Improvisation on a Theme from FEMA

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1. Issues

Emergency response is a complex system with risk analysis at the core. Local, state, and federal agencies need to invest resources wisely in a cocktail of preventions and remediations.

FEMA is one of the key components of that cocktail.

Key statistical issues include:

- HAZUS
- Safety portfolios
- Appropriate forecasting and insurance
- Appropriate charity
- Post-disaster studies
- Warning systems

2. HAZUS

HAZUS is the FEMA software system for estimating flood, hurricane, or earthquake damage.

It was built by the National Institute of Building Sciences. From earlier discussion it seems clear that no statisticians were involved in building it or validating it.

The HAZUS website is:

www.fema.gov/hazus

The HAZUS model produces estimates of the cost and location of damage. The core is a GIS that relates geography to land use. In principle, this could be used to:

- Identify the most vulnerable areas
- Preposition recovery resources
- Explore preventive measures.

The HAZUS system can operate in three levels: coarse, intermediate, and fine. The level depends upon how much ground detail is provided (i.e., zoning level information, location of specific key structures, location of individual residence structures).

The two most refined levels do not seem to be regularly used.

The National Flood Insurance Program uses hazard mapping so that land owners can assess their risk. As nearly as I can determine, this is not directly related to HAZUS, though both are under FEMA.

In principle, a HAZUS system could be used to set risk-based insurance rates.

Key statistical issues include:

- HAZUS
- Safety portfolios
- Appropriate allocation of resources
- Post-disaster studies
- Warning systems

The ways in which statisticians could help FEMA improve HAZUS include:

- Better validation of complex computer models
- Uncertainty statements that identify and propagate key components
- Designed experiments to explore the response space.
- Residual analysis to improve the next generation.

3. Safety Portfolios

The U.S. invests in a range of protections. These include FEMA (and HAZUS), building codes, the National Guard, fire departments, and so forth.

One wants to optimize the mix of these investments in the context of an uncertain future. This is exactly a problem in portfolio theory.

Our present portfolio is a patchwork of programs, all controlled by separate agencies. The evolution has been reactive rather than presbyopic.

A key area for risk analysis contribution is how to better manage resource allocation. Some programs provide broad protection (e.g., FEMA), whereas others provide very specific protection (fire codes, S&R teams)

From a procedural rationality standpoint, this is a distributed game with multiple plays.

Game theory suggests that we can probably never find the optimal play, but in the long run we can do well if we are sufficiently flexible to learn from our mistakes and to reconfigure the system. Statistics is an ingredient in doing this.

4. Forecasting

Nations self-insure. They need to estimate the disasters they will face.

Our current system is relatively blind to trends. The increasing number and magnitude of hurricanes is not part of our planning. Similarly, growth in vulnerable areas is hard to control, although we measure it.

Self-insurance has an important difference from group insurance. Suppose an oracular actuary determines how much money must be collected to cover disasters in 2006, and that the IRS responds.

Then a portion of that money can be diverted to strengthen levees or train emergency personnel, with the probable effect of reducing the net cost of the 2006 recoveries.

The statistical problem of deciding which investments are most likely to most reduce the total cost of response and recovery is an important issue.

More generally, there is a point at which a nation is dangerously underinsured against future calamities. Are we there yet? (The cost of disasters is fairly predictable.)

5. Charity

Paul Slovic raised a significant moral question: Why do we feel the plight of individuals more than the statistical summary of catastrophe?

A related question is how much is it appropriate for an individual to contribute to charity (especially relief charity)?

In principle one can determine the total amount needed, and then use the income distribution of the U.S. and the utility function of money to solve the integral equation.

This answer shows how much a person with a given income should contribute, under the presumption that all donors should feel equal pain. (But utility functions differ.)

6. Post-Disaster Study

The U.S. must review past disasters in order to do better. But there are some areas in which statisticians can make special contributions.

Some main topics are surveys, evacuation models, organizational studies, and administrative records.

The NSF has committed funds for post-Katrina surveys. One that I'm involved with is trying to collect data to build a Carleyesque agent model for relief support.

Similarly, organizational studies look at the effectiveness of different command and control structures in the relief effort, and how this should change over time.

Agent-based models are a popular method for studying evacuation behaviors. Each agent has its own covariates and a rule set that governs their decisions.

Records from statistical agencies could have been a major asset, if privacy issues were more flexible. One would like to have known the addresses of all 70+ people living alone in the 9th ward.

7. Warning Systems

Disaster alerts have costs on both sides. Some nursing home residents die when they are relocated, but they can also die if they do not.

This raises the usual issue of costs due to false alarms versus costs due to missed alarms.

8. Conclusions

Disaster response is a classic exercise in risk analysis for complex systems.

The law of conservation of robustness indicates that you cannot harden against every contingency, but you can pick your contingencies wisely.

Statisticians have several obvious ways to contribute but the greatest help we can give comes from collaboration:

- GIS-based risk
- Sociology of disaster response
- Integrated planning (game theory and portfolio theory)
- Effective organization theory.