Applying Optimal Decision-Making Techniques to Design the Best Counter Measures for a Large-Scale NPP Accident

Dmitry Yumashev, Paul Johnson and John Moriarty

University of Manchester
Making Decisions in the Aftermath of a Nuclear Accident

How can we make the best decisions today?

Weigh up the cost/benefit of every possible future scenario

Can we also take into account the decisions we might take in the future?
Optimising Long-Term Recovery Measures

Relocation
- High costs
- Permanent or temporary
- Safest option

Remediation
- Medium costs
- Partial or complete clean-up
- Requires time to implement

Food Bans
- Low costs
- Prevents contamination spread through food chains
What is Optimal Control Theory?

• Once the objective is defined clearly, the framework allows an optimal strategy to be found
• We can evaluate whether Relocation, Remediation, or Food Bans should be implemented and find their optimal timing
• The algorithm gives the optimal strategy based on the best combination of these three Counter Measures
• Optimal strategies can be tailored to individual towns and villages based on local contamination level and local economic conditions
How is it Applied?

• Consider a single district with known initial contamination levels

• Define an objective
  • Jointly minimise total cost (economic and health)
  • Keep health effects below a certain critical threshold

• Evaluate the effect of each decision
  • Direct costs – losses in production, cost of measures
  • Health costs – loss in life expectancy (J-value), associated healthcare costs

• Optimise over all possible future scenarios to obtain the optimal strategy
Response to Medium Contamination

Food Ban: Immediately

No Relocation; Remediate: Years 0 - 2

Lift Food Ban: Year 2

No population movement
Response to Large Contamination

Temporary Relocation & Food Ban: Immediately

Remediate: Years 0-2

Lift Food Ban: Year 2

Repopulate: Year 1.5 onwards
Key Findings of Our Research

• The preferred strategies in most cases are:
  – immediate but temporary food ban,
  – with no relocation but immediate remediation,
  – or temporary relocation with delayed remediation.

• For temporary relocation it is best to delay remediation by several weeks or more to allow for the natural decay of volatile isotopes.
Conclusions

• We can suggest which strategies are optimal (safest and most cost-effective) across a wide range of possible nuclear accidents in locations with varying degrees of economic development

• Significant levels of spatial and temporal flexibility in the mitigation measures are desirable

• We can estimate expected costs and how long it will take before there is a full economic recovery

• The algorithm requires all economic costs to be weighted against the health cost which can be risk-adjusted

• We have found that relocation should be used sparingly for many big nuclear accidents