## Background Information

# A Scientific View of Risk

You probably have an intuitive sense of what risk means to you. Maybe you consider smoking cigarettes or drinking and driving as risky behavior, but you do them anyway. On the other hand, you might consider drinking and driving as presenting too much of a risk and thus avoid this combination. If you are the rugged, adventurous type, you might find thrill and satisfaction in taking some risks such as skydiving, rock climbing, and bungee jumping, but be totally unwilling to accept the risk of flying, being vaccinated, or eating a rare hamburger.

Virtually every activity in life involves some level of risk. Whether we are traveling to work or school, doing household chores, operating electrical equipment, or simply taking a stroll in the park, we constantly face possible injury and death. Even staying at home does not guarantee our safety. According to Larry Laudan in the *Book of Risks: Fascinating Facts About the Chances We Take Every Day,* one's annual risk of being injured at home is about 1 in 81; each year more than 600,000 Americans are injured in their chairs and beds. Another 100,000 are injured by their clothing seriously enough to require medical treatment. Risk can never be eliminated, no matter how careful we are. Consider that automobile and other accidents claim the lives of some 94,000 Americans annually and are the leading cause of death for people under age 44. It is a sobering and often overlooked fact, but the likelihood of dying sometime in our lives is 100%.

This background document looks at some everyday risks and compares them with perceived risks of contracting cancer and other diseases through environmental pollution. It also discusses some of the reasons why the general public and risk professionals frequently have differing views on risk.

### Risk Is a Probability

A risk specialist considers risk to be the probability of a person suffering an adverse effect from some activity or exposure over a given period of involvement. Since risk is a probability, it is expressed as a fraction, or ratio, of the number of people who experienced the "adverse" effect divided by the number of people who engaged in the "activity." For example, about 42,000 Americans die in highway automobile accidents annually. If you assume 200,000,000 Americans travel the highways regularly each year, the risk of dying in a car wreck any given year is 42,000 out of 200,000,000, which is about 1:5,000 or 0.02%. (Remember percent is simply another way of expressing a ratio.) To put these numbers in perspective, the number of Americans killed every 18 months in highway accidents is nearly equal to all American soldiers killed in the Vietnam War.

Length of time spent in an activity or of an exposure is an important factor in assessing risk. For example, the average lifetime risk of dying in an highway accident is about 1:45 or 2.2%. This is about 100 times greater than the annual risk of a highway death. Omission of the time element in "statistics" cited in popular magazines or on television is not only misleading—it's also bad science. Suppose someone stated that the risk of dying while skiing is 1:1,000. This may sound like a relatively high risk; however, the statistic alone means nothing. One must weigh the risk over the amount of time spent doing the activity. For example, it's skiing for 340 hours that produces a 1:1,000 risk of death. Table 1 illustrates this principle.

**Table 1: Activities Producing a 1:1,000 Risk of Death**

| Activity | Time Spent |
|---|---|
| Rock climbing | 25 hours |
| Regular skydiving | 50 hours |
| Riding a motorcycle | 55 hours (cross-country, one way) |
| Being a 65-year-old man | 336 hours (2 weeks) |
| Skiing | 340 hours |
| Flying on a scheduled airline | 1,200 hours |
| Adapted from L. Laudan, *The Book of Risks: Fascinating Facts about the Chances We Take Every Day,* 1994. | |

As another example, consider the frequently cited statistic that 1 in 8 women will develop breast cancer sometime in their lives. The actual risk depends on the lifetime being considered. The quoted risk is for women who live to be 95 years old or greater, but few women reach this age. Like men, most women succumb to other illnesses, such as cardiovascular disease, other forms of cancer, diabetes, or stroke well before this 1:8 statistic becomes a reality in their lives.

Another way that risk probabilities can be misused is by presenting total fatalities caused by an activity without considering the number of people engaged in that activity. The next time you see a newspaper headline that says "Highway Carnage Claims 43 Lives this Holiday Weekend," think about how many people normally drive or ride in a car over a three-day weekend and how the number of fatalities compares with the average number of deaths for this many people.

The advantage of expressing risk as a ratio over time is that various risks can be objectively compared, allowing individuals and society to make informed choices about the most serious risks to address. Table 2 shows a comparative ranking of various risks average Americans face on yearly and lifetime bases.

| Table 2: Some Risks for Average Americans Annually and Over a Lifetime | | |
|---|---|---|
| Risk | Annual | Lifetime |
| You will die of heart disease. | 1:340 | 1:3 |
| You will die of cancer. | 1:500 | 1:5 |
| You will die in an automobile accident. | 1:5,000 | 1:45 |
| You will be murdered. | 1:11,000 | 1:93 |
| You will die from AIDS. | 1:11,000 | 1:97 |
| You will die in an airplane crash. | 1:250,000 | 1:4,000 |
| Adapted from L. Laudan, *The Book of Risks: Fascinating Facts about the Chances We Take Every Day,* 1994. | | |

Although these figures are useful for comparing levels of risk, a word of caution should be given about them. The odds presented are for hypothetical “average” Americans. The risk of dying in an airplane crash for someone who never flies is nearly zero. (It’s not completely zero because fatalities on the ground may occur at crash sites.) Likewise, gender, race, lifestyle, age, and genetic predisposition play strong roles in determining an individual’s actual risk. A 60-year-old smoker with a family history of heart disease has a much higher than average annual risk of dying from a heart attack. Similarly, a person’s chance of dying from AIDS is lower than average if he or she does not belong to any of the known at-risk groups. Other examples include the fact that men are twice as likely as women to die in motor vehicle accidents, of lung cancer, and of liver disease. African Americans are twice as likely as whites to die from cerebrovascular disease, diabetes, and pneumonia. Cystic fibrosis is an inherited disease occurring primarily among white Americans.

In order to compensate for these differences, most risk experts prefer to use a relative risk index, which compares the odds of something affecting a specific group with the odds of something affecting the entire population. A relative risk index is expressed in positive numbers such as 0.5 or 2.0, meaning, in this example, that a specific group is either half or twice as likely as the entire population to experience the effect in question. (Risk for the entire population is considered to be 1.0.)

Another way to express risks is in terms of a shortened life span. For example, our society reacts more strongly to a 2-year-old child drowning in a bucket of water (low risk) than to a 70-year-old man dying of heart disease (high risk). Sadly, both happen, but the child’s death is considered more tragic than the man’s because of the potential years of life lost. Thinking in terms of potential life lost can give us a new perspective on how our society might allocate resources to tackle certain risks. The levels of risk shown in Table 2 would suggest that society might be better off spending more of its money to reduce heart disease and cancer than funding AIDS research. However, what the risk numbers do not show is that heart disease and cancer largely affect seniors, whose remaining years are statistically less than the remaining years of the majority of people stricken with AIDS or killed in automobile accidents.

Table 3 is adapted from John Stossel's ABC News Special Report, *Are We Scaring Ourselves to Death?* It shows a set of environmental and everyday risks with the number of days they take off an average American's life and compares them in ranking to the number of Americans killed annually by the same risk. It is important to note that the number of deaths attributable to hazardous wastes, pesticides, and air pollution are not readily measurable, but according to the report, the numbers represent best estimates by Environmental Protection Agency (EPA) risk assessors. The actual number of deaths from these environmental risks may be far lower. With this caveat in mind, notice that although air pollution purportedly claims more total lives than homicide or driving, it still ranks lower in terms of days of life lost. This is because air pollution disproportionately affects older people who are more likely to have chronic lung problems.

**Table 3: Number of Days Taken off the Average American' s Life by Certain Activities and Exposures**

| Risk | Days of Life Lost | Approximate Number 0f Deaths Annually |
|---|---|---|
| Flying | 1 | 200 |
| Hazardous waste | 4 | 1,000 |
| House fires | 18 | 5,000 |
| Pesticides | 27 | 16,000 |
| Air pollution | 61 | 55,000 |
| Homicide | 113 | 26,000 |
| Driving | 182 | 43,000 |
| Smoking* | 2,000 | 400,000** |

Adapted from J. Stossel, *Are We Scaring Ourselves to Death?,* 1996.
* Risk computed for smokers only.
** From James Walsh, *True Odds: How Risk Affects Your Everyday Life*, 1996.

## The Relative Nature of Risk

Most risks are also relative, meaning that any given risk should be weighed with other risks or lost benefits that can result from attempts to reduce the given risk. In some cases, immediate risks such as starvation outweigh long-term risks such as carcinogens in food. For example, people living in a subsistence society could scarcely conceive of throwing away applesauce, as thousands of Americans did during the Alar scare of 1989. To some, the very real threat of starving tomorrow offsets the risk of getting cancer 40 years down the road. In other cases, the measures taken to reduce a given risk may in fact pose a greater hazard than the problem being addressed. For example, in the early 1990s, New

York City closed its schools and spent $100 million to remove asbestos that many risk professionals argued was safer to leave in place. Additionally, children were out of school, playing on the streets where the risk of injury and death was far higher than any posed by asbestos. Some risk assessors refer to such misguided attempts to reduce risk as “statistical murder.”

## Are We Really Living Dangerously?

Americans today are living healthier and longer lives than at any time in our nation’s past. According to the Centers for Disease Control (CDC), average human life expectancy in the U.S. increased by more than 30 years between 1900 and the present (47.3 to 78.1 years, respectively). The CDC also reports, “In 1900, the three leading causes of death were pneumonia, tuberculosis, diarrhea and enteritis, which (together with diphtheria) caused one-third of all deaths. Of these deaths, 40% were among children aged less than 5 years.”

One hundred years ago, between six and nine women in the U.S. died of pregnancy complications for every 1,000 live births. By 1997, according to the CDC, “the maternal mortality rate had declined almost 99% to less than 0.1 per 1,000 live births.” Over the same time period, infant mortality declined more than 90%.

Deaths due to accidents have declined as well. Data from the National Safety Council indicate that between 1912 and 1988, accidental deaths decreased by about 52%. Deaths from workplace injuries declined 90%, from 37 per 100,000 workers in 1933 to four per 100,000 in 1997.

Despite these advances, polls indicate that modern Americans are particularly worried about risks to health, safety, and the environment. One health-related worry is cancer. In 1998, about 500,000 Americans died from cancer—making it the second leading cause of death in the U.S. behind heart disease, which killed 724,000 that same year. Together, these two diseases accounted for almost 55% of all deaths. In 1900, cancer was the cause of only about 4% of deaths in the U.S. Do these figures imply an explosive cancer epidemic in this century? To answer the question, one needs to consider a number of other issues that may confound the statistics.

First, more people are living longer. Cancer is primarily a degenerative disease of the elderly. One hundred years ago, most people died from a host of other illnesses before they reached their senior years. Second, incidence rates of cancer have gone up as cancer has become more easily and readily diagnosed. There’s no way of knowing whether someone’s death which was attributed to chronic bronchitis back in 1908 wasn’t a complication of lung cancer which the family doctor had no way of diagnosing.

Consider that about 30% of all U.S. cancer deaths can be attributed directly to cigarette smoking, a habit that reached its peak in males in the 1940s and 1950s. The 247% increase in lung cancer fatalities since 1950 is commonly attributed to smokers who have now reached their most cancer-prone years. An increase in cigarette smoking in females has resulted in their currently increasing rate of lung cancer, which is now the leading cause of cancer death in both sexes. According to a 1988 National Cancer Institute update, "cancer death rates in the United States (after adjusting for age and smoking) are steady or decreasing… the age-adjusted mortality rate for all cancers combined except lung cancer has been declining since 1950 for all individual age groups except 85 and above." Mortality rates have decreased for stomach cancer by 75%, cervical cancer by 73%, uterine cancer by 60%, and rectal cancer by 65%.

On the other hand, data from the National Cancer Institute indicate that incidence rates (as opposed to mortality rates) are on the increase for some forms of cancer. Over the period 1973–1996, the incidence rates of prostate and breast cancer grew annually by about 5% and 1%, respectively. Also increasing are incidences of multiple melanoma, non-Hodgkin's lymphoma, liver, kidney, thyroid, and testis cancer. The incidence of melanoma, the most serious form of skin cancer, increased nearly 6% annually, and during the same period the overall mortality rose 36%. Again, higher incidence rates may simply be due to better early detection of these diseases.

## What Is the Exposure?

One commonly held assumption is that many forms of cancer are attributable to physical and chemical toxins in the environment. Although the exact mechanisms that cause cancer are still being unraveled, the generally accepted model holds that cumulative damage or mutations to the body's cells over a period of time triggers the onset and progression of the disease. Exposure to radiation and smoking have been linked to cancer in humans. Several industrial chemicals have been shown to cause cancer in humans and many others are suspected to be human carcinogens based on animal studies.

In the late 1890s and early 1900s, such industrial chemicals were recognized as hazardous only by looking for causes after the cancer occurred in the victims. This was the case for scrotal cancer in chimney sweeps (from soot and coal tar) and bladder cancer in dye workers (from 2-napthylamine and benzidine in aromatic amine-based dyes). More recent cases include lung cancer in asbestos miners and shipyard workers (from asbestos insulation) in the early 1940s, especially among smokers, and liver cancer in workers cleaning vinyl chloride tanks in the early 1970s. In all cases, these cancers occurred following prolonged and high exposure.

Over the decades, increased public awareness, advances in tests for hazardous chemicals, and the regulation of these chemicals have reduced the presence of highly toxic substances and the likelihood of exposure to them. Having these potent agents under control, questions remain as to risks of exposure to the wide range of chemicals encountered in everyday life.

Evidence that low-level environmental exposure to toxic substances is a significant cancer threat to the average American is much less convincing.

The number of human cancers caused by chemicals, pesticides, and other environmental pollutants is not known. According to biologist Paul Ehrlich, "The proportion of those cancers that result from exposure to toxic substances is unknown and may never be measurable, but it is probably no more than a third." However, epidemiologists Richard Doll and Richard Peto think that only about 2% of cancers can be attributed to environmental pollution. According to cancer experts Bruce Ames and Lois Gold, there is no persuasive evidence that life in the modern industrial world has in general contributed to cancer deaths.

A factor that casts doubt on synthetic chemicals being responsible for the bulk of human cancers is that many carcinogens are naturally occurring compounds in the food we eat. Over millions of years, plants have evolved chemical defenses against insects and fungi that can be as toxic as any synthetic chemical. According to Ames and Gold, one cup of coffee contains about the same weight in milligrams of naturally occurring carcinogenic materials as the pesticide residues that the average American consumes in the course of a year. A classic example of natural toxins is of an "organically" grown variety of celery that contained so many naturally-occurring pesticides that it caused contact dermatitis in the workers handling it. While the FDA regulates the addition of potentially carcinogenic additives to food and drug products (the Delaney Clause, passed by Congress in 1958), it does not do so for naturally occurring compounds.

Some environmentalists have countered that synthetic chemicals are more hazardous than natural ones because humans have evolved a Darwinian resistance to the naturally occurring toxins. This assertion is dubious for several reasons. First, many of the foods known to contain natural carcinogens, such as potatoes, have been cultivated throughout the world only during the last several hundred years. This would be considered a very short period over which to develop such a resistance. Second, most cancers manifest themselves only after the individuals have passed their reproductive years; natural selection would then not be a factor in the evolution of cancer resistance. Third, some natural chemicals still cause human cancer even though humans have been exposed to them for a very long time. For example, humans have probably ingested the carcinogenic chemical benzo(a)pyrene (a polynuclear aromatic hydrocarbon found in charred meat) at least since the invention of fire. Table 4 shows a list of some foods containing natural carcinogens.

| Table 4: Carcinogens Found Naturally in Foods | |
|---|---|
| Food | Carcinogen |
| peanuts and peanut butter | aflatoxins* |
| brown mustard | allyl isocyanate |
| basil | estragole |
| mushrooms | hydrazines |
| bacon | dimethyl nitrosamine |
| bread | formaldehyde |
| strawberries | benzene |
| coffee | dicarbonyl aldehyde methyglyoxal |
| black pepper, cinnamon, and nutmeg | safrole |
| *Produced by contaminating fungi.<br>Adapted from E. Efron, *The Apocalyptics: Cancer and the Big Lie,* 1984. | |

This information should not discourage people from consuming these foods. Many of the foods that contain natural carcinogens also contain essential vitamins, nutrients, and antioxidants that can help lower the risk of getting cancer.

## Risk Reduction and Public Policy

Risk reduction always has its costs, which may be monetary or nonmonetary. The adverse effects of risk can be measured in different ways: loss of life, health, productivity, quality of life, or time. (We are mainly concerned here with the first two types of losses.) When we try to eliminate one form of risk, we may increase other, perhaps less visible, risks or losses.

For example, people who drive to work in small cars are two times more likely to die in a crash. However, large cars generally cost more and are more destructive to the environment. Traffic accident deaths could be reduced to nearly zero if a 5-mile-per-hour speed limit were established, but such a law would bring the modern economy to a standstill. While seemingly contrary to our best intentions, we must place some finite value on human life.

In an attempt to reduce risk from consumer products, work conditions, and environmental hazards, the U.S. government has set up regulatory agencies such as the Consumer Product Safety Commission (CPSC), the Occupational Safety and Health Administration (OSHA), and the Environmental Protection Agency (EPA). The regulations put in place by these agencies are important in saving lives and improving health but require restrictions on businesses and consumers and the creation of government bureaucracies. Table 5 shows one estimate of the median cost per life-year saved by regulations imposed by some regulatory agencies.

| Table 5: Median Value of Cost/Life-Year Saved for Four Regulatory Agencies | |
|---|---|
| Agency | Median Cost per Year of Life Saved |
| Federal Aviation Administration | $23,000 |
| Consumer Product Safety Commission | $68,000 |
| National Highway Traffic Safety Administration | $78,000 |
| Occupational Safety and Health Administration | $88,000 |
| Adapted from PRC Fund website, "Are We Scaring Ourselves to Death?" www.prcfund.org/stossel/scaring.htm (accessed May 11, 2000). | |

Keep in mind that these statistics are for agencies with very different roles. The EPA deals with environmental risks to all people (not just those engaged in certain activities) and if the EPA's cost per life-year figure were included, the figure would be quite high. One should also note that other sources may calculate the estimates in this table quite differently and that individuals will react differently to these monetary values depending on their personal views on risk and on the missions of these different agencies.

## Risk Communication

In a democracy, public opinion usually determines where money is spent to address societal risks. However, the public's perception of risk is often at odds with the perceptions of scientists and professional risk assessors. According to Laudan in *The Book of Risks*, "questionnaire research shows that most people suppose that the chances of their dying of a heart attack to be about 1 in 20; in fact, the risk is closer to 1 in 3. Similarly, the average American reckons the odds of his or her dying in a car accident this year to be about 1 in 70,000; the real figure is closer to 1 in 7,000."

Some would argue that the public is not informed well enough to make decisions based on science and reason; instead, decisions are often based on unfounded fears. When Americans were asked in a July 1999 Harris poll what they were very afraid of, the top response (36%) was snakes. However, of the 150,298 Americans who died from injuries in 1996, only 13 were killed by a bite from a venomous snake, lizard, or spider. Some risk professionals criticize the news media for highly publicizing the use of an industrial chemical or pesticide that is thought to cause one cancer death in 100,000, when so many riskier activities and exposures exist in daily life. One result of skewed media coverage is that the public often ends up underestimating common risks and exaggerating low risks.

Second-hand tobacco smoke is an example of a risk that has been frequently featured in the media. A 1997 Gallup poll indicated that 50–60% of Americans surveyed thought second-hand smoke was very harmful to adults. However, the EPA estimates the risk that you will develop a fatal cancer this year caused by exposure to second-hand tobacco smoke to be 1:30,000. According to Laudan in *The Book of Risks*, eating a flame-cooked pork chop once a week is twice as likely to kill you as secondary tobacco smoke. Of course, the risk from second-hand smoke may have been greater a generation ago before wide-spread public smoking bans were in effect.

A disparity also exists between the public's and professional risk assessors' perceptions when it comes to assessing environmental risks. Table 6 shows a ranking of environmental risks as perceived by the public and the EPA's principal environmental concerns. Of the EPA's top 11 risks, the publics ranks only outdoor air pollution, ozone depletion, and occupational exposure to toxic chemicals within that group. Out of a list of 28 environmental risks, the public ranks pesticide residues in food 18th, global warming 19th, drinking-water contamination 20th, indoor air pollution 26th, and radon in homes 28th.

**Table 6: Ranking of 11 Top Environmental Risks as Perceived by American Public and U.S. EPA**

| Public (in rank order from highest to lowest) | EPA (not ranked) |
|---|---|
| hazardous waste sites | global warming |
| industrial water pollution | urban smog |
| on-job exposure to chemicals | ozone depletion |
| oil spills | toxic air pollutants |
| ozone depletion | alteration of habitat |
| nuclear power plant accidents | radon |
| industrial release of pollutants | loss of biodiversity |
| radioactive wastes | indoor air pollution |
| air pollution from factories | drinking-water contamination |
| leaking underground storage tanks | on-job exposure to chemicals |
| contamination of coastal waters | application of pesticides |

Adapted from B. Nebel and R. Wright, *Environmental Science*, 2000, p. 403.

Risk communicators and psychologists have developed a number of theories to account for the public's perspectives on risk:

- Old risks are considered safer than new risks. We're more comfortable with familiar risks. For example, alcohol is a known human carcinogen, but people still consume it because it has been around so long and is a part of so many traditional cultures. However, people tend to view nuclear power and gene treatment with a more wary eye because they are relatively new technologies.
- People feel more comfortable when they are in control of a situation. Even though we are statistically at a higher risk of dying while driving a car than flying in a plane, we feel safer because we are in control. Similarly, outrage is often a factor. People have a lower tolerance for risk that is imposed on them by others, regardless of how small the actual risk may be. This factor may account for much of the response to second-hand smoke.
- People tend to fear most that which happens least. This disproportionate fear is probably due to the media's tendency to act as an amplifier, focusing on the unusual and newsworthy stories, while ignoring the commonplace ones. Some risk professionals refer to this effect as "risk telescoping."

Many people also try to personalize risk. For example, they might say something like, "So what if only one in a million people will get cancer from pesticides. What if you're that one?" As John Allen Paulos points out in *Innumeracy: Mathematical Illiteracy and Its Consequences,* the tendency to personalize is a characteristic of people who suffer from innumeracy. They have little intuitive feel for the numbers involved. When reminded that their odds of winning a state lottery may be no better than 10 million to one, players frequently respond that *someone* has to win (implying that the odds of someone winning are similar to the odds of *their* winning).

However, some risk communicators explain that the public's sense of risk is not irrational, just different from the professionals', and equally valid. For example, people tend to fear technologies or products with particularly dreadful consequences if mishaps were to occur (for example, nuclear power). Also, to most people, it matters how we die. A death in an automobile accident or from cancer is statistically counted equally as one death, but in an accident, death may occur relatively quickly, while in the case of cancer, death may come only after a long, painful, and debilitating illness. Some people would prefer the swiftness of an accident.

Most risk assessment experts acknowledge that understanding and appreciating the public's viewpoints on risk is essential if proper risk communication is to occur. Studies and experience have shown that the public does not respond well to risk experts who claim that the public's problem is one of ignorance. "Furthermore," writes risks specialist M. Granger Morgan, "risk management is fundamentally a question of values. In a democratic society, there is no acceptable way to make these choices without involving the citizens who will be affected by them."

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