair 880/990                          | 8.8                                                                       |                                             |
| McDonnell Douglas DC-8                   | 8.1                                                                       |                                             |
| Boeing 707                               | 7.6                                                                       |                                             |
| Boeing 720                               | 3.3                                                                       |                                             |
| 2. Generation II                         |                                                                           |                                             |
| Fokker F.28                              | 7.4                                                                       | 3.38                                        |
| British Aerospace One-Eleven             | 5.7                                                                       | 0.54                                        |
| Vickers VC10                             | 3.7                                                                       |                                             |
| McDonnell Douglas DC-9                   | 3.5                                                                       | 0.49                                        |
| Hawker Siddeley Trident                  | 2.6                                                                       |                                             |
| Boeing 737                               | 2.2                                                                       | 0.74                                        |
| Boeing 727                               | 2.1                                                                       | 0.51                                        |
| 3. Generation III                        |                                                                           |                                             |
| McDonnell Douglas DC-10                  | 3.0                                                                       | 2.87                                        |
| Boeing 747                               | 1.5                                                                       | 1.51                                        |
| Lockheed 1011 TriStar                    | 1.2                                                                       | 1.21                                        |
| Airbus A300                              | 0.8                                                                       |                                             |
Table 2-42. Examples of accident rates for some airports (Konersmann 2006) – See also Fig. 2-52.

| Take off weight class | 1   | 2   | 3   | 4   | 5   | 6   |
|-----------------------|-----|-----|-----|-----|-----|-----|
| Number based on stocktaking 2005 | 4,847 | 1,792 | 5,025 | 8,806 | 3,307 | 2,603 |
| Average number of daily possible flights (take off and landing = one flight) | 5 | 8 | 6 | 5 | 3 | 2 |
| Average number of flights per year in million | 8.845 | 5.232 | 11.004 | 16.070 | 3.621 | 1.900 |
| Average number of risk relevant accidents | 9 | 1 | 5 | 4 | 2 | 1 |
| Reference accident rate $\times 10^{-7}$ | 10 | 1.9 | 4.5 | 2.5 | 5.5 | 5.3 |

Table 2-43. Accident numbers for the Frankfurt airport (Germany) based on Fricke (2006)

|                      | 2000   | 2015   |
|----------------------|--------|--------|
| Probability of accident per flight | $5.75 \times 10^{-8}$ | $5.15 \times 10^{-8}$ |
| Probability of accident per year   | 0.026  | 0.034  |

Fig. 2-53. Number of flight movements per day compared to takeoff weight (Konersmann 2006)
2.4.2.6 Space Traffic

In comparison to the other means of transport, space travel features some special properties. Firstly, the number of people moved by this means of transport is rather less. Additionally, the costs of transport are extremely high. However, in terms of risk, space travel contains a rather high risk. This has not only been shown by the losses of Space Shuttles, but was also valid for the first space flights. By 1979 about 92 astronauts had been to space. Four astronauts were killed by accidents during travel, while some astronauts were killed on earth during tests in 1967. Here, probably the best known accident was the fire of an Apollo capsule on ground. However, severe rocket explosions have also caused high numbers of fatalities. In April 1967, the Russian astronaut Komarov was killed when the parachute did not open during return. In 1970, the astronauts of Apollo 13 luckily survived the mission. In June 1971, three Russian astronauts were killed by a pressure loss during re-entry. (Mielke 1980)

Although the Space Shuttle concept was considered to improve the safety and to drop the probability of complete loss from $10^{-1}$ to $10^{-2}$ (Paté-Cornell & Fischbeck 1994), the explosion of the Challenger in 1986 and the loss of the Columbia in 2003 showed drawbacks in this Space Shuttle concept. Considering these two losses and approximately 130 missions,
one obtains $2/130=0.015$ fatality per mission. This might also be considered fatality if the number of passengers per mission would be equal and astronauts would not have a second mission. Considering the 450 people who have been to space so far and the nearly 20 fatalities, this yields to $20/450=0.04$ fatality per mission. Future space missiles should feature a further improvement of safety in terms of probability of loss as shown in Table 2-44.

Table 2-44. Probability of loss or damage for planned new missiles (Altavilla et al. 2000)

| Projects                          | Probability of damage or loss                                      |
|-----------------------------------|-------------------------------------------------------------------|
| Hermes Project                    | Failure of missile per mission $10^{-4}$                          |
|                                   | Loss of parts per mission $10^{-3}$                               |
|                                   | Overall per mission $10^{-2}$                                      |
| Assured Crew Return Vehicle (ACRV)| Failure during mission and four years in space $3 \times 10^{-3}$   |
| Crew Rescue Vehicle (CRV)         | Failure during mission and five years in space $5 \times 10^{-3}$   |
| Crew Transport Vehicle (CTV)      | Loss of missile per mission $3 \times 10^{-3}$                    |
|                                   | Heavy damage per mission $2 \times 10^{-3}$                       |
|                                   | Risk to population on ground per mission $10^{-7}$                |

2.4.3 Dumps

While the former sections discussed means of transport, this section discusses dumps, which are used for the spatial fixing of materials. Such materials are mainly solid wastes. The amount of waste materials generated has reached alarming values. For example, in the US, the amount of wastes has grown from 0.5 million tonnes per year during the 1940s to about 300 million tonnes in 1993 (Garrick 2000). In Germany, the overall amount of wastes produced has grown during the last decades too. While in 1983 about 30 million tonnes of debris was produced, in 1993 it reached 43 million tonnes (Merz 2001). Fortunately, over the last decades, the amount of wastes per capita has remained constant and the amount of special debris has fallen, even though the definition of hazardous waste has become wider. Hazardous waste is of particular interest, since it includes toxic materials.

The development of the construction of high-safety dumps or high-safety barriers designed for hazardous waste was intensively discussed during the 1980s and 1990s in Germany (HMUE 1992). This was due to the limited capacity for waste burning and disposal in Germany at the end
of the 1980s. Since then, the regulations for opening new dumps have become even harder. Dump sites are obliged to obtain permission, which is now restricted for densely populated areas. Currently, it is assumed that about 1/3 of wastes can be burned or recycled. This is probably a fitting value for most developed countries. In addition, waste is also exported from many countries. These limitations of dump sites have yielded to increased efforts since the 1980s to reduce the overall amount of wastes. Waste at present, and into the future, is treated by separation, burning, gasification, hydration or biological treatment prior to dumping (Merz 2001).

Nevertheless, in Germany, 3,000 dumps still remain in use. Most of them are used for rubble and earth excavations, while only a small number (300) being used for domestic wastes. The standard quality of these remaining dumps, however, is still rather low: only 2/3 of the dumps, treat the waste gases and only 1/5 clean the waste water. In about 10% of all domestic waste dumps, the water is not treated in any way. Approximately 70% of the domestic waste dumps pump the water into a municipal clarification plant. In the former German Democratic Republic, about 10,000 waste dumps were assumed to exist. In 1990, about 6,000 were still in use, with only 120 of them complying with dump standards (Paffrath 2004).

One has to mention, however, that even in developed countries in the 1970s, terms like “waste separation”, “dump foundation sealing”, “seepage water capture”, “degasing and control” and “aftercare” were unknown to dump designers. Nowadays, many different systems for dumps are developed and offered by companies. Such high-safety dumps include, for example, multi-barrier systems, and also the aftercare has been put into regulations. Nowadays, dumps are not seen anymore as passive storage but as reactors, in which chemical and biological processes occur. The lifetime of dumps is usually between 30 and 100 years. However, even nowadays absolute safety of dumps cannot be reached. Acceptable values about the release of materials can be found in different regulations. Here, only the requirements for the application of concrete as a second barrier against water-endangering fluids should be mentioned. Water-endangering fluids are those that which are able to contaminate bodies of water and change their properties. If such fluids are released, damage and harm to the environment and humans is assumed. Usually the so-called second barrier experiences only very rare contact with the fluid, e.g. about $10^{-4}$ per year. Based on some safety classes, acceptable failure risks in terms of volume released material per time are presented in Table 2-45 (Wörner 1997, Kiefer 1997).
Table 2-45. Acceptable released volume of water-endangering fluids per time (Kiefer 1997)

| Safety class | Safety requirement for ground and water | Acceptable volume |
|--------------|----------------------------------------|-------------------|
| 1            | Low safety requirement (for example, already contaminated ground) | 1 m$^3$/100 years |
| 2            | Usual safety requirements               | 1 m$^3$/10,000 years |
| 3            | Special safety requirements (for example, drinking water reservoir) | 1 m$^3$/100,000 years |

To calculate the final acceptable risk, the hazard of the fluid also has to be considered. This hazard rate is based on the toxicity and the migration capability of the fluid. Toxicity can be described using different measures for different animal groups. Here, the Median Lethal Dose (LD$_{50}$) has been used. The exposure of that dose yields to a mortality of 50%. As mentioned, such toxicity measures have been adapted to mammals, fishes and bacteria. In Germany, in 1998, about 2,700 cases of uncontrolled releases of such water-endangering fluids were registered. About 900 cases occurred in storage devices.

However, not all releases are documented or yield to further measures. Since 1912, in Segnitz (Germany), color pigments (Schweinefurter green) were produced. That yielded to an average arsenic concentration of 2,500 mg/kg in the soil and 9,300 mg/l in the groundwater. The concentration levels of copper reached 2,300 mg/kg in the soil. In Fürth, (Germany), a mirror production site was closed. The mercury concentration reached 20 µg/m$^3$ in the air, 3,000 mg/m$^3$ in the rubble and 4,000 mg/m$^3$ in the soil. The tar lake in Rochlitz, Thuringia, is well known. Here, nearly 20 million tonnes of brown coal smolder tar as well as nearly 10 million tonnes of oil were processed. Additionally, during World War II, the plant was bombed and about 100,000 tonnes of materials was released. The ground and the groundwater were heavily contaminated, yielding to so-called swimming oil lenses in the groundwater. Many technologies have been developed to clean such locations, for example HOT-PACK, MEC-TOOL, XTRAX, BEST, mobile oven, biological techniques and stabilization techniques. As a last example, the Wismut Company for the mining of uranium in East Germany is mentioned. The cleaning-up of radioactive waste at dump sites had cost several billion Euros (Paffrath 2002).

Further examples of the uncontrolled release of wastes can be found in the mining industry. Here, great amounts of dump sites occur, which often include toxic materials and, therefore, represent a hazard to the environment. Often the waste is stored in lakes braced by artificial dams. If such dams fail, and the water of the lake is released into the environment, then
an environmental, disaster could happen. Examples of dam failures are discussed in the following section.

2.4.4 Dam Failure

On 7th August 1975, in the central China province of Henan, after 26 h of heavy rain, the Banqiao dam, the Shimantan dam and others failed. The failure released approximately 600 million cubic-meters of water, which traveled with a velocity of 50 km/h over the valleys and plains. According to Chinese sources, about 85,000 people died within 24 h of the failure. Another 145,000 people died in the days after due to famine and disease. If these data are correct, then the failure of these dams was one of the biggest disasters in the world – only exceeded by the storm surge in Bangladesh in 1970, the Tangshan earthquake in 1976 and the Tsunami disaster in 2004. It can be seen as the biggest technical disaster of all times (Lind & Hartford 1999).

This disaster shows clearly the connection between technical and natural risks. The dam would probably not have failed under regular weather conditions. In addition, the relationship between primary and secondary disasters is visible. More people died as a result of the secondary disaster of insufficient food and disease. This is a clear sign of the collapse of the social system after the primary disaster. It is quite often described by the term vulnerability. If, during an earthquake, some bridges collapse, then the region might not be accessible by external help and is, therefore, extremely vulnerable. This has been intensively discussed. For example, in the region of Cologne in Germany, a vulnerability study has been carried out investigating the possible impacts of the collapsing of the Rhine bridges during either a flood or earthquake. In Japan, studies have considered failure of bridges after earthquakes. It does not, however, have to be only structural failures that increase the vulnerability of a region. For example, there might be a collapse of the telephone and electrical systems, and therefore no information about a disaster can be communicated. In this case, satellite observation could be used on identify sudden changes in regions.

Returning to the topic on dams, not all dam failures have resulted in such terrible disasters. From 1960 to 1996, of approximately 23,700 dams in the USA, about 23 dams failed (Lind & Hartford 1999). These failures claimed 318 lives. One of the latest dam failures occurred in Syria in June 2002 with about 22 fatalities and making 3,800 people homeless. Some dam failures are listed in Table 2-46. Figure 2-55 shows the Katse dam in Lesotho, Africa.
Table 2-46. Failure of dams (Pohl 2004)

| Dam              | Country | Year of accident | Number of fatalities |
|------------------|---------|------------------|----------------------|
| Puentes          | Spain   | 1802             | 680                  |
| Dale Dyke Dam    | U.K.    | 1864             | 250                  |
| Qued-Fergoug     | Algeria | 1881             | 200                  |
| South Fork/Johnstown | USA   | 1889             | 2,209                |
| Bouzey           | France  | 1895             | 100                  |
| Austin           | USA     | 1910             | 100                  |
| Saint Francis    | USA     | 1928             | 500                  |
| Möhne            | Germany | 1943             | 1,200                |
| Vega de Tera     | Spain   | 1959             | 400                  |
| Malpasset        | France  | 1959             | 400                  |
| Vajont           | Italy   | 1963             | 2,000                |
| Vratsa           | Bulgaria| 1966             | 600                  |
| Rapid City       | USA     | 1972             | 250                  |
| Macchu-Earth dam | India   | 1979             | 2,500                |

Fig. 2-55. Katse dam in Lesotho

A special dam failure case happened in 1963 in Vajont, Italy. This case was already mentioned in the section on debris flows and landslides. In this case, as a result of heavy rainfalls, a huge slope failure occurred. A volume of about 2 km × 1 km × 150 m moved into the lake behind the dam and caused a 70-m-high flood wave. The wave killed about 2,500 people.
in areas behind the dam. This disaster has been intensively discussed not only in the field of debris flow but also in the Courts. In this particular case, the dam itself did not fail, but the design of the overall dam system failed, because the possibility of the slide was not considered (Pohl 2004).

Even if dams completely meet their structurally intended goals, other types of risks are generated. In 1950, approximately 5,000 dams with a crown higher than 30 m existed. This number has grown to 45,000 by the year 2000. This has had major economical, ecological and social impacts. In order to build the dam on the Yangtze River in China, nearly two million people were evacuated. Currently, there is a discussion whether new massive dams can cause earthquakes (Klesius 2002).

2.4.5 Structural Failure

The failure of dams is a special case of the failure of structures. Usually the failure of structures is related to two causes: either extremely high loads, which are called accidental loads, such as impacts; or insufficient strength mainly related to human failures. Both can be found in developed and developing countries. For example, on 3 February 2004 in Turkey, a ten-story building collapsed; on 27 January 2004, a building collapsed in Cairo, Egypt, after a fire; and on 16 February 2004, a swimming pool building collapsed in Moscow killing 25 people. Also, in the spring of 2004, a part of the new terminal at an airport in France collapsed.

Examples from Germany are the collapse shown in Fig. 2-56 or the collapses of the Halstenbeker sports hall close to Hamburg in 1997 and 1998. The structure received the nickname the buckling egg. Since two collapses happened during the construction phase, nobody was injured, but the structure was never completed. The failure was due to a rather complicated structure type, which was very vulnerable to small changes to the geometry. A second example of structural failure in Germany occurred on 2 January 2006 in Bad Reichenhall. Again a sports hall collapsed in the afternoon killing 15 people, most of them children. The structural failure led to an intensive debate about the safety of public buildings in Germany. It was assumed that snow overload caused the failure, since also in Poland a hall collapsed for that reason in the same winter. This discussion echoed in the beginning of the 1970s, when many light-weight structures in East and West Germany failed under snow load. Initially, sabotage was assumed to be the cause of failure in East Germany; however, very optimistic assumptions about snow load and the change of the construction material from wood to steel were later identified as the causes. It was determined that the cause of failure in Bad Reichenhall was a combination of lack of maintenance,
structural changes over time and the application of new bonding materials. As a consequence of that disaster, the Ministry for Buildings and Structures decided in December 2006 to change the law regarding the safety standards of public buildings by requiring additional inspections.

Still, even including that event, structures in Germany remain an extremely safe technical product. In Germany in 2004, about 17,293,678 residential buildings (Knobloch 2005) and about 5,247,000 non-residential buildings (SBA 2005) were in use. The entire population of 80 million people is virtually exposed more than 20 h per day. Thus, an average yearly fatality number, of 10 is extremely low.

This low risk is mainly reached by high control efforts – not only during the design process but also at the construction site itself. A few examples should be mentioned. In 2000–2001, an overpass over a freeway interchange was erected. During the erection of the superstructure, a rather low concrete strength was reached. Many experts were asked about the cause, and heavy discussions took place about the possible reasons and who was to be blamed. At last, it turned out additives for the concrete production were produced in a chemical plant, which had accidentally labeled textile softener as concrete additive. The textile softener caused an insufficient low strength of the concrete, and the superstructure blasted right after construction in the summer of 2001. Another example is a highway bridge in Saxony close to Dresden, Germany, where during the pouring of concrete for the superstructure, too few concrete workers were at the site. Therefore, the concrete was not properly compacted and the concrete structure through test drillings was shown to have hollow cavitations. This, of course, decreased the effective cross-section of the bridge and, therefore, strongly influenced the load-bearing capacity. Parts of the bridge thus had to be rebuilt again.

In comparison to events of accidental loads, such construction cases remain as rather individual problems. Earthquakes, in particular, cause accidental loads on structures that often claim many victims. For example, many buildings collapsed due to earthquakes in Morocco on 25 February 2004, and on 6 February 2004 in Bam in Iran. About 70% of the buildings of the city were destroyed, killing between 30,000 and 40,000 people. Already in the section on earthquakes, the difference between the consequences of earthquakes in developed and developing countries was discussed. Many of the fatalities in developing countries could have been avoided by the application of modern structural codes. However, comparable problems might be observed in developed countries as well, as the next example describes.

First of all, modern codes require that the design and construction of structures be carried out by specialist staff. However, if one actually looks
at many construction sites, reality quite often gives a different impression. For example, there were many cases in Germany where nobody on-site could speak German, but all the plans were given in German. In one case, the gradient on a new bridge was wrong, and some workers were asked to grind off the concrete to meet the required gradient. Since the workers did not understand German, they grinded off the concrete until sparking. By then the reinforcement and, even worse, the prestressing elements of the bridge had already been reached.

The majority of building failures are caused by human error. The results of an investigation of 800 damaged buildings are summarized in Table 2-47 (Matoussek & Schneider 1976). The so-called damage report of the German Ministry of Buildings and Structures also supports the findings of this table. Ignorance is by far the most prominent cause of faults. A good example of ignorance was seen by the author during a visit to a hall construction site, when steel anchors were found in the dump. The site engineer then discovered that some workers had simply detached the anchors from a steel column because the concrete was poured too high. The anchoring elements were essential for the load-bearing behaviour of the column, but the workers just wanted to continue with their work.

The next major cause of damages is insufficient knowledge. This might actually be connected to ignorance either through limited communication capabilities or through the employment of cheap but badly trained workers. The negative impacts of badly trained workers cannot only be found in the field of structures but also in hospitals, nuclear power plants and other fields.

The distribution of the causes of structural damages related to the different stages of structural development can be seen in Table 2-48. About 50% of errors are made during the construction phase. This is only acceptable due to the major effort in quality control and inspection and the low vulnerability of structures under normal conditions. In general, structural materials such as steel, reinforced concrete or masonry are able to redistribute loads in case of local failures and, therefore, increase the safety of structures – especially if so called “static indeterminate structures” are designed with a high degree of robustness. The quality control itself includes a further 10% of error (Table 2-48), but in combination with the other values, it results in rather low probabilities of failure:

\[ P(I | A) = P(I) \times P(A) = 0.1 \times 0.1 = 0.01 \]
\[ P(I | E) = P(I) \times P(E) = 0.1 \times 0.4 = 0.04 \]
\[ P(I | C) = P(I) \times P(C) = 0.1 \times 0.5 = 0.05 \]

Of interest to note is the distribution of errors between the architects and the civil engineers. The common explanation is the possibility of causal
relations in the different professions. While civil engineers produce easily controllable static computations, architects create uncontrollable results – for example, the beauty or usability of a building. In the last few years, however, at least in Germany, this is changing. Architects have become more and more responsible for their products.

The above figures show that at least every tenth structure produced has faults. The majority of faults are caused by human errors. This is a latent phenomenon and does not have to result in disasters. As a result of this, control mechanisms have been developed and employed in many fields.

**Fig. 2-56.** The skewed house of Weimar (Germany)

**Table 2-47.** Causes of building damages (Matoussek & Schneider 1976)

| Causes                              | Percentage on overall damages |
|-------------------------------------|------------------------------|
| Ignorance, carelessness             | 37                           |
| Insufficient knowledge              | 27                           |
| Underestimate of influences         | 14                           |
| Forgetfulness and mistakes          | 10                           |
| Unwarranted abandonment on others   | 6                            |
| Objectively unknown situations and influences | 6                            |
Table 2-48. Probability of errors during design and construction of structures

| Stage of project       | $P$  |
|------------------------|------|
| Error of architect     | $P(A)$ 0.1 |
| Error of design engineer| $P(E)$ 0.4 |
| Error during construction| $P(C)$ 0.5 |
| Error during control   | $P(I)$ 0.1 |

The different stages of development of a structure can be investigated for the occurrence of errors as well as for the usage time. Thus, damages and failures can be divided between occurring during the construction phase and occurring during the usage phase. Initially, this may seem rather strange since one would assume that heavier loads are experienced during the usage time of the structure. However, this is not always the case. For example, on a bridge a situation might arise where, during the time of construction, a heavy mass transport of earth from one side of the valley to the other side is carried out by big trucks over the unfinished bridge. Here, maximal loading is experienced during the construction phase. Also the structure might not be finished and, therefore, the proper statical system is not yet activated. Some part of the structure may, therefore, experience a load which it will never experience again in such a magnitude. This change of system and special load types during construction can be seen for a bridge built in incremental launching method. Here, the bridge is built on one side of the valley, and then moved section by section over the columns to the other side of the valley. The advantage of building with this technique is extremely good fabrication conditions. The bridge can then be produced at one place at the prefabrication area. However, the movement of pushing the bridge over the valley includes some special loads. In addition, since the bridge is pushed every week or every second week, the concrete material has not reached the final strength.

It is, therefore, not surprising that many bridges or houses collapse during the construction phase. Table 2-49 gives a list of known bridge failures. Here, the major cause of failure, approximately 25%, is during construction. If the collapse of the formwork is also considered a failure during construction time, then the figure reaches about 50%. In some cases, bridges also collapsed during load tests, as seen in Table 2-50. Another major cause of failure is connected to accidental loads, such as impacts. Only 1/4 of the failures happened under regular conditions.

Bridge failure cannot only be classified temporally but also according to the statical way the bridge failed. In the last decades, especially, stabilizing problems have caused bridge failures. For example, at the end of the 1960s and the beginning of the 1970s, some collapses of steel box girder bridges
occurred. Examples of the failures of these bridges are the 4 Vienna Danube bridge in 1969, the Rhine bridge in Koblenz in 1971, the Cleddau bridge in Milford Haven in 1970, the Westgate bridge in Melbourne in 1970 and the reservoir bridge in Zeulenroda in 1973. Here, neglected initial deformations yielded to buckling during bridge feed.

**Table 2-49.** Causes for the failure of bridges (Scheer 2000)

| S. No. | Cause during/by                      | Number of known cases |
|--------|--------------------------------------|-----------------------|
| 1      | Construction                         | 93                    |
| 2      | Usage under normal conditions        | 86                    |
| 3      | Ship impact                          | 48                    |
| 4      | Impact of under-passing traffic      | 16                    |
| 5      | Impact of over-passing traffic       | 18                    |
| 6      | Flood and ice                        | 32                    |
| 7      | Fire and explosion                   | 15                    |
| 8      | Failure of formwork                  | 48                    |
| Total  |                                      | 356                   |

**Table 2-50.** Historical examples of bridge failures (Scheer 2000)

| Year | Location                                | Remark                                                |
|------|-----------------------------------------|-------------------------------------------------------|
| 1209 | Old London Bridge, England              | Constriction of river cross-section yielded to destruction |
| 1817 | Dryburgh Abbey, Scotland                | Chain suspension bridge destroyed by storm            |
| 1820 | Union Bridge, Berwick, Scotland         | Chain suspension bridge destroyed by storm            |
| 1830 | Durham, England                         | Chain suspension bridge showed great deformation under live loads |
| 1830 | Yorkshire, England                      | Chain suspension bridge destroyed by a cow herd only a few months after construction |
| 1876 | Ashtabula, USA                          | Collapse during snow storm under train (80 fatalities) |
| 1887 | Bussey bridge close to Boston, USA      | Steel framework bridge collapsed under train (26 fatalities) |
| 1891 | Mönchstein, Basel, Switzerland          | Bridge collapsed under train (73 fatalities).          |
| 1893 | Chester, USA                            | Framework bridge collapsed under train during rebuilding (40 fatalities) |
| 1893 | Louisville, USA                         | 165- m- long framework bridge collapsed due to hurricane/gale (22 fatalities) |
| 1907 | Quebec, Canada                          | Framework bridge collapsed during construction (74 fatalities) |
| 1931 | Bordeaux, France                        | Suspension bridge failed during inauguration party and load tests (15 fatalities) |

(Continued)
Table 2-50. (Continued)

| Year | Location | Remark |
|------|----------|--------|
| 1940 | Frankenthal close to Mannheim, Germany | Failure of lift technique (42 fatalities) |
| 1948 | Pier at Stresa, Italy | Overload by about 1,000 people (12 fatalities) |
| 1962 | Bridge at Morace, Yugoslavia | Failure of bridge claimed 21 fatalities |
| 1972 | Naga City, Philippines | Bridge overloaded during procession (145 fatalities) |
| 1977 | Bundesstaat, Assam, India | Bridge failed under train (45 fatalities) |
| 1982 | Bridge over Brajmanbari, Bangladesh | Bridge failed under overloaded bus (45 fatalities) |
| 1970 | Westgate, Melbourne, Australia | Failure of bridge by buckling (34 fatalities) |
| 1977 | Pushkin bridge close to Moscow, Soviet Union | Insufficient maintenance caused failure (20 fatalities) |
| 1981 | Bridge over Totora-Oropeska river, Peru | During maintenance bridge was overloaded and load-bearing ropes failed (50 fatalities) |
| 1994 | Sungsusteel framework bridge close to Seoul, South Korea | Mistakes during design and overload caused failure (32 fatalities) |

Although this list gives an impression that bridges collapse quite regularly, this is not true. Most of the 600,000 bridges in the US, about 120,000 bridges in Germany and about 150,000 bridges in U.K. are reliable technical products. Some of them still function well after being in use for more than a few hundred years. No other technical products are in use for such long periods that compare to buildings and structures (Proske et al. 2005).

2.4.6 Energy Production and Nuclear Power Plants

People are not only used to risks in structures, they are also exposed to risks in professions. However, there seems to be some professions more exposed to risks than others. For example, fishing is more dangerous than teaching. The topic of safety of the nuclear power industry seems to be of major public concern. However, this type of energy production might impose higher risks. All other types of energy productions should be compared in terms of the risks to humans (European Commission 2007).
Fig. 2-57. Risks of different energy supply technologies in terms of employee fatalities per energy production (Inhaber 2004)

Fig. 2-58. Total number of deaths related to energy production technologies (Inhaber 2004)
Such risks include the failure of hydroelectric dams, the explosion of gas storages, the explosion in mines or accidents in nuclear power plants. Examples can be found in Inhaber (2004). Figure 2-57 and 2-58, taken from Inhaber (2004), give fatality numbers related to energy production technology.

However, nuclear power plant seems to feature some special properties. For example, the absolute damage potential for this technology is much higher compared to other energy production technologies known so far. A study of the 19 nuclear power plant locations in Germany has assumed damages in an area with a diameter of 2,500 km and an affected population of 670 million people. Early fatalities and damages were assumed only in an area with a diameter of 20 km. After an initial 20,000 fatalities, another 100,000 fatalities, were estimated with a probability of $5.9 \times 10^{-5}$ per year (Hauptmanns et al. 1991). Many studies have been carried out to estimate the risks of this technology (GRS 1999). In the chapter “Objective risk measures”, it will be shown that, due to these considerations, the nuclear power industry is a major precursor for risk assessment.

However, all of the risk studies could not have avoided some accidents in nuclear power plants, although they might have prevented many more other accidents. The accident of Chernobyl is probably known worldwide. Many different references describe the accident in detail (Jensen 1994, IAEA 1991). Depending on the source, the number of fatalities caused by this accident differs between 42 (Haury 2001), 9,000 (IAEA), over 264,000 fatalities (IPPNW) and up to 500,000 fatalities (Haury 2001). The second biggest accident was Three Mile Island (TMI) – fortunately with no external consequences (US-NRC 2004). The magnitude of such accidents can be classified according to the INES (Tables 2-51 and 2-52). One of the recent accidents occurred in a nuclear power plant in August 2006 in Sweden. In 2007, 442 nuclear power plants in 31 countries were in operation (Busse & Sattar 2007). Currently, there are more than 10,000 reactor years of operation (Carlier 2004).

Incidentally, it should be mentioned that in the Republic of Gabun, something like a natural nuclear reactor was found. Due to the coincidence of circumstances, a nuclear reaction occurred in six different zones for probably 150,000 years. Moderation was carried out by water for decreasing $^{235}$U concentration. The natural reactor was found when the mining of uranium had started there (Rennert et al. 1988).
### Table 2-51. International Nuclear Event Scale (INES) (IAEA 2007)

| Level | Off-site impact | On-site impact | Defense degradation |
|-------|-----------------|----------------|---------------------|
| 7     | Major accident  | Major release: widespread health and environmental effects |                       |
| 6     | Serious accident| Significant release: likely to require full implementation of planned counter-measures |                       |
| 5     | Accident with off-site risk | Limited release: likely to require partial implementation of planned counter-measures | Severe damage to reactor core and/or radiological barriers |
| 4     | Accident without significant off-site risk | Minor release: public exposure of the order of prescribed limits | Significant damage to reactor core and/or radiological barriers/fatal exposure of a worker |
| 3     | Serious incident | Very small release: public exposure at a fraction of prescribed limits | Severe spread of contamination/acute health effects to a worker | Near accident |
| No safety layers remaining | | | |
| 2     | Incident | | Significant spread of contamination/overexposure of a worker | Incidents with significant failure in safety provisions |
| 1     | Anomaly | | | Anomalous beyond the authorized operating regime |
| 0     | Deviation | No | Safety | Significant Out-of-scale event | No safety relevance |
### Table 2-52. Examples of events in the nuclear event scale (IAEA 2007)

| Level | Nature of event                                                                 | Examples                                                                 |
|-------|---------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| 7     | Major accident                                                                  | External release of a large fraction of the radioactive material in a large facility (e.g. the core of a power reactor) (in quantities radiologically equivalent to more than tens of thousands of terabecquerels of iodine-131). | Chernobyl NPP, USSR (now in Ukraine), 1986                               |
| 6     | Serious accident                                                                 | External release of radioactive material (in quantities radiologically equivalent to the order of thousands to tens of thousands of terabecquerels of iodine-131). | Kyshtym Reprocessing Plant, USSR (now in Russia), 1957                  |
| 5     | Accident with off-site risk                                                      | External release of radioactive material (in quantities radiologically equivalent to the order of hundreds to thousands of terabecquerels of iodine-131). Severe damage to the installation. | Windscale Pile, UK, 1957                                                |
| 4     | Accident without significant off-site risk                                       | External release of radioactivity resulting in a dose to the critical group of the order of a few millisieverts. Significant damage to the installation. Such an accident might include damage leading to major on-site recovery problems such as partial core melt in a power reactor and comparable events at non-reactor installations. Irradiation of one or more workers resulting in an overexposure where a high probability of early death occurs. | Windscale Reprocessing Plant, UK, 1973 Saint-Laurent NPP, France, 1980 |
| 3     | Serious accident                                                                 | External release of radioactivity resulting in a dose to the critical group of the order of tenths of millisievert. On-site events resulting in doses to workers sufficient to cause acute health effects and/or an event resulting in a severe spread of contamination; for example, a few thousand terabecquerels of activity released in a secondary containment where the material can be returned to a satisfactory storage area. | Buenos Aires Critical Assembly, Argentina, 1983                         |
2.4 Technical Risks

2.4.7 Radiation

The release of radioactive material, and therefore radioactivity, is one of the major concerns about the safety of nuclear power plants. About 2,000 measurement stations observe radioactivity nearly equally distributed over Germany. Additionally, there are further measurement points around nuclear power plants. While such measurement nets have not shown significant release of radioactivity, current investigations show a higher leukemia rate for children in the vicinity of nuclear power plants (Kaatsch et al. 2008).

The reactor four in Chernobyl might have included radioactive material in the scale of \(4 \times 10^{19}\) B before explosion. About \(1–2 \times 10^{18}\) Bq were released during and after the explosion. It has been assumed that all inert gases volatilised. Additionally, about 10–20% of the nuclides iodine, cesium and tellurium discharged. Other nuclides were released at lower

| Level | Nature of event | Examples |
|-------|----------------|---------|
| 2     | Incidents with significant failure in safety provisions but with sufficient defense in depth remaining to cope with additional failures. | Vandellos NPP, Spain, 1989 |
| 1     | Anomaly beyond the authorised regime but with significant defence in depth remaining. This may be due to equipment failure, human error or procedural inadequacies and may occur in any area covered by the scale, e.g. plant operation, transport of radioactive material, fuel handling, waste storage. | |
| 0     | Deviations where operational limits and conditions are not exceeded and which are properly managed in accordance with adequate procedures. | |

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portions. Twenty-five percent of the released material exited the reactor on the first day. The rest of the material was released over the next nine days into the environment. About 115,000 people were evacuated after the accident. So far, only the unit Becquerel has been introduced as a measure of radioactivity. However, other measures with relation to radioactivity should be mentioned as well. “Gray” is the measure for the absorbed dose. While Becquerel is given per second, Gray (Gy) is given in Joule per kilogram. The dose can be used to quantify damages to creatures. Unfortunately, exact lethal dose cannot be given, and therefore the so-called median lethal dose (LD$_{50}$) given. This is the dose killing 50% of the exposed population. For humans with a good medical treatment this value reaches about 5 Gy, whereas excellent medical treatment, might shift the LD$_{50}$ up to 9 Gy. Figure 2-59 shows the distribution of the percentage of death from a population for some dose. A further measure related to the dose is the Sievert. The Sievert is also given in Joule per kilogram, but it considers the different effects of different types of ionizing radiation. $\alpha$-, $\beta$-, $\gamma$-radiation have different consequences, and therefore the Sievert gives the opportunity to compute an equivalent dose.

Of course, ionizing radiation has impacts on animals and plants. However, no effects for acute radiation exposure were found with less than 0.1 Gy (in terrestrial environment). A chronical radiation exposure of less than 1 mGy per day did not show effects. In aquatic environments, these values are 10 times higher (Paretzke et al. 2007, Wenz et al. 1980).

Returning to the accident of Chernobyl: on 26 and 27 April, the radiation reached about 10 mSv per hour. At that amount of radiation, it was decided to evacuate the population. People working in the rescue team might have been exposed up to 15 Gy. Extreme values of the radiation might have been in the order of 40 Gy. The average dose in the area lying 30 km around the nuclear power plant was 2 Gy. At least 237 people experienced severe radiation disease, and approximately 30 people died soon after the event by this disease.

Most people cleaning the area were exposed to an equivalent dose of 100–250 mSv (IPSN 1996). Most parts of the population were exposed to 15 mSv. From this amount of radiation, most parts come from the consumption of radioactive meat and milk products. About 700,000 people were exposed to 100 mSv. The related probability of cancer is about 0.005. Most countries of the northern hemisphere were affected by this release of radioactive material. However, the radiation values were rather low. For example, in Denmark, a dose of 0.02 mSv was reached as compared to the natural radiation dose of 2.4 mSv. Further information can be found in Jacob (2006). Kelleter (2006) mentions that the chance of cancer for the overall population in Russia changed from 20% to 22%. In Germany, about 2,000
additional cancer cases are assumed. However, the number of new cancer cases reaches about 330,000 per year.

Another example of a major accident, however not related to nuclear power plants, was the release of radioactive material in the Brazilian city of Goiania. Here, an X-ray apparatus was stolen and disassembled in a scrap yard. About 249 people were contaminated, and about 120,000 people were controlled for contamination.

Fig. 2-59. Stochastic and deterministic relation between radiation dose and mortality (Jensen 1994, IAEA 1991)

However, radionuclides are common in the environment. The amount of radioactive material in a typical human body is shown in Table 2-53. Table 2-54 gives some radiation values for Radon 226 in German beer and drinking water (Überkinger Quelle).

This natural radiation is not surprising since primordial radionuclides can be found in natural decomposition. The origin of nuclides can be divided into two parts: the galactic cosmic processes, namely the background radiation and supernovas, are the first part. This part is the source of all heavy nuclides in man and the environment. The solar cosmic processes, namely solar activity and solar flares, are the second part. The sun is actually the source of all light nuclides in man and the environment (Van der Heuvel 2006).

Natural primordial radionuclides with their half-life period are given in the Tables 2-55 and 2-56.
### Table 2-53. Natural radioactive material in a typical human (50 kg) in Bq (Paretzke et al. 2007)

| Nuclide     | Presence in Bq |
|-------------|----------------|
| Tritium     | 20             |
| Carbon-14   | 3,500          |
| Pottasium-40| 4,00           |
| Rubidium-87 | 600            |
| Lead-210    | 18             |
| Polonium-210| 15             |
| Radium-226  | 1.2            |
| Uranium-238 | 0.5            |

### Table 2-54. Content of Radon 226 in German beer and drinking water (Paretzke et al. 2007)

| Nuclide               | mBq/l |
|-----------------------|-------|
| Schneider Weiße       | 147   |
| Erdinger Weissbier    | 13    |
| Pkantus Weizenbock    | 9     |
| Paulaner Beer         | 33    |
| Überkinger Quelle     | 296   |

### Table 2-55. Half-life period of primordial radionuclides (Paretzke et al. 2007)

| Nuclide | Half-life period in years |
|---------|---------------------------|
| K-40    | $1.3 \times 10^9$         |
| Rb-87   | $4.8 \times 10^{10}$      |
| In-115  | $4.0 \times 10^{14}$      |
| Te-123  | $1.2 \times 10^{15}$      |
| Te-128  | $1.5 \times 10^{24}$      |
| Te-130  | $1.0 \times 10^{21}$      |
| La-138  | $1.4 \times 10^{11}$      |
| Nd-144  | $2.1 \times 10^{16}$      |
| Sm-147  | $1.1 \times 10^{11}$      |
| Sm-148  | $7.0 \times 10^{16}$      |
| Gd-152  | $1.1 \times 10^{14}$      |
| Lu-176  | $3.6 \times 10^{10}$      |
| Hf-174  | $2.0 \times 10^{15}$      |
| Ta-180  | $1.0 \times 10^{13}$      |
| Re-187  | $5.0 \times 10^{10}$      |
| Os-186  | $2.0 \times 10^{16}$      |
| Pb-190  | $6.1 \times 10^{11}$      |
| Pb-204  | $1.4 \times 10^{17}$      |
### Table 2-56. Half-life period of primordial radionuclides (Paretzke et al. 2007)

| Nuclide   | Half-life period |
|-----------|------------------|
| Tritium   | 12.3 years       |
| Beryllium 7 | 53.3 days      |
| Carbon 14 | 5,730 years      |
| Sodium 22 | 2.6 years        |

Radon concentrations in the environment are widely discussed. (Brüske-Hohlfeld et al 2006). Umhausen (2,600 inhabitants) in Tyrol, Austria, is an example of high natural ionosing. Here are some radioactivity values measured in houses:

- Yearly average dose: 2,000 Bq/m²
- Extreme values: 40,000 Bq/m²
- Highest value ever measured: 274,000 Bq/m²

In the last 20 years, there were about 41 deaths due to lung cancer in Umhausen. Statistically, only six to seven cases were expected. The major cause for the high radioactivity was probably the very high permeability of the ground, which might have been caused by a huge rock or debris flow about 10,000 years ago. Radon is not only a major contributor to natural radiation in some regions, like in Umhausen or some parts of India. In Germany, Radon contributes to about 25% to the natural radiation (Brüske-Hohlfeld et al. 2006). Moreover, radiation during flying has been considered as risk (Schraube 2006). Although accidents have happened in nuclear power plants or nuclear weapon production and storage as shown in Tables 2-57 and 2-58, the overall contribution is rather low as shown in Table 2-59. Of greater concern is the increasing radiological radiation exposure by medical treatment, for example computer tomography (DA 2007) as shown in Fig. 2-60. Here, recommendations can be found at EANM (2007).
Fig. 2-60. Radiation exposition in Germany (BfS 2007)

Table 2-57. Major accidents and routine releases of radioactivity into the environment (Paretzke et al. 2007)

| Activity                  | Mode of release |
|---------------------------|-----------------|
|                           | Routine action  | Accidental event                      |
| Military purposes         |                 |                                             |
| Weapon production         | Hanford, USA (1944–1945) | Techa River, USSR (1949–1951) |
|                           | Chelyabinsk, USSR (1948–1956) | Kysim, USSR (1957) |
|                           |                 | Windscale, UK (1957) |
|                           |                 | Rocky-Flats, USA (1969) |
|                           |                 | Tomsk-7, USSR (1993) |
| Atmospheric tests         | Nevada, USA (1951–1962) | Altay, USSR (1949) |
|                           | Semipalatinsk, USSR (1949–1962) | Marshall Islands, USA |
|                           | Novaya Zemlya, USSR (1955–1962) | (1954) |
| Nuclear fleet transport   | Kola Peninsula, USSR | Palomares, Spain (1966) |
| Weapon transport          |                 | Thule, Greenland (1968) |
| Power production          | Worldwide | Three Mile Island, USA (1979) |
| Reactor operation         |                 | Chernobyl, USSR (1986) |
| Fuel processing           | Sellafield, UK | La Hague, France |
Table 2-50. (Continued)

| Activity          | Routine action | Accidental event |
|-------------------|----------------|------------------|
| Radioisotope use  |                |                  |
| Loss of sources   |                | Cuidad Juarez, Mexico (1982) |
|                   |                | Goiania, Brazil (1987) |
| Satellite re-entry|                | SNAP-9A, Global (1964) |
|                   |                | Cosmos-954, Canada (1978) |

Table 2-58. Further information about some accidents in terms of the amounts of nuclide-specific radioactivity released in pBq (Paretzke et al. 2007)

| Event              | $^{131}$I | $^{137}$Cs | $^{90}$Sr | $^{106}$Ru | $^{144}$Ce | $^{239,240}$Pu |
|--------------------|-----------|------------|-----------|------------|------------|---------------|
| Techa River        | $6.5 \times 10^5$ | 12 | 12 | 10...20 | $\approx$10 | 11 |
| Nuclear tests 1952–1962 | 0.7 | 910 | 600 | 12 000 | 30 000 | 0.07 |
| Kystim             | 1 200 | 0.03 | 2 | 1.4 | 24 | $6.0 \times 10^{-6}$ |
| Windscale          | 0.02 | 8 | 0.003 | 140 |
| Chernobyl          | 85 | 30 | 0.0002 |
| Goiania            | 0.05 | 0.01 |

Table 2-59. Residue in Germany (Paretzke et al. 2007)

|                | mSv per year |
|----------------|--------------|
| Fallout Chernobyl | 0.015       |
| Fallout A-Bombs  | 0.01         |
| Technology and Research | < 0.02 |
| Nuclear Power Plants | < 0.001 |
| Profession       | < 0.01       |

Here, so far only ionising radiation has been considered a risk. Unfortunately, it is unclear whether non-ionising radiation might also include risks (Junkert & Dymke 2004). Such non-ionising radiation is heavily used in mobile phones. This is an example where humans are not concerned about the risk, as the advantage is so manifest and the disadvantage is so uncertain. This constellation has also been true for many chemicals.

2.4.8 Chemicals

Chemicals might impose hazards of explosion, poisoning, suffocation, fire, fire support, cauterisation, frostbite, infection or contamination of the environment.
Currently, there are about 10 million chemicals known. Between 50,000 and 70,000 of them are produced, stored, transported and used in great quantities. The European Inventory of Existing Commercial Chemicals includes about 100,000 materials or material groups that have been available in the European market since 18 September 1981. All so-called high production volume chemicals, with a volume of more than 1,000 tonnes have been investigated. These include approximately 2,600 materials. These materials were put into 140 groups, which were investigated in terms of risk (Ahrens 2001).

In the workplaces, there are about 500 scientifically based limits that set the allowable concentration values of certain chemicals; however, 5,000 substances are used in a significant amount at certain workplaces (Brandhofer & Heitmann 2007).

Hazardous chemicals have always been produced, transported, stored and used. As a toxicity measure in Fig. 2-61, the total dose for some chemicals is given. About 8,000 chemical plants exist in Germany. Usually chemical plants are quite often considered a hazard. In Germany per year, between 10 and 20 severe accidents happen in chemical plants. Therefore, the frequency of such an accident is \(1−2 \times 10^{-3}\) per year per plant (Ruppert 2000). However, it seems that the number of accidents is decreasing (Ruge 2004).

One of the worst accidents in chemical plants was a major explosion in the BASF plant in Oppau in 1921. On 21st September, about 4,500 tonnes of ammonium nitrate exploded. The explosion created a crater of a diameter of 100 m and a depth of 20 m. About 500 people were killed. After this accident, the trade and production of ammonium nitrate was forbidden in Germany.

Incidentally on 21st September 2001, a major explosion of ammonium nitrate happened, but now in Toulouse, France. The number of victims reached about 30; however, the number of injured people came to thousands. About 30,000 flats, 700 public buildings and 112 schools were damaged. The explosion caused a panic, and the drinking water supply in Toulouse was interrupted for three days (Hubert et al. 2004, Munich Re 2004a,b).

Explosions in chemical plants occur regularly worldwide. Other examples are an explosion of fuel in Cleveland in 1944 with about 130 fatalities (Considine 2000) or an explosion in a pharmaceutical plant in Kingston, North Caroline, in 2003 with about 30 injured (Munich Re 2004a,b). One of the recent accidents with fires in plants occurred on 11th December 2005 in Brucefield, Great Britain. The complete damage was about 500 million British pounds. There were 43 fatalities. However, the number could have
been much higher, became fortunately the fire broke out on Sunday in an industrial area.

However, explosions and fire are not only the result of uncontrolled release of chemical substances. Such substances might also be toxic. For example, in 1976 in Seveso in Italy, about 2kg of dioxin was released into the environment. Cows and small animals died in the vicinity of the source. About 70,000 poisoned farm stock animals had to be killed, 200,000 people received medical treatment, and several houses heavily exposed to the poison had to be demolished.

Probably the worst chemical accident happened on 3rd December 1984 in Bhopal in India. About 40 tonnes of methyl isocyanate were released into the environment killing almost 4,000 people. According to different source, between 20,000 and 250,000 people experienced long-term permanent or partial disabilities (Broughton 2005, Union Carbide 2007).

As shown in this example, the effects of released chemicals can be categorised into long-term and short-term hazards. Long-term hazards are generated by exposure to a low concentration of a chemical over the long term, whereas short-term hazards are generated by exposure to a high concentration of a spontaneously released chemical presenting an immediate danger.

Another example of the consequences of unintended release of chemicals was the fire in November 1986 at the Swiss company Sandoz. The water for fire fighting washed toxic insecticides into the river Rhine. Over a river length of 400 km, heavy damages occurred to the river flora and fauna (Rütz 2004).

The final example in this section, which was related to mining, is an accident in 2003 in China in a gas field. Although this was not essentially a chemical plant, it was related to some chemical material. The release of the gas killed about 250 people, injured more than 9,000 people and caused the evacuation of about 60,000 people (Spiegel 2003).

Many more examples could be given from production plants. However, accidents can also occur during transport. In Austria, there are over 1.7 million transportations of hazardous chemicals on roads and about 130,000 railway wagons transporting hazardous chemicals per year. There are approximately 20 accidents with trucks carrying hazardous chemicals per year in Austria. About 20% of the container ship transport worldwide includes hazardous materials. This value is surprisingly high, however why so many transportations are carried out, however many chemicals are used in daily life. Figure 2-62 some shows some common warning signs seen on many household chemical bins. Several chemicals are hidden in technical equipment. For example, ammonia is heavily used as a refrigerant in skating sport centers or in cooling houses. Chloride is used in swimming pools for
disinfection purposes. Currently, alternatives to chlorine are being developed to avoid the future application of chloride in public rooms by terrorists. Moreover, in agriculture, many hazardous chemicals are applied, such as fertilizers and pesticides.

Fig. 2-61. Total dose 50 for different chemicals

Fig. 2-62. Examples of warning signs
2.4.9 Fire

As already mentioned, fire can be a risk related to some chemicals. In general, fire is defined as “uncertain type of burning which spreads out uncontrolled” (DIN 14011 and ÖNORM F 1000 Part 2). Fire requires heat, oxygen and burning material. A list of major fires is given in Table 2-60.

Besides, several biggest conflagrations were intentionally caused during World War II. Some German cities that were heavily bombed with incendiaries experienced up to 100,000 fatalities, such as Hamburg in 1943 or Dresden in 1945.

As seen from Table 2-60, fire disasters already happened in times of early civilization. The first water pump for fire-fighting was invented in 250 B.C. by Ktesibios in Alexandria. Hero from Alexandria introduced a portable pump (NN 1997). Already, however, around 2400 to 2000 B.C., the old Egyptian language had signs for conflagration and burning city (Flemmer et al. 1999).

In 1518, the Augsburgian Goldsmith invented a drivable syringe (NN 1997). Fireplugs were introduced in Great Britain after the Great Fire of London in 1666. About the same time, the Dutch man van der Heijden invented the water hose and the hand pump for fire-fighting.

In 1676, the first fire insurance company, the Hamburgian General-Feur-Cassa, was founded. Most of the regional fire insurance companies in Germany were founded in the 18th century, for example the Lippian State Fire Insurance. Prior to insurance, people who lost their property to fire were regularly given permissions to beg. This however, did not help the people much (NN 1997).

However, technical inventions improved fire safety. Lightning rods were already known in antiquity, but were forgotten. They were reinvented by Benjamin Franklin in 1750. The first lightning rod was installed in 1769 at the Hamburgian church St. Jacobi (NN 1997). In 1829, hand pumps were substituted by machine pumps, and in 1888 in Chicago, the first turn-table ladder was introduced (Flemmer et al. 1999). Especially, the introduction of sprinkler fire-extinguishing installation decreased the number of fire victims as shown in Fig. 2-63 for Canada.

Table 2-60. List of severe fires (Flemmer et al. 1999)

| Time            | Location         | Victims                  | Remark                     |
|-----------------|------------------|--------------------------|----------------------------|
| 19 July 64 A.D.| Fire of Rome     | Not known                | Probably intentional       |
| August 70 A.D.  | Destruction of    | 1/4 of the Jewish        | Probably/partially         |
|                 | Jerusalem        | population perished      | intentional               |
| September 1666  | Great Fire of     | Only 8 fatalities, but   | London had just            |
|                 | London           | 100,000 left             | experienced a pest         |

(Continued)
| Time          | Location                  | Victims                      | Remark                                                                 |
|--------------|---------------------------|------------------------------|------------------------------------------------------------------------|
| September 1812 | Fire of Moscow            | homeless                     | epidemic the previous year. Intentional                                |
| 17 January 1863 | Fire in a church of Santiago de Chile | 2,500 fatalities             |                                                                         |
| 8 October 1871 | Great Fire of Chicago     | About 300 fatalities, but 90,000 left homeless | The damage had been estimated at about 200 million dollars yielding to the liquidation of 54 American fire insurances. |
| 8 October 1871 | Forest fire of Peshtigo, Wisconsin | 2,682 fatalities             | About 1,000 km² area of forest burnt.                                  |
| 8 December 1881 | Theatre fire of Vienna    | 896 fatalities                |                                                                         |
| 3 February 1901 | Oil field fire of Baku    | More than 300 casualties      |                                                                         |
| 15 June 1904 | Fire of the steamer “General Slocum” on Hudson river | More than 1,000 fatalities involving children and mothers |                                                                         |
| 10 March 1906 | Mine fire of “Courrières” | 1,205 fatalities              |                                                                         |
| 22 September 1928 | Fire in Novedades theater in Madrid | About 110 fatalities and 350 injured |                                                                         |
| 6 June 1931 | Glass palace in Munich    |                              |                                                                         |
| 2 March 1934 | Hakodate, Japan           | More than 900 fatalities, 2,000 injured and about 150,000 homeless | The fire occured together with a snowstorm. Most of the fireplugs were frozen. An area of about 15 km² was completely destroyed. |
| May 1937 | Fire of “Hindenburg” in Lakehurst | 35 fatalities | With about 590 flights 16,000 passengers were transported over the years. |
| 1937 | Fire of a high school in London, Texas | 294 children | Gas explosion |
| 28 July 1945 | Fire in Empire State      |                              |                                                                         |
Table 2-60. (Continued)

| Time          | Location                              | Victims                  | Remark                                                                 |
|---------------|---------------------------------------|--------------------------|------------------------------------------------------------------------|
| 16 April 1947 | Explosion of French Tanker “Grandcamp” in Texas City | More than 2,000 fatalities | 90% of all houses in Texas city destroyed, 100 million US dollars loss. |
| 28 July 1948  | Fire in BASF in Ludwigshafen           | 178 fatalities and 2,500 injured |                                                         |
| 9 June 1995   | Collision of “Johannishus” in the English Channel | 323 fatalities and over 500 injured | 2,500 people visited a circus performance, when the circus tent started to burn and fall down. |
| 1 December 1960 | School fire in Chicago                |                          |                                                         |
| 19 July 1960  | Mine fire in Salzgitter               |                          |                                                         |
| 17 October 1960 | Ship fire on Rhine                   |                          |                                                         |
| 17 December 1961 | Circus fire in Niteroi, Brasilia     | 323 fatalities and over 500 injured |                                                         |
| 22 December 1963 | Fire on “Lakonia”                    | 180 fatalities and 600 injured |                                                         |
| 11 July 1978  | Explosion of a tank truck at the camping site “Los Alfaques” in Spain | 170 fatalities |                                                         |
| 6 July 1988   | Explosion of “Piper Alpha” in the North Sea | 343 fatalities and 2,000 injured |                                                         |
| 15 April 1997 | Fire in Mina (close to Mekka)         | 210 fatalities and 500 injured |                                                         |
| 1998          | Fire of a toy production plant in Bangkok | 210 fatalities and 500 injured |                                                         |
| 17 October 1998 | Pipeline fire in Nigeria              | Probably more than 1,000 fatalities | An oil pipeline leaked and people attempted to take from a sea of oil. The oil lake exploded. |
| 30 October 1998 | Fire of discothèque in Göteborg       | 61 fatalities             |                                                         |
| 3 December 1998 | Fire of orphanage in Manila           | About 30 fatalities       |                                                         |
The main causes of death by fire are: suffocation by carbon monoxide (more than 60%), combustion (approximately 26%) and physical violation (more than 10%) (Schneider und Lebeda 2000). In Germany, fires cause an average yearly damage in the double-digit billion Euro range (Friedl 1998). Every year, about 220,000 fires are registered, but only full fires are collected in a database. That means there is an average of 2.75 fires per 1,000 capita (Mehlhorn 1997). Table 2-61 gives the direct damage of fires for different countries in relation to the gross national product. The distribution of fires subject to different building categories is shown in Table 2-62 for Finland. This distribution is partially reflected in the fire loads for different building categories shown in Table 2-63 and by the probabilities of fire for different building categories shown in Table 2-64. Causes of fires are given in Table 2-65, and Table 2-66 gives probabilities of fire accretion under different firefighting conditions.
Table 2-61. Fire damages in developed countries (Schneider und Lebeda 2000, Mehlhorn 1997, Tri Data Corporation 1998, World Fire Statistics Center London)

| Country   | Direct fire damages as percentage of gross national product | Number of fire fatalities per 1,000,000 inhabitants (Mehlhorn 1997) |
|-----------|------------------------------------------------------------|---------------------------------------------------------------------|
| USA       |                                                            | 21–27                                                               |
| Finland   | 0.19                                                       | 22–24                                                               |
| England   | 0.24                                                       | 19–21                                                               |
| Sweden    | 0.21                                                       | 16–20                                                               |
| Denmark   | 0.39                                                       | 15–20                                                               |
| Belgium   | 0.45                                                       | 20                                                                  |
| France    | 0.26                                                       | 13–19                                                               |
| Norway    | 0.34                                                       | 17–18                                                               |
| Netherlands | 0.20                                                   | 6–13                                                               |
| Germany   | 0.19                                                       | 9–13                                                                |
| Italy     | 0.15                                                       | 7–9                                                                 |
| Switzerland | 0.25                                                    | 5–6                                                                 |
| Austria   | 0.16                                                       | 7                                                                   |
| Canada    |                                                            | 18–22                                                               |
| Spain     |                                                            | 7–12                                                                |
| Japan     |                                                            | 14–16                                                               |

Table 2-62. Number of fires from 1996 to 1999 and areas of different building categories in Finland according to Rahikainen & Keski-Rahkonen (2004)

| Occupancy                                      | Fires | Total area (m²)   |
|------------------------------------------------|-------|-------------------|
| Residential buildings                          | 4,361 | 231,565,978       |
| Commercial buildings                           | 356   | 18,990,450        |
| Office buildings                               | 140   | 16,354,516        |
| Transport and firefighting and rescue service buildings | 123   | 10,627,751        |
| Buildings for institutional care               | 197   | 8,780,942         |
| Assembly buildings                             | 112   | 7,379,199         |
| Educational buildings                          | 122   | 15,801,759        |
| Industrial buildings                           | 1,038 | 40,321,357        |
| Warehouses                                     | 405   | 7,434,710         |
| Other buildings                                | 2,650 | 2,437,960         |
### Table 2-63. Excerpt from BSI (2003) and NFSC fire load densities taken from Weilert & Hosser (2007)

| Occupancy                  | Fire load density (mJ/m²) | Average | 80%  | 90%  | 95%  |
|----------------------------|---------------------------|---------|------|------|------|
| Dwellings                  | 780                       | 870     | 920  | 970  |
| Hospital (room)            | 230                       | 350     | 440  | 520  |
| Hospital storage           | 2,000                     | 3,000   | 3,700| 4,400|
| Hotel (room)               | 310                       | 400     | 460  | 510  |
| Office                     | 420                       | 570     | 670  | 760  |
| Shops                      | 600                       | 900     | 1,100| 1,300|
| Manufacturing              | 300                       | 470     | 590  | 720  |
| Manufacturing and storage  | 1,180                     | 1,800   | 2,240| 2,690|
| Libraries                  | 1,500                     | 2,250   | 2,550| –    |
| Schools                    | 285                       | 360     | 410  | 450  |

### Table 2-64. Probability of fire for different building types (Schneider & Lebeda 2000)

| Type of building           | Country    | Probability of fire per million m² floor space per year |
|----------------------------|------------|--------------------------------------------------------|
| Industry building          | Great Britain | 2                                                      |
| Industry building          | Germany    | 2                                                      |
| Office building            | Great Britain | 1                                                      |
| Office building            | USA        | 1                                                      |
| Residential building       | Great Britain | 2                                                      |
| Residential building       | Canada     | 5                                                      |
| Residential building       | Germany    | 1                                                      |

### Table 2-65. Causes of fires (Tri Data Corporation 1998)

| Cause of fire                      | Percent of fires |
|------------------------------------|------------------|
| Unknown cause                      | 47.2             |
| Arson                              | 15.5             |
| Open fires                         | 6.6              |
| Arson by children                  | 2.9              |
| Heating                            | 3.8              |
| Cooking                            | 5.4              |
| Electric distributor (cables)      | 4.5              |
| Heat radiation from other sources  | 2.4              |
| Smoking                            | 3.2              |
| Natural fires (lightning)          | 1.3              |
| Electrical appliances in household | 2.1              |
| Explosions, fireworks              | 3.0              |
| Other electrical appliances        | 2.0              |
Table 2-66. Probability of fire accretion according to firefighting equipment based on Bub et al. (1983)

| Firefighting by                                      | Probability that a fire will develop to a full size |
|------------------------------------------------------|------------------------------------------------------|
| Public fire brigade                                  | 0.1                                                  |
| Sprinkler                                            | 0.01                                                 |
| Well-equipped, factory-owned fire brigade with fire detector system | 0.001–0.01                                           |
| Sprinkler system and well-equipped, factory-owned fire brigade | 0.0001                                               |

Fig. 2-64. Number of fatalities of fire accidents in tunnels (Rackwitz & Streicher 2002)

A special type of fire is fires in tunnels. Such events receive great public attention when they happen. A list of several tunnel fires can be found in Promat Tunnel (2008), and in combination with the transport of hazardous materials in Cassini & Pons-Ineris (2000) (Fig. 2-64). Much work was carried out after the accident in the Mont Blanc road tunnel in 1999 (Bergmeister 2006, 2007, Krom & de Wit 2006). Although high temperatures can be reached, the major problems with tunnel fires are the smoke and restricted orientation capability. It has been estimated that under an optical
smoke density of 0.066 m$^{-1}$, the visibility is less than 4m, and therefore people unfamiliar with the tunnel are unable to find emergency exits. People who know the tunnel might find emergency exits with a visibility of 1m. However, in addition to limited visibility, the smoke also usually contains toxic materials like carbon monoxide or acids. With a carbon monoxide density between 600 and 800 ppm in air, humans become unconscious (Fileppo et al. 2004).

In some cases, the fire is directly related to car accidents and transportations of hazardous materials. Moreover, human behaviour in tunnels might increase risks. It is interesting to note that the type of lights in tunnels might have to fulfill some requirements in order to not cause epileptic seizures.

### 2.4.10 Explosions

Explosions and fires are often connected. An explosion is an extremely fast force based on the expansion of gases or steam (VGB 2001). The velocity of an explosion is usually so high that humans are unable to identify the sequences of it. The speed of combustion can be used for the classification of fire and explosion, as shown in Table 2-67. Table 2-68 gives examples of distances travelled by explosion particles, and Table 2-69 lists the effects of overpressure caused by explosion.

| Combustion | Combustion speed |
|------------|-----------------|
| Deflagration | Millimeter per minute |
| Explosion | Centimeter per minute |
| Detonation | Meter per second |
| Detonation | Kilometer per second |

#### Table 2-67. Classification of fire and explosion based on the combustion speed

| Year       | Distance from explosion centre | Mass (kg) | Speed (m/s) |
|------------|--------------------------------|-----------|-------------|
| Romeo Village 1984 | Fragments of tank 500 m high and 3,000 away | – | 100–170 |
| Crescent City | Fragments of tanker 100 m away | >10,000 | 85 |
| Mexico City 1984 | Fragments of tank 400 m away | 13,000 | 60–150 |
| Feyzin 1966 | Slab elements 300 m away | 70,000 | – |
| Texas City 1978 | Parts 230 m away | – | – |
Table 2-69. Effects of overpressure caused by explosion

| Overpressure in bar | Effect                        |
|---------------------|-------------------------------|
| 0.60                | Immediate fatalities          |
| 0.30                | Failure of structures         |
| 0.20                | Heavy damages to structures   |
| 0.14                | Deadly injuries               |
| 0.07                | Heavy injuries                |
| 0.03                | Glass failure                 |

Some examples of major explosions will now be provided. In 1645, a gun powder tower in Delft exploded. The explosion was heard within a 80-km radius. Nowadays, there is a market place at the origin of the explosion. In 1807, a boat loaded with gun powder exploded in the Dutch city of Leiden. About 150 people were killed, including 50 children. It was said that Napoleon visited the site of explosion and wrote an Imperial decree dealing with the location of factories inside cities based on their hazardous level. It is surprising to note that this still has not been successfully applied in practice even after 200 years. Therefore, since 1807, the number of explosions inside cities has continued to rise. For example, there was a large explosion of gun powder in 1867 in Athens (Ale 2003).

Two of the biggest explosions in history were connected to ships that were loaded with gun powder. The first of these two disasters was the explosion on 6 December 1917 in Halifax, Canada. The French transport ship Mont Blanc was scheduled to transport gun powder to the European battlefields. The ship was loaded in November in New York with gun powder that had an equivalent explosive force of 3kt TNT (Trinitrotoluene). The ship was supposed to enter the harbour of Halifax, Canada, prior to traveling to Europe. To sail to Halifax, the Narrow Canal had to be navigated before entering the city harbour. The Norwegian freighter Imo tried at the same time as the Mont Blanc to enter the Narrow Canal. Additionally, the Norwegian freighter was travelling at potentially double the allowed speed in the canal and rammed into the Mont Blanc. The collision parts of the Imo bored into the starboard side of the Mont Blanc. Benzene barrels on the deck of the Mont Blanc were damaged and leaked. Unfortunately, the captain of the Imo decided to free his ship again. As a consequence, benzene was ignited by the friction between the metal parts of the ships scraping against each other, and further benzene barrels exploded on the deck of the Mont Blanc. Therefore, the entire front part of the Mont Blanc stood in flames. The firefighting capacity of the ship was overburdened and unable to extinguish the fire. The captain of the ship, however, did not decide to sink the Mont Blanc but to abandon it. The ship then did not just explode but floated towards Richmond, a suburb of Halifax. It reached the
piers and enflamed them. Some attempts were made to tow the Mont Blanc away from the piers but they failed. In the end, the entire ship exploded half an hour after the collision. The explosion killed about 2,000 people, many of them watching the fire in the neighbourhood of the pier. About 9,000 people were injured. The ship itself was torn apart and parts of the ship were found several miles away. Several ships in the harbour were destroyed or heavily damaged. A railway bridge was also heavily damaged by the explosion and collapsed under a train. Wagons of the train fell. The explosion not only caused many casualties, but also left about 25,000 homeless (Korotikin 1988).

A comparable disaster happened during World War II in 1944 in Bombay. Here, a ship, the Fort Stikene, was loaded with 1,400 tonnes of gun powder. The ship was also transporting cotton and dry fish at the same time. It was scheduled to be unloaded on 13 April 1944. In the morning, the unloading began. In the afternoon, a fire in the cotton was found. For two and half hours, the crew tried to stop the fire, but they failed. Even worse, on the outside of the ship, a glowing spot had become visible. The fire spread out, reaching the sectors of the ship with the gun powder. Again, the ship was not sunk or pulled out of the harbour. When the ship exploded, around 13 ships in the neighborhood were lost. In a radius of 400 m, all buildings experienced heavy damages, including 50 storage facilities. The glowing parts of the ship ignited hundreds of fires in the city and began to spread. Two days later, on 15 April, the fires reached the centre of the city. The fire reached to such an intensity that it was visible from approximately 120 km away. To avoid the complete loss of Bombay, a fire protection stripe of a width of 400 m was formed. The explosion caused 1,500 fatalities, 3,000 injuries and left countless people homeless (Korotikin 1988).

Even though the Bombay explosion occurred over half a century ago, events in the last few years show that the hazards of explosions remain. While some explosions connected to the chemical industry are presented in Sect. 2.4.8 section, here the explosion of a fireworks plant in the Dutch city of Enschede in May 2000 is mentioned. This explosion completely destroyed close to 300 houses and killed 22 people.

If a plant using explosive materials is proposed, its location has to be considered. Tables 2-70, 2-71 and 2-72 can help in determining the proper distance of each plant from residential areas. There are three different distance classifications: explosive zone, damage zone and attention zone. The explosive zone is in close proximity to the explosion itself. It is defined by an overpressure higher than 0.6 bars. The damage zone is located between an overpressure of 0.6 and 0.07 bars. Here, deadly injuries can occur. In the
### Table 2-70. Criteria for land use classification according to the Italian Ministry of Public Works Decree 2001, taken from Uguccioni (2004)

| Criteria for definition | Territorial | Class |
|-------------------------|-------------|-------|
| Residential area (criteria: building index in m³/m²) | >4.5 | 1.5–4.5 |
| Places where there is a concentration of people with limited mobility, e.g. hospitals, retirement homes, nurseries, elementary schools | >25 beds | <25 beds |
| Places where a significant concentration of people outdoors can occur, e.g. marketplaces or other commercial places | >100 people | <100 people |
| Places where a significant concentration of people indoors can occur, e.g. commercial centres, office buildings, hotels, high schools, universities | >500 people | <500 people |
| Places where a significant concentration of people can occur, with limited period of presence, e.g. theatres, churches, stadiums, etc. | >100 people outdoors, >1,000 people indoors | <100 people outdoors, <1,000 people indoors max. weekly attendance |
| Railway stations and transportation network nodes | >1,000 people per day | <1,000 people per day |
| Industry, farming | Any dimension |
| Within plant fences, areas nearby within which there are no structures present and where the presence of people is normally foreseeable | Any dimension |

Note: The classes A, B, C, D, E, and F represent different levels of risk associated with land use classification.
third zone, the attention zone, no fatalities should occur, but injuries can happen. The pressure reaches up to 0.03 bars. Obviously, residential areas are only permitted in the attention zone.

As an example, an industry storage facility with 20 tonnes of explosive materials is considered. The explosive zone then reaches approximately 70 m, the damage zone reaches about 420 m and the attention zone reaches about 1,200 m. Therefore, the storage has to have a minimum distance of 420 m from the nearest residential area.

**Table 2-71.** Definition of damage threshold levels according to the Italian Ministry of Public Works Decree 2001, taken from Uguccioni (2004)

| Accident scenario | High lethality | Beginning of lethality | Irreversible damages | Reversible damages | Structural damages/Domino effects |
|-------------------|----------------|------------------------|----------------------|--------------------|-----------------------------------|
| Stationary heat radiation | 12.5 kW/m² | 7 kW/m² | 5 kW/m² | 3 kW/m² | 12.5 kW/m² |
| BLEVE/Fireball (variable heat radiation) | Fireball radius | 350 kJ/m² | 200 kJ/m² | 125 kJ/m² | 200–800 m depending on storage type |
| Flash fire (instantaneous heat radiation) | LFL | 1/2 LFL | – | – | – |
| VCE (peak overpressure) | 0.14 bar | 0.07 bar | 0.03 bar | 0.5 bar |
| Toxic release (absorbed dose) | LC₅₀ (30 min, hmn) | – | IDLH | – | – |

**Table 2-72.** Land use categories compatible with industrial plants according to the Italian Ministry of Public Works Decree (2001), taken from Uguccioni (2004)

| Probability class of events | Effect category |
|-----------------------------|-----------------|
| High lethality               | Beginning of lethality | Irreversible damages | Reversible damages |
| DEF                         | CDEF             | BCDEF | ABCDEF |
| EF                          | DEF              | CDEF | BCDEF |
| F                           | EF               | DEF | CDEF |
| >10⁻³                       | F                | EF   | DEF   |

Much research has been carried out in the field of ammunition storages as special storage case of hazardous materials. Computer programs have been developed to compute risk values, like the program ESQRA-GE from the Ernst Mach Institute in Germany (Doerr et al. 2002). Further works can be
found in Gürke (2002), Swisdak (2001), Kingery & Bulmash (1984), NATO (1997) and Prasse (1983). Ammunition is a major cause of explosions, both unintentional, as shown with examples, and intentional. The biggest non-nuclear explosion of all times occurred on 18 April 1947, when 6,700 tonnes of ammunition were used to destroy the German island Helgoland. The explosion was, however, not successful.

2.4.11 Professional Risks

People who deal with using, producing and storing ammunition are under certain professional risk. These risks can be classified as professional risks. Figures 2-65 and 2-66 show such risks in terms of accident rates for different professions. For example, mining remains a risky profession even if it is not included in Fig. 2-66. It has been estimated that more than 8,000 miners have a fatal accident per year in China. For example, in July 2001, about 200 miners died due to water breaking into a stannary. However, mining disasters have a long history. For example, in the Ruhr area, mining had already started in the 13th century. The exploitation of galleries started there in the 16th century. In 1881, an authority required that every mine has to have two vertical tunnels. This indicates that mitigation measures had been applied probably based on some fatal accidents. However, even so, the severity of such accidents has not decreased over the years, as shown in Table 2-73.

![Accident rates for different professions](image)

**Fig. 2-65.** Accident rates for different professions (Bergmeister et al. 2005)
Fig. 2-66. Accident rates for different countries (Bergmeister et al. 2005)

Table 2-73. Major mining accidents (Kroker & Farrenkopf 1999)

| Year | Location               | Number of fatalities |
|------|------------------------|----------------------|
| 1942 | Benxihu, China         | 1,500                |
| 1906 | Courrières, France     | 1,100                |
| 1960 | Shanxi, China          | 680                  |
| 1960 | Coalbrook, South Africa| 440                  |
| 1913 | Colliery, Wales        | 440                  |
| 1946 | Grimberg, Germany      | 405                  |
| 1866 | Yorkshire, England     | 390                  |
| 1907 | Monongah, USA          | 360                  |
| 1908 | Bockum, Germany        | 350                  |

However, mining is a hazard not only for miners but also for the people living in the neighbourhood of the mines. Several accidents have shown such impacts by the uncontrolled release of toxic mining materials. For example, in April 1998 in Spain, a dam for the storage of colliery wastes broke. The wastes included chemical elements like arsenic, cadmium, thallium and other metals. When the dam broke, about four million cubic-meters of wastewater and mud was released. Although most of the mud deposited close to the dam, other parts flooded an area close to a national
park and ran into the river Guardiam. The accident yielded to major ecological damage (Sjöstedt 2004).

In January 2000, the same type of accident occurred in a gold mine in Romania. Again, the dam for the colliery waste broke releasing, among other materials, about 120 tonnes of cyanide. The waste materials ran into the river Lapus, which is connected to the Theiss and the Danube. It was estimated that more than 1,000 tonnes of fish were poisoned.

An extremely tragic event was the slide of a waste site related to a coal mine in Aberfan in Wales in 1966. This slide claimed 144 victims, most of them children. In 1985, a dam broke in Trentino, Italy, killing 260 people and destroying more than 60 building (European Commission 2003).

However, mining is not the only profession with a certain degree of risk. Other professions also show higher risks as compared to the average profession value. For example, fishing and agricultural professions are exposed to such higher risks (DIRERAF 2007). The building industry also shows higher values. In the German federal state of Saxony, fatal accidents in the construction industry account for 50% of all fatal industrial accidents. The protection against accidents at work is of major interest – not only for the companies alone but also for authorities. For example, in Germany, there exists the Federal Institute for Occupational Safety and Health (BAUA 2008), Association of German Safety Engineers (VDSI 2008) and the Association of Freelance Safety Engineers and Interplant Services (BFSI). This topic is also dealt with in occupational medicine and environmental medicine and includes the assessment of temperatures (Hausladen et al. 2002) and chemicals at the workplace (Böse-O’Reilly et al. 2001).

### 2.4.12 Information Technology

Many industries have existed for decades or centuries, for example, agriculture or mining. However, in such industries, new technologies emerge and are used. In fact, many of these new technologies in such traditional industries are based on new information technologies. Electronic information processing is of utmost importance and has today changed the average working conditions in over a few decades. The personal computer was introduced about 20 years ago. Nowadays, cars, airplanes, ships, elevators, washing machines and traffic lights are at least partly controlled by this technology. Some technologies have experienced an even wider penetration by information technology, like telecommunication and financing. In many of these products, information technology can decide about life and death of humans. So if this technology fails, it might impose a risk to
humans. Therefore, in many cases, the so-called “redundant systems” are used, which still remain operable after some partial failure. Safety is understood in this field as the solution of a given problem in a given time.

However, problems are known. For example, the major public discussion about the Year 2000 problem should be mentioned. In the year 1999, computer failures probably costed about 100 billion dollars in the US alone.

Furthermore, information technology is corrupted intentionally through computer viruses. In 2001, computer viruses caused a damage of about 13 billion US dollars, in 2002 between 20 and 30 billion dollars and in 2003 about 55 billion dollars (c’t 2004, Tecchanel 2004, PC Magazin 2004).

Software engineering, as a special part of the new information technology, was introduced in 1968. Some examples of project failure should be mentioned here. The German Ministry of Finance tried to develop a software called FISCUS, which was planned to be used in all 650 tax offices in Germany and, therefore, homogenise the tax declaration system. The development of the software had already costed about 900 million Euros, but was cancelled after 13 years in 2004, as the goal still remained inaccessible. It is quite interesting to note that the program failed partly due to bureaucracy.

Another example in Germany was the introduction of the web-based program 2All in 2005. This program was designed for the new unemployment regulations in Germany called Hartz-IV-reformation. The new regulations were to be built into the program, and about 2.5 million applications were supposed to be administered through this software. When the software was introduced, only a small bug yielded rather bigger problems: the account numbers were automatically right justified instead of being left justified. Therefore, the bank transfers did not work and a huge number of people did not receive their unemployment benefits (Aßmann et al. 2006).

A third example in Germany was the introduction of the distance-based toll for trucks. Although this is an extremely complicated system, here too some software failures occurred. For example, the automatic update function in the on-board units of the trucks did not function properly causing many problems with the toll registration (Aßmann et al. 2006).

2.4.13 Food

The introduction of factory farming and industrial production of food yielded to new risks in agriculture in the last decades. While in earlier centuries crop failure due to bad weather conditions was the major risk, new risks have emerged, for example, with artificial food additives. The population is extremely sensitive to risks related to food, since food is a general
need for living. However, examples from the last decades show that indeed problems do occur (Table 2-74).

Table 2-74. Some food scandals in Europe (Dittberner 2004)

| Year | Region or country          | Problem                                                                                                                                 |
|------|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| 1971 | Rhineland-Palatinate      | Illegal amount of HCH (hexachlorocyclohexane) in milk                                                                               |
| 1972 | Baden-Württemberg         | Illegal amount of HCH in milk and vegetables                                                                                         |
| 1976 | Germany                   | Salmonellae in poultry                                                                                                               |
| 1977 | Germany                   | Illegal amount of HCH in milk                                                                                                       |
| 1979 | Hesse, Hamburg            | Illegal amount of HCH in milk                                                                                                       |
| 1979 | Nordrhein-Westfalen       | Illegal amount of thallium in milk                                                                                                  |
| 1979 | Hamburg                   | Illegal amount of dieldrin (pesticide) in 500 tonnes of Danish butter                                                              |
| 1980 | Germany                   | Detection of the synthetic hormone (diethylstilboestrol) in veal                                                                      |
| 1981 | Spain                     | Illegal mixture of olive oil with rape oil that was designated for industrial usage. About 20,000 suffered toxication, some dead.   |
| 1982 | Germany                   | Salmonellae in nearly 70% of all deep-frozen chicken detected                                                                       |
| 1984 | Bonn                      | Illegal amount of HCH in milk                                                                                                       |
| 1985 | Austria, Germany          | Detection of anti-freeze agents in Austrian and German wines                                                                      |
| 1986 | Ukraine, Europa           | Radioactivity in food caused by emission of radioactive material from the nuclear power plant in Chernobyl                            |
| 1986 | Italy                     | Red wine mixed with methyl alcohol, about 30 people died.                                                                            |
| 1987 | Germany                   | Detection of worms in sea fishes. The consumption of sea fishes fell sharply and new control procedures were imposed.               |
| 1987 | U.K.                      | First publication of BSE                                                                                                            |
| 1988 | Germany                   | Hormones found in about 70,000 calves                                                                                               |
| 1993 | Germany                   | Reports about spoilt meat in freezers                                                                                               |
| 1994 | Germany                   | Pesticide detected in baby food                                                                                                     |
| 1995 | Bavaria, Baden-Württemberg | Antibiotics found in honey                                                                                                          |
| 1996 | Germany                   | Application of toxic disinfection agents for cleaning of hen-coops                                                                  |
| 1997 | Germany                   | Illegal import of beef from U.K.                                                                                                     |
| 1997– | Italy, Belgium            | Production of butter using suet and chemicals in Italy, distribution mainly in Belgium.                                             |
| 1999 | Belgium                   | Animal feed mixed with dioxin containing industrial oil leading to, prohibition of eggs, butter and meat products                  |

(Continued)
Table 2-74. (Continued)

| Year | Region or country | Problem |
|------|-------------------|---------|
| 2000 | Spain             | Illegal amount of pesticides found in spanish capsicum |
| 2001 | Germany, Austria  | Application of hormones and vaccines for the fattening of pigs |
| 2001 | Europe            | Import of shrimps from Asia treated with antibiotics |
| 2002 | Netherlands, Germany | Import of veal loaded with chloramphenicol |
| 2002 | Sweden, Europe    | Detection of acrylamid in some foods |
| 2002 | Thailand, Hesse   | Import of Thai poultry containing nitrofuran |
| 2002 | Germany           | Nitrofen (herbicide) found in wheat |
| 2002 | Italy, Germany    | Import of turkey containing tetracyclin |
| 2002 | Germany           | Spoiled poultry in trade |
| 2002 | Germany, Mecklenburg-Western Pomerania | Storage of wheat in the ground of a former military airport, wheat contained high amounts of lead |
| 2003 | Germany, Israel   | Breast milk substitute contained insufficient amounts of vitamin B1, in Israel two babies died |
| 2003 | Italy             | Poison attack on mineral water and milk products |

One of the greatest disasters in industrial food production was probably the BSE epidemic in Great Britain and Europe. It has been found that the BSE (bovine spongiform encephalopathy) originating from sheep infected with scrapie. Unfortunately, several years ago, the idea was born to recycle these sick sheep using their animal protein for ruminant feed production. Other theories consider the spontaneous jump of the disease from sheep to cows. Independent from that theory, sick animals were used for the production of ruminant feed, resulting in the illness of more than 200,000 cows. The number of precautionary slaughters may have run into millions.

The scrapie disease has been well known since about 200 years ago, and the old farmer rule, not to use meat from such sheep, may have prevented the transmission of BSE to humans in previous times. However, the transmission from cows to other mammals has been proven, and therefore the species barrier can be exceeded. A comparable disease is already known from epidemics in Papua New Guinea. Therefore, intensive scientific works were carried out to discuss the transmission of BSE to humans. Since the middle of the 1990s, a modified version of the Creutzfeld–Jakob disease has been observed. However, the proof of the causal relationship seems to be extremely difficult. Nevertheless, in contrast to the original Creutzfeld-Jakob disease, now even young people are hit by the disease.
Currently less than 200 people are infected with the disease. This is a rather low number, but considering an incubation time period of almost 20 years, numbers can still increase dramatically. Recent studies show that incubation time and the probability of a disease depends on the genotype (Dittberner 2004, Worth Matravers et al. 2000, Prusiner 1995, Carrell 2004).

The introduction of a new technology in farming was probably the cause of the epidemics. While most consumers did not realise a change of technology, with genetically modified food, consumers are much more aware of the change. Here, many people refuse to accept such food. However, one should not forget that genetically modified food has been used for decades. Not only is breeding a technology to change the genetic code, radioactive radiation has been also used for at least 30 years to cause mutations in plants and obtain species, with genetically altered properties. In contrast to this widely applied technology, genetic engineering permits the production of transgenic creatures with genetic code from other species (Uni-protokolle 2004, Spahl & Deichmann 2001).

Independent from new diseases and genetically modified food, many other risks are emerging in relation to food. The entire diet has changed in developed countries. This includes the effects of food, design of foods or current cultural development about the skinniness of females as well as the amount of time for meals. An overview about such impacts can be found in Grimm (2001) and Pollmer (2006).

### 2.5 Health Risks

Most people in developed countries die by health problems, not by natural or technical risks. Major causes are cardiovascular diseases and cancer. Then, further causes are ranked. However, in developing countries, the figures look different. Here, infections are of much concern. Figure 2-67 shows the causes of death in Germany and in developing countries. In this section, the health risks are discussed.

#### 2.5.1 Cardiovascular diseases

About 50% of the population in developed countries die of cardiovascular diseases. Between 1975 and 1995, on average of more than 700,000 US Americans died from cardiovascular diseases per year (Parfit 1998).

The term cardiovascular disease, in general, can be defined as all morbid changes in the heart and the vascular system, but includes many different diseases. It includes, for example, coronary diseases, cardiac insufficiency,
local asphyxixia, (mostly) myocardial infarction, high blood pressure and strokes. The diagnosis is based on several techniques, such as anamneses, identifying family risks, diagnosis of the body, electrocardiogram, blood diagnosis or angiographies. Although it is the elderly who are generally exposed to this disease, some progress has been made over the last decades to decrease the incidence and mortality rates associated with this disease. For example, Finland, which experienced an over proportional burden of cardiovascular diseases, introduced a special preventive program in the 1980s. This program included the regular control of blood pressure, the prohibition of smokings, launching the subject “health and hygiene” in schools and the stimulation of the industry to provide low fat and low salt food. As a consequence of the program, the number of cardiovascular disease dropped (Walter 2004). Not only the incidence rate dropped, however, but also the mortality rate dropped through the improvement of medications like beta blockers, thrombolysis or angiotensin-converting enzyme inhibitors. It has been assumed that about 2/3 of the decrease in deaths is based on preventive measures, and about 1/3 is based on acute treatment. Therefore, an early identification of people at risk is necessary. Investigations to identify major risk groups include the:

- Framingham Heart Study, USA
- Seven Country Study, USA
- MONICA (Monitoring of Trends and Determinants of Cardiovascular Diseases), WHO
- ARIC (Atherosclerosis Risk in Communities), USA
- PROCAM (Prospective Cardiovascular Münster), Münster, Germany
- KORA (Cooperative Health Research in the region Augsburg)
- SHIP (Study of Health in Pomerania), Greifswald, Germany
- Heinz Nixdorf Recall Study (Risk Factors, Evaluation of Coronary Calcification, and Lifestyle), Essen, Germany

The studies have so far identified the so-called causal risk factors (Table 2-75), conditional risk factors and predisposing risk factors. The four major risk factors are hypertension, smoking, hypercholesteremia and diabetes. They can explain about 75–85% of all new cases. Risk calculators can be found on the internet, for example at Universität Münster (2007) or at BNK (2007). A good news about these risk factors is the fact that they are reversible or treatable. Further risk factors, which are still under discussion, include Hypertriglyceridemia, Lipoprotein-a, hyperhomocysteinemia, hypercoagulability, c-reactive protein (CRP), processes of inflammation and coronary calcium deposit (WHO 2003, Schaefer et al. 2000, Fargeman 2003, Marmot & Elliott 1995, Keil et al. 2005, Kolenda 2005).
### Table 2-75. Risk factors for cardiovascular diseases (Grundy 1999)

| Risk factor       | Categorical level                     |
|-------------------|---------------------------------------|
| Cigarette smoking| Any current                           |
| Blood pressure    | ≥ 140 mm Hg systolic                   |
|                   | ≥ 90 mm Hg diastolic                   |
| LDL cholesterol   | ≤ 160 mg/dL                           |
| HDL cholesterol   | < 35 mg/dL                            |
| Plasma glucose    | > 126 mg/dL (fasting)                 |

**Fig. 2-67.** Causes of death in developed (top) and developing countries (bottom) according to the UNO and the German Federal Statistical Office.
2.5.2 Cancer

Cancer is the cause of about 25% of all deaths in developed countries. Cancer is usually described as a malignant tumour with extensive immaturity of cells, autonomy and invasive growth as well as the ability to build metastasis (Roche 1993). Tumour cells can appear at any stage during the entire lifetime of humans. The cause is usually multi-causal and does not depend on only one factor; even causal relationships for some circumstances have been found. In most cases, the tumour cells can be identified and destroyed by endogenous defense. Especially, however, in older people, the defense tires and the number of erroneous cells increases. Therefore, at a certain age, the risk of cancer increases.

In 1997 in Germany, about 330,000 people became ill with some form of cancer. About 1/4 of the 330,000 patients were younger than 60, but the average age was 66 for men and 67 for women. People with cancer lose approximately 8 years from the average life expectancy. Fortunately, for some cancer types, the chance of survival has increased. This is mainly based on improved treatment techniques as well as on earlier diagnosis and some changes in the ratio of different cancer types. For example, the number of people with gastric cancer has decreased, while the number with large bowel cancer has increased. For the latter the chance of surviving is higher as compared to the former. (Cancer Register 1997).

The overall probability of getting cancer during one’s entire lifetime is given in Table 2-76. Although the numbers are imposed for the US, they can be extended to most developed countries. It is quite interesting to note how high such lifetime values are. For example, one in every three people will be confronted with skin cancer at some point during their lifetime. Also, every tenth smoker will be hit by some cancer. It has been estimated that about 1/4 of all cancers are connected to smoking. Figures 2-68 and 2-69 show relations between cancer and smoking. Furthermore, chemicals seem to be able to cause cancer. About 2,000 chemicals have proven to be carcinogens in animal experiments (Henschler 1993). Relations with some special professions or special type of living have been found centuries ago (Table 2-77). Causes for cancer are shown in Fig. 2-70. However, since ionising radiation is often considered as cancer risk, in Figs. 2-71 and 2-72, the causes of radiation are given again to show how such causal chains can be extended to describe causes.
2.5 Health Risks

Table 2-76. Risk of cancer during lifetime (EPA 1991)

| Carcinoid situation or material | Cancer lifetime probability |
|---------------------------------|-----------------------------|
| 1. Sun (skin cancer)            | $3.3 \times 10^{-1}$        |
| 2. Smoking (one package per day) | $8.0 \times 10^{-2}$        |
| 3. Natural radon concentration inside a house | $1.0 \times 10^{-2}$ |
| 4. Natural radiation outside of houses | $1.0 \times 10^{-3}$ |
| 5. Passive smoker               | $7.0 \times 10^{-4}$        |
| 6. Artificial chemicals inside buildings | $2.0 \times 10^{-4}$ |
| 7. Air pollution in industrial areas | $1.0 \times 10^{-4}$ |
| 8. Chemicals in drinking water  | $1.0 \times 10^{-5}$        |
| 9. Chemicals in food            | $1.0 \times 10^{-5}$        |
| (a) 60 gram peanut butter per week (natural aflatoxin) | $8.0 \times 10^{-5}$ |
| (b) once per year a trout from lake Michigan | $1.0 \times 10^{-5}$ |
| 10. Leaking of chemicals from a dump site | $1.0 \times 10^{-4} - 1.0 \times 10^{-6}$ |

Table 2-77. Early medical investigations in cancer causes taken from Henschler (1993)

| Year | Author            | Type of cancer | Work or type of living         |
|------|-------------------|----------------|--------------------------------|
| 1743 | Ramazzini         | Breast cancer  | Nun                            |
| 1761 | John Hill         | Nose cancer    | Snuff                          |
| 1775 | Percival Pott     | Scrotum cancer | Chimney sweep                  |
| 1795 | Soemmering        | Lip cancer     | Pipe smoker                    |
| 1820 | Ayrton et al.     | Skin cancer    | Arsenic therapy                |
| 1874 | Volkmann          | Scrotum cancer | Brown coal tar                 |
| 1895 | Rehn              | Cyst cancer    | Aniline worker                 |
| 1902 | Frieben           | Skin cancer    | X-rays                         |
| 1933 | CIF               | Nose cancer    | Nickel extraction              |
| 1935 | Lynch & Smith     | Lung cancer    | Asbestos                       |
| 1940 | Müller            | Bronchial cancer | Cigarette smoking             |
| 1943 | Wedler            | Mesothelioma   | Asbestos                       |
| 1974 | Creech & Johnson  | Liver hemangiosarcoma | Vinyl chloride               |
Fig. 2-68. Relationship between the average number of cigarettes smoked in a country and the number of fatal lung cancer cases taken from Henschler (1993)

Fig. 2-69. Development of the number of cigarettes smoked over time and the number of fatal lung cancer cases taken from Henschler (1993)
Fig. 2-70. Causes of cancer according to Doll & Peto (1981). Further works have been carried out, for example see Schmähl et al. (1989)

Fig. 2-71. Causes of radiation according to NRPB (1986)
2.5.3 Birth

Even common natural processes include hazards. This becomes clearly visible during childbirth. Table 2-78 shows some numbers of infant and mother mortality rates. Here, again, the difference between lesser developed countries and developed countries becomes clearly visible. This becomes even more visible in Tables 2-79, 2-80, 2-81. It has been estimated that per year about 10.6 million children under the age of five die worldwide. This overly large number should be avoidable with current knowledge (Razum & Breckenkamp 2007, IFRC 2006). In some endogenous societies, the infant mortality rate reaches up to 30% (Schiefenhövel 2004). This is a value close to that of animals. For example, for tigers in the Bangladesh swamps, the pup mortality rate reaches 60% in the first three months.

Fortunately, the infant mortality rate in developed countries yields much better values. In many countries, values less than 1% are reached. The lowest values are about 0.4%. This progress is heavily related to some medical and hygienic improvements in the late 19th century in Europe and America. This progress does not only cover birth-related morality but also virtually all diseases known on earth.
Table 2-78. Infant mortality and mother mortality rates for different countries (Zwingle 1998)

| Country      | Infant mortality rate | Average infant mortality rate: |
|--------------|-----------------------|-------------------------------|
| Columbia     | 28x10^{-3}            | Developed countries 8x10^{-3}  |
| Brazil       | 43x10^{-3}            | Developing countries 64x10^{-3}|
| Nicaragua    | 46x10^{-3}            |                               |
| Mexico       | 28x10^{-3}            | Average mother mortality rate during birth: |
| USA          | 7x10^{-3}             | Developed countries 1.0x10^{-4}|
| Russia       | 17x10^{-3}            | Developing countries 50.0x10^{-3}|
| U.K.         | 6x10^{-3}             |                               |
| Italy        | 6x10^{-3}             |                               |
| Turkey       | 42x10^{-3}            |                               |
| Germany      | 5x10^{-3}             |                               |
| Mali         | 123x10^{-3}           |                               |
| Egypt        | 63x10^{-3}            |                               |
| Nigeria      | 63x10^{-3}            |                               |
| Botswana     | 60x10^{-3}            |                               |
| Iran         | 35x10^{-3}            |                               |
| Saudi Arabia | 29x10^{-3}            |                               |
| India        | 72x10^{-3}            |                               |
| China        | 31x10^{-3}            |                               |
| Japan        | 4x10^{-3}             |                               |
| Bangladesh   | 82x10^{-3}            |                               |
| Papua New-Guinea | 77x10^{-3}           |                               |
| Australia    | 5x10^{-3}             |                               |

Table 2-79. Overall number of child deaths in different countries (Razum & Breckenkamp 2007)

| S.No. | Country   | Number of child deaths under the age of five |
|-------|-----------|---------------------------------------------|
| 1     | India     | 2,204,000                                   |
| 2     | Nigeria   | 1,059,000                                   |
| 3     | Congo     | 589,000                                     |
| 4     | China     | 537,000                                     |
| 5     | Ethiopia  | 515,000                                     |
| 6     | Pakistan  | 482,000                                     |
| 7     | Bangladesh| 289,000                                     |
| 8     | Uganda    | 203,000                                     |
| 9     | Angola    | 199,000                                     |
| 10    | Niger     | 194,000                                     |
Table 2-80. Number of child deaths per 1,000 births in different countries (Razum & Breckenkamp 2007)

| S.No. | Country    | Number of child deaths under the age of five |
|------|------------|---------------------------------------------|
| 1    | India      | 283                                         |
| 2    | Nigeria    | 260                                         |
| 3    | Congo      | 259                                         |
| 4    | China      | 219                                         |
| 5    | Ethiopia   | 205                                         |
| 6    | Pakistan   | 204                                         |
| 7    | Bangladesh | 203                                         |
| 8    | Uganda     | 200                                         |
| 9    | Angola     | 197                                         |
| 10   | Niger      | 194                                         |

Table 2-81. Spartial distribution of child deaths and ranking of the causes (Razum & Breckenkamp 2007)

|                        | Africa | Southeast Asia | Eastern Mediterranean | Western Pacific | America | Europe |
|------------------------|--------|----------------|-----------------------|-----------------|---------|--------|
| Absolute number of     | 4.4 Mio| 3.1 Mio        | 1.4 Mio               | 1.0 Mio         | 0.4 Mio | 0.3 Mio|
| deaths under the age of five per year |        |                |                       |                 |         |        |
| Number of deaths per   | 171    | 78             | 92                    | 36              | 25      | 23     |
| 1,000 births           |        |                |                       |                 |         |        |
| Perinatal complications| 26%    | 44%            | 43%                   | 47%             | 44%     | 44%    |
| Pneumonia              | 21%    | 19%            | 21%                   | 13%             | 12%     | 12%    |
| Diarrhoea              | 16%    | 18%            | 17%                   | 17%             | 12%     | 13%    |
| Malaria                | 18%    | 0%             | 3%                    | 0%              | 0%      | 0%     |
| Measles                | 5%     | 3%             | 4%                    | 1%              | 0%      | 1%     |
| HIV/AIDS               | 6%     | 1%             | 0%                    | 0%              | 1%      | 0%     |
| Accidents              | 2%     | 2%             | 3%                    | 7%              | 5%      | 7%     |
| Others                 | 5%     | 12%            | 9%                    | 13%             | 25%     | 23%    |

Mio – million

2.5.4 Adverse Effects

The goal of medical treatment is the healing and support of ill people. Usually people suffering from some kind of illness are under increased risk. If errors are made during treatment, it might directly influence the
survival probability of the patient and may result in a death, which may be avoidable.

There are different types of faults or errors during treatment. For example, a wrong diagnosis is made, a wrong treatment might be administered or the treatment might be carried out erroneously. There might also, however, be some known or unknown adverse side effects of the pharmaceutics. For example, a known adverse effect of chemotherapy during cancer treatment is a large decrease in the quality of life of the patient. In such a case, however, a gain in the quality of life after the treatment is assumed. In general, an adverse event is defined as disadvantaged but unintentional effect of a treatment, of course considering the right medical treatment and the recommended dose of the pharmaceutics.

The number of fatalities caused by adverse side effects is estimated between 44,000 and 98,000 per year in the USA. Comparable relative values exist in Canada, Australia, U.K. and New Zealand (Wreathall 2004, JCAHO 2004, Davis et al. 2001, Vincent et al. 2001, Wilson et al. 1995). Even though such values seem to be rather high, one should keep in mind that the number of fatalities without any treatment would result in much higher fatality rates. The consequence of these investigations showing such numbers should not be taken as a general criticism of the medical system, but should assist with the introduction of quality standards and risk management procedures. The number of avoidable cases is assumed to be approximately 40-70% (Wreathall 2004). The causes for such cases are human errors, miscommunication, technical failure or known side effects. However, as stated in chapter “Indetermination and risk”, the complex system “humans” will show surprising reactions. This influences the outcomes of medical treatment. An example of this is spontaneous cancer healing, which is extremely rare.

One intensively and publicly discussed adverse side effect is in relation to vaccinations. Although modern types of vaccinations are beyond any comparison with historical types of vaccinations, which had very high incidence rates of adverse side effects, even nowadays adverse effects occur. For example, in Saxony, a federal state of Germany, nearly 9.2 million vaccinations were given between the years 2001 and 2004. From these 9.2 million vaccinations, 10 cases caused adverse effects. The distribution of these cases in relation to the different vaccinations is shown in Fig. 2-73. Of course, if one looks over a longer period, the ratio changes. From 1990 to 2000, there were about 22 million vaccinations in Saxony alone, yielding to 23 cases of harm. Here, the major contribution came from the BCG vaccination (Bigl 2007).
Probably the most used pharmaceutic worldwide is acetylsalicylic acid (aspirin). Aspirin has been proven to drop the probability of cardiac infarctions or strokes. On the other hand, it increases the probability of gastrorrhagia and cerebral apoplexy. Therefore, this pharmaceutic might be applied as a safety measure. However, it might also decrease the safety for patients in other areas. While advantages and disadvantages can be weighed against each other, it becomes more difficult when a combination of different pharmaceutics is taken, which and therefore might increase the risks to patients. Smith et al. (1966) showed an exponential growth of adverse effects of pharmaceutics related to the linear growth of drugs administered. The identification of such adverse effects based on the application of different pharmaceutic is very difficult, as shown in Table 2-82. Usually the number of investigated patients during the registration phase lies between 3,000 and 5,000, and during the limited registration of three years between 10,000 and 100,000. It should be mentioned that the registration of a new pharmaceutic costs about 500 million Euros. It has been estimated that about 6% of all hospitalisation is caused by such adverse effects. Adverse effects yield to about 0.1%–0.2% of all deaths. About 80% of these deaths may be avoidable (Fauler 2006).

The problems with identifying the causal relationships (AVP 2005, Oerlinghausen 2006) between pharmaceutics and adverse effects become visible through the dysmelia syndrome incident. Here, one tablet taken during the third and sixth week of pregnancy could yield to embryopathy. The product was later withdrawn. The product cycle of different pharmaceutics is shown in Figs. 2-74 and 2-75, giving the impression that more such adverse effects are found during use. However, as the next section shows, pharmaceutics have been successfully applied against many diseases.
Table 2-82. Number of patients treated for one, two or three adverse effects with a confidence interval of 95% related on some different incidences. It becomes clear that low incidences are extremely difficult to prove (WHO 1983)

| Incidence of adverse effects | Number of patients treated for adverse effects |
|-----------------------------|-----------------------------------------------|
|                             | one | two | three |
| 1/100                       | 300 | 480 | 650   |
| 1/200                       | 600 | 960 | 1300  |
| 1/1,000                     | 3,000 | 4,800 | 6,500 |
| 1/2,000                     | 60,00 | 9,600 | 13,000 |
| 1/10,000                    | 30,000 | 48,000 | 65,000 |

Time in the market of various active ingredients prior to recall

- Clioquinol/SMON
- DES
- Thalidomide
- Fenfluramine
- Zomepirac
- Phenylpropanolamine
- Uaspandole
- Nefazodone
- Cervastatin
- Troglizone
- Milbefradil
- Trovafloxacin
- Dronfenac
- Grepafloxacin
- Tolcapone
- Rofecoxib
- Alesetron

Fig. 2-74. Time in the market for various active ingredients prior to recall subject to the type of application (Munich Re 2005b)

Fig. 2-75. Model for the development of patient numbers, sales numbers and numbers of side effects during the establishment of a drug (Munich Re 2005b)
2.5.5 Epidemics and Pandemics

Epidemics were great hazards during the development of mankind, especially before the Industrial Revolution. The Industrial Revolution yielded to a dramatic improvement in working and living conditions. Nevertheless, epidemics and pandemics did also occur after the Revolution.

While the term epidemic describes the massive occurrence of a disease in a limited area or over a limited time, a pandemic describes an epidemic that reaches major areas of a country or a continent. Throughout history, there have been several diseases that reached the status of an epidemic and/or pandemic. These diseases were mainly infectious diseases. Examples are given to illustrate the magnitude and severity of such pandemics.

Influenza in conjunction with bacterial superinfections quite often occur as an epidemic or pandemic. For example, in 1889 and from 1918 to 1919, major influenza pandemics were experienced, resulting in a large number of fatalities. The Spanish influenza in the years 1918 and 1919 emerged in four waves, claiming about 22 million lives. In Germany alone, somewhere between 225,000 and 300,000 people or 0.5% of the population died (Jütte 2006). It has been estimated that about 500 million people were infected with Spanish influenza. In recent decades, influenza pandemics have also occurred. For example, in 1957, there was an outbreak of Asian influenza with approximately 1 million fatalities, and in 1968 there was an outbreak of Hong Kong influenza resulting in about 700,000 fatalities. The latest influenza pandemic threat occurred in 2006 when a mutation of the H5N1 bird flu virus was thought to have occurred. The British government estimated that there could be up to 320,000 victims in Britain alone. However, even “normal” influenza seasons in Germany claim several thousand victims as shown in Table 2-83.

Since the 16th century, about 30 influenza pandemics have been identified. Probably well known, however, are the plague pandemics of the medieval times.

**Table 2-83.** Number of fatalities per influenza season in Germany (RKI 2007)

| Influenza season | Fatalities |
|------------------|------------|
| 1995/96          | 32,000     |
| 1996/97          | 7,000      |
| 1997/98          | 6,000      |
| 1998/99          | 20,000     |
| 1999/00          | 12,000     |
| 2000/01          | 7,000      |
| 2001/02          | 4,000      |
| 2002/03          | 17,000     |
| 2003/04          | 6,000      |
2.5.6 Bubonic Plague

The Bubonic plague, also called the Black Death, was probably the greatest plague from the 14th to 18th century in Europe. It is a highly contagious disease, which can be found in rats and is transmitted through fleas. There exist several types of plague, such as the lung plague or the skin plague. The mortality rate depends on the type of plague, but has historically reached values of 95% for the lung plague, 75% for the bubonic plague or 100% for the sepsis. The plague usually originates from plague reservoirs located in the north of Asia, such as Siberia or Mongolia. Iran and Africa are sometimes mentioned as places of origin (Roche 1993).

The first historical data concerning the plague can be found in a description of the siege of Athens during the pelopennical wars in about 430 B.C. Approximately one-third of the Athens population died at this time by the plague. In 170 A.D., there were some plague epidemics in the eastern part of the Roman Empire. In 542, the Justinian plague destroyed all goals of the Emperor Justinian to re-establish the Roman Empire. In 630 A.D., a plague epidemic occurred in the Persian Empire (Leberke 2004, Grau 2004).

Probably the worst plague pandemic occurred from 1347 to 1352. During that time, presumably 25 million people were killed by the disease, which was approximately one-quarter of the entire European population. For example, in the German city of Lübeck, 90% of the entire population was lost. Even wealthier people died: 25% of all landlords as well as 35% of the town councilmen died. In the German city of Erfurt, half the population died, and in Frankfurt/Main, about 2,000 deaths per day were counted during the pandemic (Grau 2004).

The origin of this historic pandemic can be traced back to the peninsula Crimea. Here, some Genoese traders were locked in the city of Kaffa by Tatarian and Awarian soldiers. The city was beset for quite some time. It was unclear whether the disease started inside the city or in the lines of the besieger. After the beset was over, the Genoese traders returned to Genoa, halting at Constantinople, Messina and Naples. It was in these places that the plague occurred first. The pandemic then reached virtually the whole of Europe. First, Italy was hit, followed by Vienna in 1348 and then England and Scandinavia in 1350. Even Iceland was touched by the disease. Whether the information about the number of fatalities is correct remains uncertain. It seems rather certain, however, that many regions were almost completely depopulated and became deserted. In Italy alone, it took about a century to restore the population number to what it was before the plague.

When this plague ended in the middle of the 14th century, one may not think that the plague did not return. The German city of Lübeck was hit by
the plague not only in 1350 but also in 1406, 1420, 1433, 1451, 1464, 1483, 1484, 1525–1529, 1537, 1548, 1550, 1564, 1565, 1625 and 1639. A plague pandemic occurred in Italy in 1630, in London from 1661 to 1666 and in Vienna from 1678 to 1679, each claiming about 100,000 lives. In 1720 and 1814, a plague epidemic occurred in France and Belgrade, respectively. Even at the end of the 19th century, a pest pandemic was observed in Asia, starting in 1894 in Hong Kong and reaching China, Japan and India in 1896. It has been estimated that about 15 million people died. By trade ships, this pandemic also reached Suez in 1897, South Africa in 1899, San Francisco in 1900 and Paris, in 1920. In Paris, only 20 cases were observed. The last plague epidemic was observed in 1911 in Manchuria and fought off successfully. Based on World Health Organisation data, about 1,000–3,000 cases still appear per year worldwide. In 1994 in India, an epidemic centre was identified. In general, the data show that the hazard posed by the plague has been permanently decreased over the last centuries. This development, however, is not valid for other infectious diseases, for example malaria.

2.5.7 Malaria

There exist different types of malaria: malaria quartana, malaria tertiana and malaria tropica. The disease malaria tropica can be deadly. All types of malaria are caused by a protozoan of the genus plasmodium (Plasmodium vivax, Plasmodium ovale, Plasmodium falciparum). Plasmodium are intracellular parasites. They are transmitted by Anopheles mosquitoes. The Roman philosopher Marcus Terentius Varro had assumed that malaria was caused by very small animals transmitted by mosquito bites (Köster-Lösche 1995). There is one development cycle of the plasmodium inside the mosquito and one inside the human. The incubation time, depending on the plasmodium, takes about 7 to 40 days.

The number of infected people worldwide has been estimated between 300 and 500 million. Fourty percent of the world population lives in malaria-contaminated areas. Every year, the disease claims between 1 and 3 million lives, most of them children under five years. The major areas where the disease is prevalent are Africa, South America and Asia (Fig. 2-76). Africa, however, has 90% of all infected people worldwide. Historically, malaria-contaminated areas reach much further north, for example in Europe.

There were some malaria epidemics in the 16th century (1557–1558), 17th century (1678–1682), 18th century and 19th century (1806-1811, 1845–1849, 1855–1860, 1866–1872). As a result of the increase in the
cultivation of land and the heavy application of DDT (dichlorodiphenyltrichloroethane), malaria was on the retreat. Unfortunately, however, the plasmodium became resistant. The most used pharmaceutics, chloroquine and mefloquine, to prevent malaria will now have to be applied in higher doses.

Fig. 2-76. Geographical distribution of malaria worldwide

2.5.8 AIDS

HIV (Human Immunodeficiency Virus)/AIDS (Acquired Immunodeficiency Syndrome) is a rather new disease, and only scientifically known since 1980 when it was described for the first time in the US. The first patient was Gaetan Dugas; however, based on later investigations, AIDS can be traced back to diseases from chimpanzees and other primates. This means that the disease probably did not just start in 1980 but the pandemic started then (Köster-Lösche 1995).

After an incubation time of 2–6 weeks, for about 7-10 days, a first acute HIV infection may become apparent. This infection is usually not diagnosed as HIV as no antibodies are detectable. After the acute infection, a chronic infection starts running over for an average of ten years. During that time, the immune system is increasingly damaged and the number of CD4 cells (lymphocyte) drops from 1,000 to about 200 per µl blood. At that level, the immune system is so heavily damaged that so-called opportunistic
infections occur. Based on the number of lymphocytes per µl blood, different stages of HIV infection are classified.

It was in the early 1980s about 150 people died from the disease, and about 500 people were identified as infected. By 1985, about 12,000 people were infected. According to some publications, between 34 and 46 million people are currently infected with HIV/AIDS. In 2003, between 4.2 and 5.8 million people were newly infected. This figure includes about 800,000 children. In some regions, the number of new infections is decreasing. In Germany in the 1980s, the new infection number was about 8,000, whereas currently the number is between 2,000 and 2,500. In other regions, however, the number is increasing dramatically. In some regions, however, such as southern Africa, more than 10% of the population is infected. In some Asian regions, the number of infected people is also growing significantly (Bloom et al. 2004, BfG 1997).

In 2003, about 2.3–3.5 million people died from AIDS. It has been estimated that over 20 million fatalities have been claimed since the beginning of the disease. Mathers & Loncar (2006) have estimated that the overall number of fatalities from AIDS for 2030 will be 117 million with a yearly number of victims of about 6.5 million. The strong influence of AIDS on mortality for South Africa is shown in Fig. 2-77. While in most countries worldwide, the number of deaths in the age cohorts between 15 and 40 is rather low, here a maximum is reached (van Gelder 2003).

![Mortality diagram for different age cohorts in South Africa for AIDS according to van Gelder (2003)](image)
Since the first description of AIDS and the discovery of the HIV by Robert Gallo and Luc Montagnier in 1983 and 1984, much research work has been carried. However, still the disease is not curable. In 1987, the first HIV medicine was introduced. Currently, 25 single or combination preparations, from four active substance classes are admitted for treatment.

2.5.9 Tuberculosis

Tuberculosis is an infectious disease that occurs in episodes. Between a third and a half of the entire world population is infected by this disease. Every year about 100 million people are newly infected by the pathogen *Mycobacterium tuberculosis*. The estimated number of deaths worldwide is between 2 and 3 millions. About 5,000 people worldwide die from tuberculosis every day, 95% of them in developing countries (RKI 2004).

The relationship between insufficient social conditions and the prevalence of the disease can be observed in Russia after the collapse of the Soviet Union. The radical social change yielded to the impoverishment of major parts of the population. This resulted in a dramatic increase in the number of people infected with tuberculosis. In only 10 years, the number of people infected with tuberculosis doubled. The mortality rate actually tripped. In addition, the interrupted treatment of certain people, for example prisoners, supported the development of treatment-resistant tuberculosis bacteria (RKI 2004).

2.5.10 Cholera

Historically, cholera was also a major plague. In 1817, about 600,000 Indians died from cholera. In the beginning, this disease did not affect the British; therefore, it was not of concern to them. However, after 9,000 soldiers out of 18,000 died at the British headquarters they became alert (Köster-Lösche 1995). Figure 2-78 shows an example of the pattern of cholera during a London epidemic in 1854. Here, the relation with water quality becomes visible.
2.5.11 Other Infectious Diseases and Outlook

The listing of diseases together with the number of victims could be extended arbitrarily. For example, smallpox claimed about 500 million lives between 1880 and 1980, and even nowadays measles claims about 900,000 victims worldwide. In 1995 alone, more than 50 million people died by infectious diseases (Bringmann et al. 2005). The list, however, would blast the frame of the book. For the interested reader, the UN report “Global burden of disease” is recommended.

Especially in many developing countries, the number of infectious diseases still remains high. Diseases such as malaria, amoebic dysentery, bilharziasis, leishmaniasis and sleeping sickness claim a huge number of victims. Pathogens are also becoming more and more resistant. This is true not only in developing countries but also in developed countries. For example, the pathogen *Staphylococcus aureus* has become methicillin-resistant; the enteroccocus pathogen has become vancomycin-resistant; and some phylum pathogens from staphylococcus have become vancomycin-intermediate-resistant. No new antibiotics have been developed since the 1970s with the exception of the pharmaceutic linezolid. On the other hand, many infectious diseases have been battled fairly successfully over history, for example cholera, smallpox, leprosy, syphilis and plague by pharmaceutics, and improved living conditions. This shows that...
not only the health risks but also social conditions or social risks cause the death.

2.6 Social Risks

2.6.1 Suicide

Suicide is the deliberate abortion of one’s own life. The abortion can be done either in an active way by carrying out a certain dangerous action, for example jumping from a structure, or else by endangering life-supporting actions like avoiding medicine or addicted to drinking. The worldwide number of successful suicides has been estimated by about 1 million per year. However, this value shows geographical patterns as well as change over time. In Germany, the number of suicides has dropped from 18,700 in 1982 to about 12,000 in 2000 (Helmich 2004, Eichenberg 2002). Maximum suicide rates were reached in the region of the former USSR (Fig. 2-79). In comparing between genders, more males commit suicides than females. In Russia, males commit up to four times as many suicides as females, whereas in Germany the suicide rate for men is about double that of women.

![Fig. 2-79. Development of the suicide rate in Russia (Felber 2004)](image)

The suicide rate is not constant across life stages. In general, one can state that the suicide rate increases with increasing age. Every second women
carrying out a suicide is older than 60 years. Suicide rates reach a peak in youth. In the age bracket of 15 and 29 years, suicide is the second highest cause of death (Dlubis-Mertens 2003).

In Germany, suicides contribute to 1.3% of all deaths. However, it has been estimated that the number of unreported cases is approximately 25% of the known suicide numbers. It is difficult to know how many drug misuses, car accidents and other accidents were caused intentionally. Suicide attempts are not recorded in Germany due to data protection restraints.

Media has a great impact on suicides. The internet has been used for organisation of collective suicides. Mass media reports causes sometimes called suicide links or copycat suicides. This is also called the “Werther effect”, since the first reported suicide link happened after the publication of Goethes book “The Sorrows of Young Werther”. Therefore, in several countries, there exist rules for reporting about suicides. One of the most famous examples is the ban on reporting about suicides that occur at the Golden Gate Bridge in June 1995, as the number of suicides at this structure was close to 1,000. In France, pictures from suicides are prohibited in the mass media. In Austria, reports about suicides using the underground were stopped due to a suicide link.

Examples of several preferred spots for suicides are given in Table 2-84. In Germany, some suicides happen at the Göltzschal Bridge, the biggest brick arch bridge in the world (Fig. 2-80).

Table 2-84. Some structures or locations with suicide numbers

| Structures                                      | Number of suicides |
|------------------------------------------------|--------------------|
| Golden-Gate-Bridge in San Francisco            | ~ 1,200            |
| Eiffel Tower                                   | ~ 370              |
| Skyway-Bridge in Florida                       | ~ 81 since 1989    |
| Arro-Secco-Bridge in Pasadena (California)     |                    |
| Mount Mihara Vulcano in Japan                  |                    |
| Empire-State-Building in New York              |                    |
| Space-Needle in Seattle                        |                    |

One of the major causes of suicides is depression. It is estimated that in Germany about 4 million people (5% of the population) are affected by this disease. If this is true, then suicides could be classified as a health risk rather than as a social risk. However, in most cases, depression is caused by a single dramatic social event, such as the loss of job, the loss of a partner or the loss of a child. These are damages to the social network in which people live, and if the remaining social network is not strong enough to heal the injury, then the individual human might fail.
2.6.2 Poverty

Poverty can be understood as a specific lifestyle. This lifestyle is defined by a lack of opportunities. The UNO have defined poverty as “deprivation of the basis of living”. Poverty can be measured in different ways. The poverty parameters might be based on monetary income, poverty line, unsatisfied basic needs indicator or the poverty head count index (Coudouel et al. 2003).

Poverty can be found in all geographic regions of the world and affect persons of all ages. Based on the definition by the amount of available monetary resources, about one-fifth of the earth’s population is poor, living with less than a dollar per day. This relates to 1.2 billion people. But, of course, poverty is not equally distributed geographically, even if it can be found worldwide. Developing nations, in particular, show a higher contribution to the number of poor people worldwide. Considering the limited access to even elementary health services in developing nations, nearly 60% of the population can be defined as living in poverty. In some countries, for example Mexico, values between 70% and 90% of the population are considered to be living in poverty.

Some parts of the population are more exposed to poverty than others. For example, it has been estimated that about 10.6 million children under five years of age die per year worldwide, mainly due to insufficient supply of nutrition or medical treatment (Razum & Breckenkamp 2007). A general relationship between the social status and the health of children was given by Lampert & Kurth (2007). The influence of unemployment and poverty on health has been investigated by Weber et al. (2007).
Several studies estimated the loss of life expectancy due to poverty even in developed countries. The range of lost life expectancy lies between 5 and 12 years in Germany. In other countries, a value of 7 years is mentioned (Cohen 1991). In developing countries, average life expectancy is heavily influenced by poverty, reaching an extremely low value of only 33 years in Zimbabwe. Poverty is often related to abnormal political conditions and war conditions.

2.6.3 War

Wars can yield to such a dramatic increase in mortality rates that they are often not considered a risk in the classical sense. On the other hand, wars happen regularly (Richardson 1944), and therefore values about the mortality rates should be included. It should be mentioned here that mortalities during the times of war are connected not only to military actions but also to the decrease in normal living conditions. For example, many people have died during wars by famine or insufficient medical treatment. Examples are given to stress about the loss of human lives under war conditions.

During the World War I, 34 countries with an overall population of 1.52 billion were in a state of war. About 67 million soldiers were mobilised. Approximately 13% of the soldiers died, about 30% were injured, and about 5% were disabled after the war. This gives a mortality rate of 3% ($3 \times 10^{-2}$) per year for soldiers (Schenck 1965).

In the World War II, the mortality rate for German soldiers was about 12-15% per year. Between 1939 and 1945, about 5.3 million men were killed. The mobilisation rate (soldiers per total number of men living in a country) reached nearly 50%. Over the entire war period 25% of all men in Germany died (Overmans 1999).

With a total of 50 million fatalities, the World War II could be considered the biggest manmade disaster in human history. Some suggest, however, that the wars in the 20th century actually built a chain of wars that are all connected to each other. World War I was is considered the starting point of the chain of wars, yielding not only to the vast number of fatalities but also to the collapse of many different countries, including the civil wars that lasted over several years with an extraordinary loss of lives. Examples of civil wars are the ones that occurred in Russia and China. The economical consequences of World War I might also be in part responsible for the political success of the Nazi party in Germany.

As a consequence of the World War II, Europe was divided. In Asia, empires were forever changed. For example, the influence of Japan was heavily decreased, leaving Korea as an intermediate state. This was the
basis for the Korean War as well as the Vietnam War. In the end, this chain of wars was the major contributor to a loss between 150 and 200 million lives in the 20th century. It has been estimated that between 4% and 5% of all deaths in the 20th century were a result of wars. Numbers of war-related deaths are given in Table 2-85.

Although the 20th century showed the highest number of war fatalities, wars have probably been a permanent companion of human development. Wars were lead during the old Egyptian time, during the time of the Greeks, during the Roman Empire, during the migration time and throughout the medieval ages. Table 2-86 gives the numbers of war fatalities for some major wars throughout the last five centuries.

In addition to numbers, some detailed remarks are given here. One war mentioned in Table 2-86 was the 30-year war in Europe. During that war, the loss of soldiers contributed only a minor portion to the overall loss of human life. The war was heavily marked by the violence of soldiers against the civilian population. Even worse though were the famines and epidemics. A detailed summary of victims was given by a royal Prussian doctor in the 19th century in the book “History of epidemics, famine and war during the time of the 30 year war”. For example, the Mark Brandenburg lost about half its population. However, it should be mentioned that the population was often uprooted, not killed. Therefore, the number of fatalities might be lower. During that time, it was not permitted for farmers to move away from their villages. Many farmers used the chaotic situation during the war to escape to the growing cities. Hence, of the 30-year war yielded to an uprooting of the German population.

However, the huge loss of life remains if one looks at the overall population numbers. Before the 30-year war, the German empire had a population of about 22 million. After the war, the population was estimated to be approximately 13.5 million. The loss of the Netherlands and Bohemia is already included in the numbers.

Table 2-85. Number of war-related deaths over the centuries (Eckhardt 1991, Leger Sivard 1996)

| Century   | War death in millions | Death per 1,000 people |
|-----------|----------------------|-----------------------|
| 1st–15th  | 3.7                  | Not specified         |
| 16th      | 1.6                  | 3.2                   |
| 17th      | 6.1                  | 11.2                  |
| 18th      | 7.0                  | 9.7                   |
| 19th      | 19.4                 | 16.2                  |
| 20th      | 109.71               | 44.4                  |
### Table 2-86. Number of war-related deaths for select wars (Renner 1999, White 2007)

| Conflict                                           | Period        | Number of people killed in millions | Civilian victims in percent |
|----------------------------------------------------|---------------|------------------------------------|-----------------------------|
| Peasants’ War in Germany                           | 1524–1525     | 0.17                               | 57                          |
| Dutch independence War versus Spain                 | 1585–1604     | 0.18                               | 32                          |
| 30-year War in Europe                              | 1618–1648     | 4.00                               | 50                          |
| Spanish Succession in Europe                       | 1701–1714     | 1.25                               | –                           |
| 7-year War (Europe, North America, India)           | 1755–1763     | 1.36                               | 27                          |
| French Revolutionary and Napoleonic wars            | 1792–1815     | 4.19                               | 41                          |
| Crimean War                                        | 1854–1856     | 0.77                               | 66                          |
| US Civil War                                       | 1861–1865     | 0.82                               | 24                          |
| Perugyau versus Brasil and Argentina                | 1864–1870     | 1.10                               | 73                          |
| Franco-Prussian War                                 | 1870–1871     | 0.25                               | 25                          |
| Congo Free State War                                | 1886–1908     | 8.00                               | –                           |
| US-Spanish War                                      | 1898          | 0.20                               | 95                          |
| Mexican Revolution                                  | 1910–1920     | 1.00                               | –                           |
| Russian Civil War                                   | 1917–1922     | 4.0–10.0                           | –                           |
| China: Warlord and Nationalist Era                  | 1917–1937     | 40.0                               | –                           |
| World War I                                         | 1914–1918     | 26.0                               | 50                          |
| Armenian massacres                                  | 1915–1923     | 1.00                               | –                           |
| Stalin’s regime                                     | 1924–1953     | 15–30                              | –                           |
| World war II                                        | 1939–1945     | 53.5                               | 60                          |
| Chinese Civil War                                   | 1945–1949     | 1.0–6.0                            | –                           |
| Mao Zedong’s regime including famine                | 1949–1975     | 40–45.0                            | –                           |
| Korean War                                           | 1950–1953     | 2.7–2.9                            | 50                          |
| Rwanda and Burundi                                   | 1959–1995     | 0.7–1.7                            | –                           |
| Vietnam War                                          | 1960–1975     | 3.0                                | 58                          |
| Nigeria                                              | 1967–1970     | 2.0                                | 50                          |
| Cambodia                                             | 1970–1989     | 1.2                                | 69                          |
| Bangladesh secession from Pakistan                  | 1971          | 1.0                                | 50                          |
| Afghanistan                                          | 1978–1992     | 1.5                                | 67                          |
| Mozambican Civil War                                 | 1981–1994     | 1.0                                | 95                          |
| Sudan Civil War                                      | 1984          | 1.5                                | 97                          |

In contrast to the historic wars, especially during the early ages and the medieval ages, the weapons in modern times have reached a much higher destruction power. The development of the destruction power is given in Table 2-87 in terms of explosive power and killing index. The explosive power is given in the mass equivalent of TNT. The killing index, which is used in some armies for qualification, gives the number of possible targets. Of course, this number is rather a theoretical value, which considers only the maximum gun speed. It does not consider any logistic problems with
ammunition. Based on Table 2-87, the highest destruction capacity is found with the application of nuclear bombs (Albrecht 1985).

Table 2-87. Explosive force and killing index for weapons (Albrecht 1985)

| Weapon                                      | Explosive force in TNT | Killing index |
|---------------------------------------------|------------------------|---------------|
| Javelin                                     | 18                     |               |
| Sword                                       | 20                     |               |
| Bow and arrow                               | 20                     |               |
| Crossbow                                    | 32                     |               |
| Drake, 12 pounds, 16th century              | 43                     |               |
| Flint with flintlock, 18th century          | 47                     |               |
| Muzzleloader rifle, middle 19th Century     | 150                    |               |
| Field gun, 12 pounds, 17th century          | 230                    |               |
| Breech loading fire arm, end of 19th century| 230                    |               |
| Repeating rifle, World war I               | 780                    |               |
| Field gun type Gibeauval, 12 pound grenade, 18th century | 4,000                  |               |
| Machine gun, World War I                   | 13,000                 |               |
| Machine gun, World War II                  | 18,000                 |               |
| Field gun, explosive grenade 75 mm, end 19th century | 34,000                 |               |
| Tank, World War I (two machine guns)       | 68,000                 |               |
| Airplane, World War I (one machine gun, two bombs) | 23,000                 |               |
| Field gun, explosive grenade 155 mm, World war I | 470,000                |               |
| Howitzer, grenade with proximity fuze 155 mm, World War II | 660,000                |               |
| V-2-Rocket, World War II                   | 860,000                |               |
| Tank, World War II (one gun, two machine guns) | 2.2 million            |               |
| Fighter bomber, World War II (eight machine guns, two bombs) | 3 million              |               |
| Hiroshima nuclear bomb                      | 20 kiloton             | 49 million    |
| Short-range ballistic missile type Lance    | 0.05 kiloton per war head | 60 million   |
| Short-range ballistic missile type Lance    | 1 kiloton per war head | 170 million   |
| Howitzer Caliber 155 m, type M 109          | 0.1 kiloton per war head | 680 million |
| Tactical rocket, French type Pluton        | 20 kiloton             | 830 million   |
| Phantom-fighter bomber with bomb B-61      | 350 kiloton            | 6.2 billion   |
| intermediate-range ballistic missile, French model M-20 | 1 megaton              | 18 billion    |
| Intercontinental ballistic missile, Soviet type SS-18 | 25 megaton | 210 billion  |
| USA, 1954, test of nuclear fusion bomb     | 15 megaton             |               |
| USSR, 1960, test of biggest nuclear fusion bomb | 60 megaton             |               |
Nuclear bombs are military explosive devices that use nuclear fusion or fission as the explosion energy supply. As already mentioned, the explosive power is usually given in the mass equivalent of TNT. The nuclear fission energy supplied by 1 gram U-235 corresponds with $2 \times 10^4$ kg TNT or $8.2 \times 10^{10}$ Joule. Nuclear fission is usually initiated by the bombardment of nuclides U-235 and Pu-239 with neutrons. Because nuclear fission produces free neutrons after it has started, a chain reaction can be designed. Such a chain reaction depends on the critical mass. A typical critical mass is 50 kg U-235. Because the theoretical critical load can be decreased by some technical measures, smaller bombs with less weight (two orders of magnitude) are possible. The bomb over Hiroshima used only 1 kg U-235, reaching an explosive power of about $2 \times 20^7$ kg TNT.

In contrast to the above, nuclear fusion bombs obtain their energy from nuclear fusion. While the size of bombs based on nuclear fission is limited due to the effect of critical masses, the explosive power of nuclear fusion bombs is infinite due to the possible unlimited production and storage of deuterium. In 1962, a H-bomb was ignited 400 km above the Pacific Ocean. Although the explosion of the $1.5 \times 10^9$ kg TNT equivalent bomb happened 1,500 km away from Honolulu, it yielded to a collapse in the energy supply there. The bomb with the highest explosive power was launched in 1960 by the USSR with an equivalent mass of $6 \times 10^{10}$ kg TNT (Rennert et al. 1988).

Explosive power of the magnitude of $10^{10}$ kg TNT can destroy structures completely within a distance of 8 km from the explosion centre. Within a distance of 15 km, major structural damages can be observed. An explosive power of $10^7$ kg TNT yields to major retina burns caused by the high glare effect (100 times higher than the sun). The inflame point of a $2 \times 10^8$ kg TNT breaches a distance of 4.5 km. Table 2-88 shows the transformation of the explosion energy into other energy forms (Rennert et al. 1988).

| Energy                        | Percentage |
|-------------------------------|------------|
| Shock wave                    | 50         |
| Thermal radiation             | 35         |
| Immediate ionising radiation  | 5          |
| Late ionising radiation       | 10         |

Table 2-88. Transformation of Energy forms (Rennert et al. 1988)
The explosion of a nuclear bomb with a mass equivalent of $10^6$ TNT would probably completely eliminate a city of the size New York. The bomb would be ignited about 2 km above the city (Tables 2-89 and 2-90). The thermal radiation of the explosion would yield to heavy fires in the city. The heavy radiation would be followed by a shock wave, which might partially extinguish some fires and cause new fires by transporting burning material. The fire would grow into a firestorm. The heat of the fire produces a wind with a speed of up to 160 km per hour. Such a wind would blast huge amounts of ash into the atmosphere. If one considers that perhaps hundreds of cities would experience such a tragedy, during a nuclear war it becomes clear that inconceivable amounts of dust and ash would be transported into the air. Such huge masses would heavily influence the shielding of the earth’s surface from sunlight and would yield to a dramatic temperature drop. This is called nuclear winter. Table 2-91 shows different scenarios for nuclear world wars and the amount of ash and dust that would be released. Based on the assumed worldwide effects of such a nuclear world war, it becomes clear that no winner will exist, even if no direct hits occur (Turco et al. 1985).

**Table 2-89.** Fatality radius of a nuclear bomb explosion based on the shock wave (Rennert et al. 1988)

| Explosive power in TNT equivalent | Fatality radius (km) |
|----------------------------------|----------------------|
| $10^6$                           | 0.2                  |
| $10^7$                           | 0.5                  |
| $10^8$                           | 1.5                  |
| $10^9$                           | 3.0                  |
| $10^{10}$                        | 6.6                  |

**Table 2-90.** Effects of radioactive radiation caused by a nuclear bomb explosion with the mass equivalent of $10^6$ kg TNT (Rennert et al. 1988)

| Distance from explosion (m) | Dose (Gy) | Time to death (days) |
|----------------------------|-----------|----------------------|
| 400                        | 180       | 1–2                  |
| 500                        | 80        | 1–2 (5 min capable of acting) |
| 640                        | 30        | 5–7                  |
| 760                        | 6.5       | 5–7 (2 h capable of acting) |
Table 2-91. Investigated scenarios of nuclear wars (Turco et al. 1985)

| Scenario                          | Overall explosive power in mega tonnes | Inhabited or industrialised targets in percent explosive power | Explosive power of single warheads in mega tonnes | Overall number of explosions | Ash particles < 1 μm in million tonnes | Dust particle < 1 μm in million tonnes |
|----------------------------------|----------------------------------------|---------------------------------------------------------------|-----------------------------------------------|----------------------------|--------------------------------------|---------------------------------------|
| Weak over ground explosions      | 5,000                                  | 33                                                            | 0.1–1                                        | 22,500                    | 300                                  | 15                                    |
| Full exchange of nuclear strokes | 10,000                                 | 15                                                            | 0.1–10                                       | 16,160                    | 300                                  | 130                                   |
| Mean exchange of nuclear strokes | 3,000                                  | 25                                                            | 0.3–5                                        | 5,433                     | 175                                  | 40                                    |
| Limited exchange of nuclear strokes | 1,000                                | 25                                                            | 0.2–1                                        | 2,250                     | 50                                   | 10                                    |
| Strike against military targets  | 3,000                                  | 0                                                             | 1–10                                         | 2,150                     | 0                                    | 55                                    |
| Strike against hard targets      | 5,000                                  | 0                                                             | 5–10                                         | 700                       | 0                                    | 650                                   |
| Strike against urban centers     | 100                                    | 100                                                           | 0.1                                          | 1,000                     | 150                                  | 0                                     |
| World War                        | 25,000                                 | 10                                                            | 0.1–10                                       | 28,300                    | 400                                  | 325                                   |

The current development of warfare suggests rather smaller, locally concentrated types of wars. Such wars give the public the impression that the risk for the population and the soldiers is dramatically lower as compared to historical wars. Nevertheless, the current wars in Afghanistan or Iraq does not show such expected low mortality rates. However, there might be some progress in a lower risk for American soldiers, but the mortality rate still remains high as compared to a peaceful life in developed countries. About 100,000 Iraqi fatalities were estimated for the second Iraq war in 2003 and 2004 (Roberts et al. 2004). With a population of 22 million, this gives a mortality rate of about \(4 \times 10^{-3}\) per year.

In 2003, about 300 US soldiers died in battles. Here, the number of exposed soldiers was estimated to be 100,000. This corresponds to a soldier mortality rate of \(3.0 \times 10^{-3}\). For comparison reasons, the yearly mortality rate of a German soldier in World War II was 0.1 per year. It is interesting to note that the mortality rate of US soldiers in the second Iraq war actu-
ally did not decrease after the war itself. The mortality rate remains high in the order of $3.0 \times 10^{-3}$ per year. The overall number of losses for us reached nearly 4,000 by the end of 2007 with about 30,000 injured.

In general, the number of military actions worldwide has risen as shown in Table 2-92 (Ipsen 2005). Also, the length of wars has risen as some examples in Table 2-93 show. Both effects are in contrast to the observed developments in the 1990s due to a drop in military expenditures. After the collapse of communism, world military spending dropped significantly (Table 2-94). The latest developments, however, show rather alarming signs.

### Table 2-92. Number of wars (Ipsen 2005)

| Period       | Number of armed conflicts | Increase in armed conflicts |
|--------------|---------------------------|-----------------------------|
| 1945–1969    | 5–15                      | 10                          |
| 1969–1975    | 15–30                     | 15                          |
| 1975–1992    | 5–52                      | 17                          |
| Since 1992   | ≈30                       |                             |

### Table 2-93. Length of some wars during the 20th century (Ipsen 2005)

| Country        | Beginning of war | Duration until today in years |
|----------------|------------------|-------------------------------|
| Burma          | 1949             | 56                           |
|olumbia         | 1965             | 40                           |
| Israel/Palestine| 1967            | 38                           |
| Northern Ireland| 1969            | 36                           |
| Philippines    | 1970             | 35                           |
| Cambodia       | 1975             | 30                           |
| Iraq/Kurdistan | 1976             | 29                           |

In 2005, world military expenditures reached about 1,100 billion US dollars. This represents 2.5% of the world gross domestic product. Since the middle of the 1990s, military expenditure has increased by about 30% (Table 2-94). Currently, the US is responsible for a major portion of military expenditure worldwide, mainly due to the ongoing military actions (Table 2-95). In other countries, military expenditure is increasing as well, for example Russia, China and India. This increase, however, mainly corresponds to the economic growth (SIPRI 2006). The highest military expenditure per capita is found in Israel (Table 2-96).

The high American military expenditure is strongly connected to the military actions in Afghanistan and Iraq. These military actions can be seen as a direct or indirect consequence of the terrorist attack against the World Trade Center on 11 September 2001 in New York. In addition, this shows a continuous trend from wars being fought between states to wars
between a state and a non-state organisation. This development is strongly connected to the definition of terrorism.

Table 2-94. World military spending in 1986 and 1994 in billion US dollars (Conetta & Knight 1997, US ACDA 1996, IISS 1996)

|                | 1986  | 1994  | % Change |
|----------------|-------|-------|----------|
| World          | 1297.0| 840.3 | –35.2    |
| OECD           | 622.6 | 540.9 | –13.1    |
| Non-OECD World | 674.4 | 299.4 | –55.6    |
| NATO           | 562.6 | 469.3 | –16.6    |
| Non-NATO World | 734.4 | 371.0 | –49.5    |
| Non-NATO OECD  | 60.0  | 71.6  | +19.3    |
| US             | 365.3 | 288.1 | –21.0    |
| Non-US World   | 931.7 | 552.2 | –40.7    |
| Non-US OECD    | 257.3 | 252.8 | –1.7     |
| Non-US NATO    | 197.3 | 181.2 | –8.2     |

However sometimes the so-called state terrorism occurs in wars. This has been observed by the installation of concentration camps in Germany during the Nazi times. The first concentration camps were introduced by the English in the Boer war between 1899 and 1902. The mortality rate in the camps reached up to 12% per year. That was a comparable value to some German concentration camps during the World War II. However, there were concentration camps in World War II, where the mortality rates reached more than 60% (Schenck 1965). Numbers of the systematical killing of Jews during the holocaust is, for example, given in Hewitt (1997).

Table 2-95. Current military expenditures in billion US dollars (CIA 2005)

| Country       | Current military expenditures |
|---------------|-------------------------------|
| US            | 276.7                         |
| China         | 55.9                          |
| France        | 46.5                          |
| Japan         | 39.5                          |
| Germany       | 38.8                          |
| UK            | 31.7                          |
| Italy         | 20.2                          |
| Saudi Arabia  | 18.3                          |
| Brasil        | 13.4                          |
| Korea, South  | 13.1                          |
| India         | 11.5                          |
| Australia     | 11.4                          |
| Iran          | 9.7                           |
| Israel        | 8.9                           |
Table 2-95. (Continued)

| Country        | Current military expenditures |
|----------------|------------------------------|
| Spain          | 8.6                          |
| Turkey         | 8.1                          |
| Canada         | 7.9                          |
| Taiwan         | 7.6                          |
| Netherlands    | 6.5                          |
| Greece         | 6.1                          |
| Korea, North   | 5.2                          |
| Singapore      | 4.5                          |
| Sweden         | 4.4                          |
| Argentina      | 4.3                          |
| Egypt          | 4.0                          |

Table 2-96. Current military expenditures in US dollars per capita (CIA 2005)

| Country                   | Amount |
|---------------------------|--------|
| Worldwide average         | 311    |
| Israel                    | 1,487  |
| Singapore                 | 1,003  |
| US                        | 986    |
| Brunei                    | 977    |
| Kuwait                    | 931    |
| New Caledonia             | 925    |
| Qatar                     | 911    |
| Oman                      | 893    |
| Bahrain                   | 801    |
| Saudi Arabia              | 778    |
| France                    | 778    |
| Norway                    | 687    |
| United Arab Emirates      | 654    |
| Greece                    | 574    |
| UK                        | 530    |
| Sweden                    | 495    |
| Cyprus                    | 482    |
| Australia                 | 475    |
| Germany                   | 466    |
| Denmark                   | 460    |
| Netherlands               | 404    |
| Taiwan                    | 356    |
| Italy                     | 349    |
| Switzerland               | 348    |
| Finland                   | 347    |
2.6.4 Terrorism

Terrorism can be seen as a specific type of violence and crime. Since 1983 in the USA, the most common definition of terrorism is: “The term terrorism means premeditated, politically motivated violence perpetrated against noncombatant targets by subnational groups or clandestine agents, usually intended to influence an audience.” (DoS 2004)

Only within a few years after the World Trade Center terrorist attacks in 2001, the war on terror was launched. Terrorism, however, has a long history. Data of terror victims of the last few decades have been statistically investigated by Bogen & Jones (2006). Whether this war is a sufficient safety measure to mitigate terrorism will not be discussed here; in general, the number of worldwide terrorist attacks remains high. Of course, this depends very strongly on the definition used. For example, if all attacks in Iraq are considered terrorist attacks, this remains a centre of terrorism, but the incidents there can also be considered military actions.

Obviously a peak in fatalities as a result of terrorist attacks was reached in 2001 with the attacks on the World Trade Center in New York, on the Pentagon in Washington and the airplane hijacking in Pennsylvania. While in 2001, more than 3,000 lives were claimed, in other years the number was usually less than 1,000 and only a few hundreds worldwide. For example in 2002, about 700 terrorist victims were claimed. The number of terrorist attacks worldwide is between 200 and 400 per year (DoS 2004).

The terrorist attacks show clusters at different locations and at different times. Such location clusters are clearly related to some political troubles of mainly unresolved problems. For example, such a location cluster can be found in Israel, where intensive investigations into terrorism and fighting terrorism have been carried out. For a long time, Northern Ireland and Great Britain have formed a terror location cluster. The consequences, however, of the terrorist attack at the World Trade Center in 2001 reached a new level. These consequences are not only in terms of direct victims of the incident but also the indirect consequences affecting the lives of probably a billion people in terms of political changes and level of freedom.

Further major terrorist attacks can be found in Europe. For example, the attack on a train in March 2004 in Spain claimed about 200 lives and injured more than 1,000 people. The blasting of a Boeing 747 in 1988 above Lockerbie in Scotland claimed 280 victims. During the world soccer championship in Germany, the probability of a bomb attack was estimated as 0.38% (Woo 2006).

Examples of major terrorist attacks worldwide over the last 30 years are either based on the insured value of loss or on the number of victims as can be seen in Tables 2-97 and 2-98.
### Table 2-97. Terror attacks with highest insured damages (Swiss Re)

| Insured damage | Fatalities | Date       | Incident                                                                                           | Country |
|----------------|------------|------------|----------------------------------------------------------------------------------------------------|---------|
| 19,000         | 3,000      | 11.09.2001 | Attack on the World Trade Center, Pentagon and other buildings                                      | USA     |
| 907            | 1          | 24.04.1993 | Bomb blasting in London close to the NatWestTower                                                 | U.K.    |
| 744            | –          | 15.06.1996 | Bomb blasting in Manchester                                                                       | U.K.    |
| 725            | 6          | 26.02.1993 | Bomb explosion at the underground parking lot of the World Trade Center in New York                | USA     |
| 671            | 3          | 10.04.1992 | Bomb explosion in the London financial district                                                   | U.K.    |
| 398            | 20         | 24.07.2001 | Suicide bombing at Colombo International Airport                                                   | Sri Lanka |
| 259            | 2          | 09.02.1996 | Bomb attacks against London South Key Docklands                                                    | U.K.    |
| 145            | 166        | 19.04.1995 | Bomb attack against a government building in Oklahoma City                                        | USA     |
| 138            | 270        | 21.12.1988 | Bomb explosion on PanAm Boeing 747 above Lockerbie                                                 | U.K.    |
| 127            | 0          | 17.09.1970 | Blasting of three hijacked passenger airplanes in Zerqa                                            | Jordan  |

¹ Million US-dollars 2001.

### Table 2-98. Terror attacks with maximum victims (Swiss Re)

| Insured damage | Fatalities | Date       | Incident                                                                                           | Country |
|----------------|------------|------------|----------------------------------------------------------------------------------------------------|---------|
| 19,000         | 3,000      | 11.09.2001 | Attack on World Trade Center, Pentagon and other buildings                                      | USA     |
| –              | 300        | 23.10.1983 | Bomb attack against US and French forces camp                                                     | Lebanon |
| 6              | 300        | 12.03.1993 | Series of 13 bomb attacks in Bombay                                                               | India   |
| 138            | 270        | 21.12.1988 | Bomb explosion on PanAm Boeing 747 above Lockerbie                                                 | U.K.    |
| –              | 253        | 07.08.1998 | Two bomb attacks a against US embassy in Nairobi                                                  | Kenya   |
| 145            | 166        | 19.04.1995 | Bomb attack against a government building in Oklahoma City                                        | USA     |
| 45             | 127        | 23.11.1996 | Hijacked Boeing 767-260 of Ethiopian Airlines crashed into the Indian Ocean                      | Russia  |
| –              | 118        | 13.09.1999 | Bomb attack destroyed residential building in Moscow                                              | Russia  |
| –              | 100        | 04.06.1991 | Arson in an arm cache in Addis Abeba                                                               | Ethiopia|
| 6              | 100        | 31.01.1999 | Bomb attack in Ceylinco House in Colombo                                                         | Sri Lanka |

¹ Million US-dollars 2001.
As already mentioned, terrorist attacks quite often occur in local and temporal clusters. Example of this, are the bomb warnings and attacks in the UK during the 1980s and 1990s. Many readers will probably remember the warnings during Christmas time at shopping centres or subways in London. Here, the terror attacks were strongly related to the independence endeavours in Northern Ireland; such examples can also be found in other European countries, for example Spain. The author himself has heard bomb explosions in London and has experienced the checking of railway tunnels against bombs in Spain.

Even in other countries like Germany, terror clusters occurred during the 1970s and 1980s due to the Red Army. In Japan in 1995, an attack with poisonous gas was carried out in the subway of Tokyo, killing 5 and injuring about 5,000 people. In Russia, India and Indonesia, terrorist attacks were conducted.

The magnitude of terrorist attacks is not only defined by the number of victims but also by the impact on the social systems. Such impacts can be preliminarily defined by the requirement for help (medical staff, fire brigades, police and army). A catastrophic terrorist event can cause damages that yield to the rupture of normal life in a city, region or country. This was very visible after the World Trade Center attacks, when air traffic from and to the eastern part of the US was completely closed down. Such secondary effects very often cause a much higher damage when compared to the direct initial damage not only in terms of financial values but also in terms of trust in the society and changes in the system. For example, in 2005 when an attack using liquid bombs at London Heathrow was planned, the boarding regulations for all airports inside the EU region was changed, which affected millions of passengers. Therefore, some countries, for example the Netherlands, have introduced a policy to restore normal life, since complete safety measures against intelligent terrorist attacks are impossible under normal living conditions. For example, after a terrorist bomb attack, security checks could be strengthened not only at airports but also at railway stations, buses, schools and universities and even supermarkets. This would completely alter the standard living conditions.

The classification of disastrous and non-disastrous terrorist attacks is mainly separated by the number of casualties. Usually 300–500 casualties are considered and treated by regular emergency help, whereas incidents surpassing this number require additional emergency help from neighbouring
areas. For example, incidents with 1,000 casualties require additional help from a distance of up to 200 km.

One has to be aware of the fact that during such events the medical attention is not comparable to normal treatment conditions. Some recommendations for an emergency state give about 2 min observation time per patient (Adams et al. 2004).

In general, in many countries, there are organisational structures to deal with terrorist acts of different kinds, since such acts might not only use bombs but also nuclear, biological and chemical weapons (Davis et al. 2003). Such weapons would heavily influence the social system. Therefore, special preparations for such cases are required by organisations such as the police, the secret service and also the medical systems. An example of special preparation is the storage of iodine tablets in case nuclear weapons are used either in a war or terrorist situations. Such tablets would prevent or at least lower the storage of radioactive material in the human body.

2.6.5 Crimes

Terrorist attacks are a special type of criminal acts. These might include murder and homicide; however, murder and homicide are not only committed as terrorist attacks. In general, murder is defined in laws as criminal offence against life, which is characterised by cattiness and base motives. The killing of people that does not fulfill these characteristics is called homicide.

In the US, about 22,000 people are killed per year by murder, homicide and police actions to prevent criminal acts (Parfit 1998). For comparison, Table 2-99 lists murder and homicide rates for different times and different cities (Remde 1995, Walker 2000 and BKA 2004).

Table 2-99. Murder and homicide rates for different countries or cities

| Year | Country or city              | Number of murders and homicides per 100,000 inhabitants per year |
|------|------------------------------|---------------------------------------------------------------|
| 1981 | USA                          | 10.2                                                          |
| 1989 | USA                          | 9.8                                                           |
| 1998 | USA                          | 6.3                                                           |
| 1993 | Johannesburg, South Africa  | 155.0                                                         |
| 1993 | London, U.K.                 | 2.5                                                           |
| 1999 | Dresden, Germany             | 0.8                                                           |
| 1996 | Dresden, Germany             | 1.9                                                           |
Figure 2-81 shows the development of the rate of murder and homicide in the USA for nearly a century. There seems to be a relation between times of economical wellbeing and the number of murders. It also shows that the executions may have only a limited effect on the murder rate.

For Germany, the development is shown in Fig. 2-82. The figure includes not only committed but also attempted murders. Additionally, one has to consider that the data until 1993 only represent West Germany, whereas later data for unified Germany are given (Rückert 2004). Although the interpretation of the data is difficult due to the inhomogeneity, the data in general show a decrease in the murder rate since 1993.

Often such average numbers do not consider that the frequency of criminal acts is high in some specific areas of a city or a region. Police use the possibility to draw geographic maps including data about the frequency of criminal acts. Figure 2-83 shows a part of the city map from Philadelphia indicating regions of high crime density in the year 1998 (Fragola & Bedford 2005).

![Graph showing the development of homicide rate in the US from 1900 to 1980.](image)

**Fig. 2-81.** Development of homicide rate in the US from 1900 to 1980
Fig. 2-82. Number of attempted and committed homicides in Germany (Rückert 2004)

Fig. 2-83. Example of a GIS (Geographical Information System) for identification of crime hot spots (Fragola & Bedford 2005)
The crimes mentioned here are strongly related to violence against humans. The worldwide problem of violence has been intensively studied by the WHO (Krug et al. 2002).

In the last years, violence from teenagers in developed countries has grasped major media attention, for example massacres in schools. It is well known that morbid social conditions might yield to depressive behaviour. There exists a relationship between depressive behaviour and aggressive behaviour of teenagers. Many young people cloister themselves after serious abuse, which is often caused by disproportional development in young age. This might yield to extensive TV viewing, computer consumption and finally to extreme violent behaviours (Te Wildt & Emrich 2007).

2.6.6 Drug Abuse and Alcoholism

Drug-related crimes and the trade of illegal drugs are not only a criminal hazard but also a hazard to the customer. Drug addiction is one of the biggest killers in both developing and developed countries. In Germany, about 100,000 tobacco-related deaths per year are recorded. Drugs are rarely identified as a direct cause of death; however, they are quite regularly identified as an initial cause of illnesses such as cancer (43,000 deaths per year in Germany), cardiovascular diseases (37,000 deaths per year in Germany) and respiratory diseases (20,000 deaths per year in Germany). The probability of falling ill with lung cancer and laryngeal carcinoma is twenty times and ten times higher, respectively, for a smoker. Fortunately, over the last few years, the percentage of smokers has fallen from about 60% (1980) to about 46% (1999) for males and from 54%–34% for females. Still, it has been estimated that tobacco will claim about 8.3 million lives per year in 2030.

Next to smoking, the second biggest killer is alcohol. The identification of alcohol as the cause of death still remains difficult. The estimated number of victims in Germany per year lies between 40,000 and 50,000. Data for Switzerland is given in Table 2-100. The WHO has defined a critical alcohol consumption of 20 g per day for females and 60 g per day for males. In Germany, about 10–15% of all men reach that value and about 3–5% of all women. In total, about 170,000 people are addicted to alcohol, of these about 25,000 men and 6,000 women are treated in hospitals and a further 88,000 men and 10,000 women are treated ambulant. Indirectly alcohol causes about 33,000 car accidents in Germany with about 1,500 fatalities. That is about 20% of all motor vehicle fatalities (BMG 2000).
Alcoholism can be classified according to Table 2-101. Newer research projects distinguish only two groups of alcohol addicts. Type I begins the alcohol addiction after the age of 25. The addiction is characterised by rather low social complications in comparison to a type II addict. Type II is characterised by an early start of alcohol addiction in association with heavy social complications and the early observation of alcohol and drug misuse in the kinship at a young age.

Table 2-100. Death numbers, lost life-years and chronic diseases caused by alcoholism in Switzerland for people of age between 15 and 74 (Gutjahr & Gmel 2001)

| Age   | Male | Female |
|-------|------|--------|
|       | Number of fatalities | Lost life-years | Number of fatalities | Lost life-years | Number of fatalities | Lost life-years | Mortality (%) | Lost life-years (%) |
| 15–24 | 1    | 35     | 2,728 | 12.1 | 12.0 | 118 | 9 | 504 | 6.7 | 7.7 |
| 25–34 | 12   | 483    | 2,823 | 9.4  | 9.6  | 388 | 13 | 552 | 5.6 | 6.3 |
| 35–44 | 61   | 2,162  | 1,741 | 10.9 | 11.3 | 34  | 11 | 397 | 8.7 | 9.7 |
| 45–54 | 168  | 4,273  | 1,306 | 11.5 | 12.2 | 66  | 12 | 292 | 7.4 | 8.2 |
| 55–64 | 220  | 3,232  | 587   | 7.4  | 7.8  | 81  | 10 | 148 | 5.0 | 5.8 |
| 65–74 | 236  | 1,193  | 40    | 121  | 581  | 15  | 64 | 3.2 | 3.9 |
| >74   | 235  | –      | 68    | 1.8  | –    | 412 | 70 | –   | 2.0 | –   |
| Total | 933  | 11,378 | 355   | 9,361 | 4.2  | 9.7 | 721 | 5,534 | 140 | 1,957 | 2.7 | 6.9 |

Table 2-101. Classification of alcoholism (Möller et al. 2001)

| Type of alcoholism | Type            | Addiction                  | Signs of addiction                        | Frequency (%) |
|--------------------|-----------------|-----------------------------|-------------------------------------------|---------------|
| Alpha              | Conflict drinker| Only psychological          | No loss of control, capability of abstinence| 5             |
| Beta               | Occasional drinker| None                      | No loss of control, capability of abstinence| 5             |
| Gamma              | Addictive drinker| First only psychological, later physical | Loss of control, but occasional capability of abstinence | 65           |

(Continued)
The health consequences of alcohol addiction can be diverse. For example, a chronic consumption of about 60 g of pure alcohol by males and about 20 g of pure alcohol by females can cause a cirrhosis of the liver as well as psychological successor diseases. Such diseases are acute delirium, alcoholic hallucination, alcoholic jealousy mania, personality changes, dementia, Korsakowsyndrome or Wernicke cerebropathy (Möller et al. 2001).

In addition to legal drugs such as alcohol, there are illegal drugs that are misused. In Germany, probably cannabis is the most frequently used illegal drug. It has been estimated that about 2 million people in Germany consume cannabis at least once per year. That represents 2.5% of the entire population of 80 million. Ecstasy is used in Germany by at least 500,000 people once per year (6%) (BMG 2000).

In Germany, approximately 8,000 heroin consumption beginners, about 7,000 Amphetamine consumption beginners, 5,000 cocaine consumption beginners and 4,000 ecstasy consumption beginners are registered per year. Consumption beginners are people who have been identified in connection with the misuse of drugs. They include taster and first consumers and not necessarily addicted persons (BMG 2000).

The majority of drug related deaths are either due to multiple misuse of different drugs or to the long-term misuse of drugs over several years. In 1999 in Germany, about 1,800 drug-related deaths were registered (Fig. 2-84). A further topic is the drug misuse by children and teenagers (Stolle et al. 2007). Furthermore, in addition to illegal drugs, legal drugs are also misused; however, this misuse is difficult to record. Such drugs include painkillers, sleeping pills, tranquilisers, stimulants and purge. The misuse here is mainly assumed based on general consumption data of such drugs. On average, 20% of the female and 10% of the male population have taken such pharmaceutics in the last four weeks. Considering some age-dependant cohorts, higher values can be found. For example, in the group with age greater than 50 years, up to 30% of the females used the mentioned drugs in the last four weeks (BMG 2000).

| Type of alcoholism | Type Addiction | Signs of addiction                                                                 | Frequency (%) |
|--------------------|----------------|-------------------------------------------------------------------------------------|---------------|
| Delta              | Habitual drinker| Physical Inability for abstinence, continuous low level of drunkenness               | 20            |
| Epsilon            | Episodical drinker| Psychological Loss of control for several days during excessive drinking          | 5             |

Table 2-101. (Continued)
2.6.7 Mountaineering

Obviously humans do not seek absolute safety, but they choose to make a trade-off between risks and advantages. A good proof of this statement is mountaineering. Here, humans accept a higher risk by attempting to achieve something favourable for them. Some examples to visualise such higher risks in mountain regions are given here.

At the beginning of the 1990s, about 40 people were killed during the ascent to the Pike Lenin in the Pamir Mountains (Häußler 2004). From 1975 to 2002, about 1,200 people had climbed Mount Everest. From this population, about 175 people died during attempts. In 1996 alone, 15 climbers were killed. This means that for every seven successful climbs, one climber gets killed. However, in the last years, the ratio has been improved, as shown in Fig. 2-85 (Klesius 2003). An overview of mortalities at different mountain peaks is shown in Table 2-102.
2.6.8 Sport

It seems to be strange to consider sport as a risk. However, as shown in the section on adverse effects, pharmaceutics too can be considered a risk. The original way of living of humans did not require such organised and controlled physical activities like sport. Although such activities are required, they might impose some risks of injuries to humans. Table 2-103 shows different kinds of sporting activities and related sport accidents based on 100 hospitals in the US. However, independent from the number of accidents, such accidents are in most cases not life-threatening.
Table 2-102. Fatality rates for people climbing different mountain peaks (Höbenreich 2002)

| Peak             | Height (m) | Number of people successfully reaching the summit | Percent of repetition | Number of fatalities | Ratio of fatalities during ascent | Ratio of fatalities during descent to reached peak |
|------------------|------------|--------------------------------------------------|-----------------------|---------------------|----------------------------------|--------------------------------------------------|
| Everest          | 8,850      | 1,173                                            | 299                   | 874                 | 165                              | 1:7.1 1:29.3                                     |
| K2               | 8,611      | 164                                              | 1                     | 163                 | 49                               | 1:3.4 1:7.5                                     |
| Kantschendzöngö  | 8,586      | 153                                              | 7                     | 146                 | 38                               | 1:4 1:21.9                                      |
| Lhotse           | 8,516      | 129                                              | 1                     | 128                 | 8                                | 1:16.1 1:64.5                                   |
| Makalu           | 8,463      | 156                                              | 0                     | 156                 | 19                               | 8 1:8.2 1:19.5                                  |
| Cho Oyu          | 8,201      | 1,090                                            | 92                    | 998                 | 23                               | 5 1:47.4 1:218                                  |
| Dhaulagiri       | 8,167      | 298                                              | 8                     | 290                 | 53                               | 5 1:5.6 1:59.6                                  |
| Manaslu          | 8,163      | 190                                              | 1                     | 189                 | 51                               | 3 1:3.7 1:63.3                                  |
| Nanga Parbat     | 8,125      | 186                                              | 2                     | 184                 | 61                               | 3 1:3.1 1:62                                     |
| Annapurna        | 8,091      | 109                                              | 3                     | 106                 | 55                               | 8 1:2 1:13.6                                    |
| Gasherbrum I     | 8,068      | 164                                              | 3                     | 161                 | 17                               | 3 1:9.7 1:54.7                                  |
| Broad Peak       | 8,047      | 217                                              | 5                     | 212                 | (+107)                           | 18 (1.2)% 22.2%                                 |
| Gasherbrum II    | 8,035      | 468                                              | 12                    | 456                 | 15                               | 3 1:31.2 1:156                                 |
| Shisha Pangma    | 8,027      | 167                                              | 2                     | 165                 | (+434)                           | 19 (0.3)% 10.5%                                 |
| Sum              | 4,664      | 436                                              | 4,228                 | 4,769               | 591                              | 115                                             |
| Average          | 8,282      | 333.1                                            | —                     | 42.2                | 8.2                              | 1:7.9 8.8                                      |

Table 2-103. Estimations of sporting accidents in the US for the year 1998 (NIIC 1999)

| Sport            | Number of accidents | Percent of accidents in age classes |
|------------------|---------------------|-------------------------------------|
|                  | 0–4 | 5–14 | 15–24 |
| Basketball       | 631,186 | 0.6 | 31.5 | 46.4 |
| Bicycling        | 577,621 | 7.1 | 55.0 | 15.2 |
| American Football| 355,247 | 0.3 | 45.0 | 43.1 |
| Baseball         | 180,582 | 4.5 | 50.4 | 23.3 |
| Soccer           | 169,734 | 0.5 | 45.7 | 37.6 |
| Softball         | 132,625 | 0.3 | 19.2 | 30.1 |
| Fitness equipment| 123,177 | 0.4 | 13.9 | 26.3 |
| In-line skating  | 110,783 | 0.7 | 61.1 | 18.7 |
| Trampoline jumping| 95,239 | 9.6 | 69.6 | 14.0 |
| Skiing           | 81,787  | 0.5 | 14.2 | 15.9 |
2.6.9 Panic

Mass panic is a special human behaviour yielding to crowd stampede, which can result in fatalities. It has been observed at sport events. Some examples of panics are given.

During a memorial ceremony, about 14 children were killed in stampede in June 2000 in Addis Ababa. During the Troitsa Festival in Minsk, Belarus, on 30 May 1999, about 53 people were killed at the entrance of a subway station. A fire disaster occurred in West Warwick at Rhode Island on 20 February 2003. A fire in the club “The station” caused a panic, in that 99 people were trampled to death and 190 severely injured. On 6th December 1976, a panic occurred in Port-au-Prince, Haiti, at a World Cup soccer match between Haiti and Cuba. After a goal, a fan lighted a fire cracker in the stands. Other fans believing it was gun fire panicked and knocked down a soldier. The soldier’s gun then went off and killed two children. The panic continued, and further people were trampled to death and the soldier committed suicide (CDL 2007).

The prediction of human behaviour in such situations is rather complex. There are many causes for such behaviour—like bad weather situation at the end of major open-air events, fire and smoke in closed rooms, complex building structures, rain, hail, storm, ice, time pressure and fear or hysteria—and are all contagious phenomena and possible causes. Furthermore, during such events, the individual freedom of action is limited and a new, collective behaviour emerges. This yields actually to some juristic problems, which are mentioned in Kretz (2005).

A simple recommendation such as providing more emergency exits might not help in many cases. Emergency exits are often not useful because most people try to leave the building the way they entered (Kretz 2005). Recently, some numerical models have been developed to predict crowd stampede caused by panic (Helbing et al 2000).

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