The NZSEE's % NBS risk measurement framework: Why it doesn't work

May 2015

tailrisk economics

te maha hoki o nga pihikete

About Tailrisk economics

Tailrisk economics is a Wellington economics consultancy. It specialises in the economics of low probability, high impact events including financial crises and natural disasters. Tailrisk economics also provides consulting services on:

- The economics of financial regulation
- Advanced capital adequacy modelling
- Stress testing for large and small financial institutions
- Regulatory compliance for financial institutions
- General economics.

Principal Ian Harrison (B.C.A. Hons. V.U.W., Master of Public Policy SAIS Johns Hopkins) has worked with the Reserve Bank of New Zealand, the World Bank, the International Monetary Fund and the Bank for International Settlements.

Contact:

Ian Harrison – Principal Tailrisk economics

ian@tailrisk.co.nz

Ph. 022 175 3669

04 384 8570

or

John Woolf - Senior consultant, Tailrisk economics

Ph. 021 064 8676

Introduction

In two previous papers, 'Error prone Bureaucracy' and 'The Flaw in the Score' we have explained why the New Zealand Society of Earthquake Engineering's (NZSEE) framework (set out in the document NZSEE 2006) for assessing the seismic risk of buildings does not work, and should not be used to assess building life safety risk.

This paper brings the relevant information and analysis in those papers together in a shorter and simpler document.

What should a seismic risk measurement framework do?

Seismic strengthening policy for existing buildings is primarily based around a concern with the risk that earthquakes pose to life. To do that is essential to have a framework that measures the life safety of a building, and a trigger point that separates buildings that pose an acceptable life safety risk from those that do not.

A good framework will have the following attributes:

- The trigger point for identifying excessively risky buildings should be based on an assessment of the costs and benefits of seismic strengthening. The trigger point will be set to maximize the net benefit to society.
- The life safety risk of different buildings assessed as being at the trigger point should be the same.

Does the NZSEE framework meet these tests?

The simple answer is that is does not.

- The NZSEE framework sets a trigger point of one third of the new building standard (34NBS %) to separate buildings that are 'earthquake prone' from those that are not. Buildings that do not meet this test are described as high risk. This trigger point was set without any analysis of the costs and benefits of strengthening a building to meet the test. It is now clear that the trigger point has been badly miscalibrated. The cost benefit analysis prepared for the Ministry of Business Innovation and Employment (MBIE) showed that the costs of meeting the trigger point exceeded the benefits by a factor of over twenty and our analysis presented in 'Error Prone Bureaucracy' suggests that the costs could exceed $10 billion while the benefits will be no more than $100 million.
- Buildings with the same %NBS rating in locations with the same seismic risk can have materially different life safety risks.
- Buildings with the same %NBS ratings in cities with different seismic risks can have very different life safety risks.

To understand why the NZSEE's %NBS framework doesn't work, it is necessary first to examine the new building seismic strength framework. The %NBS framework is directly linked to it, so any problems will flow through to the NZSEE existing building standard.

The next step is to consider the differences between standards that are appropriate for new and existing buildings. The new building standard is meant to serve different purposes to the existing building standard, and has been calibrated accordingly. If that standard is applied, without adjustment, to an existing building framework then errors can be, and have been, generated.

The new building standard

The key part of the 2004 New Building standard is the accompanying commentary document NZS 1170.5, which has a preliminary section that explains the logic behind the calibration of the standard. Obviously it not enough simply to construct a standard, it is also necessary to demonstrate that there is a link between the calibration of the standard and one of the key purposes, which is reducing life safety risk at an acceptable cost.

The document attempts to do this but does not do so using analytical tools such as a cost benefit analysis. Rather, it starts with what it describes as the international earthquake safety standard for new buildings of one death in 1,000,000 years, and then explains why the code could be reasonably claimed to meet that test. It sets out an analytical framework that could be used to test the life safety implications of the code, but does not actually conduct the analysis.

International standard does not exist

The first problem with this analysis is that the 1:1,000,000 international standard does not exist. The document cites the International Standards Organization's standard ISO 2894 as the source of this life safety risk standard. There is no mention in ISO 2894 (which covers general construction standards) to an earthquake safety standard at all, let alone a 1:1,000,000 standard. Further, there is no reference in the standard ISO 3000, which does cover earthquakes, to a 1:1,000,000 standard. That standard suggests that new building codes should have regard to the costs and benefits of seismic strengthening.

No cost benefit analysis

The second problem is that no attempt was made to conduct a cost benefit analysis. We do not know whether the new building standard has been set at a level that reasonably balances cost, life safety and buildings functionality considerations, and we do not know what life safety standard is generated by the standard. If is 1:1,000,000 or higher then this is a very high standard.

1:1,000,000 is the level that is widely accepted, in the life risk literature, as the standard for zero effective risk and a level of risk at which no further improvement in safety should be made. It is a level that would be targeted in reasonably exceptional circumstances – and in particular where the marginal cost of securing safety benefits to this level is very low. For most activities a much lower level of life safety will be acceptable.

Does not properly account for geographical differences in life safety risk

The third issue is how the standard deals with the different seismic risk in different locations. This is done by applying what is known as a Z-score, which is meant to compensate for lower risk in less seismically active areas. The logic here can be illustrated by an example about life safety risk. This risk is driven by a combination of two factors:

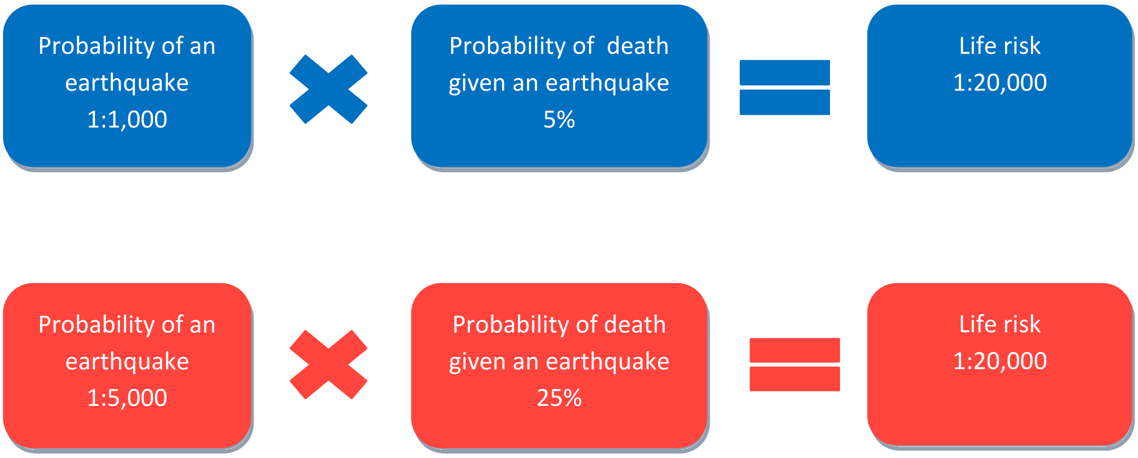
- The probability that there will be life threatening earthquakes
- The probability that a building occupant will die if there is a life-threatening earthquake. This probability will depend on the strength of the building.

A stronger building in a more seismically active area, with a higher probability of a life threatening earthquakes, can have the same risk as a weaker building in a less seismically risky area (see figure 1 for an example). Conceptually, what the Z-score should do is set the new building standards in the lower seismic risk areas so this result is achieved.

But it does not.

We were unable to locate a document that clearly explains the conceptual reasoning behind the Z score approach, and in particular, how the Seismic Risk Committee of the New Zealand Standards Association calibrated the current Z-scores from the available evidence. We have been reliably informed that there is no public documentation of this process. This is clearly unsatisfactory. The Z-score calculation is critical to the assessment of %NBS but the key documentation is not available.

Figure 1 — Equivalent risks



We also understand that the Z-scores were calibrated so they did not capture the full differences in seismic risks. This means that seismic risk is overstated in less seismically active areas, but no one appears to know by how much.

The other key issue is that the standard makes an exception, in what in principle is a probability driven framework, for lower seismic risk zones. This is not a minor tweak to the standard framework. Because the low seismic risk zones covers two thirds of New Zealand's population, it is the heart of the code.

Here actual seismic risk is largely ignored and a minimum seismic shock substituted. There is no substantive discussion or justification of this minimum, other than that it is 'necessary' to impose a seismic strengthening requirement over the low seismic zones. This seemingly minor adjustment alone, when it flows through into the new building %NBS assessments, has the effect of generating most of the earthquake prone building designations in Auckland and other low seismic risk areas.

Taken together the Z-score calibration and the low seismic zone 'over-ride' mean that the new building standard does not, by a wide margin, adjust for geographical differences in seismic risk. As noted above these problems flow into the existing building risk assessment framework.

The existing building risk measurement framework

The existing building risk measurement framework is set out in the document (NZSEE 2006). The problems with the framework are as follows.

Inadequate analysis of the relationship between life safety risk and %NBS

No attempt was made to directly calculate life safety risk at the 34NBS% standard or at any other percentage of NBS. Instead some numbers on relative risk were presented. It was stated at one point that the new earthquake prone building trigger point would have the effect of reducing risk from 25 times that of a new building to about 10 times. At another point, it is claimed that buildings at the 34 percent standard are 20 times as risky as new buildings. These claims are not supported by any evidence.

A relative rather than absolute measure of risk

Of more concern is the use of a relative, rather than an absolute measures of risk. This does not allow the user to understand the significance of the risk difference. For example, if the risk of a building collapse was one in 100 years then, for many people, a 50 percent reduction in that risk would be worth having. If, on the other hand, the risk was one in one billion then it is unlikely that anyone would be prepared to pay for a 50 percent risk reduction.

While the NZSEE risk scores do not have an obvious risk interpretation, people are naturally inclined to give them one, and these interpretations can be well off the mark. We are used to seeing things scored on a scale of 0 to 100 and naturally associate anything with a score of below 50 as a fail, and unacceptable. Our instinct is to seek a score of two thirds or above as an acceptable score. From a life risk perspective, however, a building with a low %NBS score might be very low risk.

What is required is a risk measurement metric that tells people what the absolute level of risk is, allows them to compare the risk of an 'earthquake prone' building with risks they are exposed to in their day to day lives, and helps them make a judgment on whether it makes sense to strengthen a building.

The wrong risk metric is used

The NZSEE risk assessment focuses on the probability that a building will collapse or be severely damaged, but ignores the likelihood of death or injury when a building collapses. This likelihood will vary by building type, and is generally much lower for the most so-called earthquake prone building (in particular unreinforced masonry buildings), than for more modern buildings. The point is illustrated by the Christchurch experience. Many unreinforced masonry buildings collapsed, or came close to collapsing, but there were only four deaths of occupants in those buildings – a very low casualty rate given the large number of occupants. The casualty rates in the two relatively modern building failures were much higher.

The MBIE expert report (Taig 2012) provides more detail on this point and shows how unreinforced masonry buildings are no riskier than many much more highly rated buildings. In general, unreinforced masonry buildings may only be a quarter as risky as the NZSEE has represented them to be.

The relative risk adjustment in the Z factor not adjusted for the existing building standard

We have already explained that there are issues with the way the new building standard adjusts for seismicity in different areas. These problems will flow through into the existing building framework.

There is a further problem because assessments of relative seismicity that might be relevant to the new building standard, are not appropriate for the existing building standard. With the new building standard, the concern is with building damage that poses a risk to functionality, as well as life safety. Relative seismicity appears to have been largely been evaluated with respect to the relative frequency of shocks that will present a risk to building functionality.

With the existing building standard, the concern should be just with life safety. The assessment of relative seismicity, therefore, should be based on the relative frequency of those earthquake events that present a material risk to life. The difference in focus is extremely important, as the measure of relative seismicity will depend on the size of the earthquakes. The relative difference in the probability of large earthquakes is much larger than the relative difference in the probability of small ones.

To assess the impact of all of the problems with the Z-score adjustment we compared the life safety of buildings below the 34% NBS standard in both Wellington and Auckland using GNS science data presented in MBIE documents. The methodology and results are presented in the paper “The Flaw in the Score”. If the Z-score was correctly adjusting for risk then the life safety risk of below 34%NBS buildings should have been the same. It was not. Buildings below 34% NBS in Auckland were 250 times safer than in Wellington.

Our results will depend on the particular inputs we have used, in particular the NZSEE assumption about the relative strength of buildings at and below the 33%NBS level. Taking a more cautious approach lowers the gap but Auckland buildings with the same %NBS are still at least 100 times safer than Wellington ones.

Use of the NZSEE definition of earthquake prone building

The critical claim in NZSEE (2006) is that buildings with less than a 34%NBS rating are earthquake prone as defined in the Building Act. To make this link it was argued that the key limb in the legal definition of earthquake prone, that the building should be likely to collapse, is not part of the earthquake prone test, and that the legal test is that the building exceeds its Ultimate Limit state (ULS) in a moderate earthquake. The ULS is a technical calibration point used in the design of new buildings. At that point a building would be very unlikely to collapse.

In a recent decision relating to the question of whether the Christchurch Council could require buildings to be strengthened beyond the earthquake prone building standard, the Supreme Court of New Zealand (the Court found that they could not) considered the legal meaning of earthquake prone building. The Court said that:

*" It is clear that the standard set by s 122(1) is whether the building meets the 34 per cent of NBS benchmark in a moderate earthquake and **whether it is likely to collapse in a moderate earthquake."***

As both limbs of s 122(1) have to be met, the operative test is whether a building is likely to collapse in a moderate earthquake.

The NZSEE argument that the collapse criteria not part of the standard was put to the Court but the Court did not agree.

It is highly unlikely that most of the building that have been designated as earthquake prone would be likely to collapse in a moderate earthquake. In Auckland, a moderate earthquake is defined as having a force of 0.04g which is associated with a MMI 4 earthquake on the authoritative New Zealand Modified Mercalli Intensity scale. The moderate earthquake will have the following effects:

"Generally noticed indoors, but not outside, as a moderate vibration or jolt. Light sleepers may be awakened. Walls may creak, and glassware, crockery, doors or windows rattle."

And in Wellington a moderate earthquake is defined as having a force of 0.13g and is associated with a MMI 7 earthquake with the following effects:

" General alarm. People experience difficulty standing. Furniture and appliances are shifted. Substantial damage to fragile or unsecured objects. A few weak buildings are damaged."

The likelihood that a 34%NBS building will collapse in a moderate earthquake in Auckland is close to zero. In Wellington it is extremely low - probably in the order of a one in 10,000 chance. It is not possible to mount any plausible argument that buildings at the trigger point are likely to collapse. Nor is it generally possible to mount any plausible argument that buildings with %NBS ratings that are substantially lower than 34%NBS are likely to collapse in a moderate earthquake.

The implications of the Supreme Court's decision are far reaching. Earthquake Prone Building designations by local authorities are, we understand, based on the NZSEE methodology. Most are not lawful and should be withdrawn.

The NZSEE Risk Assessments and Recommendations

The NZSEE has assigned the following risk assessments based on buildings %NBS ratings.

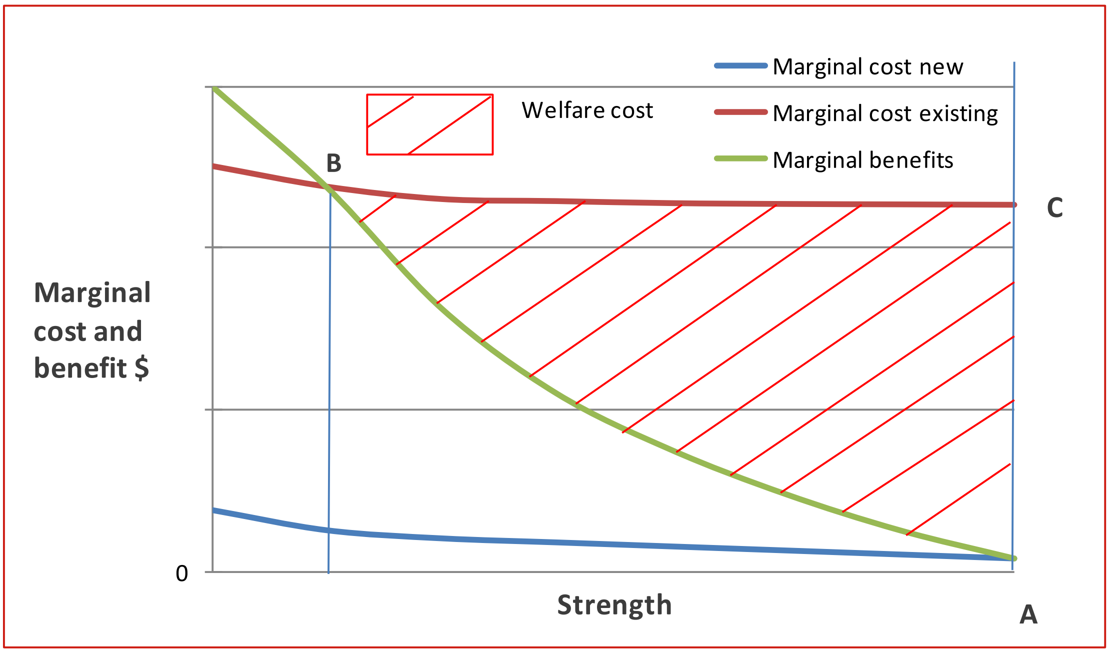
%NBS	Risk assessment
Less than 34	High risk
34-67	Medium risk
Over 67	Low risk

The NZSEE recommended that buildings should be strengthened to at least 67% NBS and preferably to 100%. This advice is based on the premise that all existing buildings should be as strong as new buildings. No consideration was given to the costs and benefits of reaching those standards.

The flaw in the NZSEE logic

The flaw in the logic of achieving the new building standard is obvious. The cost factor with new and existing buildings can be very different. The costs of upgrading a new building design for an improved level of seismic performance can be very low and in some cases may simply involve the reworking of the design at no extra cost. The cost of strengthening an existing building, on the other hand, can be very high. US government cost benefit studies show that it can often be as high as 50 percent of the replacement cost of a building and will generally mean that strengthening is not warranted. In New Zealand owners are often finding that the cost of strengthening can exceed the market value of a strengthened building. This point is illustrated in figure two, which shows, schematically, the optimal strengthening standards for new and existing buildings.

Figure 2 – Optimal strengthening for new and existing buildings



A – Optimal new building strength

B – Optimal existing building strength

C – Strengthening existing buildings to new building standard

Risk grading system is flawed

The NZSEE risk grading system represents buildings with a %NBS rating of less than 34 as high risk when they are not.

We found that that an Auckland office worker, in an unreinforced masonry building that would probably have a %NBS rating of less than 34%, has a 1 in a 140 million chance of dying in an earthquake over a year. Per hour, this risk is 16,000 times lower than being on the roads and 4000 times lower than flying.

Conclusions

The NZSEE risk assessment framework does not deliver logical and consistent results.

- Buildings with the same %NBS in different parts of the country will have very different risks
- Buildings with the same %NBS ratings in the same city can have different risks
- NZSEE framework assessments that buildings in much of New Zealand are 'high risk' are objectively and demonstrably false

- The 34%NBS trigger point for ‘earthquake prone building’ designations is not consistent with the legal trigger point.

The implications are clear:

- The NZSEE %NBS framework should not provide the basis for New Zealand’s seismic safety regime. It is time to start again and build an evidence based framework.
- Territorial Local Authorities that have based their Earthquake prone building assessments on the NZSEE recommendations should change their policies and withdraw their current designations.
- The NZSEE should withdraw its risk grading framework
- MBIE should withdraw its support for the NZSEE risk grading framework
- Building owners have suffered economic damage because of the NZSEE’s statements about building risk and flawed advice on strengthening strategies and are entitled to seek compensation for their loses. Under New Zealand law the NZSEE’s statements are a slander of title. A slander of title involves a party publishing matter that is untrue, disparaging to another's property and impacts on the value of that property.

References

NZSEE Study Group on Earthquake Risk Buildings (2006) ‘Assessment and Improvement of the Structural Performance of Buildings in Earthquakes’

Taig T., TTAC Limited and GNS Science (2012) ‘A Risk Framework for Earthquake Prone Buildings Building Policy: a report produced for the New Zealand Ministry of Business, Innovation and Employment’

Tailrisk Economics (2014) ‘Error Prone Bureaucracy’

Tailrisk Economics (2014) ‘The Flaw in the Score’