13 Natural Disaster Risk Management

We have considered business operational risks in the contexts of supply chains, information systems, and project management. By definition, natural disasters are surprises, and cause inconvenience and damage. Some things we do to ourselves, such as revolutions, terrorist attacks, and wars. Some things nature does to us, to include hurricanes, tornados, volcanic eruptions, and tsunamis. Some disasters are caused by combinations of human and natural causes. We dam rivers to control floods, to irrigate, to generate power, and for recreation, but dams have burst causing immense flooding. We have developed low-pollution, low-cost (at the time) electricity through nuclear power. Yet with plant failure, new protective systems have made the price very high, and we have not figured out how to acceptably dispose of the waste. While natural disasters come as surprises, we can be prepared. This chapter addresses natural domain risks in the form of disaster management.

Emergency Management

Natural disaster management is the domain of government, fulfilling its responsibility to protect the general welfare. 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 them than they deliver in some cases, such as hurricane recovery. In 2006 Hurricane Katrina provided one of the greatest tests of the emergency management system in the U.S.:

1. Communications outages disrupted the ability to locate people
2. Reliable transportation was disrupted or at least restricted
3. Electrical power was disrupted, cutting off computers
4. Multiple facilities were destroyed or damaged

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5. Some bank branches and ATMs were flooded for weeks
6. Mail was disrupted up to months.

Disasters are abrupt and calamitous events causing 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 of natural, man-made, and combination of disaster. 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.[1]

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 combination 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. The role of information technology in disaster management to include the functions of:[2]

- **Information Extraction**—gathering data from a variety of sources and storing them in efficient databases.
- **Information Retrieval**—efficiently searching and locating key information during crises.
- **Information Filtering**—focusing of pertinent data in a responsive manner.
- **Data Mining**—extract patterns and trends.
- **Decision Support**—analyze data through models to make better decisions.

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 U.S. developed a National Incident Management System. A similar system used in Europe is the Global Emergency Management Information Network Initiative.[3] 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.

Systems in place for emergency management include the U.S. National Disaster Medical System (NDMS), providing virtual centers designed as a focal point for information processing, response planning, and inter-agency coordination. NDMS is a federally coordinated system augmenting disaster medical care. Its purpose is to supplement an integrated National medical response capacity to assist State and local authorities in dealing with medical impacts of major peacetime disasters, as well as supporting military and Veterans Affairs medical systems in casualty care. EMSS has also been implemented in Europe.[4] Intelligent emergency management systems are appearing as well.[5]

An example decision support system directed at aiding emergency response is the Critical Infrastructure Protection Decision Support System (CIPDSS).[6] CIPDSS was developed by Los Alamos, Sandia, and Argonne National Laboratories sponsored by the Department of Homeland Security in the U.S. 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. Primary goals are:

1. To develop, implement, and evolve a rational approach to prioritize CIP strategies and resource allocations through modeling, simulation, and analyses to assess vulnerabilities, consequences, and risks;
2. To propose and evaluate protection, mitigation, response, and recovery strategies and options;
3. To provide real-time support to decision makers during crises and emergencies.

A key focus it to aid decision makers by enabling them to understand the consequences of policy and investment options prior to action. Decision support systems provide tools to examine trade-offs between the benefits of risk reduction and the costs of protection action. Factors considered include threat information, vulnerability assessments, and disruptive consequences. Modeling includes system dynamics, simulation, and other forms of risk analysis. The system also includes multi-attribute 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 U.S. 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[7] 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.

Example Disaster Management System

Sahana is foundation offering a suite of free open-source web-based disaster management system software for disaster response.[8] The primary aim of the system is to alleviate human suffering and help save lives through efficient use of information technology. Sahana Eden is a humanitarian platform customizable to integrate with local systems for planning or coping with crises. Vesuvius is a disaster preparedness and response software providing support to family reunification as well as hospital triage. Mayon provides emergency planning agencies with tools to plan preparedness, response, recovery, and mitigation. Sahana can bring together government, emergency management, non-government organizations, volunteers and victims to disaster response. It is intended to empower victims, responders, and volunteers to more efficiently utilize their efforts, while protecting victim data privacy.

Sahana is a free open-source software system initially built by Sri Lankan volunteers after the 2004 Asian tsunami.[9] It has the following main applications:

1. Missing persons registry—bulletin board of missing and found persons, and information of who is seeking individuals.
2. Organization registry—a tool to coordinate and balance distribution of relief organization to affected areas.
3. Request/Pledge management system—log of incoming requests for support, tracking relief provided and linking donors to relief requirements.
4. Shelter registry—tool to track location and numbers of victims by temporary location.
5. Volunteer coordination—tool to coordinate contact information, skills and assignments of volunteers and responders
6. Inventory management—tool to track location, quantities, and expiration dates of supplies
7. Situation awareness—a geographic information system showing current status.

Sahana has been successfully deployed in many disasters including after the tsunami as shown in Table 13.1:

The Sahana system uses plug-in architecture, which allows third party groups easy access to system components, while simplifying overall integration. The system does not need to be installed, but can be run as a portable application from a USB drive (using a USB flash drive). The system can be translated into any language. Granular security is provided through an access control system. The user interface can be viewed through a number of devices, to include a PDA.

Table 13.1 Sahana deployments[10]

Location	Year	Event	Details
Sri Lanka	2005	Tsunami	Deployed for the Government of Sri Lanka
Pakistan	2005	Earthquake	Deployed for the Government of Pakistan
The Philippines	2006	Mudslide	Southern Leyte
Indonesia	2006	Earthquake	Yogjarkata
New York City	2007–2008	Hurricanes	Coastal storm planning
Peru	2007	Earthquake	Ica
China	2008	Earthquake	Chendu-Shizuan province
Myanmar	2008	Cyclone	Monsoon disaster planning
Haiti	2010	Earthquake	Disaster planning

Disaster Management Criteria

We review criteria sets used by two disaster management applications involving multiple criteria. The first involved the engineering decision of protecting buildings from earthquake damage.[11] This of course is a more technical decision than what we described in the banking industry, but the point is that risks appear in almost every walk of life. Here the decision was to design buildings to be as secure as possible. Earthquakes are common. Building codes in the past have been insufficient. Building design retrofit alternatives have been developed to modify performance in terms of stiffness, strength, and ductility. Criteria that could be applied to seismic risk management are given in Table 13.2:

Their model would enable building designers to score alternatives on each of these eight risks and to express decision maker preferences.

The US Water Resource Council[13] has a comprehensive set of 20 performance criteria for infrastructure policies and investments given in Table 13.3:

A generic multiple criteria model was developed within this list[14] with the criteria of:

- Protection from coastal inundation
- Protection of public infrastructure systems
- Protection against storm surges and flooding
- Protection of wetlands and environment
- Protection of recreational activities

This model was to be used for specific coastal protection evaluations, with normal options of building different types of revetments, seawalls, or nourishing beaches or dunes. The evaluation they provided included evaluation under different scenarios

Table 13.2 Seismic risk management criteria[12]

Economic/Social criteria	Technical criteria
Installation cost	Skilled labor required
Maintenance cost	Need for foundation intervention
Disruption of use	Significance of risk damage
Functional capability	Significance of limitations

Table 13.3 US Water Resource Council criteria

Provide protection for and reduce displacement of residents	Provide protection for and reduce displacement of residents
Provide protection for and reduce displacement of residents	Ensure long-term economic productivity
Provide urban and agricultural flood damage protection	Provide protection and reduce displacement of businesses and farm
Ensure employment/income distribution and equality	Protect wetlands, fish, and wildlife habitats
Protect commercial fishing and water transportation	Provide agricultural drainage, irrigation, and erosion control
Ensure power production, transmission, and efficiency	Provide floodplain protection
Protect recreational activities	Provide drought protection
Protect against natural disasters	Protect endangered and threatened species and habitats
Protect air quality	Protect prime and unique farmland protection
Protect historic and cultural values	Protect wildlife and scenic rivers

Multiple Criteria Analysis

Once criteria pertinent to the specific decision are identified, analysis can be selection of a preferred choice from a finite set of alternatives, making it a selection decision. (Finite alternatives could also be rank ordered by preference.) Multiple objective programming is the application of optimization over an infinite set of alternatives considering multiple objectives, a mathematical programming application (see the chapter on DEA as one type). Chapter 3 presented the SMART multiple criteria method, which fits with this case as well.

We can use a petroleum supply chain case to demonstrate the SMART procedure.[15] We begin with three alternatives relative to risk management in the petroleum supply chain:

1. Accept and control risk
2. Terminate operations
3. Transfer or share risk

The hierarchy of criteria could be as follows, to minimize risks:

- Exploration/production risk
- Environmental and regulatory compliance risk
- Transportation risk
- Availability of oil resource risk
- Geopolitical risk
- Reputational risk

We can create a decision matrix that can express the relative performance of each alterative on each criterion through scores.

Scores

Scores in SMART can be used to convert performances (subjective or objective) to a zero-one scale, where zero represents the worst acceptable performance level in the mind of the decision maker, and one represents the ideal, or possibly the best performance desired. Thus a higher score indicates lower risk. Note that these ratings are subjective, a function of individual preference. Scores for the criteria could be as in Table 13.4.

Table 13.4 indicates that the benefits of accepting the risk involved in this project would have very good potential to obtain sufficient oil. If the project was to be abandoned (the "Terminate" alternative), oil availability would be quite low. Hedging in some manner (the "Transfer" alternative) such as subcontracting, would reduce oil availability significantly, although this is expected to be better than abandoning the project. With respect to environment/regulatory factors, the greatest risk reduction would be to not adopt the project. Transferring risk through subcontracting would also be much more effective than taking on the project alone. Transportation risk could be avoided entirely by abandoning the project. Much of this risk could be transferred. The firm has the ability to cope with some transportation issues, but the score is lowest for the option of Accept and Control Transportation Risk. Accessing oil would be highest for adopting the project, with slight advantage to the Accept option as it provides more control than the Transfer option. Terminating the project would require obtaining oil on the market at higher cost. Geopolitical risk would be eliminated by terminating the project. The other two options are rated equal on this dimension. Risk to reputation could also be eliminated by terminating the project. The firm would have more control over

Table 13.4 Relative scores by criteria for each option in example

Criteria	Accept	Terminate	Transfer
Exploration/production	0.8	0.2	0.5
Environment/regulatory	0.1	1.0	0.6
Transportation	0.2	1.0	0.9
Oil availability	0.9	0.2	0.6
Geopolitical	0.3	1.0	0.4
Reputation	0.2	1.0	0.5

risk response if they retained complete control over the project than if they transferred through insurance or subcontract.

The score matrix given in Table 13.4 provides a tabular expression of relative value of each of the alternatives over each of the selected criteria. It can be used to identify tradeoffs among these alternatives.

Weights

The next phase of the analysis ties these ratings together into an overall value function by obtaining the relative weight of each criterion. In order to give the decision maker a reference about what exactly is being compared, the relative range between best and worst on each scale for each criterion should be explained. There are many methods to determine these weights. In SMART, the process begins with rank-ordering the three criteria. A possible ranking for a specific decision maker might be as given in Table 13.5.

Swing weighting could be used to identify weights.[16] Here, the scoring was used to reflect 1 as the best possible and 0 as the worst imaginable. Thus the relative rank ordering reflects a common scale, and can be used directly in the order given. To obtain relative criterion weights, the first step is to rank-order criteria by importance, indicated by the order of Criteria in Table 13.6. Estimates of weights can be obtained by assigning 100 points to moving from the worst measure to the best measure on the most important criterion (here oil availability). Then each of the other criteria are assessed in a similar comparative manner in order, assuring that more important criteria get at least as much weight as other criteria down the

Table 13.5 Worst and best measures by criteria

Criteria	Worst measure	Best measure
Oil availability	Oil embargo	Successful project—in-house
Exploration/production	No project	Successful project—in-house
Environment/regulatory	Oil spills	No project
Reputation	Oil spills	No project
Transportation	Oil spills	No project
Geopolitical	War in drilling area	No project

Table 13.6 Weight estimation from perspective of most important criterion

Criteria	Assigned value	Weight
1 Oil availability	100	0.282
2 Exploration/production	90	0.254
3 Environment/regulatory	70	0.197
4 Reputation	60	0.169
5 Transportation	20	0.056
6 Geopolitical	15	0.042
Total	355	1.000

Table 13.7 Value score calculations

Criteria	Weight	Accept	Terminate	Transfer
1 Oil availability	0.282	×0.9 = 0.254	×0.2 = 0.051	×0.6 = 0.152
2 Exploration/production	0.254	×0.8 = 0.203	×0.2 = 0.051	×0.5 = 0.127
3 Environment/regulatory	0.197	×0.1 = 0.020	×1.0 = 0.197	×0.6 = 0.118
4 Reputation	0.169	×0.2 = 0.034	×1.0 = 0.169	×0.5 = 0.084
5 Transportation	0.056	×0.2 = 0.011	×1.0 = 0.056	×0.9 = 0.051
6 Geopolitical	0.042	×0.3 = 0.013	×1.0 = 0.042	×0.4 = 0.017
Totals		**0.534**	**0.566**	**0.549**

ordinal list. Here we might assign moving from the worst measure on Exploration/production 80 points compared to Oil availability's 100. For purposes of demonstration, assume the assigned values given in Table 13.6:

The total of the assigned values is 355. An estimate of relative weights is obtained by dividing each assigned value by 355.

Value score

The next step of the SMART method is to obtain value scores for each alternative by multiplying each score on each criterion for an alternative by that criterion's weight, and adding these products by alternative. Table 13.7 shows this calculation:

In this example, the terminate was ranked first, followed by the option of transferring (outsourcing), followed by accepting risk. However, these are all quite close, implying that the decision maker could think more in terms of other objectives, or possibly seek more input, or even other options.

Natural Disaster and Financial Risk Management

Risk is the probability of an adverse event occurring with the potential to result in loss to exposed element. Natural hazards are meteorological or geological phenomena that due to their location, frequency, and severity, have the potential to affect economic activities. A natural event that results in human and economic losses is an environmental problem contributed by the development in the region. Natural catastrophe risk is generally characterized by low frequency and high severity, though the level of severity varies quite significantly. The extent of the development contributes to the financial vulnerability to the catastrophic effects of the natural disaster. On the same token, the vulnerability of a firm from hazard events depends on the size of its investment and revenue exposures in the region. Natural hazards can be characterized by location, timing, magnitude and duration. The principal causes of vulnerability include imprudent investments and ineffective public policies.

Natural disaster losses are the result of mismanaged and unmanaged disaster risks that reflect current conditions and historical factors.[17] Disaster risk exposure comes from the interaction between a natural hazard (the external risk factor) and vulnerability (the internal risk factor).[18] Proactive disaster risk management requires a comprehensive process that encompasses a comprehensive pre-disaster evaluation involving the three broad steps involving the following activities:

- identification of the potential natural hazards and evaluation of investment at risk;
- risk reduction measures to address the vulnerability, and
- risk transfer to minimise financial losses.

The need to integrate disaster risk management into investment strategy is necessary to manage corporate value and reduce risk in the future. These should be supported by effective governance (e.g. policies, planning, etc.), supplemented by effective information and knowledge sharing mechanisms among different stakeholders.

First, **risk identification** involves creating an awareness and quantification of risk through understanding vulnerabilities and exposure patterns. The process also includes analysis of the risk elements and the underlying causes of the exposure. This knowledge is essential for development of strategies and measures for risk reduction. For example, firms operating in an earthquake-prone zone would need to keep abreast of information on real-time seismic patterns complemented with forecasts on expected hazards. This is complemented with the necessary exposure analysis using mapping, modelling and hazard analysis to assess industry and corporate risk. The evaluations should include calculating a probability profile of occurrence and impacts of hazard events in terms of their characteristics and factoring these elements into the firm's decision-making process. Thus, risk identification and analysis provide for informed decision-making on business investment that will effectively reduce the impacts of potential disaster events and prioritization of risk management efforts.

Second, **risk reduction** involves measures to avoid, mitigate or prepare against the destructive and disruptive consequences of hazards to minimize the potential financial impact. The mitigation measures are actions aimed at reducing the overall risk exposure associated with disasters. This requires an ex-ante business strategy that combines mitigation investments and pre-established financial protection. In this respect, firms can prevent natural disaster losses by avoiding investment in disaster prone regions (i.e. prevention investments) or they may take actions to locate and structure its business operations to avoid heavy investments in disaster prone regions. Such actions require short- and long-term strategic business planning and disaster recovery mechanisms, such as those pertaining to supply chain management. Risk mitigation planning is aimed at taking into account the economic impacts of disasters such as earthquakes. The access to relevant information is important to better-informed decision making and planning. For example, access to hazard information such as frequency, magnitude and trends are required for disaster risk mitigation for corporate investment decisions.

Finally, **risk transfe**r mechanisms enable the distribution of the risks associated with natural hazard events such as floods and earthquakes to reduce financial and economic impacts. This might not fully eliminate the firm's financial risk exposure but it allows risk to be shared with other parties. The common risk transfer tool is catastrophic insurance, which allows firms to recover some of their disaster losses and thus managing the financial impacts of disasters. Other financial instruments include catastrophic bonds (cat-bonds) and weather risk management products. The issuance of catastrophe risk linked bonds by insurance or reinsurance companies enables them to obtain coverage for particular risk exposures in case of predefined catastrophic events (e.g. earthquakes). These catastrophe bonds allow the insurance companies transfer risk and obtain complementary coverage in the capital market and increase their capacity to take on more catastrophe risk coverage.

The use of insurance for mitigating financial losses from natural catastrophes is generally lacking in the private sector in developing countries.[19] Catastrophe risk is a public shared risk ("covariate" risk) and collective in nature, therefore, making it difficult to find individual and community solutions.[20] An effective insurance market is essential for financing post disaster recuperation and rehabilitation of firms. In the absence of a sophisticated insurance market, the government normally acts as financier for disaster recovery efforts. Governments can also influence the risk financing arrangements by encouraging the establishment of insurance pools by the local insurance industry and covering higher exposures in the global reinsurance and capital markets.

Property insurance policies for firms in earthquake prone provinces may not be readily available due to inadequate local regulation of property titles, building codes and developmental planning. In this respect, the local governments play an important role in ensuring proper public policies are implemented and regulations enforced to lower premiums and achieve higher insurance coverage in these provinces.

There is a bigger range of instruments for risk financing in the markets today. Other than insurance coverage for disaster risk, new instruments such as catastrophe risk swaps and risk-linked securities are also available in the global capital market. In 1994, the original capital market instrument linked to catastrophe risk called a catastrophe bond was introduced. Since then, more risk-linked securities are available including those providing outright funding commitments to recover economic losses from disasters. These contingent capital instruments are based on estimating the amount of risk involved through risk and loss impact estimates to build a disaster risk profile for the client. The implied risk profile is used to identify and define the risk-linked financial instruments.

Natural Disaster Risk and Firm Value[21]

The current dynamic business environment embraces the international flow of investment to facilitate success and growth. Firms with sustainable competitiveness and growth are likely to enhance their market value. Business globalisation invariably means that firms become more proactive in scouting for opportunities in foreign markets in order to sustain and build corporate value. Other than the social, economic and political risk factors normally considered in foreign investment evaluations and enterprise risk management processes, firms also need to take into account natural disaster risk. The premiums for catastrophe risk insurance are expensive and there must be a compelling case or economic incentives for firms to establish adequate insurance coverage on their assets. We are interested in the economic impacts of natural catastrophes from a financial management perspective.

The primary objective of the firm is to maximise shareholder wealth and an effective corporate risk management program enhances corporate value. The existent literature contains a respectable body of theories and general acceptance in the market that corporate value can be created with the proper understanding and management of risk. There is a perception of risk associated with investments and traditional finance suggests such perceptions imply that there must be a reward in the form of a risk premium for investors to take on this risk. The firm as a corporate investor is no different in that it also requires a risk premium for assuming risk. The magnitude of the firm value depends on how efficient and effective it can manage its risk exposure. From a firm value versus risk management perspective, it is possible to construe the firm's value as a function of all relevant risk factors.

While the frequency and severity of natural hazards are dictated by the natural phenomenon itself, the losses caused can be controlled by understanding and managing the business development and population density according to the vulnerability of the geographical location. Business development and population density tend to have a positive correlation and therefore natural catastrophe risk has profound social and economic impacts on the local inhabitants and economy.

Contemporary enterprise risk exposure modelling tends to ignore natural hazards and focus on estimating the severity and frequency of financial or operational exposures. The global warming phenomenon has brought about a heightened awareness of many environmental risks that may affect business. Hence, there is a need for firms and policy makers to model, monitor and measure the risk exposure from natural hazards and prepare to manage the potential impacts.

The impacts from a natural catastrophe include the loss of property, life, injury, business interruption and loss of profit. From a firm's perspective, the financial impact on its market value can be mathematically specified as:

$$Firms\ value\ at\ risk = f\ (hazard, vulnerability) \tag{1}$$

From Eq. (1), the firm's value at risk from natural phenomena is a function of hazard and vulnerability. Equation (1) integrates the impact on the firm's value from natural phenomena and their consequence or exposure. The natural disaster risk management process has to be managed properly from the beginning therefore, it is important that firms improve the evaluation, coordination, efficiency and control of business development and management process to minimize such risks. The issues in this context are the considerations and measures that are available to firms in the natural disaster risk management process. Vulnerability in turn is a function of three factors:

$$Firms\ vulnerability = f\ (fragility, resilience, exposure) \tag{2}$$

Effective risk management requires attention to three factors—hazards, exposure, and vulnerability. Primary disaster impacts include potential physical damage to production facilities and infrastructure. But there also are often secondary impacts, to include business interruption form lack of materials and information, especially in interacting supply chain networks. Risk is a function of hazard and vulnerability, while vulnerability is a function of fragility, resilience, and exposure.[22]

Coase's theory of the firm stresses that the impetus for the emergence of business corporations is the specialised institutional structure that comes into being to reduce the transaction costs.[23] Since the threat of natural disasters, like the volatility of financial prices, implies potential transaction costs to the firm, it is imperative to manage catastrophe risk as it can affect the cost of capital, the cost of production, and revenues. Financial theory suggests that rational firms would hedge their risk exposure to remove the variability in their cash flows. The significance of this view is that by removing variability, firms enhance the predictability in cash flows allowing them to invest in future projects without uncertainty about the negative impact of price fluctuations. The manifestations of variability as a result of a natural catastrophe are disruptions to the firm's supply chain, production, logistics, manpower and clientele. The management issues to be addressed in relation to catastrophe risk management using risk transfer instruments are moral hazard and adverse selection. Moral hazard occurs when the firm fails to implement preventive measures after the risk transfer has taken place and reports excessive losses. Adverse selection happens if the firms uses inside knowledge about the exposure to obtain more favorable terms in the risk transfer policy from the issuing company.

The firm's overall exposure to natural catastrophes like earthquake need to be analyzed based on the region's vulnerability to assess the collective need for risk mitigation arrangements. Therefore, it is necessary to identify and map the major catastrophe risks that affect the region and assess how the business can be organised by adopting a risk neutral structure and/or how to obtain aggregate risk-financing arrangements.

The financial impact of natural disasters is determined by the frequency of an event occurring and by the severity of the resulting loss. The vulnerability to natural catastrophes can be reduced significantly through risk mitigation to lessen the impact of disasters. The catastrophe risk exposures in individual investment projects can be mitigated using a project-based approach to manage catastrophe risk through risk transfer such as insurance to reduce specific project exposures. Risk can also be reduced through corporate planning by building earthquake resistant structures, implementing risk neutral logistics or supply chain, market diversification and other such actions that minimise the overall asset at risk of the firm.

Financial Issues

Natural disasters can cause serious financial issues for firms as they affect the efficient management and performance of their assets and liabilities. The structural risks associated with natural disasters constitute one of the major sources of risk for most enterprises.[24] Disaster hazards can cause damages and losses to firms in partial or total destruction of assets and disruptions in service delivery. Natural disasters also cause macroeconomic effects in the economy as a whole and can bring significant changes in the macroeconomic environment. The effects of a natural disaster can interact with some of the normal risks faced by firms, including strategic management, operational, financial and market risks. These effects will reveal corporate vulnerabilities related to poor financial decisions.

The following financial issues in relation to risk management are analysed in this section:

- systematic and unsystematic risk exposure
- investment evaluation and planning
- investment to meet strategic demands
- financial risk management and compliance

Firms are constantly trying to develop more efficient models to evaluate the size and scope of risk exposure consequences using risk modelling approaches such as shareholder value at risk (SVA), value at risk (VAR) and stress testing.

Systematic and Unsystematic Risk

The overall corporate risk can be divided into *alpha* (the competency of the company's management or unsystematic risk) and *beta* (the market or systematic risk). The *alpha* risk is of an idiosyncratic nature can be eliminated by diversifying the investment portfolio, leaving *beta* as the main variable. The risk exposure of a firm can come from the political, economic or operating environments. The operating environment refers more specifically to the idiosyncratic internal and external environments in which the firm conducts it business and the inherent risks to the firm. In this context, the natural disaster risk posed by earthquakes and floods would fall within the definition of external environment. The implication of disaster risk in the internal environment would be related to the internal processes and resources available to manage this risk.

In terms of unsystematic effects of natural disasters like an earthquake, losses related to disruptions in service delivery are the result of a combination of the direct damages to the firm's assets institution and its human resource. The better prepared a firm is in risk managing its resources the lesser the impact of damages and losses to its assets and facilitate in post-disaster business recovery. Systematic risk effects to the firms can be illustrated by damages to the overall infrastructure in the region causing major disruptions to its operations even if the firm is reasonable unscathed at the micro level.

Government normally intervenes in disaster risk management to mitigate systemic risk as damage from disasters tends to be large and locally covariate and the remedial actions are targeted at the provision of public goods, such as infrastructure. The World Bank (2000) suggests that governments are more effective in covering covariant risks, while most idiosyncratic or unsystematic risks may be handled better by private providers. [25]

Investment Evaluation

An investment evaluation is conducted when a firm is considering a major expenditure. The variables taken into consideration are the cash flows, growth potential and risk associated with the project. The common tools used in investment evaluation are the net present value and internal rate of returns methods. Both these methods incorporate a parameter to measure the risk exposure inherent in the project. As the basic tenet of financial management is one of risk-return optimization. A central feature in modern risk management is the issue of risk and return relationship in investment decisions. The basic link between risk and return says that greater rewards come with greater risk and firms investing in a high natural disaster prone area would need to acknowledge this in their investment. This acknowledgement of catastrophe risk in investment evaluation is similar to accounting for political or economic risks of a country.

The price of risk is commonly referred to as the risk premium. A firm as the investor would demand a risk premium commensurate with the risk characteristics of their investment for the higher risk exposure of operating in a region with greater natural disaster risk. The risk premium to compensate for potential disaster risk can be built into the risk equation by factoring in liquidity risk from destabilizing cash fluctuations, and default or credit risk. Moreover, liquidity risk and credit risk interact under disaster conditions escalating risk premium and thus the cost of capital. This will impact on firms after the disaster when they go back into the capital markets to raise credit to rebuild their business.

Natural disasters typically trigger operational risks resulting in disruptions to cash flows and possible default of loan obligations to creditors. However, firms with efficient liquidity management will minimize the disaster effects on cash flows. The nature and magnitude of the disaster and clients' profile are factors that will influence the severity of cash flow disruptions and the ensuing credit risk. The firm can manage a credibility problem and spiralling cost of capital from a disaster if it made prior financial arrangements with creditors. These effects may lead to short term liquidity crises and heightened cost of capital in the medium term for firms. Credit risk is particularly heightened by a disaster due to disruptions to cash flows and serious loss of assets used as collaterals for loans. Unless prior arrangements are in place for creditors to mitigate repayment risks and redress the deterioration in the quality of securities, firms may face delinquency actions and loss of financial facilities.

Strategic Investment

Firms can reduce cash flow variability through business portfolio diversification by engaging in different investments, different locations and activities whose returns are not perfectly correlated. In the context of natural disaster risk management, strategic investment refers to making a financial commitment in a location after considering the risk implications and the available investment alternatives. That is, investment in risky environments must be consistent and sensitive to the risk and return profile of the firm. For instance, making a decision to invest in a new supply chain process in a disaster prone area may require looking at risk neutral alternatives. The risk neutral option may be more costly but would be appropriate if the new supply chain is to service the entire firm's operations. A Cost Effectiveness Analysis (CEA) technique can be used to compare the monetary costs of different options that provide the same physical outputs.

The commercial challenges after a natural disaster are the resumption and maintenance of client services and the financial viability of the business. Firms are caught unprepared and will struggle during a disaster to provide emergency and recovery services to their clients without adversely affecting its own financial position. The strategic perspective of disaster effects is on the adequacy of organisational and financial planning on the part of management in relation to the firm's business growth and the resultant structural design. Firms that have experienced rapid growth but do not comprehensively plan and design their business model around a disaster contingency plan are likely to be more affected by a disaster. Rapid business expansion without a appropriately well designed business model, planned investments and logistics addressing disaster risk will likely experience exacerbated problems during a disaster.

Risk Management and Compliance

To fully address corporate risk exposure with respect to natural disasters, companies need a comprehensive risk management process that identifies and mitigates the major sources of risk. Formulating a detailed risk program with capabilities for risk identification, assessment, measurement, mitigation, and transfer is necessary in a complete risk management strategy. A comprehensive corporate risk management process requires effective techniques that provide a systematic evaluation of risks, which then enables risk managers to make judgments on acceptable risks. Such a process should allow insight into primary areas of uncertainty by identification of the risk factors, highlighting likely outcomes of events and measuring the possible financial impact on the company. The process must also have built-in techniques that can provide a cost-benefit analysis of hedging options as a basis for prioritizing risk strategies. Through the risk management process, a company is able to set its risk tolerance level and any unwanted exposure may be avoided or hedged and the company is left bearing the risk it is willing to assume.

A firm-wide risk management system, using tools like the value at risk (VaR) model, which is capable of capturing the aggregate effect of financial risk exposure to financial, is important to enhance the company's overall market value. The VAR model summarizes the value at risk in a worst case scenario of possible loss under normal conditions.

Conclusions

The severe climatic changes brought about by global warming are evident by the freezing temperature which caused damages amounting to billions of dollars in China in February 2008. The rapidly changing built environment in China also means that new risk assessment models need to be developed to accurately reflect and risk assess the real impact. Financial risk modelling and management using computer simulations incorporating probabilistic and statistical models would be valuable for evaluating potential losses from future natural catastrophes for better managing potential losses. Firms operating in high natural disaster risk areas should use risk modelling for investment evaluation, risk mitigation, disaster management and recovery planning as part of the overall enterprise wide risk management strategy. They also need to identify new business strategies for operating in disaster prone regions and financial instruments to manage risk.

Governments play an important role in financial markets in encouraging financial institutions to support borrowers in risk reduction and to mitigate the impacts of natural disasters.

Notes

1. Mueller, R.S. III (2004). The FBI, *Vital Speeches of the Day* 71:4, 106–109.
2. Hristidis, V., Chen, S.-C., Li, T., Luis, S. Deng, Y. (2010). Survey of data management and analysis in disaster situations. *The Journal of Systems and Software* 83:10, 1701–1714.
3. Thompson, S., Altay, N., Green, W.G. III, Lapetina, J. (2006). Improving disaster response efforts with decision support systems, *International Journal of Emergency Management* 3:4, 250–263.
4. Lee, J.-K., Bharosa, N., Yang, J. Janssen, M., Rao, H.R. (2011). Group value and intention to use – A study of multi-agency disaster management information systems for public safety, *Decision Support Systems* 50:2, 404–414.
5. Amailef, K., Lu, J. (2011). A mobile-based emergency response system for intelligent m-government services, *Journal of Enterprise Information Management* 24:4, 338–359.

6. Santella, N., Steinberg, L.J., Parks, K. (2009). Decision making for extreme events: Modeling critical infrastructure interdependencies to aid mitigation and response planning, *Review of Policy Research* 26:4, 409–422.
7. Aleskerov, F., Say, A.L., Toker, A., Akin, H.L., Altay, G. (2005). A cluster-based decision support system for estimating earthquake damage and casualties, *Disasters* 3, 255–276.
8. www.sahana.lk/overview accessed 2/22/2010.
9. Morelli, R., Tucker, A., Danner, N., de Lanerolle, T.R., Ellis, H.J.C., Izmirli, O., Krizanc, D. and Parker, G. (2009) Revitalizing computing education through free and open source software for humanity, *Communications of the ACM* 52:8, 67–75.
10. www.sahana.lk/overview accessed 8/2/2016; Wikipedia, Sahana FOSS Disaster Management System, accessed 8/2/2016.
11. Tesfamariam, S., Sadiq, R., Najjaran, H. (2010). Decision making under uncertainty – An example for seismic risk management, *Risk Analysis* 30:1, 78–94.
12. Ibid.
13. Karvetski, C.W., Lambert, J.H., Keisler, J.M., Linkov, I. (2011). Integration of decision analysis and scenario planning for coastal engineering and climate change, *IEEE Transactions on Systems, Man, and Cybernetiocs – Part A: Systems and Humans* 41:1, 63–73.
14. Ibid.
15. Briggs, C.A., Tolliver, D. and Szmerekovsky, J. (2012). Managing and mitigating the upstream petroleum industry supply chain risks: Leveraging analytic hierarchy process. *International Journal of Business and Economics Perspectives* 7(1), 1–12.
16. Edwards, W. (1977). How to use multiattribute utility measurement for social decisionmaking, *IEEE Transactions on Systems, Man, and Cybernetics*, SMC-7:5, 326–340.
17. Alexander, D. 2000, *Confronting Catastrophe: New Perspectives on Natural Disasters*, Oxford University Press, New York.
18. Cardona, O. 2001, Estimación Holistica del Riesgo Sísmico Utilizando Sistemas Dinámicos Complejos. Barcelona, Spain: Centro Internacional de Métodos Numéricos en Ingeniería (CIMNE), Universidad Politécnica de Cataluña.
19. Guy Carpenter & Company 2000, *The World Catastrophe Reinsurance Market*, New York.
20. Comfort, L. 1999, Shared Risk: Complex Systems in Seismic Response, Pergamon, New York.
21. Extracted from Oh, K.B., Ho C. and Wu. D. Natural disaster and financial risk management. Int. J. Emergency Management, Vol. 6, No. 2, 2009.
22. Merz, M., Hiete, M., Comes, T. and Schultmann, F. (2013). A composite indicator model to assess natural disaster risks in industry on a spatial level. Journal of Risk Research 16(9), 1077–1099.
23. Coase, R. H. 1937, 'The Nature of the Firm', *Econometrica*, no. 4, pp. 386–405, repr. in G.J. Stigler, and K.E. Boulding, (eds.), 1952, *Readings in Price Theory*, Homewood, Ill.
24. Sebstad, J. and M. Cohen. 2000. "Microfinance, Risk Management, and Poverty: Synthesis of Field Studies Conducted by Ronald T. Chua, Paul Mosley, Graham A.N. Wright, Hassam Zaman", Study submitted to Office of Microenterprise Development, USAID, Washington, D.C.
25. World Bank 2000, *World Development Report 2000/2001: Attacking Poverty*, Oxford University Press, New York.