Nuclear Emergency Management: driven by precedent or international guidance?

Simon French
University of Warwick
simon.french@warwick.ac.uk

Nikolaos Agryris
University of Warwick
n.agryris@warwick.ac.uk

ABSTRACT

The NREFS project is re-evaluating the management of radiation accidents, paying attention to environmental, financial and safety issues and to the threat and response phase. In designing our project some two years ago, we were concerned to avoid any assumption that a future accident will be similar to a past accident, in particular the Chernobyl and Fukushima Accidents. After a year of research on the issues to be considered and the criteria that could or should drive the decision making, our concern has increased. We have found that international guidance provided by organisations such as ICRP and IAEA lack the specificity to help decision makers. Precedent set in the handling of earlier accidents provides much clearer and tighter guidance – and, moreover, one may feel that that the public will expect them to follow such precedent. Unfortunately the circumstances of a future accident may make precedent inapplicable. Consequently we believe that there is an urgent need to think more widely about nuclear emergency management.

Keywords

Chenobyl Accident; Fukushima Accident; international guidance; multi-criteria decision analysis; nuclear emergency management.

INTRODUCTION

In French*, et al.* (2013) we introduced the NREFS project. Its overall aim may be summarised as a reconsideration of fundamental thinking about the emergency management of a radiation accident, particularly in the early phases, drawing in some recent developments in J-value theory to evaluate health consequences, financial mathematics including real options and the use of multi-criteria decision analysis (MCDA) within the context of multiple scenarios. The project is funded as funded as part of a UK-India Civil Nuclear Research Collaboration, which brings an important contextual dimension. Inevitably the Indian authorities have to plan to deal with much greater population densities than has been common in thinking on nuclear emergency planning. Evacuation may not be a feasible option in the early phase of an accident. Given the quality of the housing stock in many Indian districts sheltering may be impractical, at least in the sense that remaining indoors will have significant protective value. Even in Western Europe there are nuclear plants so close to population centres that evacuation may be impossible in the early phase, e.g. the plant at Hartlepool in the UK. For smaller countries any exclusion zone might cover a significant proportion of the country making it unviable.

Our contribution to the project revolves around the use of MCDA and consequently we have been collating and reviewing the criteria that have been used or recommended for use in responding to and recovering from a radiation accident. We have compared the responses to Chernobyl and Fukushima, international guidance and the academic literature. As we have done so we have become increasingly concerned at the weakness of international guidance relative to the clear precedents set by the responses to the very few radiation accidents that have occurred – thankfully! – to date. Precedents set public expectations and if there is no counterweight to those of Chernobyl and Fukushima, there will be expectations that residents with a few tens of kilometers will be evacuated and an exclusion zone established. Yet this might not be possible. The resulting dislocation between expectations and the practical response will almost inevitably create huge public concern and stress with consequent social and health impacts that could be of the same order as those impacts arising from the radioactive contamination. Proactive, participative emergency planning around each plant which is sensitive to the local social, political, geographic and economic contexts, supported by *strong* international guidance could counter the expectations set by precedent, reducing the potential for public stress. This paper argues that such strong guidance is needed urgently. Moreover, without such guidance any implementation of MCDA into the processes and support systems to plan for and manage the early phase of a radiation accident will tend to be vague and generic.

THE CHERNOBYL AND FUKUSHIMA ACCIDENTS

Since the inception of nuclear power there have been four major accidents: Windscale, Three Mile Island, Chernobyl and Fukushima, as well as several other smaller accidents with few if any off-site impacts (Nenot, 2009). The Windscale Fire of 1957 happened in another era, was covered by aspects of national secrecy and handled accordingly. The Three Mile Island Incident in 1979, coming just after the film *The China Syndrome*, did much to raise public concerns and fears about a major nuclear accident. There was negligible off-site release, however, and so set little precedent to establish public expectations for emergency management, save perhaps for the need for better and faster information. Longer term it had major impacts on energy policy worldwide, all but ending the growth in the use of nuclear power in the US and other countries. So it is the Chernobyl Accident of 1986 and Fukushima Accident of 2011 that have set precedents and inhabit the public's psyche in their expectations for handling a major radiation accident.

In both the Chernobyl and Fukushima Accidents, it was feasible to evacuate the local population and create an exclusion zone. In the case of Chernobyl, Prypiat was a substantial town, but it was the only substantial town within 30km of the plant and, moreover, the majority of its economy revolved around the plant, the rest of the region being agricultural with no other significant infrastructure or economic activity within 30km of the plant. The creation of an exclusion zone was costly, but feasible. In the case of Fukushima, the radiation accident was a part of a much larger catastrophe in which the Tsunami had devastated large swathes of land and infrastructure and killed around 20,000 people. Evacuating the population and creating an exclusion zone was a dreadful consequence of the radiation release; but, in the context of the Tsunami's devastation, it would seem less dramatic and thus more feasible than it would have had the release had some other cause. The circumstances of a future accident may be such that it is not straightforward politically or economically much less physically feasible to evacuate the local population and establish an exclusion zone. Even sheltering may be difficult if the release continues for an extended period. In addition to these demographic and economic issues, we note that some reactors are so close to nation's borders that any evacuation or exclusion zone would extend into two or more countries[1].

Before Chernobyl, emergency planning for radiation accidents was generally driven by simplistic cost-benefit thinking on evaluating different protective and restorative measures. The cost of any measure was compared with radiation dose that would be averted (and hence the risk of cancer and impact on life expectancy in the population at risk). Such comparisons, within constraints on maximum allowed exposures, provided the basis of ranking and choosing different measures. The Three Mile Island Accident had catalysed much reflection on the appropriateness of this; but it was the Chernobyl Accident and its aftermath that showed clearly necessity of considering socio-political consequences, particularly the acceptability of different measures to the public. Moreover, many studies since Chernobyl have shown that the health effects due to stress are commensurate with the health effects that arise from the radiological exposures (IAEA, 1991; 2006; Karaoglou*, et al.*, 1996; Lochard*, et al.*, 1992). So even within criteria relating to health it is important to consider more than averted dose.

The response to and recovery from the Chernobyl Accident has also led to MCDA approaches to evaluation replacing cost-benefit analysis as a general methodological framework (Papamichail and French, 2013). This began during the International Chernobyl project of 1990-91 (French*, et al.*, 1992; International Atomic Energy Agency, 1991; Lochard*, et al.*, 1992). During five decision conferences that took place in the autumn of 1990, MCDA analyses demonstrated the need to consider criteria beyond radiological health impacts and financial cost was particularly clear. The first three took place with attendees from the three affected republics: Ukraine, Byelorussia and the Russian Federation. Each was attended by the Vice-President of the Republic's government responsible for managing the recovery, several government officials and advisors, local mayors and their advisors, doctors and academicians from appropriate disciplines and observers from the International Community. The fourth conference was conducted at all Union level with government officials from the Soviet Administration. Finally, because of the close agreement between the first four conferences, a fifth conference agreed a summary decision model and analysis.

1 While Chernobyl affected three republics (Ukraine, Byelorussia and the Russian Federation), at the time of the accident they all lay in the USSR.

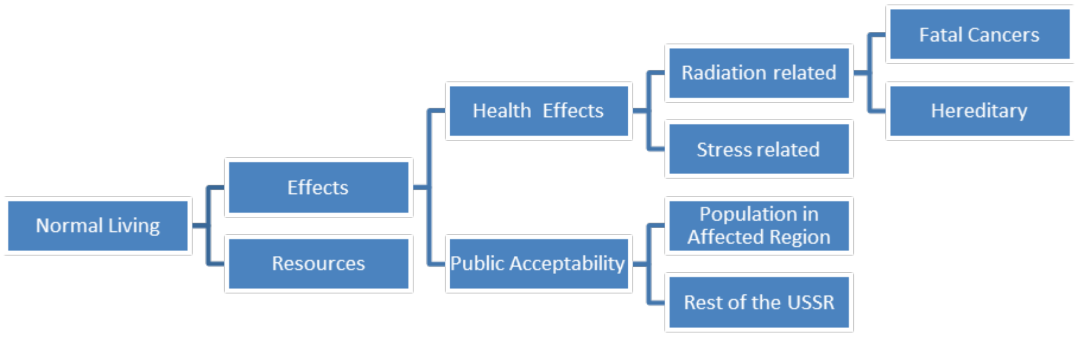

Figure 1. Final Criteria Hierarchy developed in the Summary Decision Conference

Central to MCDA modelling is a criteria hierarchy, i.e. a graphical representation of the factors that are taken into account in decision making. The hierarchies used in these conferences were remarkably similar. The criteria hierarchy used in the fifth conference is shown in Figure 1. It was clear that decision making had sought to balance the cost (resources) of a recovery measure with its effects; but that the effects include not just the radiological impact, but also health effects arising from psychological stress and aspects of political acceptability to the different groups of affected and unaffected populations.

Since Chernobyl there have been many studies reflecting back on Chernobyl or developed around hypothetical future accidents and this broad structuring of the criteria have been found repeatedly (Andrews, *et al.*, 2008; Geldermann and Rentz, 2003; Hamalainen, *et al.*, 2000; Larsson, *et al.*, 2010; Mustajoki, *et al.*, 2007). However, during our reflections on the MCDA analyses used in these studies, we have become concerned that there may still be a tendency to consider too few criteria. Perhaps we are being blinded by the specifics of the Chernobyl Accident and failing to think as widely as may be needed in the circumstances of a future quite different accident. For instance:

- The cost or resources criteria have tended to be defined as the direct cost of implementing a measure. Indirect or opportunity costs are not clearly included – though these may be driving factors in the attitude of stakeholders in unaffected regions. For instance, if the establishment of an exclusion zone would conflict with the use of some unrelated infrastructure, how would this be included in the evaluation? In the decision conference in Byelorussia (Lochard, *et al.*, 1992) there was a period of considerable discussion around the high percentage of GDP that some strategies would consume, but this was used eventually to filter out some possible strategies as infeasible, rather than include their large opportunity costs in the costing model.
- Even when attention is confined to direct costs, there are issues about how this is assessed and included in the MCDA model. Costs were estimated in broad subjective terms in the Chernobyl MCDA models, though a range of measures were used ranging from cost in rubles and resources consumed to 'hassle' in implementation. In those studies the overall results and ranking of strategies were broadly robust to the choice of how costs should be measured. However, this does not mean that direct costs were unambiguously defined.
- Although there has been considerable empirical research into the general environmental impact of the Chernobyl Accident and the importance of the environment has grown substantially in driving many societal decisions over the past quarter century, none of the criteria used or proposed directly focus on environmental impact.

In the original planning of NREFS we had expected some similar studies to have been conducted post Fukushima and we intended to draw on these to further understand the factors that should be included in MCDA models of emergency management decisions during response and recovery. However, little has been forthcoming since the Fukushima events. Data and details are missing from many reports – and probably not just because of the issue of translating Japanese into English. An Inquiry by the Japanese Parliament, or rather Diet, recognised significant failings in the culture of the Japanese nuclear industry and its emergency planning and response to the event, including its reluctance to publish data. Much information seems to be withheld still from the public and international communities.

EVALUATING STRATEGIES: RECOMMENDATIONS BY THE ICRP AND THE IAEA

We have also looked to international guidance to see if there is further advice and clarity on the criteria to consider. We reviewed documents from two international bodies: the International Commission for Radiological

Protection (ICRP) and the International Atomic Energy Agency (IAEA). We emphasise that our review took a decision-theoretic perspective: how might the advice be incorporating into the evaluation of interventions to mitigate the consequences of nuclear emergencies. We examined ICRP's most recent guidance is given in its (ICRP, 2007) and two additional publications (ICRP, 2009a; b). The IAEA has issued a set of "requirements" for adequately preparing for and responding to nuclear and radiological emergencies (IAEA, 2002; 2007; 2011).

Both the ICRP and IAEA agree on two common *principles for protection*:

- **Justification**: "Any decision that alters the radiation exposure situation should do more good than harm. This means that (in taking action) one should achieve sufficient individual or societal benefit to offset the detriment it causes" (ICRP, 2009a).
- **Optimization**: "The likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors. This means that the level of protection should be the best possible under the prevailing circumstances, maximising the margin of benefit over harm. In order to avoid severely inequitable outcomes of this optimisation procedure, there should be restrictions on the doses or risks to individuals from a particular source in the context of emergency exposure situations" (ICRP, 2009a).

These principles raise many questions about the evaluation of interventions for radiological protection. What are the economic and societal factors that need be considered in measuring the good/benefit and harm of different interventions? How should these different factors be aggregated? What is a threshold for "reasonably achievable"? Neither the principles nor the ICRP and IAEA guidance in general prescribe specific answers to these questions. Throughout their recommendations their advice on criteria to consider, while undoubtedly broadly acceptable, lack the specificity to guide actual decision making. For instance:

- "[The expected reduction in exposure be] explicitly included in the decision-making process" (ICRP, 2007).
- "[An intervention's consequences are not limited to radiation and include] other risks and the costs and benefits of the activity. Sometimes, the radiation detriment will be a small part of the total" (ICRP, 2007)
- "[E]mergency planners … [should] remain flexible in their use of the guidance and should work with interested parties to adapt the recommendations so as to take account of local, social, political, economic, environmental, demographic and other factors" (IAEA, 2011).
- "The non-radiological consequences of the response shall be considered in order to ensure that the response actions do more good than harm" (IAEA, 2002)
- "The social and political value of reducing exposure and limiting inequity in the exposure … needs to be included when justification of protection strategies is being carried out" (ICRP, 2009b)
- "public concern, effects on economic conditions and employment, long term needs for social welfare and other non-radiological effects of longer term protective actions shall be considered" (IAEA, 2002).

How any of these imperatives should be implemented in practice is left vague. Of course, one may protest that specificity should come within *national* guidance while remaining compatible with international guidance. But so far, we have found little more specific there.

DISCUSSION

Our project is barely half way through and there is much more to do and consider, but already we are concerned that *real* guidance on decision making in responding to a radiation accident is lacking. Precedent in matters such as evacuation, the establishment of an exclusion zone and choice of criteria to evaluate measures may dominate decision making in any future event. We are aware, of course, that many of the issues that concern us will be addressed by local emergency planning specific to each nuclear plant. But one of the key learning points from the Chernobyl Accident was then need for consistent response across different regions. Inconsistent planning and responses between different regions will inevitably raise public concerns and stress with probable concomitant health effects. Only *strong* international guidance can hope to bring coherence and counter any drive to follow precedent.

ACKNOWLEDGMENTS

This work is being carried out as part of the NREFS project, Management of Nuclear Risk Issues: Environmental, Financial and Safety, led by City University, London and carried out in collaboration with

Manchester, Warwick and Open Universities as part of the UK-India Civil Nuclear Power Collaboration. The authors acknowledge gratefully the support of the Engineering and Physical Sciences Research Council (EPSRC) under grant reference number EP/K007580/1. The views expressed in the paper are those of the authors and not necessarily those of the NREFS project.

REFERENCES

1. Andrews, W.L., Helfrich, M., Harrald, J.R. (2008) The use of multi-attribute methods to respond to a nuclear crisis, *Journal of Homeland Security and Emergency Management*, 5, 1, .
2. French, S., Kelly, G.N., Morrey, M. (1992) Decision conferencing and the International Chernobyl Project, *Radiation Protection Dosimetry*, 12, 17-28.
3. French, S., Argyris, N., Nuttall, W.J., Moriarty, J., Thomas, P.J. (2013) The Early Phase of a Radiation Accident: Revisiting Thinking on Evacuation and Exclusion Zones, in: Comes, T., Fiedrich, F.F., S., Geldermann, J., Müller, T. (Eds.) *Proceedings of the 10th International ISCRAM Conference* http://www.iscramlive.org/portal/iscram2013proceedings, Baden-Baden, Germany.
4. Geldermann, J., Rentz, O. (2003) Environmental decisions and electronic democracy, *Journal of Multi-Criteria Decision Analysis*, 12, 2-3, 77-92.
5. Hamalainen, R.P., Lindstedt, M., Sinkko, K. (2000) Multiattribute risk analysis in nuclear emergency management, *Risk Analysis*, 20, 445-468.
6. IAEA (1991) The International Chernobyl Project:Technical Report, in, International Atomic Energy Agency, Vienna.
7. IAEA (2002) Preparedeness and response for an Nuclear od RAdiological Emergency, in: *Safety Standards Series*, International Atomic Energy Agency, .
8. IAEA (2006) Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine, in, Wagramer Strasse 5, P.O. Box 100, A-1400 Vienna, Austria. http://www.iaea.org/Publications/Booklets/Chernobyl/chernobyl.pdf.
9. IAEA (2007) Arrangements for Preparedness for a nuclear and radiological emergency, in, IAEA, .
10. IAEA (2011) Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency General Safety Guide, in: *International Safety Standards*, International Atomic Energy Agency, .
11. ICRP (2007) The 2007 Reccommendations of the International Commission on Radiological protection, *Annals of the ICRP*, 37, 2-4, .
12. ICRP (2009a) Application of the Commission's Recommendations for the Protection of People in Emergency Exposure Situations, *Annals of the ICRP*, 39, 3, .
13. ICRP (2009b) Application of the Commission's Recommendations to the Protection of People Living in Long-term Contaminated Areas After a Nuclear Accident or a Radiation Emergency, *Annals of the ICRP*, 39, 3, .
14. International Atomic Energy Agency (1991) The International Chernobyl Project: Technical Report, in, IAEA, Vienna.
15. Karaoglou, A., Desmet, G., Kelly, G.N., Menzel, H.G. (1996) The Radiological Consequences of the Chernobyl Accident, in, European Commission, Luxembourg.
16. Larsson, A., Ekenberg, L., Danielson, M. (2010) Decision Evaluation of Response Strategies in Emergency Management Using Imprecise Assessments, *Journal of Homeland Security and Emergency Management*, 7, 1, doi: 10.2202/1547-7355.1646.
17. Lochard, J., Schneider, T., French, S. (1992) International Chernobyl Project. Summary Report of Decision Conferences held in the USSR, October-November 1990., in, European Commission, Luxembourg.
18. Mustajoki, J., Hamalainen, R.P., Sinkko, K. (2007) Interactive computer support in decision conferencing: Two cases on off-site nuclear emergency management, *Decision Support Systems*, 42, 2247-2260.
19. Nenot, J.-C. (2009) Radiation accidents over the last 60 years, *Journal of Radiation Protection*, 29, 301-320.
20. Papamichail, K.N., French, S. (2013) 25 years of MCDA in nuclear emergency management, *IMA Journal of Management Mathematics* 24, 4, 481-503.