NUCLEAR SAFETY AND RELIABILITY

WEEK 12

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1. Comparison of Risks

This material is well presented in Chapter 16 of McCormick. The topic of risk comparison is as broad as societal activity. It could deal with the question of whether heart transplants are more effective in reducing risks than, for example, preventive medicine campaigns. If the society has limited funds this becomes a vital question. Should more traffic lights be installed, or should the money be used for food banks? Should a new air traffic control system be installed, or should the funds be committed to cancer research? Is it most effective to put money into further improvement of reactor safety, or should the money be put into acid rain reduction? Are nuclear plants less risky or more risky than oil-fired power plants? Each question is related to all the others, because the discretionary wealth of any society is strictly limited so that not everything we wish to do can actually be done.

It is the basic premise of risk comparison that one is seeking an equitable distribution of risks; that is, one in which each individual carries a fair share of the overall societal risk burden. Such an ideal state probably never can be realized; however, whenever we consciously decide to allocate money to some specific risk-reduction program, we must realize that some other risk is increased through a forced decrease in safety-related funding.

The risk comparison field is quite new. In addition, risk is difficult to calculate objectively. Biases and (perhaps) unconscious predispositions can affect the results very strongly - the discussion is at the border between engineering and sociology. The underlying argument seems to be about the choices that individuals would make, if they had the power, regarding the type of society in which they would prefer to live. A classic argument is whether or not industrialization represents "progress". This argument has been particularly strident in the United States; its history goes back to the debate between Alexander Hamilton and Thomas Jefferson. Hamilton favored an industrial nation, while Jefferson preferred an agrarian economy. The Hamilton-Jefferson debate has been reviewed periodically in the US, and has been reopened most recently by Rachel Carson's book "Silent Spring". This book can be considered as the source from which the American environmental movement has sprung. It addressed some very real problems caused by industrialization, but its basic appeal was to the "agrarian soul" of Americans.

In a society where the most vocal element of the population has enough material goods by any sensible standards, one can expect these people to look for other sources of satisfaction, and

to create sociological causes of various kinds. The environmental movement is one of these. Environmentalists generally do not seriously consider the real needs of people in the lower economic echelons of the society, those who depend heavily on active industries for their well-being. While the richer fraction of the society will generally benefit from a cleaner environment, they will not have to pay the price of reduced economic activity suffered by the poorer elements of the society. They have a perspective that largely excludes a major part of the community.

It is obvious that industrial activity in North America has resulted in great damage to the natural environment as it existed prior to industrialization. We have grossly modified our natural environment, not only through building large houses and broad expressways, but perhaps most drastically through improvements in human sanitation and health care. These factors are primarily responsible for the recent vast increase in the world's human population that is the main cause of current environmental pressures.

We find it easy to overlook the fact that the same industrial activity that produces environmental damage is the source of our wealth and power; in fact, most of our environment is what it is because we demand that it be so. The engineer's task is to minimize negative environmental effects while maximizing economic benefits of whatever activities society chooses to undertake.

Figure 12.1 (from work by Ernie Siddall) gives some insight into the health advantages of modern life. The general trend of Canadian "early death"; that is, death before age 65, has been steadily downward over the past 50 years. This graph indicates that Canadian females have lower early death probability than males - though recent indications are that the changing lifestyles of women are tending to increase this probability.

The most interesting aspect of the Figure is the effect of wealth on the early death probability. The 1971 statistics plotted on the graph were all collected within metropolitan Toronto so as to remove some of the usual environmental uncertainties. It is clear that poor people living in Toronto have a shorter life expectancy than do rich people. The disadvantage is much larger for males than for females. It is obvious that, at least among this particular group of people and at this particular time, being rich confers health benefits - it might be concluded that some level of wealth (which is known to have followed industrialization) is beneficial to the individual and to the society.

A major assumption in the above is that individual longevity benefits the society as a whole. This relationship is not clear.

It often is assumed that some type of technology can be devised which will allow us to make any choice of lifestyle, - in many ways the non-technical majority of the people have more faith in technology than do the technologists. It is essential for engineers to avoid promising benefits that cannot be delivered.

The role of the engineer in this debate is to offer as clear and unbiased an opinion as can be prepared, regarding the economic, social, and environmental impact of the choices which face the society at any point in time.

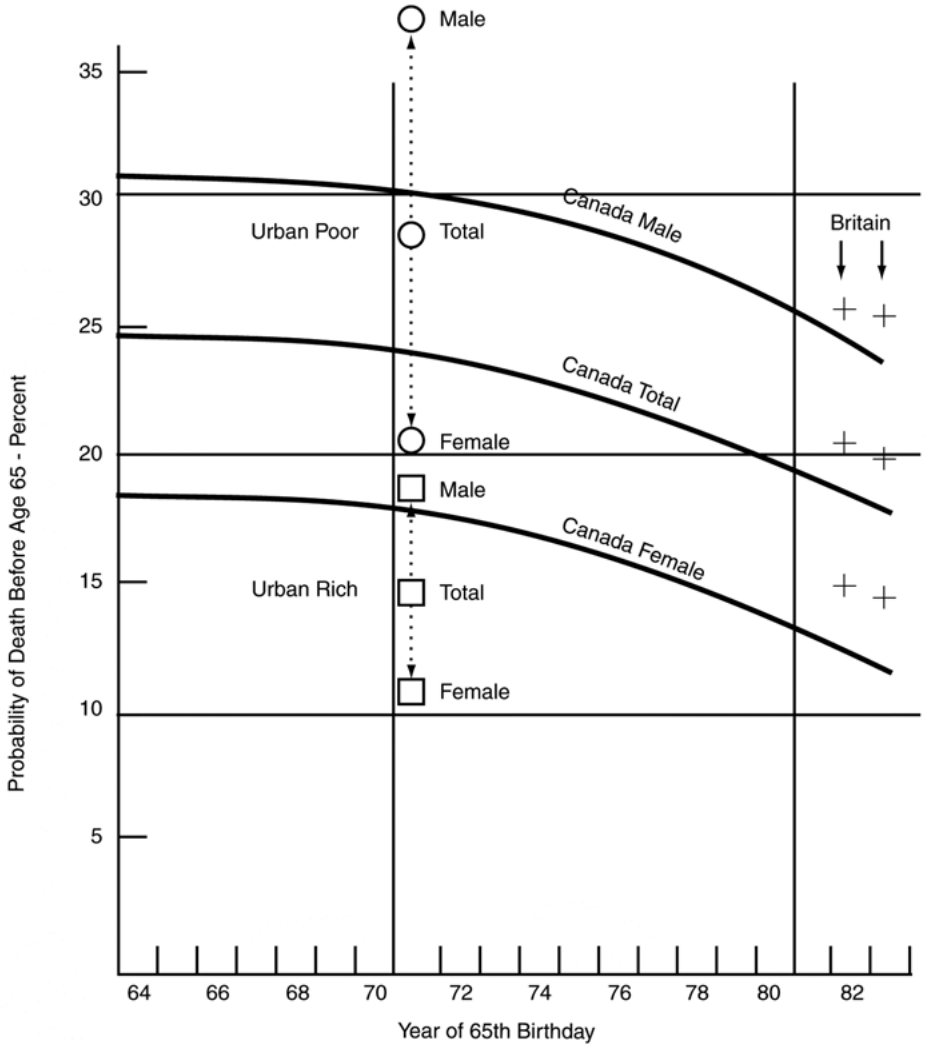

FIGURE 12.1
LIFE TABLE PROBABILITY OF DEATH BEFORE AGE 65

2. Risk-Benefit Assessments

This material is presented in Chapter 17 of McCormick. The approach is based on the assumption that increased risk must be balanced by a corresponding benefit. This requires a figure for the value of disability or loss of life; it is here that the arguments begin. The rationalists' objective is to achieve a reasonable balance, across the various activities of the society, between the dollars that must be spent in saving a life and the number of lives saved. For instance, is the

(hypothetical) extra safety device in a new CANDU station cost-effective relative to the same amount of money spent in the area of preventive medicine? The method recognizes the existence of finite resources that can be allocated by choice to various life-saving activities.

The answering, humanistic, argument states essentially that any single human life has infinite value, so that consideration of risk-benefit balance is meaningless. Unfortunately, this approach offers no alternative. Decisions that require specific allocation of scarce resources necessarily involve risk selection. For instance, a hospital director whose budget has been reduced must make a choice of which lives to save. The society as a whole should accept responsibility for guidance to such individuals; otherwise, they are constrained to accept whatever decisions are made on their behalf.

In the United Kingdom, a Health and Safety Directorate has been established with overall responsibility for risk balancing between various main activities of the society. It likely will take generations before a semblance of risk equity is achieved. The concept is quite new to Canada, and will surely be discussed at length before being implemented.

3. Risk Acceptance

This material is presented in Chapter 18 of McCormick. Only a general knowledge of this material is required.

There have been several attempts to judge which risks are acceptable in the current society, and those that are not. In general, the conclusion arises from any individual's desire to minimize his or her own risk by transferring as much as possible to others, in particular the government. Consideration of risk acceptance calls up all of the social factors mentioned earlier, and has very little chance of being objective. This does not reduce its importance.

The most likely path toward adjustment of individuals to the society's risk level is through clear and comprehensive information distribution as well as debate on the essentially sociological and philosophical questions which come from these questions.

4. Wrap-up

The course has attempted to outline some of the methods that can be used to evaluate the potential risk of an engineering undertaking, using nuclear power as an example. The same methods are now being used to assess the risk of many other industrial processes. The methods are the same in all ventures; the essential components are a deep knowledge of the technology, readiness to look carefully for dominant failure modes and effects, discipline to continue investigation of safety over the whole life of an installation, and knowledge to address and solve those problems revealed by safety investigations. Recognition that safety is a human problem rather than a technological problem is the most basic principle.

It is expected that virtually every project with which engineers are involved in Canada over the next 40 years will be subjected to some form of risk and benefit analysis. Methods will be refined through the test of experience but will remain uncertain, especially for new technologies with no well-developed accident history. The inherent uncertainty in risk analysis is basic: prediction of both risk and benefit involve prediction of the future.

As is true with any plans for the future, risk and benefit analysis will involve many factors other than purely technical ones; in particular, the society's values and goals must be considered. The engineer's role in the overall planning process is to present the known facts in proper perspective and to judge the most probable result that might arise given the many uncertainties which exist. This always has been one of the engineer's main goals; the difference is that modern societies have come to expect more complete and precise assessments before embarking on ventures with inherent risk - which includes all human ventures.

It is hoped that the material covered will assist those engineers who do these analyses in carrying out their duties, and will help those who are not directly involved to understand what is going on.