NZSEE 2010 Conference

Incentives for Mitigation - Who pays, Who benefits?

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1 Introduction

At the 2008 annual conference of the New Zealand Society for Earthquake Engineering Thomas and Irvine (2008) presented a very interesting paper arising from an investigation of the state of the foundations and sub-floor structures of typical houses in Wellington City. The investigation had indicated that in a large proportion of timber houses in Wellington these building sub-elements were very deficient in terms of earthquake resistance posing a significant risk to these houses if a major earthquake were to occur. The paper described an analysis of the relative costs and benefits of upgrading the deficient foundations and sub-floor systems to meet NZS3604:1999 if the buildings were to be subjected to a simulated M7.5 earthquake on the Wellington fault. The analysis included both direct losses to buildings and contents as well as indirect costs such as the provision of emergency services, temporary accommodation and costs of injuries and loss of life. Assuming a 50 year average dwelling life the authors produced estimated benefit/cost ratios for different annual risks of the simulated Wellington fault earthquake. From their results it could be concluded that in terms of direct losses the benefits would only outweigh the costs if the annual probability of an earthquake was greater than about 0.3% , but if indirect costs are taken into account the overall benefits would outweigh the costs for an annual probability of earthquake greater than about 0.1%.

The paper raises significant issues about the costs and benefits of mitigation. Like many such investigations of the benefits and costs of making changes, either to existing buildings or to design codes in respect of new buildings, it is only concerned with the overall risk of loss to society as a whole without consideration of how these risks are borne, and who would pay for the upgrading and who would benefit from them. This is very important when it comes to deciding who should pay for the upgrading and what incentives should be given for doing it. If A is expected to pay for it and B gets the benefit there will be a disincentive for A to do it, irrespective of any overall benefit to the greater society. By focussing only on the costs and losses it also neglects the significance of insurance in the overall analysis. There are costs associated with insurance which the property owner pays through an annual premium which effectively increase the lifetime costs of buildings. In return the property owner is effectively guaranteed that any damage will be repaired and the costs refunded including replacement as new if major damage occurs – ie the owner will actually benefit from the loss if the building is old, which is one reason why insurers have problems with arson in respect of old buildings. The main risk carriers are the insurance companies, the reinsurance companies to whom insurance companies cede most of their earthquake risk, and the New Zealand Government, for which read the New Zealand taxpayer, in respect of the indirect costs. In general the benefits are likely to be shared in some way among all these, plus the owner if the premium is reduced.

In practice there are also many more risks to buildings in Wellington than one simulated earthquake on the Wellington fault, and it is unrealistic to assume a life expectancy of dwellings of 50 years for those being upgraded. According to the authors there are a significant proportion of houses built before 1940 so these are already more than 70 years old. Realistically these will have an attrition rate due to replacement so is unlikely that all of them will all be around in 50 years time. Realistic cost benefit analysis needs to take both these factors into account as well the complexity of the insurance risk transfers and the costs associated with it. In New Zealand in respect of housing this is further complicated by the role of the Earthquake Commission which carries a major but decreasing portion of the risk – before transferring a significant portion of it to overseas reinsurers – and charges a fixed premium rate which does not recognise differences in risk between individual dwellings due either to location or construction standard.

Fortunately tools now exist in the form of catastrophe loss models which can take all these complications into account and provide a more realistic assessment of the costs and benefits and how they are distributed amongst the key stakeholders (Grossi & Kunreuther, 2004). To date these tools have been primarily used by insurance companies and reinsurance companies to manage their risks, but they have the potential for much wider use, particularly in relation to analysing the costs and benefits of mitigation as demonstrated by Kleindorfer, Grossi & Kunreuther (2004) who looked at the costs and benefits of specific upgrades of older housing in California in respect of earthquake risk, and Florida in respect of hurricane risk, based on US practice.

The primary purpose of this paper is to highlight the importance of taking the costs and benefits of insurance into account in cost benefit analysis of mitigation in developing policies on mitigation, including who pays for it, in a context more representative of the situation in New Zealand. Rather than looking a specific upgrade of a particular type of building the analysis in this paper looks at the benefits or otherwise of a specific level of upgrade in terms of reduction of annual average risk to produce a maximum cost which a design engineer would need to meet in designing the requisite upgrading. The particular risk levels used are hypothetical but considered representative for much older construction, and the insurance structures assumed are simplified versions of the actual structures used in New Zealand, but embody the main characteristics. While the basic tools exist to undertake this work, significant research is required to develop vulnerability models of building behaviour as a function of ground motion which will be sufficiently sophisticated in the fragility modelling of their components and sub-assemblies to enable the reductions in risk due to specific upgrading to be reliably estimated. The authors hope that the paper will encourage an increase of this type of research as well as more detailed research on the overall costs and benefits of mitigation in relation to who pays and who benefits, without which it will be difficult to develop sustainable policies on mitigation.

2 Basic Principles of Catastrophe Insurance

An understanding of catastrophe insurance is necessary for understanding the true costs of catastrophic events and the benefits that arise from mitigation.

Insurance in all its forms is based on the application of a single basic theorem that is normally taught in an introductory course on probability and statistics – the Central Limit Theorem. The Central Limit

Theorem indicates that if a number of similar independent risks are combined the coefficient of the variation of the combined risk will be less than that of the individual risks, the reduction being greater the larger the number of individual risks (Ang and Tang, 1975). The maximum credible loss associated with a financial risk with a large coefficient of variation will be many times the mean loss. If this maximum credible risk is also large in relation to the financial situation of the person or business carrying the risk it can be very difficult to manage. Insurance exploits the Central Limit Theorem by combining large numbers of similar risks, which individually have large coefficients of variation and are considered by the owner to be unmanageable, to produce an overall risk to the insurance company that has a small enough coefficient of variation that it is manageable.

There is a cost associated with doing this so it is only worthwhile if the owner's assessment of the maximum credible loss at risk is significant in terms of the owner's wealth. For most homeowners their house fits into this category. The risk of significant damage is small but there is a small but significant risk of having a total loss which would significantly affect their financial well being. Such long tailed risks have very large coefficients of variation. However when combined with thousands of other similar risks, providing the risks are independent – eg fire risks arising from within the building – then the coefficient of variation of the resultant risk to the insurance company can end up very small making it very manageable. The average annual loss per policyholder will be same for the insurance company as for the average individual policyholder. The insurance company needs to cover this plus an additional amount to cover the retained risks associated with the resultant lower coefficient of variation as well as administration costs and a return to the investors better than they would get from putting their investment in a bank. This additional amount over the annual average loss is defined by Kleindorfer et al (2004) as the Insurance Loading Factor, λ_I. The value of λ_I reflects the degree to which the insurance company has been able to utilise the Central Limit Theorem to reduce the coefficient of variation of the original risk ceded to it by the policyholder. Typically for independent fire and theft for home and contents insurance, excluding catastrophe risk, it will be of the order of 20-30 percent of the assessed average annual loss.

Catastrophe losses from events like earthquakes are not independent. If an earthquake occurs then all the buildings in the area affected are at risk of damage from the same event – ie the individual risks to buildings are correlated. This means that for these risks the conditions of the Central Limit Theorem break down and the insurance company gets no reduction in coefficient of variation from combining the risks from this type event in a region that can be affected a single event of this type. By covering different types of catastrophic events – tropical cyclones, floods, bushfires, etc – over a larger area the company can get some benefit from combining the event risks, but often they are not similar in size, which also limits the applicability of the Central Limit Theorem, and the number of independent risks is still often small so the coefficient of variation of the combined event risks is still large. Unless the insurance company is a global insurance company with widespread risks around the world, insurance companies turn to reinsurance companies to overcome this problem.

Reinsurance companies accept catastrophe insurance risks from all around the world and thus are able to accumulate a significant number of independent event risks, many more at the lower end of possible size than at the higher end. The less the number of similar independent risks that can be combined the greater the resulting coefficient of variation of the combined risks retained by the reinsurance company and the higher the loading factor that needs to be applied in determining the reinsurance premium to be charged to the insurance company (Walker, 2003). For a potential maximum insured event losses of the order of a billion dollars, of which there are many, it might be as low as 50%, but if there are potential insured losses of the order of 100 billion dollars as in the Caribbean and Gulf of Mexico region from hurricanes, of which there are only one or two worldwide at this time, it may be so many multiples of the estimated average annual loss as to make the risk uninsurable by normal reinsurance means – which is why to date no satisfactory solution has been found to the provision of a sustainable system of hurricane insurance in this region. For insured earthquake event risks of the size similar to that posed by an earthquake on the Wellington fault the loading factor is probably of the order of 150 percent resulting in a reinsurance premium rate of the order of 2 ½ times the estimated average annual loss.

The premium individual policyholders pay for cover depends on how the overall costs of reinsurance and administrative costs are allocated by the insurance company. At one extreme are government disaster insurance funds such as that which was managed by the original Earthquake and War Damages Commission (EWDC) in New Zealand where a single premium rate was charged and large reserves were allowed to accumulate by buying no reinsurance and relying on a Government guarantee to meet any deficiency in the Fund in the event of a major event loss – resulting in a very significant accumulation of reserves to be passed on the restructured Earthquake Commission (EQC) as a result of no major events occurring during its approximately 50 years of operation. At the other extreme are commercial insurance companies, which charge each policyholder a premium that takes some account of the risk to the individual insured property, and who fully cover any major event loss through reinsurance, maintaining reserves which are relatively small compared to the maximum credible loss to which they are exposed. The EWDC was also different in that it covered property for its depreciated value only, but current practice in New Zealand by both is to provide cover for replacement value. This change has consequences for cost-benefit analysis as it means a property which is severely damaged by an insured event is worth more to the owner than in its undamaged state – which also significantly increases the moral hazard of insurance of older properties.

In practice there is a spectrum of ways catastrophe insurance is provided between these two extremes. For instance the EQC has retained the common fixed premium rate, but has changed the cover to replacement value and limits its liability to the first $100,000 loss in the case of buildings and first $20,000 loss for contents, with commercial insurance companies covering the risk above these limits. This means that because most losses are partial losses the EQC still assumes most of the risk – typically 80-85 percent at the present time – although the proportion is slowly decreasing with inflation of building costs and the value of contents. Although having relatively large capital reserves the EQC also buys a significant amount of reinsurance to ensure its sustainability independent of government support in the event of a major loss event. On the other hand while the premiums charged by most insurance companies for commercial and industrial property, and the top up of dwelling and contents cover, vary according to location and the general nature of the property, it is likely that most companies use a relatively broad system which does not recognise differences at the individual property level. They may also retain event losses up to the order of 10 percent of their perceived probable maximum loss to reduce reinsurance costs.

These differences in insurance systems can have a significant impact on the analysis of the costs and benefits of mitigation, and particularly on how they are distributed between the policyholder, the insurer and the reinsurer.

3 Modelling the Benefits of Mitigation

In this section the benefits associated with mitigation are modelled for a number of simplistic scenarios. The primary purpose is to demonstrate an overall procedure for undertaking such analysis to include the effects of insurance, but the results are also used to draw some general conclusions about the likely nature of the outcomes in New Zealand if more detailed studies were undertaken. The approach adopted is to assess the benefits arising from a prescribed level of mitigation, which will indicate the maximum amount which can be spent on upgrading to ensure that there will be a net benefit.

Two basic insurance structures are considered.

1) A highly capitalised government fund type structure providing full replacement cover (ie no deductible) for a uniform fixed premium rate with its funds being covered by a government guarantee resulting in no requirement for reinsurance, which will be termed the ‘fixed premium’ structure.
2) A commercial insurance company type structure providing full replacement cover with the upper 90 percent of its catastrophe event loss risk covered by reinsurance and the bottom 10 percent retained, and charging a risk based premium assuming the reinsurance cover costs 2.5 times the average annual loss and the insurer charges 1.2 times the overall average annual loss to ensure administrative costs are covered and an additional 0.3 times the portion of the average annual loss retained by it, which will be termed the ‘risk rated premium’ structure.

For the purpose of the exercise the benefits arising from mitigating the earthquake risk to a 70 year old dwelling is considered for each of these insurance structures for different assumed locations in terms of earthquake risk and size of concentration of risks from same events in the locality. The benefits are assessed over time periods into the future varying up to 30 years. The building is assumed to have a replacement value of $200,000 and contain contents with an insured value of $50,000. It is further be assumed that the building depreciates at a real rate of 1 percent of replacement value per year but because of continuous replacement and a strong tendency for underinsurance of contents the insured value of contents approximates their depreciated value. This means the current depreciated value of the building is $60,000 and that it will continue to depreciate at $2,000 per year in current values, while contents will remain constant at $50,000 in current values.

Three locations with the following characteristics are modelled:

- a high risk location in a large community at risk,
- a high risk location in a small community at risk,
- a low risk location in a relatively large community at risk.

It is assumed that in the high risk region the estimated annual average loss risk is 0.2% and in the low risk location it is 0.02%. It is assumed that probable maximum event insured losses in the high risk regions will be 90% reinsured, but that in the other regions the probable maximum event insured losses will be less than the insurance company’s retention and hence not subject to reinsurance.

The benefits to different stakeholders of reducing the estimated average annual loss by 50% by upgrading the building, excluding the costs doing this, are investigated Assuming that building costs and contents values increase in line with inflation, the analysis can be undertaken in terms of current dollar values.

Table 1 summarises the analysis of the impact on the householder if the building is located in the high risk large community. The net worth is the depreciated value less the accumulated premiums paid during the subsequent lifetime plus the accumulated expected claims, which will be equal to sum of the estimated average annual losses based on replacement values since it assumed that any losses will be refunded by the insurer. The net benefit is the difference between the net worth following upgrading and the net worth if there is no upgrading, and represents the maximum funds that could be spent on the upgrading for there to be an overall benefit to the householder. It will be seen that the two different insurance structures produce very different results. While there are significant benefits to the householder from the upgrading with the risk rated premium structure of insurance, the householder is actually financially worse off with the fixed premium structure, primarily because there is no change to the premiums paid but a reduction in the probability of having a claim. As a result there is actually a financial disincentive to the householder to upgrade.

Table 1
Comparison of Impacts on Householder
(All values in current dollars)

	Fixed Premium		Risk Rated Premium	
Subsequent Life (years)	10	30	10	30
No Upgrading				
Capital Value ($)	90,000	50,000	90,000	50,000
Accumulated Premiums Paid ($)	17,400	52,200	1,250	3,750
Expected Accumulated Claims ($)	5,000	15,000	5,000	15,000
Net Worth ($)	77,600	12,800	93,750	61,250
Upgrading				
Capital Value ($)	90,000	50,000	90,000	50,000
Premium Paid ($)	8,700	26,100	1,250	3,750
Claims ($)	2,500	7,500	2,500	7,500
Net Worth ($)	83,800	31,400	91,250	53,750
Nett Benefit ($)	6,200	18,600	-2,500	-7,500

Figure 1 compares the results of the analysis shown in Table 1 with similar analyses assuming the property is located in the other two locations considered. It will be seen that while under a risk rated premium structure there will still be benefits, while under the fixed premium structure the householder will still be worse off, in both situations – ie the high risk region with small community at risk and the low risk region with a large community at risk – with risk rated premiums the benefits of upgrading are much less with consequences for the amount of money that could be spent on the upgrading for there to be an overall net benefit to the householder.

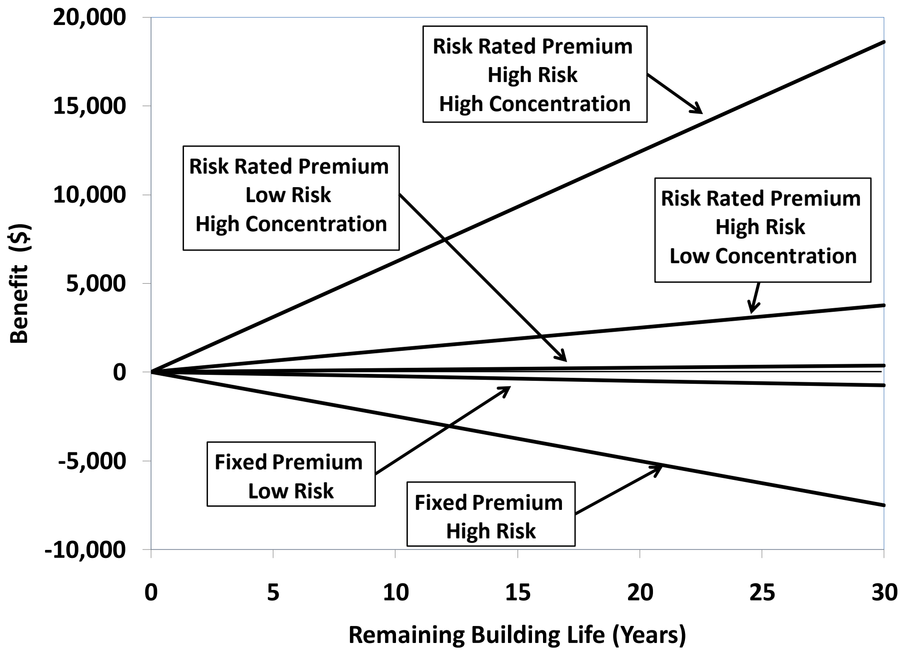

Figure 1 Benefits to the Property Owner from Mitigation

The greatest benefits arise in regions of high risk and high concentration of risks because of the influence of the higher price associated with reinsurance, which will be governed by the probable maximum event insured loss associated with these regions. In high risk regions of low concentration if the probable maximum event losses is below the retention limit of the insurance company as assumed in this example, the premiums will not be subject to the higher reinsurance costs if they are fully risk rated.

Table 1 summarises the analysis of the impact on the two different insurers if the building is located in the high risk large community. The net gain is before administrative costs are taken into account so should not be regarded as profit. While the net gain for the risk rated premium insurance structure is reduced by the mitigation so is the premium income with the gain as a percentage of premium income remaining the same, meaning that from a business point of view there is no gain to the insurer from the upgrading, but in terms of premium income there is no loss. In the case of the fixed income insurance structure the net gain is negative indicating a net loss – which is to be expected in a high risk area with fixed premiums as this approach implies that the premiums in high risk areas will be subsidised by those from low risk areas. It will be seen however that there is a significant decrease in the magnitude of the loss indicating a significant gain to the insurer from the mitigation. Comparison with Table 1 shows what the property holder loses the insurer gains implying that the insurer who will have the incentive to pay for the upgrading providing the cost is less than the gain to it from mitigation.

In relation to reinsurers with the example of the fixed premium insurance structure they do not participate, and in the case of the risk rated premium insurance structure their income will reduce in proportion to the reduction of liability to claims so that the net effect from a business point of view will be zero – but it will give them additional capacity to cover other risks.

Table 2
Comparison of Impacts on Insurers
(All values in current dollars)

	Risk Rated Premium		Fixed Premium	
Subsequent Life (years)	10	30	10	30
No Upgrading				
Re/I Costs	11,250	33,750	0	0
Re/I Claims	4500	13500	0	0
Premium Income	17,400	52,200	1,250	3,750
Claims Paid	5,000	15,000	5,000	15,000
Net Gain	5,650	16,950	-3,750	-11,250
Gain/Premium	32%	32%	-300%	-300%
Upgrading				
Re/I Costs	5625	16875	0	0
Re/I Claims	2250	6750	0	0
Premium Income	8,700	26,100	1,250	3,750
Claims Paid	2,500	7,500	2,500	7,500
Net Gain	2,825	8,475	-1,250	-3,750
Gain/Premium	32%	32%	-100%	-100%

In the case of the risk rated premiums from a commercial type insurance company if the premium is fully risk rated before and after mitigation then there is no direct benefit or loss to the insurance and reinsurance company under the simplifying assumptions of this example.

There will also be the benefits to government from the reduction of need for government services following a disaster as a result of mitigation, which have not been modelled.

4 Implications for Incentives

The scenarios considered are simple ones which do not fully reflect the full complexity of the insurance and reinsurance transactions. Nevertheless they highlight the importance of taking insurance and reinsurance factors into account.

Although the fixed premium insurance structure modelled is different from that managed by the EQC, because the EQC dominates the provision of household insurance in New Zealand based on a fixed premium it is expected that as with the householder in the example, mitigation by upgrading old buildings will result in an estimated financial loss for householders, particularly in high risk areas, and hence there may be an appreciable financial disincentive for them for mitigation. Of course there will be a gain to householders from the increase in personal safety in a major event, suggesting this would need to be also included in the analysis in terms of the associated financial impact for the overall benefits, if any, to be properly assessed. On the other hand the analysis suggests that depending on the cost there could be significant benefits to EQC from it paying for mitigation.

While there can be significant benefits to householders from mitigation if subjected to fully risk rated premiums in high risk areas, it must also be recognised that under such a scheme the householders would be paying a much higher annual premium. In the example considered, for which the average annual risk is not atypical of that to older buildings in Wellington, the annual risk rated premium for earthquake alone is about $1750, which is much higher than current premiums paid by Wellington residents. Consequentially any suggestion of changing from the present fixed premium EQC scheme to a fully risk rated scheme would be likely to face significant political problems.

The premiums paid by commercial and industrial businesses may be closer to risk rated values and so it is more likely that there may be direct financial benefits to them from mitigation, but it would require detailed modelling to ascertain the actual financial benefits. In practice there is likely to be a degree of smoothing between high risk and low risk areas – ie with those in low risk subsidising those in high risk areas to some degree, although not as much as occurs with household insurance. It must also be recognised that the full benefits of mitigation may not be passed on as both insurers and reinsurers may take a conservative view of the estimated reduction in risk arising from the mitigation. Consequently any analysis of the benefits to property owners based on full risk rating of premiums is likely to give upper limits to the benefits.

One group of stakeholders is assured of benefits from mitigation. This is the government and thus taxpayers. This suggests that there is strong case for government involvement in the funding of mitigation. This might be by a combination of stick or carrot approaches. The stick approach would by legislating that it must be done in high risk areas with large communities at risk, and carrot would be some form of subsidy or tax deduction, some of which might be funded by EQC, to help defray the expenses, recognising that there will be a benefit to all taxpayers and the EQC, but that those who choose to live in high risk areas should bear more of the cost.

5 Modelling Needs

The modelling undertaken in this exercise is very simplistic. However complex catastrophe loss risk models as well as the necessary financial risk management models now in common use in the insurance industry are well fitted for this task. Indeed the Minerva earthquake model used by EQC already incorporates most of the features needed for such exercises including the ability to allocate costs between policyholders, the EQC and reinsurers, and to model financial outcomes for several years into the future. While many of the most advanced models have been developed by commercial companies and are consequently not available for public use, it is not uncommon for these commercial companies to make their software available to researchers – in return for getting access to the intellectual capital of the researchers – and there is an increasing number of increasingly sophisticated earthquake loss risk models becoming available as open software (Daniell 2009).

The greatest weakness of current models for cost benefit analysis of mitigation is the lack of reliable models of the effect on vulnerability of specific details of proposed systems of upgrading. Currently this is an active field of research in some centres, largely driven by the move towards performance based design (eg Ellingwood et al 2004, Li & Ellingwood 2009). Most of this work to date appears to have been focussed on US construction. Particularly at the domestic housing level forms of construction differ widely between different countries as well as within countries. Developing fragility models at the level of sophistication required to distinguish between older forms of construction and proposed upgrading details is likely to be very challenging, but necessary if rational approaches to mitigation are to be developed. In addition to this there is a need to develop more sophisticated procedures for the analysis and costs of mitigation utilising the improved catastrophe loss risk models in combination with probabilistic financial risk management models.

6 Conclusions

For mitigation policies to be successful they must either be imposed by legislation or encouraged by incentives. Incentives will not work if A is expected to pay for mitigation measures, but the benefits accrue to B. Insurance changes the way money flows in respect of building lifetime economics. The analysis described in this paper demonstrates the importance of including insurance transactions in analysing the benefits of mitigation and to whom they accrue if incentives are to play a significant role. From the simplified analysis presented it can be deduced that the either the policyholder, insurer or even the reinsurer can be the primary beneficiary depending on the detailed structure of the insurance system. Determining the actual value of the benefits and how they are distributed in practice requires much more sophisticated procedures than used in this demonstration example. The basic tools exist to do this but effectively utilising them will be very dependent on significant advances in earthquake engineering research directed at the fragility of critical elements of older construction and the possible structural details for improving the seismic performance of this construction.

7 References

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