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Health Physics Vol. 36 (June), pp. 707–722
Pergamon Press Ltd., 1979. Printed in Great Britain

A CATALOG OF RISKS

BERNARD L. COHEN and I-SING LEE
Department of Physics and Astronomy, University of Pittsburgh,
Pittsburgh, PA 15620

(*Received* 5 *June* 1978; *accepted* 11 *September* 1978)

Abstract—Information on risks is collected from various sources and converted into loss of life expectancy throughout life and in various age ranges. Risks included are radiation, accidents of various types, various diseases, overweight, tobacco use, alcohol and drugs, coffee, saccharin, and The Pill, occupational risks, socioeconomic factors, marital status, geography, serving in U.S. armed forces in Vietnam, catastrophic events, energy production, and technology in general. Information is also included on methods for reducing risks, risks in individual actions, "very-hazardous" activities, and priorities and perspective. Risks of natural and occupational radiation and exposure to radioactivity from the nuclear industry are compared with risks of similar or competing activities.

INTRODUCTION

THE PUBLIC is constantly harrangued about all sorts of risks, and its perception of risks plays an important role in governmental decision making. The risks of radiation have especially been emphasized in the popular press. This creates a very serious problem since the public does not understand risk. It gets highly excited about radiation risks which are almost never fatal, whereas it largely ignores other risks which claim thousands of lives every year.

One possible reason for this situation is that risks are not generally expressed in understandable terms. They are usually given as annual mortality rates, which are nearly always smaller than 10^{-3}, whereas there is good evidence that the public recognizes little difference between an annual risk of 10^{-3}, 10^{-6}, and 10^{-9}. An expression of risk more understandable to the public would be in terms of days of life expectancy lost; one purpose of this paper is to translate the data into those terms. A complication in that process is that the value of lost life expectancy is generally viewed as varying considerably with the age at which the time is lost—a year lost in the prime of life by a parent of small children is generally more regretable than a year lost in advanced old age. We therefore give results in terms of life expectancy lost in various age ranges.

DEFINITIONS AND CALCULATIONAL PROCEDURES

The basic information in calculating life expectancy is a set of $R(I)$, the mortality rate (or probability of death) during year I defined as starting on the Ith birthday. Given $R(I)$, one may calculate $P(M, N)$, the probability of death at age N for a person who is alive on his Mth birthday, as

$$P(M,N) = [1 - R(M)] \times [1 - R(M+1)] \cdots [1 - R(N-1)]R(N). \quad (1)$$

It may be noted that $P(K, K) = R(K)$, and

$$\sum_{N=M}^{\infty} P(M,N) = 1. \quad (2)$$

The life expectancy between ages M and Q (actually between the Mth and Qth birthdays), $E(M, Q)$, is then

$$E(M,Q) = \sum_{N=M}^{Q-1} P(M,N)\cdot(N - M + 0.5) + \sum_{N=Q}^{\infty} P(M,N)(Q-M). \quad (3)$$

For $Q = \infty$, (3) was shown to be mathematically equivalent to the standard procedure (PH75) for calculating life expectancy.

It should be noted from (3) that for an intermediate age S

$$E(M, Q) \neq E(M, S) + E(S, Q) \qquad (4)$$

since the second term on the right side of (4) presumes that all members of the group are alive at age S whereas this is not true for the term on the left side of (4).

$R(I)$, based on 1974 statistics (PH75), are used with (1) and (3) to calculate the values of $E(M, Q)$ shown in Table 1. Results are shown there for the total U.S. population, for all males, all females, all whites, all non-whites, white males, white females, non-white males, and non-white females. All of these are necessary for analysis of some of the risks we will be discussing since $R(I)$ are often given separately by sex and/or race.

It would clearly be very cumbersome to present data for all values of M and Q, so some selection is necessary. Additional data beyond that given in the Tables are available from the first author.

In most situations, data are available as the mortality rate due to a particular risk, x, as a function of age, $r_x(I)$. If the risk x were eliminated, $R(I)$ would be reduced to $R_x(I)$ given by

$$R_x(I) = R(I) - r_x(I) \qquad (4)$$

and the $R_x(I)$ may be used with (1) and (3) to calculate revised values of $E(M, Q)$, which we designate $E_x(M, Q)$. The loss of life expectancy, $\Delta E(M, Q)$, due to the risk x is then

$$\Delta E(M, Q) = E_x(M, Q) - E(M, Q). \qquad (5)$$

Table 1. E(M, Q) in years for various groups used as comparisons

Group	Age range 0–55	55–70	70–85	85–∞	0–∞
Total population	52.6	13.3	10.5	5.4	71.3
All males	52.0	12.7	9.3	4.4	67.6
All females	53.4	13.9	11.3	5.6	75.3
White males	52.3	12.7	9.3	4.3	68.3
Non-white males	49.7	12.0	9.1	5.5	61.7
White females	53.5	14.3	11.4	5.4	75.9
Non-white females	52.0	13.0	10.5	6.7	69.7

Table 2. ΔE(M, Q), loss of life expectancy in days for some simple age dependences of r and p for various population groups

Group, r or p	Age range 0–55	55–70	70–85	85–∞	0–∞
Tot. pop., $r = 1 \times 10^{-5}$	5.25	0.372	0.259	0.096	9.98
$r = 100 \times 10^{-5}$	534	37.4	26.0	9.60	1024
$p = 1.001$	1.00	0.614	1.37	1.53	5.04
$p = 1.1$	99.9	60.9	133	142	482
$r = 10 \times 10^{-5}$, white male	52	3.5	2.2	0.66	92
white female	54	4.0	2.9	0.95	111
non-W M	48	3.3	2.2	1.0	78
non-W F	51	3.6	2.6	1.4	97
$p = 1.01$, white male	11	7.6	15	13	49
white female	6.7	4.1	12	15	44
non-W M	20	10	16	16	62
non-W F	12	6.5	14	17	56
$r = 10 \times 10^{-5}$ age 18–64 white M	23	3.1	0	0	50
white F	24	3.5	0	0	61
non-W M	21	2.9	0	0	41
non-W F	23	3.2	0	0	53

Some simple examples of interest are shown in Table 2; these include calculations of $\Delta E(M, Q)$ for $r_x(I) = 1 \times 10^{-5}$ and 1×10^{-3} for all I. We see that $\Delta E(M, Q)$ depends linearly on the $r_x(I)$ to rather good accuracy over a very wide range.

In some situations, data are available as mortality ratios, $p(I)$, defined as

$$p(I) = R_y(I)/R(I) \qquad (6)$$

where R_y are the mortality ratios for some group of interest, y. Since the $R(I)$ are known, the $p(I)$ are readily converted to $R_y(I)$, allowing the calculation to proceed as before. Examples for $p(I) = 1.001$ and 1.10 are given in Table 2. Here we see a rather accurate linear dependence on $[p(I) - 1]$ although in this case the added risks are different for each I. These linearities imply that if two different risks have the same age dependence, the $\Delta E(M, Q)$ for one can be derived from those for the other by simply multiplying by the ratio of the $r_x(I)$ or $[p(I) - 1]$.

We now proceed to consider various categories of risk and calculate $\Delta E(M, Q)$ for them. In some situations where available data are limited, we will consider only the total change in life expectancy, $\Delta E(0, \infty)$ which we abbreviate as ΔE.

RADIATION

The BEIR Report (NA72) develops and uses an absolute risk model and a relative risk model for estimating effects of low-level radiation, and in each case considers "plateau lengths", i.e. duration of increased susceptibility to cancer due to radiation exposure, of 30 years and full lifetime. In the absolute risk model there is little difference between the results for the two plateau lengths, so we adopt an average between the two. In the relative risk model, there is a substantial difference between the two plateau lengths when exposure to children is involved; we therefore give results for both cases.

The loss of life expectancies due to natural radiation, taken to be 100 mrem/yr whole body exposure, are listed in Table 3 for the three cases discussed above. The mortality rates $r(I)$ are taken from the BEIR Report pp. 172 and 173.

The data for the absolute risk model given in the BEIR Report, p. 173, lead to a total of about 1850 fatalities per year whereas the BEIR Summary gives a best estimate of 3500. To be consistent with the latter, one should multiply values by $3500/1850 = 1.9$. This procedure gives $\Delta E = 9$ days. The same treatment for the relative risk model with the 30 yr plateau, which results in 3170 fatalities/yr according to the BEIR Report, p. 172, means multiplying 8.1 times 3500/3170 which gives $\Delta E = 9$ days, and for the relative risk model with infinite plateau this gives $\Delta E = 23 \times 3500/8930 = 9.0$. The BEIR estimate is therefore $\Delta E \simeq 9$ days.

In a previous paper (Co79) it was shown that the basis for the relative risk model is highly questionable, and the form in which it is used in the BEIR Report is almost certainly erroneous. On the other hand it is shown that an age dependent absolute risk model is quite reasonable and that the form of the age dependence, so long as it is even crudely consistent with the data, is essentially irrelevant. The results for the absolute risk model are therefore the more credible. Perhaps the best procedure is therefore to use the number from the BEIR absolute risk model in Table 3 and multiply by $19/5 = 1.8$. If the natural radiation level is different from 100 mrem/yr, all values in Table 3 should be scaled proportionally, and the same is true, of course, if there are additional sources of exposure received regularly (averaged over a few years) such as that due to fallout.

The average dose to those occupationally exposed to radiation is about 500 mrem/yr, and this additional exposure may persist from ages 18 to 65. The loss of life expectancies from this exposure, calculated with the BEIR absolute risk model, are also listed in Table 3. For some occupationally exposed persons, the annual exposure may be up to ten times higher, 5000 mrem/yr; in such a case, the values in Table 3 should be scaled proportionately. For consistency with the BEIR Report Summary, an additional factor of 1.8 should probably be applied, raising ΔE from 500 mrem/yr to $18 \times 1.8 = 36$ days of lost life expectancy.

Routine releases of radioactivity from the nuclear industry would be expected to give the average American an additional exposure of about 0.2 mrem/yr (Co76; AP78; Po76; NR76) if all U.S. electric power were nuclear. This is 0.2% of natural radiation exposure and therefore gives $\Delta E = 0.002 \times 11 = 0.022$ days = 30 min.

Table 3. $\Delta E(M, Q)$, loss of life expectancy due to natural radiation (100 mrem/yr) at all ages and occupational radiation (500 mrem/yr) from age 18–64

Basis	Age range 0–55	55–70	70–85	85–∞	0–∞
BEIR absolute	1.4	0.63	0.52	0.23	5.0
BEIR relative (30 yr)	1.7	0.98	1.3	0.82	8.1
BEIR relative (lifetime)	2.0	4.3	7.1	4.5	23
Occupational	2.2	4.3	3.8	1.3	18

ACCIDENTS

Mortality rates as a function of age are given in the National Safety Council annual booklet "Accident Facts"; to be consistent with our data base, 1974 statistics are used (NS75). The results are listed in Table 4 for

Table 4. $\Delta E(M, Q)$, loss of life expectancy in days for average American due to various types of accidents

Type of accident	Age range 0–55	55–70	70–85	85–∞	0–∞
All accidents	202	19	31	19	435
Motor vehicle	106	7.1	6.7	3.0	207
Pedestrian	18	1.6	2.6	1.4	37
Pedalcycle	3.2	0.08	0.05	0.02	5.1
Accid. in home	42	4.1	13	9.3	95
Falls	7.7	2.7	14	11	39
Drowning	23	0.9	0.6	0.2	41
Fire, -burns	12	1.6	2.3	1.2	27
Poison (sol., liq.)	7.9	0.7	0.5	0.2	17
Suffocation	6.1	0.7	0.8	0.5	13
Firearms	6.4	0.3	0.2	0.07	11
Poison (gas)	3.6	0.3	0.2	0.09	7.5

all accidents, accidents in the home, and for those due to motor vehicles (total, and pedestrian deaths only), pedalcycles, falls, drowning, fire and burns, poisoning by solids and liquids, suffocation, firearms, and poisoning by gas. An especially evident effect of different age dependences may be seen by comparing numbers for motor vehicles and falls; for ages 0 to 55, the ratio of loss of life expectancies for these is 14, whereas for ages 85 to ∞ it is 0.28, a variation by a factor of 50.

There are substantial differences in accident risks between males and females. Mortality rates from major causes of accidental death in 1968 (Me71) are used to obtain the results in Table 5. We see that, in general, males are more susceptible to accidents—7% of all males vs 4% of all females die in accidents—and that the differences are especially large for automobile accidents (including pedestrian fatalities), drowning, and firearms (too small to be listed for females). Total loss of life expectancy due to accidents, ΔE, is 669 days (1.8 yr) for males and 363 days (1.0 yr) for females. Accident mortality has decreased by 22% over the past decade, which means that improved safety has added about 110 days to the life expectancy of the average American over this period.

DISEASE

Mortality rates vs age for various diseases from "Statistical Abstract of the United States" (Ce75) are used to calculate the $\Delta E(M, Q)$ in Table 6. The values for heart disease and cancer are given in years (in the first four lines) whereas for other diseases they are given in days.

It is apparent that heart disease is largely a male problem up to age 55, but at older ages it affects both sexes equally. Homicide and suicide are largely male problems at all ages, whereas stroke and diabetes are more prevalent killers in females.

Table 5. $\Delta E(M, Q)$, loss of life expectancy in days due to accidents for all U.S. males and all U.S. females

Accident type, sex	Age range 0–55	55–70	70–85	85–∞	0–∞
All accidents—M	333	38	40	12	669
F	108	18	36	13	297
Motor vehicle—M	195	15	13	4.1	363
F	67	7.1	7.2	2.6	150
Pedestrian—M	24	3.6	4.3	1.3	49
F	11	1.4	2.2	0.79	24
Falls—M	12	7.4	15	4.6	49
F	3.4	5.4	21	7.6	52
Fire, burns—M	14	3.0	3.2	0.98	31
F	10	1.8	2.7	0.96	26
Drowning—M	31	1.0	0.66	0.21	49
F	6.2	0.21	0.23	0.08	11
Industrial—M	21	3.2	1.5	0.45	45
Firearms—M	11	0.64	0.29	0.09	19
Choking—F	2.8	0.70	0.88	0.32	8.0
Poison—F	3.9	0.53	0.29	0.10	9.7

Table 6. $\Delta E(M, Q)$, loss of life expectancy in days (years in first four lines) due to various diseases for all U.S. males and females

Disease–sex	Age range 0–55	55–70	70–85	85–∞	0–∞
Heart disease—M	0.50	0.93	2.3	0.67	6.3
F	0.19	0.50	1.9	0.69	5.4
Cancer—M	0.34	0.43	0.82	0.25	2.6
F	0.32	0.34	0.58	0.21	2.8
Stroke—M	28	59	196	60	389
F	27	61	246	88	627
Pneumonia, Influenza—M	21	20	60	18	141
—F	14	13	49	18	142
Homicide—M	71	5.4	1.9	0.6	136
F	19	1.4	0.86	0.31	43
Suicide—M	55	10	8.4	2.6	131
F	21	4.5	2.2	0.80	62
Diabetes—M	9.3	11	26	7.9	70
F	8.7	14	39	14	120
Cirhosis of liver—M	31	22	13	4.1	130
—F	17	11	6.4	2.3	85

OVERWEIGHT

Data on mortality ratios for overweight people are available from the "Build and Blood Pressure Study" by the Society of Actuaries in 1959 (Me60) which covered experience on 5 million people insured by 26 large insurance companies between 1935–53. Since the overwhelming number of those insured were white, the standard groups used are white males and white females. Results are given in Table 7 for each sex and for weights 10, 20, and 30% above average. It is perhaps somewhat surprising that the increase with percent overweight is less than linear—one might expect more like a quadratic dependence (Pa58). However, the average weight is about 10–15% above the optimum

Table 7. $\Delta E(M, Q)$, loss of life expectancy in years as a function of percentage overweight for white males and females

Sex	% overwt.	Age range 0–55	55–70	70–85	85–∞	0–∞
Male	10	0.21	0.33	0.63	0.51	1.6
Male	20	0.43	0.53	0.99	0.78	2.7
Male	30	0.73	0.84	1.5	1.1	4.1
Female	10	0.07	0.12	0.35	0.41	1.0
Female	20	0.16	0.28	0.77	0.85	2.3
Female	30	0.23	0.40	1.0	1.1	3.1

(defined as the weight for maximum life expectancy—Me77a) so 10 and 30% above average are probably about 23 and 46% respectively above the optimum. This makes the ratio of about a factor of 3 between their effects seem not unreasonable.

An average male weighs 160 lb, so a 10% change is 16 lb; this causes $\Delta E \approx 1.3$ yr = 16 months, or about 1 month/lb. An average female weighs 120 lb, so a 10% change is 12 lb, and it causes $\Delta E = 1.0$ yr = 12 months, or again, about 1 month/lb.

TOBACCO

The principal studies of effects of smoking on mortality rates are those by Dorn on 294,000 holders of veteran's life insurance policies (Ka66) and the American Cancer Society study directed by Hammond of over a million men and women (Ha66). Summaries of these are given in PH67 as the ratio of mortality rates for smokers and non-smokers, (S/N), vs age. Since a large fraction of the population does smoke, not smoking represents an appreciable increase of life expectancy over the average. About 50% of all men and 25% of all women are smokers, so we assume that the mortality ratio relative to that of the whole population for males is $(S/N)^{1/2}$ and $(S/N)^{-1/2}$ for smokers and non-smokers respectively, and for females we take these to be $(S/N)^{3/4}$ and $(S/N)^{-1/4}$; note that these are set to give the proper ratio of mortality rates for smokers and non-smokers, namely S/N.

The results are listed in the left columns of Table 8. The data for males in the two studies are quite consistent and are therefore averaged; only the Hammond study gives results for females. Negative values for non-smokers in Table 8 indicate a negative loss (i.e. a gain) in life expectancy. The large differences between risks for males and females is partly explainable by the fact that women smoke fewer cigarettes per day and do not inhale as frequently or as deeply as males.

There is a great deal more detail available on smoking risks, including such dependencies. Table 9 gives the results for some of these from the Hammond study. In many cases, the statistics were too poor to derive an age dependence, so the following procedure was used:

For heavy male cigarette smokers there was a very characteristic mortality ratio age dependence, peaked at age 50, about 80% of the peak value at ages 40 and 65, and 65% of the peak value at age 80. This age dependence was fit to the data where such fits were reasonable. They were not reasonable for women, for pipe and cigar smokers, and for those who had stopped smoking for more than 5 yr. For these cases, the mortality ratio age dependence was essentially constant for 45 to 75, and somewhat less at younger and older ages; the age distribution for women was fitted to all of these cases in Table 9.

Table 9 lists total loss of life expectancy beyond age 20 for each category of smoker. Losses of life expectancy between various

Table 8. $\Delta E(M, Q)$, loss of life expectancy in years for smokers relative to non-smokers

Group	Age range				
	20–55	55–70	70–85	85–∞	20–∞
Av. male	0.68	1.20	1.52	0.95	5.9
Av. female	0.08	0.22	0.23		1.17
Male—20/day—then stopped 10+ yr	0.17	0.56	0.95		2.3
Male—no inhalation	0.62	1.1	1.0		4.6
Male—deep inhalation	1.2	2.4	2.7		8.6

Table 9. Years of life expectancy lost due to various smoking patterns

Type of smoking	Men	Women
Cigarettes—average	6.2	2.2
1–9/day	4.5	0.2
10–19/day	6.2	1.7
20–39/day	6.8	3.5
over 40/day	8.6	
inhalation—none	4.5	0.6
slight	6.4	1.9
moderate	7.2	2.5
deep	8.6	4.6
began after 30	2.0	1.1
25–29	4.5	1.9
20–24	5.7	2.7
15–19	7.7	2.7
before 15	8.6	
had smoked >20/day		
still smoking	7.6	
stopped 1–4 yr	6.9	
stopped 5–9 yr	3.9	
stopped 10+ yr	2.3	
had smoked 1–19/day		
still smoking	5.9	
stopped 1–4 yr	3.8	
stopped 5–9 yr	3.8	
stopped 10+ yr	0.3	
Cigars only—average	0.9	
1–4/day	0.1	
5+/day	1.2	
no inhalation	0	
inhalation	3.2	
Pipe only—average	0.6	
no inhalation	0	
inhalation	1.4	

pairs of ages are given for four cases, one female and three male, in Table 8. Values for other cases listed in Table 9 may be linearly interpolated from these, being careful not to confuse between males and females.

It may be noted that there is a puzzling discrepancy between Tables 8 and 9 for average female data; in the former, the difference in life expectancy between smoking and non-smoking females is 1.17 yr, whereas in the latter it is 2.2 yr, nearly a factor of two discrepancy. The latter number and all numbers in Table 9 are based on mortality ratios given in the original report on the Hammond Study (Ha66) whereas the former is based on mortality ratios attributed to that study in a later Public Health Service Review (PH67) using an evaluation procedure that is not explained. The originating groups for both publications were consulted, and neither was willing to concede an error. We therefore present the results from both. For males, there is little difference between the mortality ratios given in the two references.

In view of the large losses of life expectancy listed in Tables 8 and 9, it is interesting to consider what risks for various causes of death are brought about by smoking. Table 10 shows the mortality rates between ages 35–84 for various categories of smokers relative to non-smokers (Ka66) for a selection of fatal diseases. This may be used in conjunction with Tables 6 and/or 8 to estimate the loss of life expectancy due to various diseases as a result of smoking.

ALCOHOL AND DRUGS

Risks to individuals from use of alcohol and drugs are not easy to treat generally or to quantify, but it may contribute perspective to develop estimates of the average loss of life expectancy due to their use in our Society. We use a treatment from NS73.

There are three causes of death on the international list that are directly due to alcohol: alcoholic psychosis—ICDA No. 291—600 deaths/yr; alcoholism—ICDA No. 303—3000 deaths/yr; and cirhosis of liver—alcoholic—ICDA No. 571.0—9500 deaths/yr. About 50% of all motor vehicle deaths are due to alcohol—23,000/yr. About 20% of other accidents, suicides, and homicides are due to alcohol, contributing 12,000, 4300 and 2700 fatalities per year respectively. About 10% of cancers of the esophagus and oral cavity may be blamed on alcohol, contributing another 600 and 700 deaths/yr respectively. This adds up to a total of about 56,000 deaths/yr that may be blamed on alcohol. On an average each of these deaths eliminates

Table 10. Mortality rates for males (relative to non-smokers) in age range 35–84 due to selected causes (Ka66)

	Total deaths	Cigarette—(av./day) Total	1–9	21–39	>40	Cigar	Pipe	Ex-cigarette
All causes	26,166	1.71	1.31	2.0	2.3	1.10	1.07	1.29
Cancer—all types	5383	2.1	1.3	2.7	3.24	1.22	1.25	1.49
buccal cavity	87	3.7	2.1	5.9	9.3	4.11	3.1	1.61
pharynx	58	9.6	4.6	14.4	21.7	0	2.0	1.63
esophagus	104	5.9	2.5	11.9	8.4	5.31	2.0	1.66
stomach	342	1.48	1.69	1.57	1.75	1.20	1.40	1.03
pancreas	344	1.83	1.37	2.2	2.7	1.52	0.74	1.32
lung	1256	10.8	4.8	16.9	23.6	1.59	1.84	4.7
prostate	440	1.71	1.69	1.52	2.4	1.50	1.53	1.63
kidney	141	1.54	0.72	1.96	2.6	0.77	1.32	1.65
leukemia	269	1.49	1.18	1.62	1.40	1.00	1.58	1.55
Bronchitis and emphysema	379	8.6	4.1	11.1	15.0	0.79	2.4	7.6
Influenza and pneumonia	136	1.59	1.36	2.1	0.91	0.71	0.96	0.93
Cardiovascular—all	16,392	1.62	1.29	1.83	1.99	1.05	1.06	1.21
cerebrovascular lesions	2008	1.40	1.26	1.54	1.88	1.08	1.06	1.07
coronary heart disease	10,890	1.61	1.26	1.82	1.97	1.04	1.08	1.21
arterio-sclerosis	692	1.72	1.18	1.85	2.71	0.97	0.99	1.16
Stomach ulcer	90	4.1	2.7	4.1	9.2	2.9	2.8	3.4
Cirhosis of liver	319	2.8	2.3	3.0	5.8	2.9	0.60	1.02
Violence	1042	1.13	0.77	1.28	1.8	0.91	0.91	0.95
Ill defined—unknown	723	1.62	0.93	2.1	3.6	1.13	0.80	1.30

about 20 years of life expectancy, so this loss averaged over the U.S. population is

$$\frac{56{,}000 \times 20 \text{ man-yr lost}}{2.2 \times 10^8 \text{ man-yr lived}} = 0.005 \text{ lifetime}$$

$$= 0.35 \text{ yr.}$$

Improper use of drugs in medical treatment is estimated to cause 75,000 deaths/yr. No estimates have been given of average lost life expectancy per case, but if we guess that this is about 10 yr, the average American loses about 0.25 yr of life expectancy from this cause.

About 2000 deaths/yr are directly due to illicit drugs. In addition, about 40% of suicides by poisoning with analgesic or soporific drugs, 10% of homicides, 2% of motor vehicle deaths, and 1% of other accident deaths are probably due to illicit drugs, bringing the total number of fatalities to about 6000/yr. The average victim loses perhaps 25 yr of life expectancy, which, spread over the total U.S. population, corresponds to an average of 0.05 yr (18 days) reduction in life span for the average American.

COFFEE, SACCHARIN, AND THE PILL

It is estimated (NS73) that 24% of male and 49% of female deaths from bladder cancer are due to coffee drinking. This accounts for 1450 male and 1350 female deaths per year. If it is assumed that there are 180 million coffee drinkers in the U.S., and that each case represents an average of 15 years lost life expectancy, this represents

$$\frac{(1450 + 1350) \times 15 \text{ yr lost}}{180 \times 10^6 \text{ yr lived}} = 2.3 \times 10^{-4} \text{ lifetime lost}$$

$$= 6 \text{ days.}$$

In attributing six days of lost life expectancy to coffee drinking, we ignore all effects other than bladder cancer, such as the known mutagenic properties of caffeine, and effects on the nervous system, weight control, etc.

According to the U.S. Food and Drug Administration (FD77) if everyone in the U.S. were to drink one diet soft drink each day throughout life, there would be an additional 1200 bladder cancers per year. A calculation similar to that above indicates that drinking one diet soft drink per day reduces life expectancy by 2 days. It is interesting to point out that ingesting an extra 100 calories per day, as in drinking a regular soft drink, would increase one's body weight by about 7 lb (Co78) and thereby reduce life expectancy by 7 months or 210 days.

It is estimated that 10% of female deaths from phlebitis and thrombophlebitis are due to oral contraceptives (FD77), which amounts to 150 fatalities per year. If there are 30 million users in the U.S. (75% of all females aged 20–55), and each fatality represents 40 yr of lost life expectancy, an average user of "the pill" gives up 5 days of life expectancy by its use.

OCCUPATIONAL RISKS

Data on mortality rates from work accidents are available annually (NS75, 76, 77) categorized by industry. These are shown in Table 11. The frequencies of disabling injuries, (defined as disabling beyond the day of the accident) are also listed there as a matter of interest; we see that mortality is not the only important aspect of occupational risk.

If we assume that these accidents occur with equal probability at all ages between 18 and 64, the data in the bottom lines of Table 2 can be used by multiplying all values by the ratio of the mortality rates in Table 11 to the 10×10^{-5} assumed in Table 2. The total losses of life expectancy upon entering the occupation, $\Delta E(18\text{–}\infty)$ are listed in the last column of Table 11 for males. Other values of

Table 11. Occupational accidents

Industry type	Workers (000)	Deaths per 100,000	Disabling injuries (000)	Days lost life exp.
All industry	87,800	14.7	2200	74
Trade	20,300	6	400	30
Manufacturing	19,000	8.7	470	43
Service	20,800	9.7	410	47
Government	14,900	11	320	55
Transportation and Public Utilities	4800	32.7	190	164
Agriculture	3500	55.3	190	277
Construction	3700	60.3	210	302
Mining, Quarrying	800	65.7	40	328
Radiation (0.5 rem/yr)			0	40

$\Delta E(M, Q)$ and values based on sex and race may be scaled proportionately from Table 2.

The last line of Table 11 gives the occupational risk of radiation exposure in the nuclear industry based on an average whole body exposure of 500 mrem/year. It is evident that this risk is not large relative to other occupational risks. Some occupational radiation exposures are as much as ten times larger than this average, but it should be recognized that the risks listed for other occupations are also averaged rather than risks to those most exposed.

Many occupations involve mortality risks other than accidents. There may be exposure to toxic chemicals or dusts, unusual temperatures, or other environmental factors which cause delayed deaths not classified as accidents.

There have been at least two studies of mortality ratios for various industries, one based on U.S. mortality in the year 1950 by U.S. Public Health Service (PH62), and a study of 1955–64 experience with industries holding group life insurance published by Society of Actuaries (So67). Their data are listed in Table 12; in both of these studies, statistical accuracies are rather poor, but we take the average between them and assume that these mortality ratios apply at all ages between 18 and 64 to calculate effects on life expectancy. Our results are listed in the last two columns of Table 12 for loss of life expectancy up to age 70 and for total loss of life expectancy.

Table 12. Mortality ratios in various U.S. industries from studies by U.S. Public Health Service and Society of Actuaries

Industry	Workers in 1965 (000)	Mortality ratios USPHS	Mortality ratios S of A	Years added life exp. 18–70	Years added life exp. 18–∞
Agriculture		0.96	0.87	+0.5	+0.7
Coal mining	142	1.42	1.53	−2.2	−3.2
Other mining	200	1.08	1.32	−0.9	−1.4
Oil, gas recovery	282	0.98	1.14	−0.3	−0.4
Construction	3200	1.18	1.22	−0.9	−1.4
Mfg—metals, machinery	6000	0.88	1.12	0	0
clothing	1350	0.74	0.70	+1.5	+2.1
rubber, chemicals, etc.	1900	0.86	0.92	+0.6	+0.8
paper, printing	1600	0.90	1.05	+0.1	+0.2
Railroad	737	1.21	1.29	−1.2	−1.8
Motor freight	965	1.71	1.23	−2.2	−3.2
Airlines	230	1.02	0.95	0	+0.1
Communication	880	0.81	0.80	+0.9	+1.4
Wholesale trade	3260	0.66	1.00	+0.8	+1.3
Retail trade	9300	1.1	0.80	+0.2	+0.4
Finance, insur., real est.	3040	0.97	0.84	+0.5	+0.7
Business	1070	0.98		+0.1	+0.2
Medical services	2160	0.93		+0.3	+0.5
Education services	940	0.59		+2.1	+3.1
Local transit			1.37	−1.7	−2.5
Elec.—gas			1.10	−0.5	−0.7
Fireman			1.52	−2.3	−3.5
Policemen			1.42	−1.9	−2.8
Post office		0.83		+0.9	+1.3

We see from Table 12 that coal mining is perhaps the most dangerous major occupation, costing an average of over three years of life expectancy. A breakdown on causes of death indicated that coal miners have a large excess of respiratory disease, but the most important factor is accidents, including even automobile accidents. Apparently the life of a miner is not conducive to being careful even when outside of mines.

Since Table 12 is calculated under the assumption that ratios return to unity immediately after retirement, it under-estimates the effects; surely exposure to toxic substances between ages 18 and 64 can cause premature death at later ages. Another problem with Table 12 is that it lumps all workers in an industry into a single group, including management, workers and office personnel. But the most important difficulty with Table 12 is that it is heavily influenced by socioeconomic factors. These are discussed in the next section.

SOCIOECONOMIC FACTORS

Information on mortality ratios by job type is available from the Public Health Service study of mortality in the year 1950 (PH62a; Me75). Occupations are grouped as:

I. Professional (4%, 0.5%)

II. Technical, administrative, managerial (10%, 3%)

III. Proprieters, clerical, sales, skilled (40%, 14%)

IV. Semi-skilled (24%, 30%)

V. Unskilled (8%, 31%).

The percentage of whites and non-whites that are in each group is given in parenthesis.

Results on life expectancies for these groups relative to the U.S. average are listed in the top lines of Table 13 for whites only. We see that the differences between Classes I and V approach 4 yr. If non-whites had been included, they would have been twice as large.

Data from England and Wales (Re71) indicate an even larger spread among occupational classes. The mortality ratios (to the

Table 13. ΔE(M, Q), losses in life expectancy in years from average for various socioeconomic, education and racial groups

Group	Age range 0–55	55–70	70–85	85–∞	0–∞
Occup. Class: I	−0.57	−0.13	−0.26	−0.23	−1.7
II	−0.39	−0.23	−0.48	−0.44	−1.8
III	−0.27	+0.08	+0.17	+0.14	−0.23
IV	−0.09	−0.06	−0.13	−0.11	−0.40
V	+0.59	+0.19	+0.36	+0.30	+2.0
Educ.—Fem.—College	−0.12	−0.21	−0.65	−0.90	−2.2
high school	−0.07	−0.13	−0.37	−0.48	−1.2
8 years	−0.05	+0.09	+0.26	+0.31	+0.79
<8 years	+0.19	+0.33	+0.92	+0.99	+2.7
Educ.—Male—College	−0.28	−0.49	−1.0	−1.0	−2.9
high school	−0.04	−0.06	−0.13	−0.11	−0.33
8 years	−0.07	+0.13	+0.25	+0.21	+0.64
<8 years	+0.18	+0.31	+0.60	+0.48	+1.5
Race(Cal)—White	−0.10	−0.04	+0.20		−0.08
Negro	+2.0	+0.47	+0.50		+5.2
Japanese	−1.3	−0.88	−0.65		−5.4
Chinese	−1.2	−0.14	+0.16		−2.4
Insured males	−0.29	−0.44	−0.37		−2.0
Insured females	−0.10	−0.23	−0.23		−1.3

whole population) averaged over ages 15–64 are listed in Table 14. We see that the effects are very similar between men and their wives, which indicates that we are dealing more with socioeconomic factors than with occupational risks.

It is interesting in this regard to note that *causes* of death also relate to occupational class. Data on this for U.S. white males are shown in Table 15. We see that Class I males are much less likely than Class V to die from tuberculosis, influenza, and accidents, and there are strong tendencies of this type for cancer, cirhosis of liver, and suicide. Data from England and Wales are qualitatively similar and indicate that trends for wives also follow the same patterns, including the lung cancer and influenza trends. The fact that some diseases in Table 15 do not show a dependence on occupational class would seem to indicate that medical care is not an important factor, but there are data (Me77a) on salary dependence listed in the last column of Table 15 which indicate that money is an important factor. Low salaried individuals have a 30% higher overall mortality rate and at least a 50% higher mortality rate from lung cancer, cerebrovascular disease, influenza, pneumonia, and accidents than those with medium or high salaries.

Another line of evidence connecting life expectancy with socioeconomic factors comes from the dependence of mortality ratios on educational attainment. Data on this are available (Ki68) for both male and female divided up into the following four groups:

(A) One or more years of college
(B) High school graduates
(C) Elementary school graduates
(D) Less than 8 years of schooling.

Single mortality ratios are given for ages 25–64, but it seems most reasonable that the factors that cause differences should continue to operate for the remainder of life in this age range so we have assumed this to be the case.

Results are included in Table 13. We see that the extreme differences in educational attainment give over 4 yr difference in life expectancy. The differences are even larger for women which again indicates that occupational hazards are not a dominant factor.

There are data on mortality ratios for business executives listed in "Who's Who in

Table 14. Mortality ratio averaged over ages 20–64 in U.S. and 15–64 in England and Wales for various occupational classes (for U.S. in 1950; England and Wales 1959–1963)

Population group	Occupational class: Class I	Class II	Class III	Class IV	Class V
U.S. total males	0.82	0.85	0.97	1.00	1.53
U.S. white males	0.83	0.84	0.96	0.97	1.20
Eng.—Wales males	0.76	0.81	1.00	1.03	1.43
Eng.—Wales females					
married	0.77	0.83	1.02	1.05	1.31
single	0.83	0.88	0.90	1.08	1.21

Table 15. Mortality ratio for various causes of death for U.S. white men, age 20–64, by occupational class

Cause of death	Occupational class: Class I	Class II	Class III	Class IV	Class V	Low/med./high salary
All causes	0.82	0.83	0.96	0.97	1.21	1.3
Tuberculosis	0.36	0.40	0.69	1.03	1.58	
Cancer—all	0.89	0.91	1.06	1.04	1.16	1.2
lungs, bronchus	0.81	0.91	1.16	1.15	1.20	1.5
Diabetes	0.98	0.99	1.10	0.88	0.90	1.3
Cerebrovascular	0.87	0.79	0.89	0.80	0.94	1.5
Arteriosclerotic	1.15	1.09	1.16	1.00	1.03	1.1
Influenza, pneum.	0.57	0.51	0.73	0.95	1.53	1.7
Cirhosis of liver	0.90	0.88	1.07	1.22	1.58	
Accidents	0.50	0.68	0.82	1.07	1.73	1.5
Suicide	0.90	0.86	0.99	1.02	1.47	1.8

America" in 1950–51 followed over the next decade, and on executives of companies included in the 1957 Fortune list of 500 industries with largest sales, followed over the next 15 yr (Me74). These are converted to increases of life expectancy relative to the average white male in Table 16. We see that these men, who are near the the top of the socioeconomic ladder, live nearly 5 yr longer than average—twice the largest increases for those in the broader top classes considered in Table 13.

Top political leaders do not do nearly as well. The excess longevity of some groups (Me70, 71b, 71c, 75a, 76) are listed in Table 17. We see that Governors, Congressmen, Senators, and even Supreme Court Justices (who would seem to lead less pressured lives than the others) do not enjoy the increased life expectancy of the highest socioeconomic classes, and that being President of the United States in this century is one of the most dangerous jobs available. The statistics for this last group are somewhat distorted by the assassination of John F. Kennedy at a relatively young age; but even without this case, life expectancy of twentieth century presidents has been 3.0 yr less than for average white males.

Mortality ratios are available on a rather different group, baseball professionals, who played in the major leagues for 5 or more years (Me75b). Excesses in their life expectancy relative to average white males (most of those who have died played in the era when major league players were white) are given in Table 16. This group, which is characterized by excellent physical condition at younger ages and perhaps better than average economic status, typically lives about 3 yr longer than average.

Table 16. — ΔE(M, Q), increase of life expectancy in years relative to all white males for special groups

Group	Age range 40–55	55–70	70–85	85–∞	40–∞
Corporation executives	0.16	0.81	1.8	2.2	4.7
Business executives	0.25	1.1	1.2	0.15	4.3
Baseball players	0.13	0.57	1.0	0.96	2.9

Table 17. Average lifetime of twentieth century U.S. political leaders as compared with contemporary U.S. white males

Office	Additional longevity (yr)
Presidents	−5.1
Mayors of New York City	−1.3
Congressmen	+0.2
Senators	+0.4
Governors	+0.5
Supreme Court Justices	+1.4

It is evident from Table 1 that there are important racial differences in life expectancy between whites and non-whites, and it is not easy to separate these from socioeconomic factors. Some evidence on this question may be obtained by considering a breakdown of non-white races. Data are available (Me74a) on this from California which has a sizeable population of Chinese and Japanese. Results for life expectancy are included in Table 13. We see that the differences between Japanese and Negros exceed 10 yr, which is far larger than the differences due to socioeconomic factors we have identified. It would seem that there truly are important purely racial differences of a few years in life expectancy.

One possible indicator of socioeconomic status for which data are available is insurance coverage. Physical examinations connected with purchase of insurance would distort data for the first few years, but their effect should be inconsequential 15 yr later; in fact, mortality statistics for holders of individual insurance policies are quite similar to those having group insurance, which requires no physical examination (Me71a). However, both of these categories have considerably lower mortality rates than average. Data are available for white males and white females, and results on life expectancies calculated from them are included in Table 13. It seems that just being the type of person who buys life insurance means that one will probably live 1.3–2 yr longer than average.

MARITAL STATUS

One of the most important factors correlated with mortality rates is marital status. Data are available for white and non-white males and females on mortality rates at various ages when single, married, divorced, and widowed (NC70). The losses of life expectancy relative to those who are married are shown in Table 18. The marital status for

Table 18. ΔE(M, Q), loss of life expectancy in years of unmarried relative to married people

Unmarried group	Age range 20–55	55–70	70–85	85–∞	20–∞
Single—white male	1.50	0.97	1.47	1.04	6.04
non-W male	3.30	1.20	1.60	1.51	8.79
white female	0.56	0.12	0.90	1.45	3.21
non-W female	1.12	0.50	2.23	3.27	6.01
Widowed—white male	3.60	1.29	1.66	1.38	9.99
non-W male	6.59	2.59	2.48	2.18	15.1
white female	0.95	0.29	1.21	1.66	4.66
non-W female	1.97	1.39	3.07	3.75	9.51
Divorced—white male	3.68	2.42	2.30	1.44	12.4
non-W male	4.55	2.42	2.36	1.70	12.2
white female	0.89	0.39	0.96	1.22	4.47
non-W female	0.82	0.59	1.98	2.83	5.30

Table 19. Average lifetime (1969–71) for white males and average per capita income (1970) in various states

State	Average lifetime	Per capita income U.S. aver.	State	Average lifetime	Per capita income U.S. aver.
ND	73.09	0.805	MD	71.55	1.09
MN	73.04	0.968	NY	71.48	1.19
SD	72.96	0.782	MI	71.47	1.05
UT	72.95	0.811	OH	71.44	1.01
NB	72.89	0.955	DE	71.42	1.14
CT	72.88	1.241	IN	71.32	0.95
KS	72.87	0.973	AZ	71.30	0.92
IA	72.64	0.95	IL	71.23	1.14
WI	72.64	0.96	TN	71.22	0.79
OR	72.20	0.94	NH	71.21	0.97
CO	72.18	0.97	PA	71.16	1.00
FL	72.16	0.94	NC	71.08	0.82
RI	72.07	1.00	MT	71.01	0.88
MA	72.01	1.10	NM	71.00	0.78
ID	71.99	0.83	ME	70.98	0.83
WA	71.95	1.02	AL	70.93	0.74
CA	71.95	1.13	LA	70.70	0.78
OK	71.85	0.85	KY	70.66	0.79
NJ	71.84	1.19	DC	70.64	1.27
TX	71.74	0.91	GA	70.62	0.85
AR	71.71	0.73	MS	70.50	0.66
VT	71.62	0.84	SC	70.32	0.75
VA	71.61	0.94	WV	69.78	0.77
MO	71.57	0.95	NV	69.43	1.15

an individual changes with time, whereas Table 18 assumes that it remains constant over the age range indicated. It should therefore be used with some caution over very large age ranges. It is nevertheless clear that not being married is one of the greatest risks people voluntarily subject themselves to. It is also interesting to note that men apparently suffer much more than women from being unmarried.

GEOGRAPHY

Average lifetimes vary considerably among the states of the United States. To avoid racial differences, we list data for whites only in Table 19 (NC75). Since we have shown that economic status has an important effect on life expectancy, we also list per capita income relative to the U.S. average (Ce75). It is clear that economic status can explain only a very small part of the 3.5 yr difference between the extremes in Table 19. The largest differences are between rural northern states and rural southern states, which suggests that geography plays an important role.* This may be correlated with differences between northern and southern Europe which are of about the same magnitude (Norway-73, Sweden-74, Denmark-72 vs Italy-70, Greece-69, Spain-70), although there may be racial differences in the European situation. In any case, it is difficult to escape the conclusion from Table 19 that moving from one state to another can change one's life expectancy by 1 or 2 yr.

It is interesting to note that risks of mortality from a given disease also vary substantially from state to state. For example, annual mortality rates per 100,000 population from cancer are 190 in the northeast (199 in RI) vs 155 in the south central states (145 in TX) [and 123 in the mountain states (91 in UT)], whereas for cerebrovascular diseases, the rates are 95 in the northeast (87 in NY) and 120 in the south central states (Ce75). Variations in mortality from accidents are especially large; rates are 91 in NM and WY vs 38 in NY, NJ and CT.

There is a statement in the literature that people in rural areas live 5 yr longer than those in urban areas (Te58). Some effort was made to check this, but without success. In Table 19 we see that life expectancy for whites in District of Columbia, which is entirely urban, is not more than 1 yr less than in surrounding rural states. National Center for Health Statistics does not compile data on a rural vs urban basis. Their data on metropolitan areas (which include some rural components) are not grossly different from those for non-metropolitan areas (which in-

*The per capita incomes listed in Table 19 are for the entire population rather than for whites only. So for rural southern states which have large populations of low income non-whites, per capita incomes in Table 19 are considerably lower than for whites. This is further evidence that economic status does not explain the differences in life expectancy.

clude small cities). Table 12 indicates that farmers live about 0.7 yr longer than average. There is some indication that people in suburbs live longer than those in urban or rural areas, although socioeconomic factors would be relevant here. It seems propable that urban–rural differences do not cause more than 1 yr difference in life expectancy.

ARMED FORCES

Combat duty in wartime is clearly a dangerous situation. If we assume that the average member of the Armed Services killed in Vietnam died at age 25, the average loss of life expectancy from being sent to Vietnam was as given in Table 20. Deaths in the armed forces are especially notable for the large fraction of lost life expectancy that occurs in the prime years of life. The ratio of death rates in Vietnam to average death rates for men of the same age in this country was about 10 for the army, 5 for the navy, 20 for the marines, and 3 for the air force.

Table 20. Loss of life expectancy for members of the U.S. Armed Forces sent to Vietnam

Branch	Lost life expectancy
Army	1.1 yr
Navy	0.5
Marines	2.0
Air force	0.28

CATASTROPHIC EVENTS (NR75)

The news media generally give extensive coverage to incidents involving large loss of life, and the public has a considerable awareness of such risks. The effects of these risks in terms of average lost life expectancy are listed in Table 21. Hurricanes have caused about 90 deaths per year in the U.S. during this century. If an average fatality corresponds to 35 yr of lost life expectancy, the average American loses 0.5 days of life due to this hazard. Tornadoes have caused an average of 118 deaths/year in recent times, and there have been about 1100 deaths from earthquakes in this century (2/3 of them in the 1906 San Francisco earthquake). An average of 200 people per year die in airline crashes in this country, and for every ten of these, there is one person on the ground killed. An average of 35 Americans die each year in large explosions (resulting in 8 or more fatalities). Dam failures have caused an average of about 35 fatalities/year in U.S., but estimates of potential dam failures indicate that a long term average may be more than twice that many. Large fires with 10 or more fatalities occur about once a year in the U.S., accounting for only 2% of the total effects of all fires and burns given in Table 4. There is frequently a great deal of publicity over accidental releases of poisonous gases, but rarely are there any deaths involved. Estimates of potential catastrophes of this type indicate that they may cost the average American about 0.1 days of life. The risk of dying as a result of a nuclear power plant accident if we had all nuclear power in this country would reduce life expectancy by 0.5 hr according to the Rasmussen Study, or by 2 days according to Union of Concerned Scientists (UC77); only a few percent even of these fatalities would occur within the first few months, and the remainder would represent an undetectable increase in cancer risks over the following half century.

Table 21. Loss of life expectancy due to catastrophic events, averaged over the U.S. population

Catastrophic events	Total lost life expectancy (days)
Hurricanes	0.5
Tornadoes	0.5
Earthquakes	0.1
Airline crashes (passengers)	1.0
Airline crashes (people on ground)	0.1
Major explosions	0.2
Dam failures	0.5
Major fires	0.5
Chemical releases	0.1
Nuclear reactor accidents:	
within following 50 years	0.02–2*
noticeable, within first year	0.0004–0.1*

*Assumes all U.S. power nuclear. First figure from Rasmussen Report; second figure from Union of Concerned Scientists.

There seems to be some support for the idea that the important thing about catastrophic events is not the average risk from them, but how frequently they occur. The argument here is that public morale is the important issue, there being no hope of educating people to understand risks. Estimates of the average number of years between events of a given type causing 1000 or more fatalities are listed in Table 22. The pessimistic values for nuclear accidents are from Union of Concerned Scientists (UC77).

Table 22. Average number of years between catastrophes of given type which cause 1000 or more fatalities

Type catastrophe	Av. years between
Hurricanes	20
Earthquakes	40
Air pollution episodes	20
Dam failures	50
Explosions	150
Fires	200
Poison gas releases	1000
Airline crash	3000
Nuclear plants (400 GW)	
fatalities within months	200,000–1000*
fatalities within 50 yr	300–10 (?)*

*First numbers are from Rasmussen Study; second numbers from Union of Concerned Scientists. The 10 (?) is based on their estimate of one meltdown every 5 yr; to produce many fatalities, such a meltdown must be followed by a containment failure, the probability of which they do not estimate but we take their estimate to be 50%.

ENERGY PRODUCTION

There is a widespread impression that even if there were no fuel shortages, we must reduce our use of energy to avoid catastrophic environmental problems. Table 23 lists estimates of the number of fatalities per year in the U.S. caused by generation of energy. Many of these estimates are from Co76. The coal transport estimate is from Sa74. The mortalities from gas and oil induced fires are estimated as 2 and 10% respectively of all deaths from fires. The asphyxiation deaths from gas are estimated as a third of all asphyxiations, most of which are from carbon monoxide which we do not include here. Hydroelectric dam failure estimates are from Table 21 assuming 40% of large dams are hydroelectric. Gas explosions are from Wi74.

The 24 days of lost life expectancy in Table 23 is relatively trivial compared to a great many of the risks we have been discussing. We may therefore conclude that energy generation is something less than a major threat to our health and safety.

TECHNOLOGY

One sometimes hears the opinion expressed that technology is an overall threat to our health and safety. The simplest test of this is to compare life expectancies in technologically developed and undeveloped countries; this is done in Table 24 (Eh72). We see that technology can clearly be credited for several decades of increased life expectancy.

Another approach to this question is to recognize that technology produces wealth, and we have extensive evidence that wealth increases life expectancy. Losses of life expectancy due to technology may be patterned after our treatment of risks in production of energy. Energy production is well recognized as our most polluting single industry, and it probably accounts for at least 30% of all fatality producing industrial pollution. We may therefore estimate that all of the pollution produced by industrial technology probably does not reduce our life

Table 23. Fatalities per year among public due to energy generation

Source	Fatalities per yr	Av. years lost	Days reduced life exp.
(A) Coal			
air pollution	10,000	10	11.5
transport accidents	300	35	1.0
			$\Sigma = 12.5$
(B) Oil			
air pollution	2000	10	2.2
fires	500	35	2.0
			$\Sigma = 4.2$
(C) Gas			
air pollution	200	10	0.2
explosions	100	35	0.4
fires	100	35	0.4
asphyxiation	500	25	1.5
			$\Sigma = 2.5$
(D) Hydroelectric			
dam failures	50	35	0.2
			$\Sigma = 0.2$
(E) Nuclear (400 GW)			
routine emissions	8	20	0.018
accidents	8	20	0.018
transport	<0.01	20	—
waste	0.4	20	0.001
plutonium toxicity	<0.01	20	—
			$\Sigma = 0.037$
(F) Electrocution	1200	35	5.0
Grand total			24

Table 24. Life expectancies in various regions and countries

Region or country	
United States, Canada	71
Australia, New Zealand	71
Europe	70
United Kingdom, France, Germany	71
Poland, Rumania	68
Yugoslavia	65
Portugal	64
Latin America	60
Argentina	67
Mexico	61
Peru	57
Haiti	40
Asia	50
Japan	71
Turkey	55
India	45
Indonesia	42
Africa	43
Egypt	52
Kenya, Ghana	42
Congo	40
Chad, Upper Volta, Ivory Coast	32
Guinea	30

expectancy by more than 100 days. The added wealth resulting from it clearly saves us many times that number of days.

METHODS FOR REDUCING RISKS

A few methods for reducing risks without making major sacrifices are listed in Table 25. It is estimated that using seat belts or air bags would avert about a quarter of all motor vehicle fatalities. The effect of car size is from statistics that fatalities per vehicle-year are more than twice as high in small cars as in large cars (II75). It has been estimated that smoke alarms in homes would eliminate between a third and a half of all deaths due to fires. According to the Walton Report (Wa76), a PAP test has one chance in 4000 of averting death from cervical cancer, and each life saved adds about 40 yr of life expectancy.

Table 25. Days of life expectancy added by various actions

Action	Added life exp. (days)
Using seat belts	50
Installing air bags in car	50
Buying larger cars*	50
Smoke alarm in home	10
Training family in resuscitation	> 100
Annual PAP test	4

*Standard rather than sub-compacts, or large rather than standard.

PRIORITIES AND PERSPECTIVE

In Table 26 we have assembled many of the values of ΔE developed in this paper and listed them in order of decreasing ΔE. We have combined and averaged some categories to reduce complexity.

To some approximation, the ordering in Table 25 should be Society's order of priorities. However, we see several very major problems that have received relatively little attention (at least from the health standpoint) whereas some of the items near the bottom of the list, especially those involving radiation, receive a great deal of attention. Perhaps a few specific suggestions are in order here:

1. To reduce the number of unmarried adults, government agencies might organize computer dating services. More sociological research on that problem might be stimulated. Favorable publicity on the advantages of marriage might be encouraged.
2. To control overweight, calorie content of foods could be printed on labels to make people aware of them. Publicity on dangers of overweight could be disseminated.
3. Detailed studies could be undertaken aimed at understanding differences in life expectancies in various states.
4. Less attention should be paid to radiation hazards, catastrophes, saccharin, etc.

Table 26. Loss of life expectancy (ΔE) due to various causes

Cause	days
Being unmarried—male	3500
Cigarette smoking—male	2250
Heart disease	2100
Being unmarried—female	1600
Being 30% overweight	1300
Being a coal miner	1100
Cancer	980
20% Overweight	900
< 8th Grade education	850
Cigarette smoking—female	800
Low socioeconomic status	700
Stroke	520
Living in unfavorable state	500
Army in Vietnam	400
Cigar smoking	330
Dangerous job—accidents	300
Pipe smoking	220
Increasing food intake 100 cal/day	210
Motor vehicle accidents	207
Pneumonia–influenza	141
Alcohol (U.S. average)	130
Accidents in home	95
Suicide	95
Diabetes	95
Being murdered (homicide)	90
Legal drug misuse	90
Average job—accidents	74
Drowning	41
Job with radiation exposure	40
Falls	39
Accidents to pedestrians	37
Safest jobs—accidents	30
Fire—burns	27
Generation of energy	24
Illicit drugs (U.S. aver.)	18
Poison (solid, liquid)	17
Suffocation	13
Firearms accidents	11
Natural radiation (BEIR)	8
Medical X-rays	6
Poisonous gases	7
Coffee	6
Oral contraceptives	5
Accidents to pedalcycles	5
All catastrophes combined	3.5
Diet drinks	2
Reactor accidents—UCS	2*
Reactor accidents—Rasmussen	0.02*
Radiation from nuc. industry	0.02*
PAP test	−4
Smoke alarm in home	−10
Air bags in car	−50
Mobile coronary care units	−125
Safety improvements 1966–76	−110

*These items assume that all U.S. power is nuclear. UCS is Union of Concerned Scientists, the most prominent group of nuclear critics.

RISKS IN INDIVIDUAL ACTIONS

In on-the-spot decision making, one must consider the risk in a single individual action. If we assume linearity, the values listed in Table 27 are obtained for smoking, ingesting calories, and using saccharin. The risk of crossing a street is based on pedestrian fatalities and the assumption that the average person crosses 5 streets per day. The very large values are from far-reaching decisions having effects for an extended period of time, so they should probably not be considered as on-the-spot decisions.

It may be noted that smoking a cigarette has the risk of 7 mrem of radiation, and an overweight person eating a pie a-la-mode runs a risk equal to that of 35 mrem.

Table 27. Risks in individual actions

Individual action	Minutes life expectancy lost
Smoking a cigarette	10
Calorie-rich dessert	50
Non-diet soft drink	15
Diet soft drink	0.15
Crossing a street	0.4
Extra driving	0.4/mile
Not fastening seat belt	0.1/mile
1 mrem of radiation	1.5
Coast to coast drive	1000
Coast to coast flight	100
Skipping annual PAP test	6000
Moving to unfavorable state	800,000
Buying a small car	7000
Choose Vietnam army duty	600,000

VERY HAZARDOUS ACTIVITIES

Some activities, like automobile racing or tight-rope walking, are generally viewed as extremely hazardous; we here convert some of these to loss of life expectancy. If such an activity involves mortality risk of 1/1000 per year, and the average victim loses 35 yr of life, $\Delta E = 0.035$ yr or 13 days. For other risks, ΔE scales proportionally.

Information on these is given in Table 28, with the data derived from statistics for recent years (Me74b; Me76a). The "professional motorcycle racers" refers to members of American Motorcycle Assn. Professional aerialists include tightrope walkers, trapeze artists, aerial acrobats, and high pole balancers. "Hard-hat" divers are deep sea divers who use a rubber suit, a metal helmet, heavy weights, and a hose to an air pump on the surface; decompression sickness is their major hazard. Smoke stack construction refers to bricklayers and masons engaged in building smokestacks; their major hazard is falling.

Table 28. Risks in hazardous activities (Me74b; Me76a)

Occupation	Participants	Recent av. deaths/yr	ΔE/yr of participation
Championship auto racing	5000	1.9	5 days
Automobile drag racing	145,000	7.4	0.7
Go-cart racing	18,000	0.6	0.4
Midget auto racing	2800	2.2	10
Motorcycle racing	115,000	22	2.5
Professional motorcycle racers	4000	6	20
Snowmobile racing	15,000	2	1.9
Sports car racing	11,000	3.3	4
Sprint car racing	8500	8.2	13
Stock car racing	26,000	10.2	5
Figure 8 stock car	2000	0.2	1.3
Professional aerialists	300	0.12	5
Navy frogmen	200	1	65
Navy "hard-hat" divers	1150	0.5	6
Commercial "hard-hat" divers	3500	11	40
Abalone divers	170	2	150
Sponge divers	100	0.17	22
Smoke-stack construction	100	1	130

Much of these data are crude, but they should be valid to within a factor of 3 or so, and as an average they should be somewhat better. It would seem that these activities rarely would reduce life expectancy by more than 5 days or so per year of participation, so even 30 yr of participation would not be as dangerous as gaining 10 lb of body weight.

Acknowledgements—The authors would like to acknowledge the assistance of H. N. Jow in developing the computer program and of D. N. Cohen (Carnegie–Mellon) is proving the mathematical equivalence of our formulation and the standard one, and helpful suggestions from H. E. Griffin and L. H. Kuller of University of Pittsburgh Graduate School of Public Health, Jerry Cohen of Lawrence Livermore Laboratory, and Ms. Marion Geerken of Metropolitan Life Insurance Co.

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