# Risk Assessment: The Joint IAEA/IIASA Research Project

by Harry J. Otway

Since the dawn of civilisation man has maintained a wary consciousness of the perils of his environment. However, until rather recently, the nature of these hazards did not change appreciably; their effects were limited to relatively small geographical areas and discrete time intervals. Thus, exposure to these hazards could, to some extent, be influenced by the actions or skills of the individual.

The interest in risk assessment is due to concerns about the dangers man has created for himself. In recent decades technological systems of unprecedented size have been developed and the side-effects of these large-scale systems are correspondingly larger, sometimes of world-wide significance for extended time periods*. A new category of risks which accompany the benefits provided by man's technology, has emerged; here the actions and skills of the individual are essentially ineffective.

The occurrence-probabilities of many of these side-effects are not accurately known because there has not been enough experience with these technologies to obtain statistical measures of risk. Further, there are often uncertainties in the consequences (should a specific side-effect occur) because of an incomplete knowledge of the relevant natural laws necessary for prediction. Häfele (1) has referred to an age of "hypotheticality", where theoretical estimates of risk must substitute for experience.

The resulting societal response to these risks has been observed in the emergence of attitudes which tend to regard much that is new as being potentially harmful; the fundamental value of science to society is also being questioned. A variety of individual and group demands have been put forward for a closer examination of the benefits and risks of technological innovations and, indeed, many such advances are encountering difficulties in gaining acceptance by the public.

The nuclear energy field presents an excellent case study in risk assessment** because the public response to these risks is, in many cases, providing a very real limitation to the development of nuclear power programmes. Further, the nuclear field provides many risk situations that are of research interest, such as: examples of cost-effective standard setting where operational risks may be reduced by control equipment expenditures; the possibility of large-consequence, but infrequent, accidents; accident occurrence probabilities which can only be estimated, thus are highly uncertain; the non-random distribution of risks and benefits to different groups of people; concerns about possible future (genetic) risks where benefits are realised at the present time.

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* Some examples of side-effects with global implications are potential changes in world climatology due to atmospheric pollution, the global distribution of krypton-85 and the interaction of aerosol spray propellants with the earth's ozone layer.

** Pahner (references 2 and 3) has hypothesised that nuclear energy represents a general example of societal concerns about technological development as well as a particular example of the psychological displacement of anxieties relating to the military uses of nuclear energy.

The Joint IAEA/IIASA Research Project (Joint Project) was formed in mid-1974 pursuant to an agreement between the Director General of the IAEA and the Director of the International Institute of Applied Systems Analysis (IIASA). Organisationally the Joint Project comes under the Energy Systems Project of the IIASA and the IAEA Department of Technical Operations, Division of Nuclear Safety and Environmental Protection.

One of the prime objectives of the Joint Project is to develop information required for decisions in areas such as:

- the design of control and safety systems
- the development of operational philosophies
- the setting of rational regulatory standards
- policy-level decisions on the selection and deployment of energy systems.

Space limitiations do not permit a detailed discussion of the structure and process of risk assessment. More information is available in references 4 and 5.

As of July 1975 the project consisted of eight professional and two General Services staff. The IAEA provides the Project Leader and General Service staff and the IIASA three scientists. IAEA Member States (Fed. Rep. Germany, Japan, Sweden, France, United Kingdom and United States of America) have indicated their interest in this work by providing seconded scientists on a cost-free basis.

Additional scientific collaboration is obtained through IAEA-sponsored research contracts with the University of Vienna Psychological Institute, the Study Group for International Analyses and the European Centre for Social Welfare Training and Research.

The following disciplines are represented in the Joint Project: Physics, Public Health, Systems Engineering, Economics, Anthropology, Psychiatry/Medicine, Psychology and Sociology.

## RESEARCH PROGRAMME AND PRELIMINARY RESULTS

The research activities of the Joint Project may be divided into five sub-tasks, which will be described in this section. Preliminary results will be briefly summarised; readers are referred to the referenced publications for details.

### Advanced Methods in Risk Estimation

Due to the relatively small statistical data base it is difficult to make risk estimates for low-frequency, large-consequence accidents such as those that might occur in nuclear power facilities. Mathematical techniques, such as fuzzy set theory, are being applied to making macroscopic risk estimates which may then be compared with estimates based upon microscopic techniques such as accident/fault tree analysis (6). This work represents a supplement to the methodologies used in the U.S. Reactor Safety Study (7).

### The Application of Risk-Benefit Principles to Standard Setting

An important factor in standard setting is that of expressing disparate variables in consistent units so that comparisons may be made between risk reduction and its cost. This is especially difficult in the case of activities which involve risks to human life. The Pareto theoretical approach is being adapted to the evaluation of such risks and the possibility of using Pareto criteria for the treatment of statistically and non-statistically distributed risks is being examined. The effects of further variations are also being considered in this theoretical work, for example, the question of genetic risks that occur in the future where the benefits are short-term and are taken by the present generation.

A survey has been made which concentrates upon practice (mainly in France and the U.S.A.) in evaluating public projects involving life saving (8). Further, a review of theoretical models for determining the "value" of mortality risk in decision-making has been completed (9). These theoretical treatments have been applied to nuclear power plant economics (10) and the problem of quantifying environmental risks (11).

An application was made to the treatment of tritium and krypton-85 in nuclear facilities (12, 13). This work indicates that, based upon the number of publications on the health and safety effects of these two isotopes, more attention has been given to the control of tritium releases. However, the world-wide radiation dose from tritium released in the nuclear industry is not only less than that from krypton, but it is smaller than that from naturally occurring tritium and far smaller than that due to residual tritium from weapons testing. This means that adding controls to further reduce tritium releases from the nuclear industry would hardly change the total tritium dose. Since there is essentially no krypton background level, krypton controls would have a direct effect. An estimate of the cost of reducing tritium releases by 50%, using current technology, is about $170 000 per man-rem of radiation exposure avoided. A comparable cost for reduction in krypton releases would be about $10 per man-rem. The theoretical considerations mentioned earlier would indicate that $200 is a reasonable expenditure for the avoidance of one man-rem of whole body irradiation. The conclusion here is that futher consideration might be given by the nuclear industry to the relative expenditures for control of these two isotopes.

**The Perception of Risks**

The perception of risks is a crucial factor in determining attitudes; obviously people respond to a threatening situation based upon what they perceive it to be rather than what it might actually be. An effort is therefore being made to develop survey techniques for determining how various types of risk are perceived. A further goal is the identification of the variables which influence risk perception and the determination of their relative importance.

A survey has been done in Austria (14) as a replication of one previously done in Canada (15), to obtain ordinal rankings for various hazard situations. The objective of the Austrian study were primarily to gain experience in administering this type of survey and to develop computer programmes for data analysis. A secondary objective was to make a cross-cultural comparison of risk perception.

The overall cross-cultural rank-size correlation coefficient for the two groups was found to be $r = 0.62$. In the Canadian group the effect of the experience with specific risks was found to be most important in determining response (experienced respondents vs. inexperienced, $r = 0.45$). This was not found in the Austrian sample ($r = 0.81$) where the most important determinant of risk perception was found to be the subjects' self-rated ability to imagine themselves in particular risk situations ("good" imaginability vs. "poor", $r = 0.59$). This latter result is conjecturally interesting in the case of nuclear power plant risks where imagination must substitute for experience, and difficulty in imagining a specific hazard correlates with the higher ranking of that hazard.

A further preliminary survey (16), designed to be less culturally dependent by using pictures of risk situations, confirmed by factor analysis that the most important determinant of risk perception is the active-passive dimension. That is, risks such as technological risks where the individual has no control over outcome or exposure tend to be ranked higher. This study is being refined to look for determinants of perception in a group of only passive risk situations. This is a collaborative effort with the University of Vienna, Psychology Institute.

**Preferences Related to Risk Acceptance**

Starr (17) postulated some determinants of risk behaviour based upon the analysis of national accident statistics. This work developed a philosophical basis for risk assessment and served to draw attention to the importance of such research. Based upon these analyses Starr suggested three major determinants of risk acceptance and assigned weightings to them. The major points were:

"1. The indications are that the public is willing to accept 'voluntary' risks roughly 1000 times greater than 'involuntary' risks.
2. The statistical risk of death from disease appears to be a psychological yardstick for establishing the level of acceptability of other risks.
3. The acceptability of risk appears to be crudely proportional to the third power of the benefits (real or imagined) ... ."

The methodology used was reviewed and an attempt was made to reproduce the Starr results (18). The results could not be reproduced using this method and it was concluded that, while the Starr hypothesis regarding the identification of these determinants (at least 1 and 3 above) was probably philosophically correct, the results could not be justified on the basis of his analysis. It was further concluded that the mathematical relationships indicating the relative importance of the determinants must be regarded as unlikely.

Further efforts in this direction will concentrate upon the combination of statistical analysis and behavioural theories employing an iterative process of empirical, multi-variable analysis. This work is a collaborative effort with the Study Group for International Analyses, Vienna.

**Information Transmission and Group Dynamics**

The communication of scientific information plays a role in the development of societal attitudes. Groups serve a mediating function between the individual and the larger society, because the individual interacts with society through his membership in various groups, e.g., family, professional, fraternal, etc. Therefore, an understanding of group dynamics is important in learning how individual attitudes and preferences are aggregated to form attitudes at the societal level. In the case of nuclear power plants it has been observed that until a project is made known there is no immediate concern about nuclear hazards among most inhabitants of the area. Once the plans are announced, people soon become acquainted with thinking about the possible threats, real or imagined; they are forced by circumstances to form relevant opinions. The project then starts being judged on a number of levels: individual, group, community, national and perhaps even international. As the responses to the proposal gradually emerge it has been noted that various interest groups start to form, develop their sources of information and, in many cases, work actively to promote or oppose the proposed facility.

As a preliminary step in understanding this problem, risk phenomena in traditional, small-scale societies have been analysed (19) to aid in the construction of models of this process. The observation of several interest group situations has allowed the derivation of a set of typical interest group characteristics (20). A systems analysis application to nuclear power plant siting has been published (21). Models of interest group dynamics in modern societies are being constructed in collaboration with the European Centre for Social Welfare Training and Research (Vienna) through an analysis of several nuclear power plant siting controversies.

**The importance of risk assessment research in providing information necessary for decisions regarding the selection, design, deployment and operation of technological systems such as energy systems is undoubtedly important, and the research programme of the Joint IAEA/IIASA Research Project will continue to develop this field further.**

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* Those references marked with an asterisk* represent publications of the Joint IAEA/IIASA Research Project or the International Institute for Applied Systems Analysis. Copies may be obtained by writing to: H. Otway, Project Leader, Joint IAEA/IIASA Research Project, IAEA, P.O. Box 590, A-1011 Vienna.

# IAEA Technical Co-operation Activities

**This is the first of a series of articles outlining the different kinds of technical assistance requested by and given to Member States in specific regional areas. These divisions are principally delineated by geographic boundaries, and each is supervised by an "area officer." The first covers the particular requirements of the IAEA Technical Assistance Programme dealing with**

# Europe and the Middle East

by Arturo E. Cairo

**In the United Nations system a "developing country" is one which is entitled to receive technical assistance under the United Nations Development Programme (UNDP). In Europe the following Member States of the IAEA are entitled, at the present time, to receive such assistance: Albania, Bulgaria, Cyprus, Czechoslovakia, Greece, Hungary, Iceland, Poland, Romania, Spain, Turkey and Yugoslavia. The Member States in the Middle East region which receive assistance from or through the Agency are: Afghanistan, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Saudi Arabia and the Syrian Arab Republic. Other developing countries in these two areas which are not Member States and have not yet requested country programme assistance from the IAEA, are: Bahrain, Democratic Yemen, Malta, Oman, Qatar, the United Arab Emirates and Yemen Arab Republic.**

The assistance provided to the above Member States has been of a very distinctive nature in terms of the subjects covered and the volume of aid extended. This is partly due to the varying stages of progress in the introduction and use of nuclear technology in the developing countries in the two areas.