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SEISMIC RETROFITTING – TESTING FEASIBILITY

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ABSTRACT

As a result of the findings and recommendations of the Royal Commission of Inquiry into the Canterbury Earthquake Swarm of 2010-2011 the New Zealand Government has introduced new legislation that will require the mandatory strengthening of all earthquake-prone buildings in New Zealand. An earthquake prone building is currently defined as a building that is less than one third the seismic strength of a new building. If an owner does not wish to strengthen their buildings then they must demolish them. Seismic retrofitting of buildings is a form of property development and as such, the decision to retrofit or not should be based on a robust and soundly conducted feasibility study. Feasibility studies on seismic retrofitting can be particularly challenging for a number of reasons thus making it difficult for owners to make informed and sound decisions relating to their earthquake prone buildings. This paper considers the concept and process of feasibility analysis as applied to earthquake prone buildings and discusses the current challenges posed by such feasibility studies. A number of recommendations are made in an attempt to help develop a best practice model for decision making relating to earthquake prone buildings.

Keywords: Seismic retrofitting, Feasibility analysis, Earthquake-prone buildings

INTRODUCTION

The purpose of this paper is to discuss the concept of feasibility within the context of property development and in particular to consider how the concept of feasibility applies to the mandatory seismic retrofitting of earthquake-prone buildings in New Zealand. Earthquake-prone buildings are defined as buildings that will have their ultimate capacity exceeded in the event of a moderate earthquake and are buildings with a seismic capacity of less than 33% of new building standard (NBS).

A review of the relevant literature showed that substantial emphasis has been placed on finding technical structural engineering solutions to seismic retrofitting and to the analysis of existing building stock. This engineering emphasis has also flowed through into policy research and analysis and macro level cost benefit analysis. Little attention or research appears to have been undertaken in terms of identifying the characteristics of the building owners, the property market characteristic of their buildings or the motivations and decision making processes of the building owners. While structural engineering is a key component of earthquake mitigation this paper asserts that it is valid and useful to consider seismic retrofitting as an exercise not just in structural engineering but as an exercise in property development.

Earthquake mitigation measures such as seismic retrofitting of existing buildings are seen as a rational response to the risk posed by earthquakes. Evidence from past studies on hazard mitigation suggest that seismic retrofitting of earthquake prone buildings (EPBs) reduce loss of life and property, disaster relief costs, business interruption, and social and environmental losses from an earthquake disaster (Nuti and Vanzi 2003, Rose *et al.* 2007). However, despite these benefits and the growth of the technical knowledge base on earthquake risk mitigation, property owners are often unwilling to retrofit their EPBs (Hopkins 2005). The unwillingness of owners of EPBs to retrofit their EPBs has been a critical issue in earthquake pre-disaster planning and management. Many factors such as cost, risk perception and efficacy of mitigation measures interact to influence seismic retrofit decisions (Egbelakin and Wilkinson 2010, Lindell and Prater 2000a).

Many socio-psychologists have focused on the impact of risk perception on mitigation decisions, concluding that how people perceive and personalise earthquake risk significantly influences the types of protective decisions and behaviour adopted (Lepesteur *et al.* 2008, Lindell and Prater 2000b, Lindell and Prater 2002, Mulilis and Duval 1995, Tierney *et al.* 2001, Weinstein *et al.* 1998). Sociologists have studied the social aspects of earthquake risk mitigation. The idea that risk is essentially a cultural and social construct has been strongly argued by sociologists such as Douglas and Wildavsky (1982). As they put it "the measurement of risk is scientific, the acceptability of risk is political". The current debate in New Zealand on seismic mitigation revolves around both the measurement of risk levels in different parts of the country and also the degree to which these risks should be accepted by the community.

Some research in New Zealand (Egbelakin and Wilkinson 2010, Egbelakin *et al.* 2011) has tried to identify the impediments to the successful implementation of earthquake mitigation. It was identified in this research that although the level of awareness was high amongst building owners that were surveyed there was limited appetite for carrying out seismic retrofitting. High costs and low benefits of seismic retrofitting were found to be impediments. The research also identified a lack of trust and belief in seismic techniques and professionals which is a problem that has been exacerbated by controversy and publicity over widely varying seismic assessments of the same building by different engineers. For example, it has been reported (Cantabrians Unite, 2012) that a building in Greymouth had five separate evaluations carried out which resulted in assessments of 5%, 28%, 30%, 54% and 67% of new building standard (NBS). This particular building was a 17 year old single level retail building of comparatively modern construction which should have made it easier to get consistent results.

The quality of risk information provided to owners, the communication style, and the characteristics of the agencies responsible for conveying this information also affect building owners' willingness to adopt protective measures (Mileti and Fitzpatrick 1993, Mulilis and Lippa 1990, Pidgeon *et al.* 2003, Tierney *et al.* 2001).

There has been some limited economic research focussing on the financial viability of valuation decisions and policies regarding hazardous situations, thus providing a rationale on the overall economic benefits of implementing various mitigation measures (Bernknopf *et al.* 1990, Cohen and Noll 1981, Schulze *et al.* 1987). A number of studies on earthquake risk and property market prices found correlations between risks information and communication style, property values, location, government initiated policies and programs, house prices, investment decisions and owners' attitudes towards implementing mitigation measures (Beck *et al.* 2002, Onder *et al.* 2004, Palm 1985, Palm 1987, Willis and Asgary 1997).

In dealing with the risk relating to earthquakes there is clearly a scientific element relating to the need to study a natural phenomenon. However, what is an acceptable level of risk for society is a subjective and political question. In order to aid policy development and insurance underwriting a large body of literature has been produced by experts in the fields of engineering, insurance, and economics. In particular a lot of effort has been put into improving the field of hazard assessment and various types of cost-benefit analysis (CBA). Earthquakes are low probability but high consequence events. The challenge of calculating the probability of earthquakes occurring and of then estimating their likely impact has received a lot of attention from both the insurance industry and earthquake engineers (Cardona *et al*. 2008a, Cardona *et al*. 2008b, Vanzi 2002, Bommer 2002).

Any CBA is reliant on the gathering of accurate data and sound scientific assumptions. This is particularly the case for low probability but high consequence events such as earthquakes. A traditional CBA was applied as part of the policy development undertaken by the New Zealand government. This CBA (Martin Jenkins, 2012) calculated the net present value of mandatory strengthening as negative $1,680 million. The benefits were assessed as reduced building damage, and a reduced loss of life and injury. The analysis was done on a macro level with no attempt to split out the private and public components of the costs and benefits or to consider the costs and benefits on an individual building basis.

Any attempt to carry out CBA on seismic retrofitting buildings in New Zealand is currently hamstrung by a lack of good data relating to existing building stock and the costs of retrofitting. There has been significant research done on building performance (Ingham and Griffith, 2011), and retrofitting techniques but basic information relating to earthquake strengthening costs is lacking in relation to New Zealand with the exception of some work done by Hare (Hare, 2009). Hare analysed the costs of seismic retrofitting a sample of heritage buildings in Christchurch. The general lack of cost information was highlighted in the Royal Commission and appears to contrast with the situation in the USA where extensive research has been done by the Federal Emergency Management Agency (FEMA, 1994).

Cost benefit analysis tends to be on a macro level that considers the problem at a national, regional or city scale. Typically the methodology looks at the total benefits and costs with no attempt to consider to whom the benefits accrue or who must bear the costs of the mitigation. While this may be useful in terms of the insurance industry and policy analysts it fails to address the benefit to cost ratio from a building owner perspective. For many owners this ratio is negative and is a major impediment to both voluntary and mandatory seismic retrofitting as discussed by Nahkies (Nahkies, 2009, Nahkies, 2013). Although this problem has been highlighted in the media, professional publications and submissions to the government review there remains a lack of empirically based academic research in this area. Research using the small provincial town of Waimate, New Zealand as a case study illustrated how empirical data could be gathered and also highlighted the 'feasibility gap' that is the major impediment to seismic retrofitting in many parts of New Zealand (Nahkies, 2014).

On the 4th September 2010 the Canterbury region suffered a 7.1 magnitude earthquake which caused significant damage in Christchurch city but no loss of life. Thousands of aftershocks of varying strength have occurred since but on 22nd February 2011 a 6.3 magnitude earthquake struck Christchurch causing the catastrophic collapse of many buildings and killing 185 people and injuring many more. The February earthquake caused extensive damage to the Christchurch Central Business District (CBD) leading to the subsequent demolition of the majority of buildings in the CBD.

As a result of the earthquakes and the resultant loss of life and damage, the New Zealand Government convened a Royal Commission of Enquiry on the 13th April 2011. The Commission met for the first time on the 4th May 2011 and were required to provide a Final Report to the New Zealand Government by not later than the 12th November 2012.

This Final report was delivered in several parts. Part One delivered on the 29th June 2012 consisted of 3 Volumes. Part Two of the Final Report was delivered on the 10th October and consisted of Volume 4 "Earthquake-prone Buildings". This volume recommended practice, policy and legislative changes to help minimise the risks to public safety from earthquake-prone buildings. This report was eventually released to the public on the 7th December 2012 and identified and highlighted the lack of progress that had been made in New Zealand in terms of seismic retrofitting despite legislation promoting this process that dates from the 1950's.

The earthquakes and the Royal Commission of Enquiry also triggered an earthquake-prone building policy review by the Ministry of Business, Innovation and Employment (MBIE) which began in March 2012. The aim of the review was to eventually introduce new legislation in the form of a "Building Act Amendment Bill". As part of this process MBIE released a consultation document "Building Seismic Performance" on the same day that the Royal Commission report was released. The MBIE document set out proposals to improve the New Zealand earthquake -prone building system.

The consultation document contained a number of proposed changes to the current legislation and compared and contrasted them with the recommendations contained in the Royal Commission Report. The MBIE consultation document called for submissions which closed on the 8th March 2013. As part of the consultation process a series of public information meetings were also held as well as additional meetings with stakeholder groups directly involved with implementing the earthquake-prone building system. Although the Royal Commission recommendations were not binding on the government they were clearly considered as part of the review process.

Following the MBIE review and consultation the Building (Earthquake-prone buildings) Amendment Bill was introduced into Parliament and passed its first reading on the 5th March 2014. The major features of the Bill are the following:

- All local authorities are required to assess buildings within 5 years
- Owners of buildings identified as earthquake-prone are required to either strengthen or demolish their buildings within 15 years
- Owners of some heritage buildings are able to apply for a 10 year extension
- The setting up of a publicly available national register of earthquake-prone buildings
- The delinking of fire and disabled access upgrades from seismic upgrades in certain circumstances
- Exemptions from national timeframes for a limited number of buildings upon application

Despite widespread support from virtually all of the political parties the Bill has attracted considerable debate. Many of the submissions to the Local Government and Environment Select Committee considering the Bill were highly critical. Some of the criticism was that the Bill was too 'soft' and did not adequately reflect the recommendations of the Royal Commission. However, the bulk of the criticism was that the Bill was too draconian and inflexible and would impose too high a cost on communities and individuals. The Select Committee are due to release their report on the Bill on the 30th March 2015 and there are expectations that there will be significant amendments to the Bill. It is expected that the proposed legislation will be 'softened' to better achieve a balance between cost and safety.

Regardless of the eventual outcome in relation to the legislation, the successful implementation of any seismic retrofitting programme will rely on creating an economic environment where the option of retrofitting is the best option for the property owner. The property owner is the decision maker and unless seismic retrofitting is the most attractive option they may well choose to demolish their buildings or attempt to circumvent the legislation by whatever means are available to them. The decision making process of the property owner and the vexed question of feasibility that confronts the private property owner are both important factors to consider when developing policies to encourage seismic retrofitting. Automatically assuming that the majority of owners will upgrade their building to comply with the legislation is dangerous as clearly the owner has a number of alternative options.

WHAT ARE THE OPTIONS AVAILABLE TO THE OWNER?

The owner of a building forced by statute to carry out a mandatory seismic retrofit will make their decision based on their own particular circumstances and their analysis of their potential options. They will attempt to analysis which of their various options maximises their well being. For the owners of investment property their well being is maximised by achieving the best financial result. Due to the impacts of the proposed mandatory strengthening this may mean a case of trying to achieve the smallest loss rather than the traditional property development goal of achieving the maximum financial gains. The four basic options available to the owner in response to the proposed legislation are to:

1. Do nothing (defer decision)
2. Sell the property
3. Demolish the building
4. Carry out a seismic retrofit

The costs and benefits of each of these options will need to be considered in order to arrive at a rational decision.

The Do Nothing (Defer) Option

The "Do Nothing Option" is only viable for the time periods available under the proposed legislation. However, this option also raises a number of questions in terms of the robustness of any enforcement procedures proposed by the legislation. There may be the potential to mount legal challenges and use delaying tactics to buy more time. For most owners there is the potential to put off any seismic retrofit for at least 15 years but with the expectation that they will eventually be served a notice enforcing action in terms of either retrofitting or demolition. Thus the "Do Nothing" option is only an interim strategy before one of the other options must be chosen.

This option does have a number of potential advantages in that there will be time to carry out thorough investigations and feasibility studies. Those feasibility studies are likely to be more accurate as there will be better cost and market information available based on a large number of completed projects carried out by those "early movers" quick to comply with the legislation. There is also the possibility of benefitting from improved technical solutions and construction efficiencies due to the increased research and work in the seismic retrofit industry. Demand for materials, contractors and design consultants may be less in future years than is currently the case. Any earthquake related stigma may also have dissipated over time and this may improve the economics of retrofitting. There is also a chance that the legislation may change over time. Changing legislation has caught out many owners who have already carried out seismic retrofits under old legislation but now find themselves non-complying with the current and proposed legislation.

There are also a number of potential disadvantages in that it may be difficult to retain tenants if the property is an investment property. The costs of insurance may be high or insurance may be hard to obtain due to the unstrengthened nature of the building. Potentially high holding costs associated with this option may cause financial difficulties for some owners. It is also possible that banking covenants may not allow this option for some owners as they may not have sufficient equity or debt servicing to satisfy a lender. As a result a mortgagee sale may be triggered.

Clearly the advantage and disadvantages would need to be weighed up but for some owners taking a "wait and see' approach may be a good option as an interim measure.

Sell the Property

By selling the property the owner is able to avoid the need to become a developer. They run the risk of achieving a low sale price if there is market stigma attached to their building either because of heritage controls on the building or perceptions relating to earthquake strengthening. They may also achieve a high price if they can find an uninformed purchaser not familiar with the market or the limitations of the property.

The outcome of the sale will likely depend on the number of competing properties on the market. If large numbers of owners take this option then this may lead to an oversupply situation which will depress market values. This is a danger for some provincial towns in New Zealand where the proposed legislation could trigger a recession in the commercial real estate markets particularly if there is little existing demand for new buildings.

Demolish the Building

This is an action that may be forced on the owner in order to comply with the proposed legislation if they have done nothing within the currently proposed 15 year timeframe. It may also be an action they choose to do voluntarily as it makes better economic sense than carrying out a seismic retrofit. For many owners the demolition option is reliant on the ability to be granted a consent to demolish a heritage building. This ability will vary from heritage building to heritage building depending both on the heritage status of the building and the specific planning rules that apply in the locality.

In their assessment of this option the owner needs to get a clear indication of the likely costs of demolition which for some buildings can be substantial. The costs of demolition will then need to be deducted off the value of the site to get the net redevelopment value of the land. They must also consider their options post demolition in terms of whether they then intend to sell the property or alternatively whether they wish to develop some form of replacement building.

For some properties there may be a substantial benefit to the demolition option if it allows them to unlock development potential lying dormant in the site. Alternatively it may be a poor alternative where the underlying land value is low in comparison with the demolition costs.

Carry Out Seismic Retrofit

In order to decide how this option 'stacks up' the owner will typically need to carry out a feasibility study. At a basic level at least the owner will need to compare the market value of their property "as is" with the market value "after strengthening". Ideally the value difference between the two valuations will exceed the costs of strengthening thus providing a positive economic incentive to carry out the work. If the cost of the retrofit exceeds the value added to the property then the owner is losing money by carrying out the retrofit and has no economic incentive to carry out the work.

For certain types of property and owners, non-financial factors may also be important in terms of decision making. This is often the case with owner occupiers, where the value added impact of seismic retrofitting may be measured using different criteria to that of market value. The impact on the value-in-use of the property may be more important than the value-in-exchange of the property particularly for special purpose or non-traded properties such as churches, halls, schools etc. However, many earthquake-prone buildings are commercial properties owned as investments and decisions relating to whether to carry out seismic retrofitting will hinge around their feasibility.

THE CONCEPT OF FEASIBILITY

In a general sense the term feasible is synonymous with words such as practicable, achievable, attainable, viable and realistic. The term "feasibility" is defined by the Oxford Dictionary as the "state or degree of being easily or conveniently done" and a "feasibility study is defined as "an assessment of the practicality of a proposed plan or method".

Seismic retrofitting is a form of property development and in reviewing the literature the most widely accepted and quoted definition of "feasibility' in relation to property development was that formulated by James Graaskamp (Jarchow, 1991). His definition is as follows:

A real estate project is feasible when the real estate analyst determines that there is a reasonable likelihood of satisfying explicit objectives when a selected course of action is tested for fit to a context of specific constraints and limited resources

Each part of the definition is important in terms of providing clarity around what is actually meant by a real estate project being feasible.

The term "reasonable likelihood" provides a grounding of realism in that the expected outcome must not be fanciful or improbable while at the same time recognising that the ultimate completion of the project brings with it risks and no guarantee that the final results will match the feasibility study outcome.

The “satisfying explicit objectives” requires that the parameters of success are set before any conclusions regarding feasibility can be made. The objectives of all “stakeholders” should be taken into account and not just those of the developer. The type of building and developer will influence the likely objectives. For example an owner- occupier like a Church doing a seismic retrofit may have quite different objectives to that of the owner of an investment property doing a seismic retrofit. For entrepreneurial developers the major explicit objective is to make a satisfactory profit from the development. Clearly in all cases the public sector will also have objectives which they will promote by both regulatory and non-regulatory means.

The definition also talks about a “selected course of action” which means that out of a multitude of potential options one must be tested and selected as being feasible. The chosen option will ideally be the optimum that is likely to achieve the best result for the developer and other stakeholders. The element of time must also be considered as the selected course of action must be implemented within a certain “window of opportunity”. As a result all feasibility studies have a limited ‘shelf life’ before they need updating.

The selected course of action is tested to show that it fits within the “context of specific constraints”. These constraints will be physical in terms of the site and will also include legal and resource management constraints. For seismic retrofits the physical characteristics of the existing building will also need to be considered as part of the site constraints.

As well as specific constraints the definition also refers to “limited resources”. This recognises that the developer must have access to sufficient capital, labour and knowledge to be able to carry out the development. A project that is feasible for one developer may not necessarily be feasible for another developer due to the different amounts of resources that are available to different developers.

There are a number of challenges to carrying out a good feasibility study for any substantial property development. These challenges can be even greater for many seismic retrofit projects. This is illustrated by considering the application of the Graaskampf definition to seismic retrofitting.

THE CONCEPT OF FEASIBILITY APPLIED TO SEISMIC RETROFITTING

Reasonable likelihood

Forecasting financial results in the form of a feasibility study requires the making of assumptions and the estimation of costs and returns. Forecasts can be improved and risk reduced where the estimates are accurate and the assumptions are either confirmed as correct or replaced by known variables. As discussed in more detail later in this paper gathering accurate data and validating assumptions can be particularly challenging for seismic retrofits.

Satisfaction of explicit objectives

The explicit objectives for any development will be unique to the developer and the development project. However in general for a seismic retrofit project there will be a clear objective relating to seismic risk reduction. The engineering profession in New Zealand has tried to capture or describe this risk reduction by using percentage NBS as the benchmark for structural strength (and thus risk). In the case of a mandatory retrofit imposed by legislation as a minimum the retrofit would be expected to meet the requirements imposed by the legislation – currently proposed to be 33.33% NBS. In certain cases the owner may decide to exceed the standards imposed by the legislation.

Where development is being carried out to make a profit there would be financial objectives that would need to be met in order for the development to be considered to be feasible. For ‘normal’ property developments a satisfactory developers ‘margin’ or profit should be created to compensate the developer for their work to bring the development to fruition and to compensate for the risk involved in the development. The size of this margin will vary from developer to developer depending on the risk they perceive for the development and the perceived effort required. For normal developments the margin must be attractive enough to motivate the developer to want to undertake the development. For mandatory strengthening projects the owner/developer is potentially being forced to do the development but will still realistically factor in the effort and risk involved when considering feasibility.

Forecasting the financial outcome of the retrofit project will often be highly challenging due to the difficulty of obtaining accurate costs and returns. Clearly a key component of any feasibility study is an estimate of the costs involved in doing the development. Estimating the cost of a new build is generally easier than estimating the costs of making changes to old buildings. It is easier to define the scope of works relating to new buildings where as when working with old buildings there may be incomplete plans and specifications to allow the accurate assessment of how the building was constructed and how it will perform structurally. To an extent this lack of knowledge can be overcome by testing, but this takes time and money. Due to the age of the building it may have deteriorated in various ways depending on maintenance programs and the environmental conditions acting on the building. Such deterioration may not be uniform which means that even more testing is required. Initial assumptions regarding construction and condition may prove wrong once testing is completed or work is begun. Seismic retrofitting often involves partial deconstruction or demolition which may also show that initial assumptions are wrong. There may also be difficulties in accurately estimating the time frames required to carry out the retrofit project.

The seismic performance of buildings is also heavily influenced by ground conditions so that geotechnical investigation may be required or once again assumptions may need to be made in the absence of testing.

Multiple potential design alternatives may be available with different combinations of labour and materials each with their own cost scenarios. If a mandatory strengthening regime is enforced this is going to lead to considerably increased demands on a construction industry already stretched due to the Christchurch rebuild. This in turn leads to inflationary pressures that make it more difficult for quantity surveyors to accurately estimate costs.

A major issue with seismic retrofits is correctly defining the scope of the project. The Project Management Institutes document "A Guide to the Project Management Body of Knowledge" (PMBOK Guide) describes the scoping exercise as developing a detailed description of the project and product. It states that "the preparation of a detailed scope is critical to success and builds upon the major deliverables, assumptions and constraints that are documented during project initiation." The structural engineer often takes the lead role in designing the seismic retrofit with much of the emphasis regarding choice of upgrade solution based around the optimum structural design. There is a danger that this focus on the structural elements of the project actually leads to a sub-optimal solution and that project costs are either under estimated or are higher than they need to be because too little attention is paid to the non-structural components of the seismic upgrade project. Research by Riddell (2013) showed that the non-structural costs can be as significant as the structural costs. Riddell carried out detailed cost analysis relating to seismic upgrades to 66.66% of NBS for three different buildings and came up with the following results.

Building Description	**Structural Alterations**	**Other Costs**	**Total Costs**	**Structural Costs as % of Total Costs**
3 Storied URM Building of 1893m² built in the 1880's	\$407 m²	\$1192 m²	\$1599 m²	25.45%
2 Storied URM building of 727m² built in the 1930's	\$433 m²	\$1406 m²	\$1839 m²	23.54%
2 Storied URM building of 306m² built in 1912	\$604 m²	\$2172 m²	\$2776 m²	21.76%

Although the analysis is based on a small number of buildings it does highlight that the structural component of the seismic upgrade may represent a comparatively small proportion of the total project cost. To the cost of the structural alterations a number of "Other Costs" need to be considered such as the following items:

- Persons with Disabilities Upgrade
- Fire Upgrade
- Services Reinstatement
- Ancillary Works (Demolition, reinstatement, modifications to allow structural alterations)
- Consultants (Lead and sub consultants)
- Tenant Costs (Rent holidays, relocation costs, legal costs)
- Contractors Preliminary & General
- Contingency Costs

As well as the challenges of accurately forecasting the scope and cost of a seismic retrofit the need to estimate the financial returns from the development is also likely to be difficult. Depending on the market there may still be a degree of market 'stigma' attached to an old but strengthened building not unlike the stigma that can attach to a contaminated site that has been remediated. Such 'stigma' can be hard to measure and can vary significantly over time depending on perceptions relating to earthquake risk. The real estate market is an inefficient one where accurate market information may be difficult to obtain and validate. Lack of good comparable sales or rental information may cause problems along with distortion in the market caused by market transactions between poorly informed vendors or purchasers.

In some markets where there is a high proportion of earthquake prone buildings such as some provincial towns the results of mandatory seismic retrofitting may totally change the market in terms of supply and demand for property. For example the price of land might be reduced by a flood of redevelopment sites released to the market due to widespread demolition of earthquake prone buildings.

Selected course of action

In considering feasibility a selected course of action must be identified. In practice multiple options are often tested in the form of a rough "back of the envelope' feasibility analysis before more time and money is spent on the option identified by this screening process as being the best. Selecting the best option in terms of seismic retrofitting can be difficult due to the challenge of identifying the most appropriate level of strengthening to aim for. Instead of designing for the level of strength required by the legislation there may be good reasons to try and achieve a higher level of strengthening. For example, it may be that the occupants of buildings do not feel safe at this level and require a higher level before they are willing to lease a building. This has been the case in some markets where corporate tenants concerned at the need to comply with their obligations under the Health and Safety in Employment Act have been requiring buildings to be strengthened to at least 66% of NBS. As a result buildings in Wellington have been undergoing seismic strengthening even though they are comparatively modern buildings that already exceed 33.33% of NBS. An example of this is the Majestic Building.

Going to higher levels also provides a degree of future proofing as it may allow for a "change of use" to occur in the building without triggering the need for additional strengthening. Current legislation requires that a building undergoing a "change of use" must be brought up to "as near as reasonably practicable" to the standard of a new building. This allows a degree of discretion to the Building Consent Authority in which the sacrifice or cost that must be met by the owner can be weighed against the public benefits accruing from the upgrade. Where the cost is prohibitive a level less than 100% of NBS is often accepted as being adequate. This is a pragmatic approach that recognises that it is not always feasible both from an engineering or a financial point of view to achieve 100% of NBS.

Heritage buildings can be particularly problematic due to the desire to make the earthquake strengthening work as unobtrusive as possible which can increase the technical and financial challenges considerably. There is also the irony that high levels of strengthening work ideally should be achieved to better safe guard the heritage building from potential earth quake damage. The challenge is to do this in a way that that does not destroy the very heritage fabric that you are trying to protect.

In many instances the process may well need to be an iterative one where multiple designs achieving different levels of structural strength are costed out and tested for fit in terms of market and heritage requirements.

Although there are common building typologies that can and have been identified and well proven upgrade systems there is often a bespoke element involved in any seismic retrofit. Different engineers may come up with different designs depending on their expertise and confidence. The level of experience and expertise with analysing existing structures and developing appropriate upgrade solutions is highly variable across the engineering profession with the bulk of the education effort traditionally applied to learning about new construction and modern materials. There is a danger in the current risk averse environment that over engineered solutions will be employed in retrofit projects when cheaper options may be sufficient.

Tested within the context of specific constraints

Identifying the specific constraints relating to seismic retrofitting requires good analysis of the site which requires analysis of both the soils providing support for the buildings and the buildings themselves.

Specific constraints also take the form of land use controls imposed under the Resource Management Act. Many earthquake-prone buildings also have heritage value and have various levels of protection from demolition or alteration. When doing retrofits they must be done in a way that reduces negative impacts on the heritage value of the building which adds to the technical difficulties and costs of the retrofit. It also may be far from clear as to whether the owner is allowed to pursue the option of demolition.

It has been widely expected that the health and safety requirements of the Building Act would 'trump' any heritage protection controls imposed by the Resource Management Act. Speculation has been that large numbers of heritage buildings would be demolished due to their earthquake-prone nature despite existing heritage rules protecting them. However, recent case law relating to the Harcourts Building in Wellington has cast some doubt regarding this.

The Harcourts Building was completed in 1928 for T&G, an Australian insurer. It comprises 7 storeys of office accommodation and a small rooftop flat. The ground floor is occupied by retail premises. It was listed for protection in the Wellington District Plan in 1994 and is a Category I listed building under The Heritage NZ Act.

In June 2011 Mark Dunajschik, the owner of the building was quoted in the Dominion Post as saying the Harcourts Building had lost nearly half its value since the Christchurch quakes. He said it was previously valued at between $20m and $22m but was now worth only about $12m. He signalled his intention to demolish and build a 25 storey office building on the site.

The building had been assessed by the Wellington City Council as meeting only 17% of the new building standard and thus was deemed to be an "earth-quake prone building." As a result the Council issued a section 124 notice on the 27th July 2012 to the owners requiring them to either strengthen the building or demolish it within 20 years.
Dunajschik applied for a resource consent to allow demolition and the Wellington City Council Planners recommended the consent for demolition be granted due to the risk posed to public safety. The hearing was held in December 2012 and the resource consent was declined.

This decision was appealed to the Environment Court who upheld the original decision. Dunajtschik then appealed against the Environment Court decision in the High Court. The High Court found in his favour and the case was sent back to the Environment Court. The Environment Court re-heard the case but came to the same decision as previously which is to not to allow demolition to take place due to the loss of heritage value that will occur.

The situation with the Harcourts Building is an interesting one as it highlights the dilemma faced by many building owners with earthquake-prone buildings. Comprehensive feasibility studies were prepared at substantial cost that reached the conclusion that due to the high costs of earthquake strengthening (estimated at $10.85 million) the property in an "as is" state is worth nothing. If the buildings were able to be demolished it is estimated to be worth $3.17 million as a redevelopment site, however that is no longer a feasible option.

The Harcourts Building also highlights the unresolved tension between the Resource Management Act which seeks to protect heritage and the Building Act which seeks to promote a safe built environment. It shows that the option to demolish may not always be available to an owner and this will need to be an important consideration in any feasibility study.

Limited Resources

Feasibility is not a hypothetical situation but one that must be achievable or practicable for a particular developer. In the case of a 'normal' development the role of the developer is a voluntary one and the feasibility analysis process is carried out so that the developer does not undertake a development beyond their resources. In the case of mandatory seismic retrofits the role of developer is forced on the owner regardless of their resources and thus the retrofit may not be feasible for the owner. The legislation has the impact of creating a large number of accidental developers who may be ill equipped or resourced to undertake developments. Resources required to undertake developments are capital and knowledge – both of which may be hard to acquire for the owner. These accidental developers may have little understanding of the development process or know what is required to carry out a feasibility analysis.

CONCLUSIONS

The lack of progress in retrofitting earthquake-prone buildings that was exposed by the Christchurch earthquakes and highlighted by the Royal Commission is a result of market forces and poor feasibility. The imposition of stronger regulation is unlikely to solve this problem. However, the potential delinking of disabled persons and fire upgrades will improve the feasibility for many buildings.

Unless the feasibility equation is improved the result of stronger regulation is likely to lead to widespread demolition of buildings rather than seismic retrofitting. This is an outcome that has not been considered in any cost benefit studies or adequately acknowledged by policy makers.

There are a number of non-regulatory approaches that could enhance feasibility such as tax relief, financial grants, and free advice that need to be considered. The use of non-regulatory approaches has the benefit of allowing a recognition of the mix of public and private benefits and costs that are applicable to seismic retrofitting.

Policy development has been clearly handicapped by a lack of information relating to the number and type of buildings that are earthquake prone, the likely costs and value impacts of seismic retrofitting and the characteristics and resources of the owners of earthquake-prone buildings.

As well as handicapping policy development the lack of accurate cost information is a serious issue for owners carrying out feasibility studies in order to make sound decisions. Unless the scope and cost of the retrofits can be accurately assessed the value of any feasibility study as a decision making tool will be severely compromised. There is some evidence that both scope and cost are currently being underestimated with too little attention being paid to the non-structural cost items associated with retrofits.

Seismic retrofits can often be complex and challenging development projects requiring extensive development expertise. Many owners of earthquake prone buildings lack this expertise and are unlikely to understand the development process.

There is current uncertainty as to the degree to which heritage protection legislation 'trumps' earthquake prone building regulation which therefore can introduce uncertainty into the feasibility analysis process.

The feasibility of retrofitting could be considerably improved by allowing staged development where the main driver of the retrofit is regulation and not the market. This may take the form of allowing a securing process similar to the "bolts and braces" approach used to strengthen URM buildings in San Francisco. The next stage is to bring the building up to a higher level based on the "sweet spot" of the building as discussed by Ferner *et al* (2014) as being a level of strengthening that utilises existing building elements as much as possible. A third stage could eventually be undertaken to strengthen the building up to some suitable "aspirational" level.

Both the current and proposed legislation place too much emphasis on achieving an often arbitrary and contentious percentage of NBS. Increased focus should be placed on the identification and remediation of major risk elements in the building. Such an approach would be complimentary to the staged development approach.

Feasibility could be improved by flexible time frames. This flexibility could be based around negotiations in terms of proposed risk reduction and staged development. For example early implementation of Stage One could 'buy' you more time to do Stage 2. Such an approach would achieve the greatest gains in risk reduction over the shortest time. Where there are good reasons to either speed up or slow down the process these should be negotiated and 'locked in' with the owner. For example this might revolve around planned maintenance and/or changes in tenancy.

RECOMMENDATIONS

Identify and consider all options

All four options of defer, sell, demolish, or retrofit should be considered by the owner. This will require a number of consultants including a valuer in order to obtain market information that will be key to assessing the various options for the owner. Within the retrofit option there will be a number of options to consider with a key decision to be made regarding what level of seismic upgrade to implement and the extent of additional non seismic upgrades to be included.

Allow Adequate Time and Money

The feasibility study may be challenging and potentially require substantial time and money which the owner will need to budget for. Considerable time may also be required in terms of completing the feasibility study. For example completing engineering assessments of the building and site may be a lengthy process.

Ensure full scope of works is considered and costs

Care must be given to ensuring that a full "scope of works" is developed when analysing costs and that due consideration is given to the non-structural component of the project. Care must be taken that costs are not missed out or alternatively double counted.

Use a multidisciplinary design team early in the process

In projects where the non-structural costs are significant a range of design expertise should be employed early in the design concept stage and the lead designer should not necessarily be the structural engineer. For example with buildings of high heritage value a conservation architect should be used early in the process to help guide structural designs. The cheapest structural solution may not always be the optimum design as any potential structural savings may be 'swamped' by increased costs of a non-structural type. Advice from contractors and valuers may also be valuable at the preliminary design stage.

Use an appropriate project delivery option

In considering project delivery options the owner should consider other options to the traditional tender process. Other options such as design-build or negotiated contract should be considered as they may reduce the time and costs involved.

Consider timing and staging of development

If the initial feasibility of retrofitting appears poor then the owner should consider the option of staging the retrofitting and/or deferring it until market conditions or other circumstances become more favourable.

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