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Risk from Natural Disasters

Introduction

Natural disasters by definition are surprises, causing a great deal of damage and inconvenience. Earthquakes are among the most terrifying and destructive natural disasters threatening humans. Emergency management has been described as the process of coordinating an emergency or its aftermath through communication and organization for deployment and the use of emergency resources. This chapter provides the state-of-the-art studies of risk and emergency management related to the Wenchuan earthquake that happened in China in May 2008.

Natural disasters are the biggest challenge that risk managers face, due to the threats that go with them.[1] Natural disasters by definition are surprises, causing a great deal of damage and inconvenience. Some things we do to ourselves, such as revolutions, terrorist attacks and wars; terrorism led to the gassing of the Japanese subway system, to 9/11/2001, and to the bombings of the Spanish and British transportation systems. Some things nature does to us – volcanic eruptions, tsunamis, hurricanes and tornados. The SARS virus disrupted public and business activities, particularly in Asia.[2] More recently, the H1N1 virus has sharpened the awareness of the response system world-wide. Some disasters combine human and natural causes – we dam up rivers to control floods, to irrigate, to generate power – and even for recreation, as at Johnstown, PA, at the turn of the 20th century. We have developed low-pollution, low-cost electricity through nuclear energy, as at Three-Mile Island in Pennsylvania and Chernobyl. We have built massive chemical plants to produce low cost chemicals, as at Bhopal, India.

Lee and Preston provide a review of high-impact, low-probability events, focusing on analysis of the Eyjafjallajökull volcano.[3] This event was representative of "black swans",[4] that is, impossible-to-predict events with a very low likelihood but high costs of mitigation. Other examples include Hurricane

Katrina in New Orleans, the Japanese earthquake and tsunami of 2011, and the 2003 SARS outbreak. What we don't do to ourselves in the form of wars and economic catastrophes, nature trumps with overwhelming natural disasters.

These disruptions are major components of supply chain systems, which have become key components of today's global economy. The ability to cope with unexpected events has proven critical for global supply chain success, as demonstrated by Nokia in the past few years, as well as production halts experienced by Toyota and Sony due to the 2011 earthquake and tsunami in Japan.

Preparing for high-impact, low-probability events

In a natural disaster, there will inevitably be many who feel that whatever the authorities did was overkill and unnecessary, just as there will be many who feel that the authorities didn't do enough to (1) prevent the problem, and (2) mitigate the problem after it occurred. It is the nature of emergency management to be unthanked. Transparency, especially during and after a crisis, helps to assure the public that decisions are made on the best available evidence in order to gain public confidence and to manage vested interests.

Globalized supply chains, particularly those based on just-in-time methods, are vulnerable. Famous historical examples include Nokia's response to a March 2000 lightning strike in Albuquerque, NM, leading to a fire in a Royal Philips Electronics fabrication line that supplied RFID chips. Both Nokia and its competitor Ericsson were served by this key supply chain link,[5] and Philips estimated that at least a week would be required to return to full production. Ericsson passively waited – but Nokia proactively arranged for alternative supplies, as well as redesigning products to avoid the need for those chips. Nokia gained significant advantage in this market, turning in a profit while Ericsson suffered an operating loss.[6] Lee and Preston state that the maximum tolerance for supply chain disruption in a just-in-time global economy is one week.

Lee and Preston draw the following recommendations from the Eyjafjallajökull experience:

1. *Stress-testing risk mechanisms*: This recommendation includes specifics calling for broad coordination with governments and businesses to determine as much as possible that costs and risks of worst-case situations are identified. They also call for scenario-building exercises and sharing of best practices.
2. *Crisis communication*: Care should be given to develop robust communication, to include websites, especially to keep the public and the media informed of risks. Independent, risk notification hubs supported by governments, businesses and industry associations were called for.

3. *Enhancing business resilience and shock response*: Governments should set up global pooling systems for reinsurance. A reference library of observations from past events was also called for. Businesses were cited as needing preparedness for management continuity, and to conduct cost-benefit analyses for alternative disruption actions.

Integrated supply chains have delivered improvements in efficiency and improved the value of products we have available to us as consumers. However, highly optimized supply chain networks are inherently risky, in part because they eliminate most system slack in order to lower costs. The impact of unexpected events (Lee and Preston use SARS in 2003 and the Tōhoku earthquake/tsunami in 2011 as examples) can be highly disruptive. The white paper does a good job of classifying the risks of various exported products to the European Union. Analysis of the impact of extended disruption was noted. Additional impact of global warming was also evaluated.

Be prepared

While natural disasters come as surprises, we can nevertheless be prepared. In some cases, such as Hurricane Katrina or Mount Saint Helens, we get warning signs, but we never completely know the extent of what is going to happen.[7] Emergency management has been described as the process of coordinating an emergency or its aftermath through communication and organization for deployment and the use of emergency resources.[8] Emergency management is a dynamic process conducted under stressful conditions, requiring flexible and rigorous planning, cooperation, and vigilance. During emergencies, a variety of organizations are often involved, and commercial rivalry can lead to normal competition, rivalry, and mutual distrust. At the governmental level, one would expect cooperation in attaining a common goal, but often so many diverse agencies get involved that attention to the overriding shared goal is dimmed by specific agency goals. Cooperation is also hampered by differences in technology.

Risks and emergencies

Risks exist in every aspect of our lives. In the food production area, science has made great strides in genetic management. But there are concerns about some of the manipulations involved, with different views prevailing across the globe. In the United States, genetic management is generally viewed as a way to obtain better and more productive sources of food more reliably. However, there are strong objections to bioengineered food in Europe and Asia. Some natural diseases, such as mad cow disease, have appeared that are very difficult to control. The degree of control accomplished is sometimes disputed.

Europe has strong controls on bioengineering, but even there a pig breeding scandal involving hazardous feed stock and prohibited medications has arisen.[9] Bioengineering risks are important considerations in the food chain.[10] Genetic mapping offers tremendous breakthroughs in the world of science, but involve political risks when applied to human resources management.[11] Even applying information technology to better manage healthcare delivery risks involves risks.[12] Reliance on computer control has been applied to flying aircraft, but hasn't always worked.[13]

Risks can be viewed as threats, but businesses exist to cope with risks. Different disciplines have different ways of classifying risks. We propose the following way of classifying risks: field based and property based.

- *Field based classification*: Financial risks, which basically include all sorts of risks related to financial sectors and financial aspects in other sectors; these include, but are not restricted to, market risk, credit risk, operational risk, operational risk, liquidity risk.

Nonfinancial risks, which includes risks from sources that are not related to finance. These include, but are not restricted to, political risks, reputational risks, bioengineering risks, and disaster risks.

- *Property based classification:* We think risks can have three properties: Probability, dynamics, and dependence. The first two properties have been widely recognized in inter-temporal models from behavior decision and behavior economics.[14] The last property is well studied in the finance discipline.

The probability of the occurrence and severity of risks mainly involves the utilization of probability theory and various distributions, to model risks. This can be dated back to the 1700s, when Bernoulli, Poisson, and Gauss used to model normal events, and generalized Pareto distributions and generalized extreme value distribution to model extreme events. The dynamics of risks mainly deals with stochastic process theory in risk management. This can be dated back to the 1930s, when the Markov processes, Brownian motion and Levy processes were developed. The dependence of risks mainly deals with correlation among risk factors; various copula functions are built, and Fourier transformations are also used here.

Technical tools

Many tools have been developed to aid emergency management. Reported examples from geoscience include image enhancement through combining multiple images into a clearer composite image (mosaicing).[15] Televideos and wireless communications devices have been applied to aid quick response to disasters in the oil and natural gas sector.[16] Statistical analysis of growth models have been used to categorize disasters into three categories of growth (damped exponential, normal, fluctuating), so that news stories can be monitored at the onset of a disaster to better predict those events that will dissipate, as opposed to those that will grow into serious disasters.[17] Advanced modeling in the form of multi-objective evolutionary algorithms in combination with geographical information systems have been developed to support evacuation planning.[18]

Even open source software products play a role.[19] SAHANA (Sinhalese for relief) is a Sri Lankan open source system built after the 2004 Asian tsunami. SAHANA supports finding missing people, managing volunteers and aid resources, and other disaster-related activities. SAHANA was deployed in the 2008 Burma cyclone and the 2008 Sichuan earthquake. Another open source system is Innovative Support to Emergencies, Diseases and Disasters (InSTEDD), started in 2006 by Larry Brilliant of the Google Foundation. InSTEDD is designed to process data from multiple sources (weather reports, news, field reports, sensor data), to detect and manage disease outbreaks.

Emergency management

Local, state and federal agencies in the United States are responsible for responding to natural and man-made disasters. This is coordinated at the federal level through the Federal Emergency Management Agency (FEMA). While FEMA has done much good, it is almost inevitable that more is expected of it than it delivers in some cases, such as hurricane recovery in Florida in various years and the Gulf Coast from Hurricane Katrina in 2005. National security is the responsibility of other agencies, military and civilian (Department of Homeland Security – DHS). They are supported by non-governmental agencies such as the American Red Cross. Again, these systems seem to be effective for the greater part, but are not failsafe, as demonstrated by Pearl Harbor and 9/11/2001.

Disasters are abrupt, calamitous events that cause great damage, loss of lives, and destruction. Emergency management is accomplished in every country to some degree. Disasters occur throughout the world, in every form: natural, man-made, and combination. Disasters by definition are unexpected, and tax the ability of governments and other agencies to cope. A number of intelligence cycles have been promulgated, but all are based on the idea of:

1. Identification of what is not known;
2. Collection – gathering information related to what is not known;
3. Production – answering management questions;
4. Dissemination – getting the answers to the right people (Mueller, 2004).

Information technology has been developing at a very rapid pace, creating a dynamic of its own. Many technical systems have been designed to gather, process, distribute, and analyze information in emergencies. These systems include communications and data. Tools to aid emergency planners communicate include telephones, whiteboards, and the internet. Tools to aid in dealing with data include database systems (for efficient data organization, storage, and retrieval), data mining tools (to explore large databases), models to deal with specific problems, and combinations of these resources into decision support systems to assist humans in reaching decisions quickly or expert systems to make decisions rapidly based on human expertise.

Emergency management support systems

A number of software products have been marketed to support emergency management. These are often various forms of a decision support system. The Department of Homeland Security in the US developed a National Incident Management System. A similar system used in Europe is the Global Emergency Management Information Network Initiative (Thompson et al., 2006). While many systems are available, there are many challenges due to unreliable inputs at one end of the spectrum, and overwhelmingly massive data content at the other extreme.

Decision support systems (DSS) have been in existence since the early 1970s. A general consensus is that DSSs consist of access to tailored data and customized models with real-time access for decision makers. With time, as computer technology has advanced and as the internet has become more available, there has been a great deal of change in what can be accomplished. Database systems have seen tremendous advances since the original concept of DSS. Now weather data from satellites can be stored in data warehouses, as can masses of point-of-sale scanned information for retail organizations, and output from enterprise information systems for internal operations. Many kinds of analytical models can be applied, ranging from spreadsheet models through simulations and optimization models. While the idea of DSS is now over 30 years old, it can still be very useful in support of emergency management. It still can take the form of customized systems accessing specified data from internal and external sources, as well as a variety of models suitable for specific applications needed in emergency management situations. The focus is still on supporting humans making decisions, but if problems can be so structured that computers can operate on their own (Hal in 2001 comes to mind), decision support systems evolve into expert systems. Expert systems can be, and have been, used to support emergency management.

An example decision support system directed at aiding emergency response is the Critical Infrastructure Protection Decision Support System (CIPDSS).[20]

CIPDSS was developed by Los Alamos, Sandia, and Argonne National Laboratories, sponsored by the Department of Homeland Security in the US. The system includes a range of applications to organize and present information, as well as system dynamics simulation modeling of critical infrastructure sectors, such as water, public health, emergency services, telecom, energy, and transportation. The system also includes multiattribute utility functions based upon interviews with infrastructure decision-makers. CIPDSS thus serves as an example of what can be done in the way of an emergency management support system.

Other systems in place for emergency management include the US National Disaster Medical System (NDMS), providing virtual centers designed as a focal point for information processing, response planning, and inter-agency coordination. Systems have been developed for forecasting earthquake impact[21] or the time and size of bioterrorism attacks. This demonstrates the need for DSS support not only during emergencies, but also in the planning stage.

Conclusions

Emergencies of two types can arise. One is repetitive – hurricanes have hammered the Gulf Coast of the US throughout history, and will continue to do so (just as tornadoes will hit the Midwest and typhoons the Pacific). A great deal of experience and data can be gathered for those events, and our weather forecasting systems have done a very good job of providing warning systems for actual events over the short term of hours and days. However, humans will still be caught off-guard, as with Hurricane Katrina. The other basic type of emergency are surprises. These can be natural (such as the tsunami of 2004) or human-induced, such as September 11, 2001. We cannot hope to anticipate, nor will we find it economic to massively prepare for, every surprise; we don't think that, for example, a good asteroid collision prevention system would be a wise investment of our national resources. On the other hand, there is growing support for an effective global warming prevention system.

The first type of emergency is an example of *risk* – we have data to estimate probabilities. The second type is an example of *uncertainty* – we can't accurately estimate probabilities for the most part. (People do provide estimates of the probability of asteroid collision, but the odds are so small that they don't register in our minds. Global warming probabilities are near certainty, but the probability of a compensating cooling event in the near future currently evades calculation.)

We have reviewed some of the tools that have been reported for use in supporting disaster or emergency management. This issue includes papers that report on the effectiveness of response systems in the 2008 Sichuan earthquake. It also includes two papers addressing tools, one developed to improve evaluation of damage, the other applying genetic algorithm models to aid rapid decision-making in emergencies. A fourth paper addresses financial tools to deal with the insurance aspects of emergency response.

Thus the crux of the problem in supporting emergency management is that tools exist to gather data, and tools such as data mining exist to try to make some sense of it, but the problem is that we usually won't have the particular data that will be useful to make decisions in real time. It is also reasonably certain that after any event, critics will be able to review what data was available and to point to tell-tale information that could have enlightened decision-makers at the time but didn't, for example, after World War II, the US was flooded with people who thought that the US Navy should have known the Japanese would bomb Pearl Harbor. CNN and national networks have very predictable scripts for every emergency, with reporters playing to the camera, pointing out the gross malfeasance of those in control in not knowing, preparing for, and countering whatever happened. That's how they raise their ratings – the audience likes conspiracy theories. But having data is not enough – human minds have to comprehend the core information, and the more information that is provided, the harder that is. The solution is not LESS information, but some filters to focus on the critical core would help provide a solution. The next problem, though, is that we don't know how to create such filters, especially in new problem domains.

Emergency management is thus a no-win game. However, someone has to do it. They need to do the best they can in preplanning:

1. gathering and organizing data likely to be pertinent;
2. developing action plans that can be implemented at the national, regional, and local level; this can include development of and implementation of building codes, environmental awareness, and insurance systems;
3. organizing people into teams to respond nationally, regionally, and locally, trained to identify events, and to respond with all needed systems (rescue, medical, food, transportation, control, etc.); this can include the training and development of planners and managers of response teams.