



## Engineering disaster insurance schemes for the 21<sup>st</sup> Century

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**ABSTRACT:** In several countries, mostly wealthy ones, those who suffer loss directly from natural disasters are relieved of much of this burden through being insured. In general this provides a relatively quick and efficient means of providing cash in the aftermath of a disaster to meet the costs of repair and reconstruction, thus facilitating the recovery process. Unfortunately this is not the case in many poorer countries. For them it often means turning to international agencies such as the World Bank for reconstruction loans, adding further burdens to already struggling economies. To alleviate this situation the World Bank is promoting the design and implementation of a regional and national disaster insurance schemes. Most current schemes were the result of political decisions based on very limited understanding of the risks involved, often in the aftermath of disasters. Today, as a result of advances in technology, schemes can be engineered using sophisticated design tools which can simulate the performance of schemes including the risks to which they are exposed and the financial risk management variables such as premium rates, cover conditions, fund investment returns and reinsurance. This paper outlines some of the basic principles for the design of disaster insurance schemes in the modern world that have emerged from this development.

### 1 INTRODUCTION

When a major disaster occurs as a result of major damage to buildings from hazards such as earthquakes and tropical cyclone winds, the first priority, the emergency response phase, is to ensure people are safe and temporarily housed, and critical facilities are temporarily restored. When this is in hand attention turns to the recovery phase. This covers the permanent repair and reconstruction of the damaged buildings and facilities, and replacement of damaged goods and machinery. For this phase to proceed, funds are required. There are limited sources from which these can come. In general few owners have sufficient reserves which can be quickly liquidated to provide the necessary funds if the damage is significant. One alternative is to obtain a loan, but loans generally require security, and if the building or facility is already security for a previous loan obtained to purchase it, then this option may not be available, or if available may not be affordable in addition to the existing loan. A second option is to rely on the Government or charities for relief funds. These will generally be less than desired, but enough to get started in combination with savings and a smaller loan. The third option is insurance.

After a disaster, insurance is generally by far the best option. Obtaining relief funds from the Government for repair and reconstruction can be a long drawn out affair involving a large amount of bureaucratic paper work and decision making. Generally the rules and procedures will have to be established, and before that decisions will have to be made on the funds to be made available. Even applying for a loan is likely to take time, and charities are normally concerned with emergency response relief, not recovery relief. By contrast insurance is quick and efficient, using systems already set in place to provide funds almost automatically according to already established rules and procedures.

In countries like Australia and New Zealand where almost all privately owned buildings and facilities, and many publicly owned ones as well, are covered by insurance against earthquakes and tropical

cyclone winds, funding is not the major issue as far as repair and reconstruction is concerned, allowing the attention to be focused on organising the other resources required to restore the community. In many other countries this is not the case. This has been highlighted by a number of earthquake disasters in recent years such as the earthquake which hit Kobe in 1995 where only about 3 percent of homes were insured, and then only partially (AHG 1995), and the earthquakes in Taiwan and Turkey in 1999, where an even lower proportion of homes were insured. In Kobe it was a significant problem, but because Japan was a wealthy country with a high level of savings, the community was able to cope by and large, without putting great stress on the national economy. In Taiwan a considerable demand was put on the Taiwan economy. However, because the economy was strong it was able to absorb the impact, but there was concern about its ability to always be able to do this. In Turkey the economy was not strong enough to absorb the impact and the government turned to the World Bank for assistance by way of a long term development loan.

Turkey is only one of a number of countries who have been turning to the World Bank in recent years for assistance for funding reconstruction following a major disaster (Lester 1999). The World Bank is not a charity. It is a bank, and it provides assistance through long term loans, loans which have to be repaid. For a poor country these repayments can be a major burden on their economy for many years. The escalation of such requests to the World Bank, and its concern about the long term impact of the loans, have led to it making such loans conditional on the development of national disaster insurance schemes to reduce the financial pressures on Governments following disasters. Turkey was used as a pilot study for the development of this approach. Taiwan is not eligible for loans from the World Bank, but it has also recognised the value of this approach. In 2001 it developed an interim national earthquake insurance scheme for dwellings, and at the same time initiated a major longer term research study of a comprehensive permanent scheme of disaster insurance covering all types of disasters and all types of losses (Aon 2002).

Insurance by itself does not reduce the overall financial burden. However it spreads it over time and the world wide community in such a way that the problems associated with sudden unexpected and unplanned demands for large levels of funding are greatly reduced. Used unwisely it can be a disincentive for mitigation, but used wisely it can be used to enhance mitigation efforts, and in certain circumstances be used as an incentive for mitigation.

There are a considerable number of government backed disaster insurance schemes around the world, some of which like the New Zealand national residential earthquake insurance scheme are often quoted as models for the development of the new schemes. However almost all the older schemes are in wealthy countries, and a product of relatively wealthy economies with a well educated building industry work force, and relatively strong levels of building control – and are at a mature stage of development. The demand for the new schemes is often in relatively poor countries, where the relatively high levels of risk are often compounded by much lower standards of building and building control – and they have to begin from scratch. Consequently while there is much that can be learned from existing schemes, there is a degree of new thinking that is required.

## **2 GENERAL DESIGN REQUIREMENTS**

### **2.1 Policy Conditions and Premium**

Natural disaster insurance schemes are a response to a situation where the private insurance market is not working in respect of ensuring all, or a significant group, in the community are covered for losses arising from catastrophic events (Kunreuther & Roth 1998). In general there are two main reasons for this situation. Either insurance is not available because the private insurance industry has decided the risk is uninsurable, or cover is available but, because of its cost or cultural factors, property owners are not interested in buying it. A current example of the unavailability of cover in many countries is terrorism cover. In respect of natural disasters, however, the second reason is the most common cause of lack of insurance cover. The New Zealand earthquake scheme began because the 1943 Masterton earthquake revealed that although insurance was available few property owners had purchased it (EQC 1995). In Kobe limited cover was available but very few had purchased it. It was the same in Taiwan at the time of the 1999 Chi-Chi earthquake.

Why do property owners not buy disaster insurance when it is available? There appear to be two reasons. One is cost, and the other is cultural – and the latter is often as important as the former. Where earthquake insurance has to be purchased as an additional cover – which is the normal situation throughout most of the world – a large proportion of property owners will elect not to buy it. This appears to be due to a perception that disasters are very rare events, and if they happen to experience one, they will not be alone, and someone will look after them. Most disaster insurance schemes are introduced by governments as a means of overcoming this problem.

This generally means there must be a degree of compulsion, except where unavailability not buyer resistance is the primary problem. For most schemes this means either making the purchase of disaster insurance compulsory in conjunction with the purchase of ordinary fire insurance, which is the normal approach in wealthy countries where a high proportion of properties are covered by normal fire insurance, or making it a universal requirement, which is the only solution where ordinary fire insurance is not common, which is often the situation in less wealthy countries.

Compulsion through government regulation requires political action. Political action requires political acceptance. Political acceptance requires affordability. Affordability will depend on the premiums. And premiums will depend on the policy conditions as well as the risks. One of the myths of natural disaster schemes is that the premiums are simply a function of hazard risks. This may be true for ordinary insurance where policy conditions are essentially fixed in terms of replacement value of indemnity value. But if disaster schemes were limited to these conditions, then in poorer countries they would often be unaffordable, and therefore politically unacceptable, and hence not viable.

The design of viable natural disaster schemes in other than wealthy countries inevitably means providing limited levels of cover, sufficient to meet basic social objectives such as providing a minimum level of habitation, but not necessarily sufficient to provide the same level of comfort as previously enjoyed. Determining this level will involve political considerations as well as a detailed knowledge of the risks and their actuarial implications for premiums.

## **2.2 Risk Transfer and Financing**

What makes disaster insurance different from normal fire insurance is that it is concerned with events which are characterised by very large losses which rarely occur in any particular region or country, although occurring more frequently on a world wide basis. Disaster insurance premium income in one year from a particular region will generally be only a very small percentage of the likely losses which will be claimed from the scheme in the event of a disaster. A major part of the design of disaster insurance schemes is therefore devoted to this problem, since once premiums are being paid, the scheme is liable for any losses which it is intended to cover. Among the current mature schemes there are essentially three ways in which this issue is managed.

The most well known approach is the traditional insurance approach of developing a pool of funds from the premiums from which claims can be paid. The Natural Disaster Fund managed by the New Zealand Earthquake Commission (EQC), which forms the backbone of New Zealand's earthquake insurance scheme for dwellings, is one of the best examples of this approach ([www.eqc.govt.nz](http://www.eqc.govt.nz)). Its current size is sufficient to meet all but the very largest estimated losses from a conceivable earthquake in New Zealand, and it is of sufficient size that the investment income from it plus the premium income is sufficient to ensure its long term sustainability – which is the primary objective of most designers of disaster insurance schemes. However it is only in this position because it is nearly 60 years old, it has never suffered a major loss, it has remained relatively free of government interference over much of its life, and most importantly, for the first 40 years or so the government took the excess risk while the Fund grew – a point often overlooked by those who promote the establishment of such pools as the answer to disaster insurance.

The other well known approach, often used in association with the pool approach, is the use of reinsurance. Reinsurance is the traditional method by which the insurance industry generally copes with disaster insurance. Reinsurance provides a method of spreading risks world wide in an orderly manner. Reinsurance works by individual reinsurance companies limiting their exposure to any particular event, and insurance companies purchasing reinsurance in portions from different

companies. The price of reinsurance is a function of the estimated risk, market conditions and risk tolerance of the reinsurance companies. Reinsurance involves a transfer of risk from an insurance company to a reinsurance company at a price to cover the risks associated with such an activity. The price of reinsurance essentially sets the market cost of the insurance risks associated with disasters. Reinsurance can be used alone with just a small pool to cover annual attrition losses and administrative expenses. This is the basis of the Norwegian scheme ([www.Naturskade.no](http://www.Naturskade.no)). In this approach the annual insurance premium paid by property owners varies according to the market value of reinsurance, and full cover always exists, an optimum solution from a rationalist economic point of view. However its weakness is that fluctuating premiums have problems politically – particularly when they increase.

The third alternative is where the government collects the premiums and carries the risk itself. The major example of this is Spain ([www.consoseguros.es](http://www.consoseguros.es)) which has one of the oldest and most comprehensive systems. Premiums are actuarially determined, but effectively paid into general government funds, from which claims are also paid. (This approach is rarely advocated by the insurance industry, since it is excluded entirely from the system!)

In practice most schemes are a combination of these approaches, with a mixture of fund accumulation, reinsurance and government guarantees to meet possible shortfalls. Historically the determination of the adopted approach was largely based on subjective and political considerations, but tools are now available for determining the optimum combination compatible with political considerations.

### **2.3 Organisational Structure**

Schemes vary from those organised and managed purely by the insurance industry under government regulation, which is the case with the Norwegian scheme, to those which are organised and managed purely by governments, apart, generally, from the collection of the premiums which is undertaken by insurance companies in association with normal fire insurance premiums and then passed on to the government organisation, of which the EQC is an example.

The organisational structure will depend in large part on the state of the local insurance industry, and its willingness to be involved. It will also depend on the level of compulsion associated with the scheme, and how well the purchasing of insurance is established in the community. If the purchase of ordinary insurance is not well established, and a universal system is desired then the government will have to decide between using its own fund collection system – eg property tax system – to collect premiums, and using the existing insurance network which may exist for commercial insurance to collect the premiums and pass them on to it.

The organisational structure will generally comprise two components, the decision making group, and an operational group appointed to run the scheme as directed by the decision making group.

### **2.4 Claims Handling**

A characteristic feature of disaster insurance schemes is a long period with only a small number of claims, and, by comparison, occasional very short periods with an extremely large numbers of claims. Where the insurance industry is very involved individual companies are often responsible for handling the claims for those whose premiums they collect. Since the handling claims is core business for insurance companies this is usually well within their capability, although some special measures may need to be introduced. For government only schemes it can pose a greater challenge. The EQC has led the way in utilising technology and outsourcing to develop an appropriate claims handling system for this situation (Middleton 2001).

## **3 ENGINEERING THE DESIGN**

### **3.1 Engineering**

In the context of this paper, engineering is defined as the application of mathematical and scientifically based models to the design of disaster insurance schemes. It does not replace the political decision

making process, which is an inherent part of disaster insurance schemes, but provides a rational basis for this process.

### **3.2 The Risk**

The estimation of risk is the foundation of the engineering approach. In this context the risk is not just the risk of the hazard, although this is an important aspect. Nor is it the risk of damage, which is often the concern of structural engineers. Nor is it the risk of total financial loss due to damage caused by the hazard, although it will be a factor. Primarily it is the risk of loss accruing to the disaster insurance scheme under the proposed policy conditions. For instance in the case of the EQC for single family dwellings it is the first \$100,000 of loss based on replacement cost less a small deductible. This requires a relatively simple set of policy conditions based on normal insurance policy conditions. In the case of the current Taiwan Residential Earthquake Insurance Programme where such policy conditions would result in unaffordable premiums, the cover is much more limited. In this case the cover is for a fixed amount only payable if the building is declared a 'total loss'. In this case the estimation of risk has to include the risk of being a 'total loss', as this term is anticipated being interpreted.

Having defined the risk, the primary objective is to determine the estimated loss exceedance probability (EP) curve, which is generally expressed in terms of event losses as a function of estimated return period or its inverse, the average number of occurrences per year, this being the appropriate form required for actuarial calculations related to premiums, reinsurance and sustainability. Tools for doing this have become relatively common during the last ten years, being known in the insurance industry as catastrophe loss models (Walker 2000). They utilise Geographic Information Systems (GIS) technology and comprise four basic components. For an earthquake loss model, one component will simulate the ground shaking caused by a defined earthquake in terms of magnitude, location and fault characteristics, one will map the insured properties geographically together with information on the characteristic features of each property which will influence the risk of loss under natural hazards, one will estimate the insured losses to all the properties due to the simulated earthquake based on the estimated ground shaking intensities, and the other will simulate the occurrence of the total population of earthquakes in terms of magnitude and frequency of occurrence. These are complex computer models which can take of the order of years to develop, and which once developed require constant enhancing due to improvements in knowledge.

A number of loss models are available commercially on a licensed basis, while a number of companies and organisations have developed their own models for in-house use. Most of these have been developed for normal insurance use and need to be customised for use in disaster insurance design, due to the special policy conditions that may need to be modelled (Shephard et al 2002). The models are regionally dependent because they are dependent on local hazard characteristics and local building characteristics. Most of the development to date has focussed on the needs of normal insurance companies and existing insurance exposure to hazards. If new schemes are being planned for countries where there is a low level of existing disaster insurance, the development of these models is generally one of the first major tasks if a rational approach to their design is to be adopted.

### **3.3 Premium Modelling**

Once an EP curve or table of event losses as a function of return periods has been established it is a relatively straightforward exercise to calculate statistical characteristics such as the estimated average annual loss and the standard deviation of the annual losses over the whole range of estimated losses or for specified ranges of losses. The latter is important for reinsurance calculations, since reinsurance is normally purchased in layers. There is usually a lower limit known as the retention, below which the losses are retained by the insurance company, and an upper limit known as the probable maximum loss (PML) above which the insurance company also normally retains the risk.

Pricing methods for reinsurance vary among reinsurers, but among the increasing number who base their pricing on the results of catastrophe loss modelling, a common method is to use the average layer loss times some factor greater than one to allow for the long term average loss and reinsurance company administration costs and profit, plus the standard deviation times some factor as an

additional risk cost to account for the annual volatility. By using this approach an estimate can be made of the estimated cost of reinsuring the whole risk. Added to the estimated scheme administration costs this provides a target for the required premium income from the scheme, which may be termed the Market Value Premium.

The Market Value Premium will depend on the specified policy conditions on which it is based. For these policy conditions it provides a basis for the fair pricing of individual premiums in terms of the market value of risk. Generally this would be established using average values of reinsurance prices over time if it is intended to have relatively stable premiums over time – a desirable situation politically. If total premium income exceeds this value then property owners are subsidising the scheme, the beneficiaries of which will be future property owners, while if premium income is less than this value then property owners are being subsidised by the scheme, generally at the expense of either future or past contributors. When establishing new schemes, if intergenerational equity is to be maintained there appears to be sound reasons for basing actual premiums on the Market Value Premium established in this way.

The catastrophe loss models are not restricted to the production of EP curves. Because of the detailed information embodied in them on the hazard risk and building vulnerability they can also be used to determine the contribution to the Market Value Premium of each individual property, providing a method for the establishment of risk based premiums as a function of location and building characteristics. Such an approach is equitable, and also acts as an incentive for mitigation. However it does represent a major break from the traditional approach towards disaster insurance which was to combine as many hazards as possible together, over as many properties as possible, and charge a uniform premium rate on the basis that it is easier politically to have the majority of the population paying a more, but not a lot more, than necessary, rather than having the majority paying a relatively small amount, and a small but significant minority at high risk paying much larger premiums. In the past it was also easier administratively to handle uniform premium rates, but with modern computers this is no longer an issue.

Having calculated the individual rates, possibly on both bases, a decision has then be made on affordability. If it is deemed the premiums are too high then the policy conditions will need to be tightened, if they are considered very affordable the conditions might be loosened, and the exercise repeated. In many cases the limit of affordability for premiums will have been previously established, and so the process is one of engineering the policy conditions to meet the criteria of affordability previously defined. This is the opposite approach to that often envisaged by those with a traditional insurance background who assume that premium rates are output, not input to the design of disaster insurance schemes.

### **3.4 Sustainability Modelling**

The balance between premiums and risk is one of two numerate criteria that must be met in the design of disaster insurance schemes. The other is sustainability. This will depend on the risk transfer and risk financing arrangements associated with the scheme. Reinsurance pricing is incorporated in the determination of the Market Value Premium but it is not assumed that reinsurance will actually be used. This depends on the design of the risk transfer and risk financing arrangements. In this context risk transfer refers to the actual assumption of risk by a third party – e.g. a reinsurer – for a price, whereas risk financing refers to the provision of funds in the event of a loss which will subsequently be repaid – e.g. a guaranteed bank loan. (Historically some reinsurers looked on reinsurance as risk financing rather than risk transfer expecting to be able to recuperate losses from their loyal clients through greatly increased premiums for an number of years until the loss was repaid. This approach is incompatible with the modern competitive reinsurance market, and would now be viewed with suspicion by regulators and hostility by taxation departments.)

Sustainability modelling requires the modelling of all the financial activities associated with an insurance scheme including the actual insurance risk, the administrative costs, and the income from invested reserves for a number of years into the future – typically ten years – and comparing the performance of the scheme in terms of fund growth and probability of ruin for different proposed approaches to risk transfer and risk financing. The modelling of the financial performance of the fund

is normally done using what is known as an 'asset' model which models the performance of funds into the future as a function of such financial variables as interest rates, bond rates, currency rates and stock market performance indicators, including the risks associated with them. The modelling of the insurance risks requires modelling of likely growth in insured values due to the construction of new properties, extensions to existing ones, and inflation, and the revised EP curves which result. The modelling of reinsurance can include the changes in market price due to market cycles. The objective is to engineer the risk transfer and risk financing approaches to achieve maximum growth for the minimum acceptable probability of ruin, the latter being another factor dependent on political considerations since any failure of such a scheme will have political repercussions. The EQC has been a leader in the use of this approach for the management of disaster insurance schemes (Middleton 2001).

Not only is it important to model how the scheme will behave given the current starting point, but how it will perform if a major event occurs resulting in a large loss to the scheme. The ability to recover from such a loss is essential to sustainability. Part of the political decision making is the specification of the level of loss in terms of event loss return period which should be used for this so-called 'stress testing'.

The output of this modelling will depend on the individual characteristics of each scheme, but some generic results are:

- It is important to ensure that premiums and policy conditions are indexed for inflation if the scheme is to be sustainable, especially if the cover is of the first loss type;
- The only types of schemes which are sustainable from the start are those which are effectively fully reinsured from the start, or in which the government assumes most of the risk at the start.
- If partial reinsurance of the risk is employed in conjunction with the growth of a disaster fund, it is much more effective when purchased at lower layers of loss with the objective of protecting the fund, rather than when purchased at higher layers of loss with the purpose of covering the risk above the level covered by the fund.

A major consequence is that despite the common desire for the establishment of disaster funds as a means of providing independent sustainability of associated disaster insurance schemes in the long term – such as the current situation of the EQC – this is only possible if the government assumes a high level of risk during the early years of the scheme, or property owners are charged premiums well in excess of the market value of the associated risk with the sole purpose of making things better for the property owners in the future. As the fund grows the income from it can be used in part to protect the fund through reinsurance, thus ensuring that if there is a major loss the scheme will have some funds to enable it to continue.

No scheme can be guaranteed in terms of sustainability unless backed by a government guarantee such as that provided by the government to the EQC, or provided with a guaranteed limit by government regulation. The latter approach is used in Japan and has been adopted in Taiwan for its earthquake insurance scheme. With this approach the total liability of the scheme is limited to a nominated amount, and if claims exceed this amount then payment of them will be partial in terms of the ratio of the limit to the total claims value. As it often takes months or even years to establish the total claims cost, it is not clear how such an approach will be implemented in practice.

#### **4 CONCLUSIONS**

Advances in modelling natural hazards and their impact utilising GIS technology have provided sophisticated tools for utilising an engineering approach to the design of disaster insurance schemes at a time when there are increasing pressures on governments in regions of high risk from natural hazards to adopt such measures. A primary source of the pressures is the World Bank as a consequence of escalating demands on it from poorer countries for large loans to fund reconstruction activities following major disasters.

There are a number of well established natural disaster schemes in existence, including the EQC scheme in New Zealand, but these are mostly in wealthy countries. Although there are lessons to be learned from them, the difference in cultural setting makes them generally unsuitable for direct transplantation to these poorer countries. Political factors play a major role in the development of disaster insurance schemes, but the engineering approach of using models to evaluate possible solutions and determine the optimum design solution provides a valuable technique for the establishing a basis for sound political decision making.

The basic framework of the models is now well established and provides a framework for the analysis and integration of local information on hazard risk and building vulnerability, and the consequent analysis of premiums and sustainability. The principal limitation in many countries is likely to be affordability with the result that maximum premium values will be set as input and the design of schemes will hinge on the determination of policy conditions providing a level of cover which meets minimum social objectives without premiums exceeding the maximum affordable value.

In analysing premiums a useful bench mark is the Market Value Premium which has been defined as the estimated premium income which would be required to fully reinsure the risk and cover scheme administration costs. This can be relatively easily established from the EP loss curves output from catastrophe loss modelling of insured losses for specified policy conditions. The design can be engineered by evaluating the Market Value Premium for different sets of policy conditions and comparing the implied property premiums with the prescribed maximum values to satisfy affordability.

Disaster insurance schemes must also be sustainable. Financial risk management models using the EP loss output from catastrophe loss models can be used to simulate performance for several years into the future. This analysis shows that unless the approach of effectively annually fully reinsuring the risk and not developing a fund is adopted, then governments need to assume most of the risk during the early years to allow the fund to develop to a level that the investment income is able to pay for protection of the fund through reinsurance, after which the government support can be gradually tapered off.

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