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A global approach to risk management:

Lessons from the nuclear industry

Although the nuclear industry has focused primarily on its own needs in assessing and managing risk, many of the lessons it has learnt can be adapted to broader classes of risk and other contexts.

Governments are endeavouring to manage not only the interdependencies and interactions among hazards, between various systems and the forces influencing the overall context of risk management, but also the increasingly important international dimension of risk. The sheer complexity of these variables requires a holistic approach to the subject of risk.

Many conventional risks look set to take on new forms, and new hazards are emerging, some of which are characterised by considerable uncertainty on the one hand and the possibility of extensive and perhaps irreversible harm on the other. In particular, these trends point to a marked increase in the future in the probability of vital systems (technological, infrastructural, ecological, etc.) being damaged by a single catastrophic event (natural or man-made) or a complex chain of events. From the point of view of highly organised modern societies, such potential damage to the systems on which society increasingly depends (health services, transport, energy, food and water supplies, information and telecommunications, safety and security) could have serious and global consequences.

The experience needed to build a holistic approach is being drawn from various sectors of activity, many of which have been addressing their own sectorial risk assessment and management for some time. The nuclear industry is one of the sectors that has extensive experience to share.

From its earliest days, risk assessment and management has been at the heart of the nuclear industry. Attempts to assess and manage nuclear risks have recently begun to be viewed by nuclear regulators in the context of comparisons to other, broader risks. Several key aspects have emerged from ongoing studies that should be useful in looking at more complex risks and risk interactions. Broadly, these key aspects may be found in:

- the assessment and management of nuclear safety;
- the assessment and management of radiation exposure to the public, the environment and workers;

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- the planning, preparedness and management necessary in case of a nuclear emergency.

Although the nuclear industry's experience in these areas may not directly involve global-scale risks or complex, interlocking aspects, much of what it has learnt can still be applied in such scenarios.

Risk-informed regulation and nuclear safety management

Nuclear safety regulation is traditionally deterministic, with prescriptive rules about plant design, operation and quality assurance. In general, conservative assumptions are used in order to compensate for the lack of knowledge of the events considered and the physical processes involved. Such an approach in many cases leads to substantial safety margins. The rules and regulations currently in place were conceived at a time when probabilistic safety assessment (PSA) was not well developed. Probabilistic considerations were nevertheless used to conclude that certain accidents need not be considered in the design basis (e.g. pressure vessel rupture).

Improved computing power over the years has allowed PSA to mature. With time, plant accidents and plant-specific PSAs have identified limitations in the deterministic process. A main limitation is that in the identification of defence-in-depth measures (such as independent function of multiple safety systems), the lack of quantitative insights on risk makes it impossible to assess the adequacy of such measures. Therefore, the deterministic approach tends to apply excessive conservatism in certain areas and inadequate conservatism in others. For example, the assumption of single failure is not conservative in sequences where multiple-component failures are shown to be likely and should be given consideration in the design. Furthermore, although deterministic assumptions may largely be valid for designing equipment, they do not provide the operational and systemic insights necessary to support safe operation and maintenance. Because of these reasons, it is now recognised that PSA is an essential complement to the deterministic process both in the design and operational support of nuclear power plants.

From a nuclear safety point of view, probabilistic safety assessment is used during both the design and the operating stages of a nuclear power plant to identify and to analyse every possible situation and sequence of events that might result in severe damage to the reactor core. To the extent that PSA outcomes and insights can have an impact on the design and operation of nuclear power plants, they can also have an effect on regulation. Regulatory bodies are often faced with licensee submittals in which the results of PSA studies played a large role, such as the relaxation of technical specifications. Another example is where PSA has been used in planning the outage period. The widespread use of PSA in a regulatory context has, however, met with more or less acceptance in different countries.

JAERI, Japan

View of a nuclear safety test facility in Japan.

Both deterministic and probabilistic approaches have their strengths and weaknesses. Used in combination along with sound engineering, they can form a valuable tool for the nuclear industry

and its regulatory decision-making process, as well as the basic methodologies for improving industrial safety generally.

Assessing and managing radiation exposure

A key aspect of assessing and managing the risk to an individual from radiation exposure is science's ability to estimate the health detriment that is – or could be – caused by such exposure. The risk/dose relationship is only a hypothetical assumption used by scientists and regulators to place an upper limit on possible health effects. Yet it is an essential tool in managing an exposure situation.

Specifically, an individual's exposure can be estimated for situations that are planned, that already exist, or that could result from an accident situation. Planned situations would include the development of a new facility (hospital, research laboratory, nuclear reactor, etc.) that would expose workers, and that would or might release radioactive materials to the environment that would then expose members of the public. Situations that already exist would include legacies such as abandoned or formerly used factories or research facilities that were contaminated with radioactive materials during their operation. Situations that could result from an accident would include a fire or explosion in a research or industrial facility using radioactive material, or a serious accident at a nuclear power plant, which could result in exposure to both workers in the proximity of the accident and to members of the public from the radioactive materials released. In all these situations, individual exposure can be estimated in an *a priori* sense, measured directly using radiation measurement devices, or "reconstructed" after the fact, using environmental measurements and estimates of the individual's location and habits over time.

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Monitoring radiation in the vicinity of the Bohunice nuclear power plant in the Slovak Republic.

From these exposure assessments, the health risks for exposed individuals can be estimated. Here, "health risk" refers to the occurrence of some types of radiogenic cancer or leukaemia. While developing cancer or leukaemia following radiation exposure is not a certainty, the greater the individual's exposure, the greater the risk that he or she will develop cancer.

It is this assessment of risk that can be used in a comparative fashion to determine how best to manage the risk. Management, in radiological protection terms, has for some time been expressed as keeping exposures as low as reasonably achievable (ALARA). The factors that are routinely considered when making these judgements include such basic items as the cost of reducing the exposure by a specified amount, and the amount of exposure (worker and public) that would be saved by the protection measures proposed. More complicated are the aspects that decision makers use when judging what is meant by "reasonably achievable" in each specific case. This depends upon many less tangible or quantifiable factors, such as the inherent value of the dose-causing activity – both for those exposed and society as a whole. In recent years, the process of optimising radiological exposure to levels that are ALARA has begun to integrate various forms of stakeholder involvement. In this way, there is more chance that the final decision will enjoy acceptance. The type and number of stakeholders involved in such processes vary from case to case.

A key aspect of this process is distinguishing between the science of risk assessment (quantification, discussion of uncertainties, elucidation of possible protection options, etc.) and the social aspects (relating to the acceptance of risk). Both elements play important parts in the decision-making process.

The notions of risk assessment and management described here, and which are applied in radiological protection at nuclear power plants, industrial facilities, hospitals and research laboratories, could be applied to many other types of risk, systemic or otherwise.

Nuclear emergency planning, preparedness and management

Another important area in which the nuclear industry has developed significant experience that is applicable in a wider framework is that of nuclear emergencies. Because of the risk of large reactor accidents causing large off-site release of radioactive materials, the nuclear community has, particularly since the Three Mile Island and Chernobyl accidents, substantially increased its ability to prepare for and, if necessary, react to nuclear accidents. Efforts have addressed several areas, but the most applicable to a broader context are the areas of harmonisation and communication.

It has been repeatedly demonstrated, through exercises and studies, that responses to the release of radioactive materials need to be harmonised because there can be so many actors and/or variables. Primarily, this concerns how and when various levels of government authorities will implement protective measures. For example, what criteria should be used to decide whether to evacuate a potentially exposed population, or to provide such a population with stable iodine tablets for the protection of the thyroid gland in case of a release of radioactive iodine? Should an accident have the potential for transboundary effects, modern communications (press, TV, radio, internet) will rapidly inform populations in the affected regions of any protection measures being implemented, and discrepancies may appear. Co-ordinating potential protection approaches among responsible officials before an accident occurs, and achieving a well-harmonised response afterwards would be instrumental in avoiding such situations. The public's perception, valid or not, of a conflicting or biased approach could lead to a lack of acceptance of protection measures, along with a general erosion in its trust of government. Even if a particular situation does not create physical transboundary effects, the way in which governments address such issues will still be questioned outside the country where the accident took place. National decisions, particularly regarding the import and export of food and goods and the protection of people passing through

The internet is increasingly being tested and used for emergency communications.

or near any affected areas will have international implications.

The other key issue, related closely to harmonisation, is the need to quickly and effectively communicate. This includes communication within government decision-making structures, from government to the public, from national government to other national governments, and from government to relevant international organisations. To facilitate these exchanges, it is necessary to have pre-established lines and means of communication so that governments and experts can communicate rapidly. Emergency communication to the public is a central role of government, but may need to be reconsidered in the context of large or specific emergencies. In the nuclear community, international conventions and treaties have been established to describe when and how such emergency communications should be made, as well as what essential information should be included in the initial notification. A structure for communications, through the International Atomic Energy Agency (IAEA), was established under the international Convention on Assistance in the Case of Nuclear Accident or Radiological Emergency in 1986.

It is widely accepted through the experiences from emergency exercises and studies, that such notification and communication structures are essential to appropriately manage an emergency situation. The institutional implications, both national and international, of the need and obligation to communicate include the need to allocate appropriate resources to this task, as well as the need to account, structurally, for these lines of communication. Such communication lines could also facilitate the national decision-making processes in other types of emergency situations. ■