A DECADE OF PROGRESS SINCE THE EDGECUMBE EARTHQUAKE: RISK AND INSURANCE

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SUMMARY

The 2 March 1987 Edgecumbe earthquake of magnitude (ML) 6.3 resulted in a total loss of some NZ$430M and an insured loss of about NZ$330, (non inflation adjusted). Coupled with other world wide natural disasters resulting in large loss costs, particularly insurance costs, the Edgecumbe earthquake contributed to increasing international costs from natural hazards. As well as putting increasing demands on the world insurance markets it also drew attention of insurers to the potential of earthquake loss in New Zealand. With insurance at higher premium rates, and in some situations difficult to obtain cover, there developed increasing demand for loss assessments and risk management applications. The basic development of earthquake loss methodologies had been established in the early 1980's. Developments of the decade following the Edgecumbe earthquake have focused on refinement of these methods, research and collection of data, applications of computer systems, and extensions to other applications.

INTRODUCTION

The Edgecumbe earthquake was a very significant contributor to natural hazard losses in New Zealand, see Figure 1. As well as being a reminder of potential losses from earthquake it reinforced a New Zealand trend of increasing losses from natural hazards, (flood and storm).

The Edgecumbe earthquake also contributed to the international trend of exponential increases in losses from the effects of natural hazards. See Figures 2 and 3. The contribution of earthquake to these losses is shown in Figure 4, which includes losses shown in Table 1.

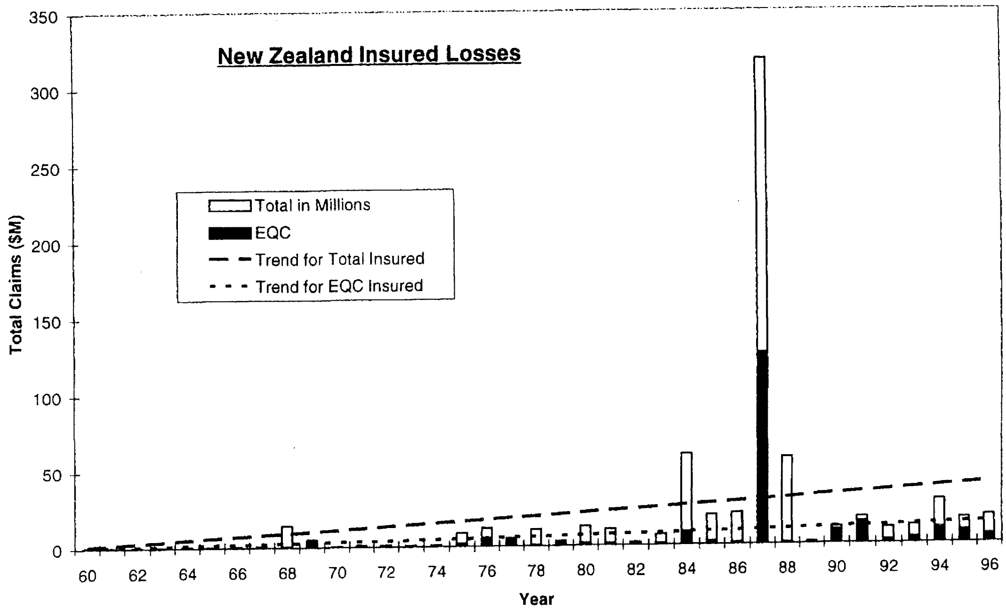

FIGURE 1: New Zealand insured losses from Natural Hazards. (Earthquake Commission and Private Insurers)

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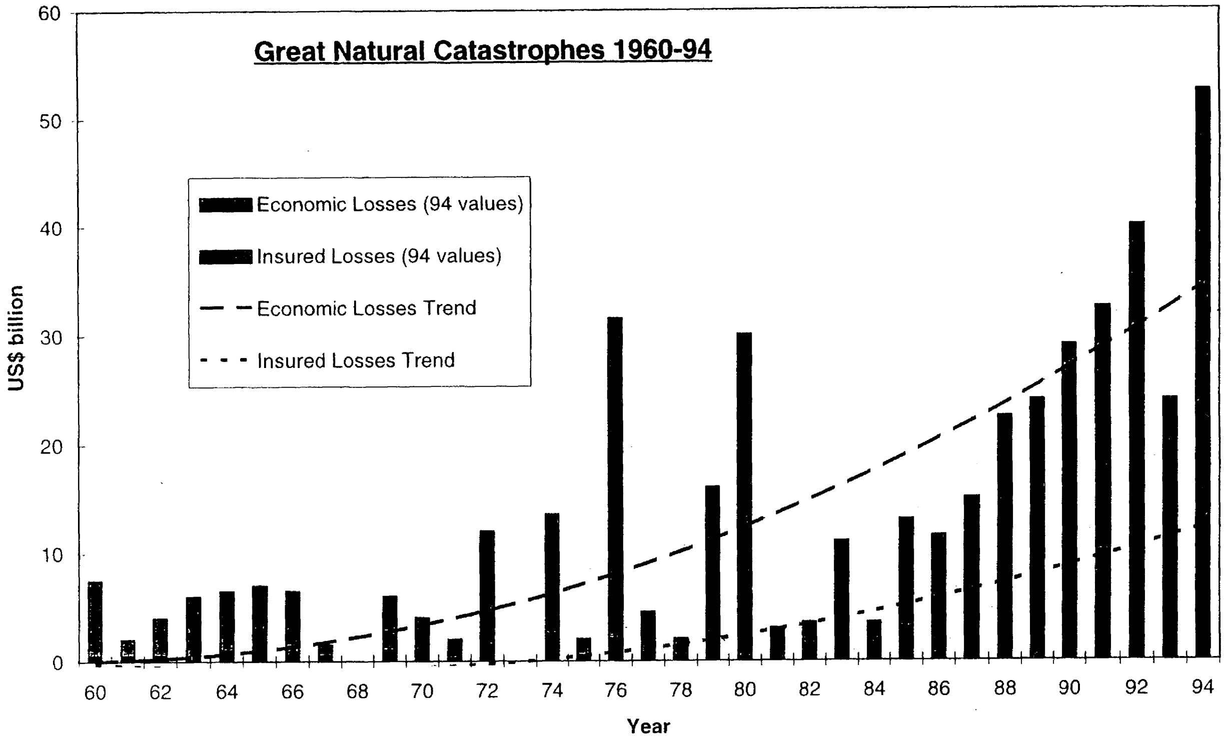

FIGURE 2: Great Natural Catastrophe Loss Costs, 1960 to 1994. Munich Reinsurance, Schadenspiegel 1/95.

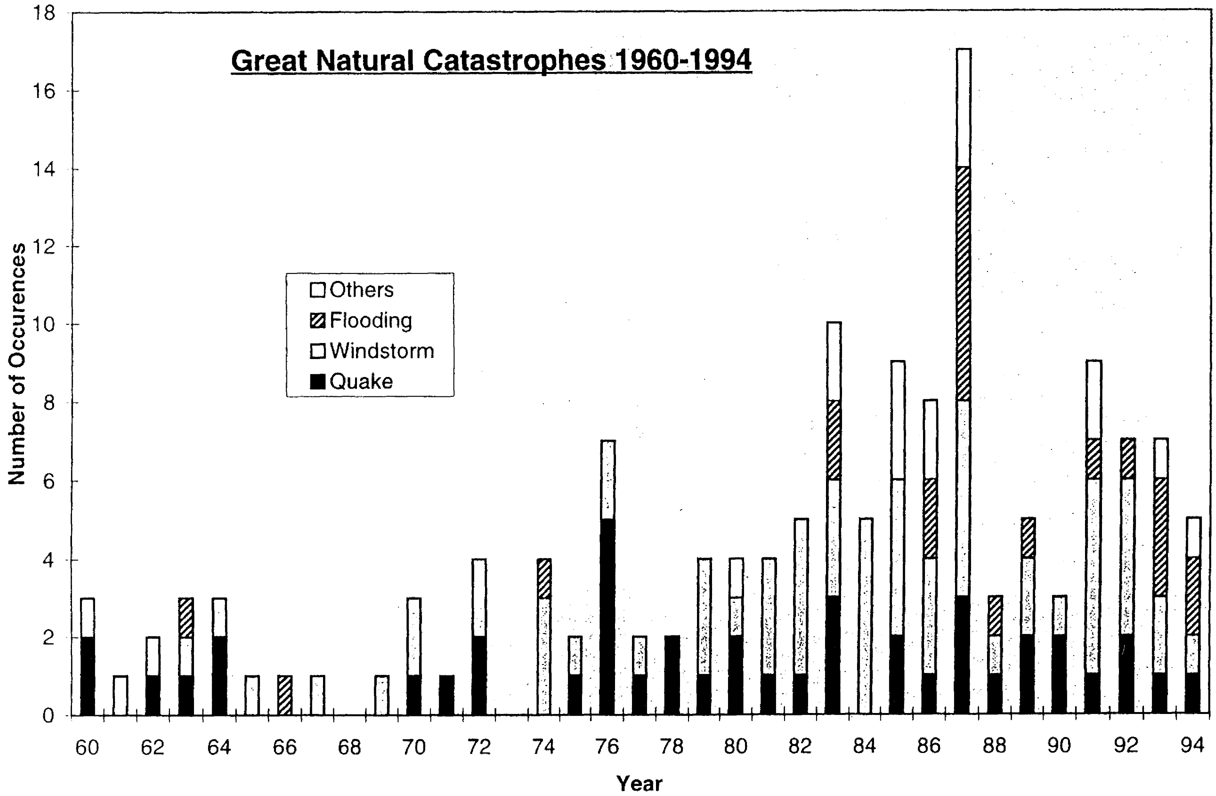

FIGURE 3: Number of Occurences of Great Natural Catastrophe Events, 1960 to 1994. Munich Reinsurance, Schadenspiegel 1/95

Increased international losses are considered to result from both an increase in natural hazard events, see figure 3, and increasing exposures from community infra structural development. There is also a distinct trend for insured losses to be a larger proportion of overall losses as insurance becomes a means of risk management.

It is noted that the trend to higher natural hazard loss costs, both in total and for insurance, continues when even just considering the Northridge earthquake of 17 January 1994 with insured losses of about US$12.5 billion and total losses estimated as approaching US$40 billion; and the Kobe earthquake of 17 January 1995 with total losses of about US$100 billion, (insured losses about US$2 billion).

As well as global stress on insurance; whereby international markets for reinsurance became tighter with increased prices, and applied differential prices and selective cover for perceived higher risk areas; the Edgecumbe earthquake of 1987 and the Newcastle (Australia) earthquake of 1989 drew attention to the South Pacific as higher risk regions. Insurers in both countries sought quantification of their risks by commissioning loss studies. Similar world wide approaches increased risk study developments covering all hazards.

Experience of infrastructure damage from earthquakes in highly developed regions identified that utilities or 'lifelines' contributed to medium and long term losses, possibly becoming more significant than losses to housing and buildings than had previously been considered. This lead to extension of risk study considerations to include water supply, sewage disposal, transport, communications, power systems etc, as well as estimations of casualties, economics and other societal effects.

NEW ZEALAND LEGISLATION

Legislation in New Zealand subsequent to the time of the Edgecumbe earthquake has also contributed to the demand for earthquake damage assessment and risk management development.

The previous Earthquake and War Damage Act and the current Earthquake Commission Act make provision for earthquake insurance. From previously covering insurance of a wide range of properties it now only addresses domestic residential insurance.

The Civil Defence Act 1983 has defined the local government's responsibility for emergency preparedness, response and recovery procedures. Earthquake has always been considered a source of emergency so that most local government civil defence plans allow for this contingency. Such emergency planning is best based on at least qualified emergency scenarios, and improved when based on quantified scenarios.

The Resource Management Act 1991 is legislation establishing a heirachy of policies and requirements towards sustainable management of natural and physical resources. It is a proactive act with some emphasis on the avoidance and mitigation of risk associated with natural hazards. Under the Act, responsibilities for addressing natural hazards and their effects are clearly defined and distributed amongst Central, Regional, and Territorial Government. Key functions of local government at all levels are the collection and distribution of information on natural hazards, and developing policies and objectives related to community risk management.

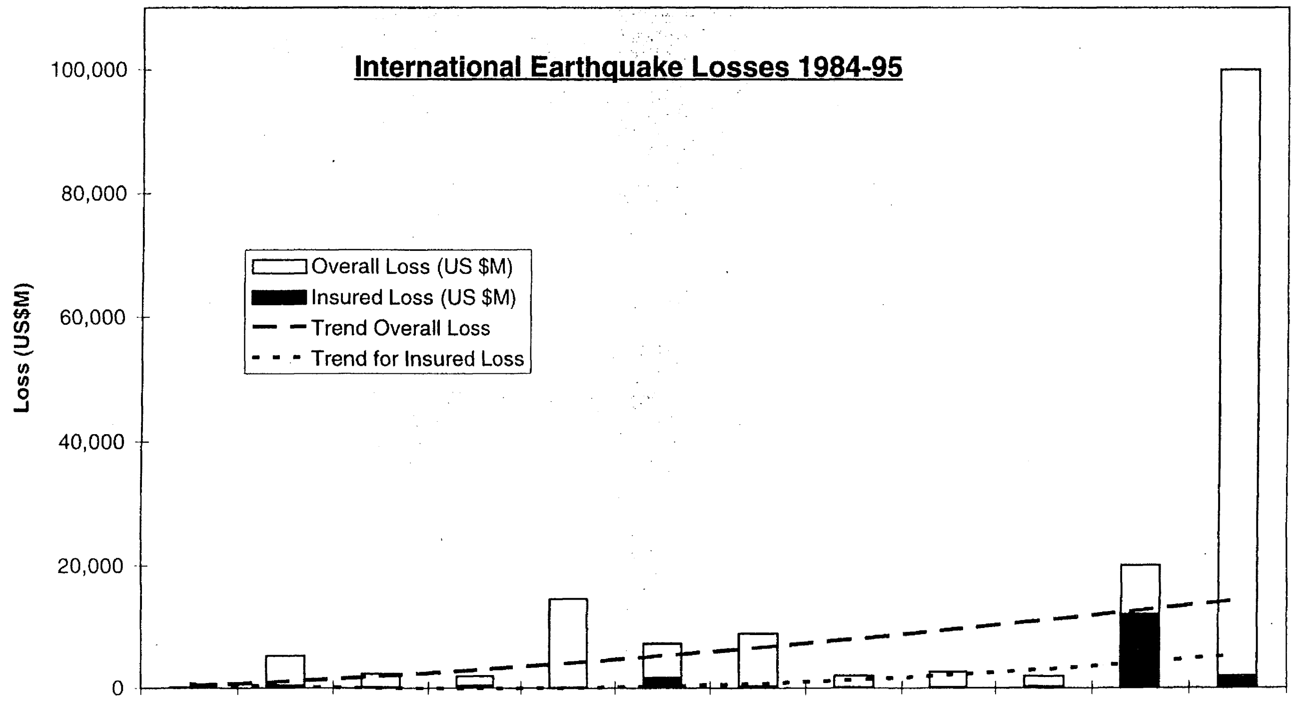

FIGURE 4: International Earthquake Loss Costs, 1984 to 1995. Munich Reinsurance, Schadenspiegel Special Issue 1994, with Addition of Northridge and Kobe Losses.

TABLE 1: Earthquake Review, 1984-1989. (From Munich Re, Schadenspiegel, Special Issue 1994).

DATE	REGION	MAGNITUDE	OVERALL LOSS (US$ mill.)	INSURED LOSS (US$ mill.)
14.09.84	Japan (Central Honshu)	6.90	122	
03.03.85	Chile (Valparaiso)	7.70	1200	90
15.08.85	Hungary (Balaton)	5.90	15	
19.09.85	Mexico	8.10	4000	275
13.09.86	Greece (Peloponnes)	6.20	745	
10.10.86	El Salvador (San Salvador)	5.40	1500	75
15.11.86	Taiwan (Hua-lien)	7.80	2	
02.03.87	New Zealand (Edgecumbe)	6.30	350	270
05.03.87	Ecuador (Napo Province)	6.90	1100	
01.10.87	USA (Whittier)	5.70	358	73
21.08.88	Nepal, India	6.70	320	
06.11.88	China (Yunnan)	7.30	269	
07.12.88	USSR (Armenia)	6.80	14000	
23.01.89	USSR (Tadzikistan)	5.50	25	
17.10.89	USA (Loma Prieta)	7.10	6000	920
28.12.89	Australia (Newcastle)	5.40	1200	670

The Building Act 1991 specifies earthquake performance requirements for new buildings, plus requirements for the ongoing use of existing buildings with reference to unsafe and earthquake prone buildings. It also has requirements for Land Information Memoranda and Project Information Memoranda which address local hazards for consideration in addition to provisions of the Act and means of compliance (standards and codes).

Local Government reforms of 1989 include requirements to value assets and to have management strategies in place by 1997 which clearly demonstrate an ability to maintain these assets. The Local Government Law Reform Bill 1997 requires local government implementation of strategic financial planning including asset management plans, from which logically follow needs for risk management planning.

Commercial, corporate, operational (as in utilities management activities) and personal interest in risk management processes are likely to be strongly driven by recommendations from the Emergency Services Review. The apparent approach is that responsibility for risk management, and meeting the effects and losses from natural hazards, lies with the "owner". This is a logical extension of the Government's "user pays" principle. Each individual, owner, business, corporate, utility, and level of local government, is to be entirely responsible for risk management of owned, or operated facilities. An "all hazards" approach clearly includes earthquake. The national government remains 'insurer' of last resort to be active when the event or effects become so large that even good protective measures become overwhelmed. This activity level is to be set relatively high.

LOSS MODEL DATA

The above factors of increasing insurance demands has resulted in accelerated development of loss assessment and risk managements methodologies internationally, and together with the changing legislation there have been similar developments in New Zealand.

Risk management includes **knowing the risk**. Knowing the risk includes quantification of the probability and the related damage or loss level.

In earthquake engineering, risk is often expressed in the form:

RISK = function(HAZARD, EXPOSURE,
VULNERABILITY, COST)

The terms in the function bracket can be expanded to represent the data items used for risk assessment, eg, specifically for earthquake risk:

Hazard

Source Related. Two types of loss assessment are often considered; probabilistic based on variable seismicity with assigned probable return times, and deterministic which is based on a specific source scenario and its probability.

In New Zealand currently the Probable Maximum Loss for domestic and general commercial exposures focuses on the Wellington region as presenting the balance of earthquake loss level and probability of occurrence. In turn the PML then results from the Wellington fault event. Similar and larger losses can occur in other regions and from other sources but these are associated with lower probabilities. The same may not be true for other considerations, eg power generation.

Earthquake source data includes location (specific fault or zone), magnitude, depth, characteristic (length and type of fault movement - thrust or strike/slip or subduction zone), and probability of occurrence. Strong motion shaking characteristics of amplitude, frequency content and duration are determined from attenuation functions according to the source, modified by specific site conditions.

An example of a seismicity model is that of Smith, [1] as modified following the Edgecumbe earthquake.

Site Related. Site location ground conditions of geology, topography and subsoil formation, (type, density, thickness, watertable), determine the ground shaking, and permanent ground deformation (liquefaction, landslip) and tsunami potential characteristics for the risk.

Measurement of ground shaking is still often expressed in terms of Modified Mercalli because of the need to reference historical data. There is a trend to other instrumental measures, of acceleration and velocity. Some work is being done to directly relate attenuation to damage indices for various types of structures.

Exposure

Inventory. Descriptions of the buildings or infrastructure at their respective locations, including structural form, materials, height, configuration, proximities (pounding), age, design standard and construction quality, function, and other vulnerability characteristics of veneers, chimneys, heavy tile roof etc, and value.

The as built inventory is related to site details for effects of ground interaction of deformation and co-resonance.

People populations, accommodation characteristics and location are data for casualty risk studies.

Exposures. The numbers of inventory risks related to the specific study interest, eg local government, insurance company, or emergency management study. As discussed later such data is as difficult to obtain as scientific hazard data.

Vulnerability

Damage parameters expressed as vulnerability and damage ratios relate the ground shaking and deformation to the extent of damage of the inventory at risk.

The use of vulnerabilities and damage ratios are perhaps the key parameters in the loss assessment process. Development of values that are confidently and universally accepted are constrained through the lack of definitive data. There are both theoretical (force-deformation - structural element and induced damage) methods, and post earthquake site and insurance data review methods used as the basis for determining damage ratios. Analytical methods do not truly reflect insurance or full repair or replacement costs actually incurred. Care must be taken with the application of site determined data for completeness of the dataset upon which the losses have been proportioned. Most data records count and classify the damaged buildings but tend to ignore the total inventory or the population of buildings exposed to the event, making it difficult to establish percentage damage ratios. Also the form of inspection and counting of loss values varies according to the application, eg for local government the habitability and safety damage is assessed, while for insurance applications it is the insured loss that is assessed. There can be significant differences.

Estimates of casualties have to relate to building damage, entrapment and injury/death rates in turn.

Assessment of secondary effects such as fire following earthquake, business interruption, economical and other societal costs require compounding of various damage and other parameters.

Cost

Damage is often expressed in terms of percentage of replacement cost for the built environment.

LOSS ASSESSMENT METHODOLOGIES

The basic development of loss assessment methodologies appeared to be well established in the early 1980's prior to the Edgecumbe earthquake. Consultants had undertaken studies for insurance companies and the NZ National Society for Earthquake Engineering had carried out a study for the Earthquake and War Damage Commission in 1984. [2]

The 1980 report by Darwin [3] investigates the earthquake hazard in Wellington and features all of the data shown above to determine damage and casualty values and rates using a scenario approach considering two earthquakes and analysis methods similar to those used currently. The EERI Committee on Seismic Risk reported [4] on methodologies in 1989, and a subsequent state of the art review is presented by FEMA in [5].

Methodology developments in the decade following the Edgecumbe earthquake have been made in analysis models and in applications of computing techniques, particularly for personal computers and the use of Geographic Information Systems (GIS).

The development of GIS has significantly enhanced risk assessment methodologies. GIS provides a means of storage, review and presentation of data as well as analysis methods and presentation of results. Use of GIS fits with the visualisation of the loss assessment process as a set of map layers representing the spacial data noted above. Taken together with analysis functions working both across and through the respective map layers then other 'results' map layers are generated giving values at respective locations. Summations of 'results' layers give overall losses. [6]. A New Zealand application has been made by Aggett [7].

DATA QUALITY

The most significant development in earthquake risk assessment in the last decade has been in the refinement of necessary QUANTIFIED data to higher resolution and greater levels of confidence.

This applies to all data listed above.

Quantified hazard data has been established for several local government areas, with an excellent example being the work carried out by Wellington Regional Council. In the region earthquake sources have been identified, zonation mapping developed, and risk assessments made. The work has been encapsulated in presentations of maps for professional and public use [Hopkins, NZNSEE Technical Conference, 1997] Other local governments, including but not limited to; Auckland, Waikato, Hawke's Bay, [Berryman, NZNSEE Technical Conference, 1997], Manawatu-Wanganui, Nelson and Christchurch; have or are undertaking hazard studies. It is important to note that the value of hazard studies is their quantification of source location, magnitude and probability of occurrence to enable loss assessment and risk management activities.

The Department of Statistics census data is a source of dwelling data and Valuation New Zealand a source of all building data to establish inventories. Unfortunately their definitions of dwelling/building differ and establishing exposures for loss assessments for various requirements requires approximations. Inventory and exposure data for insurance and local government applications have specific and different data classifications. Recording of construction materials in valuation records reflects external appearance and the number of building stories is not recorded and must be derived from site coverage and total areas. For higher confidence levels inventory data needs classifying by site inspections. Inventory data, while having improved and become more reliable and accessible in the last decade, is critical to loss assessment and would benefit from ongoing development.

The requirement for asset management by local government and the commercial demands on other service and utility managers is resulting in development of their asset registers. When asset registers are complete and reliable they form a good basis of inventory in loss studies.

Insurers, while some have difficulty meantime in being able to specify what properties they have insured, where, and for how much, have and are developing databases that enable exposures to be specified by classification in some detail. Insurance exposures currently benefit from sample site surveys to establish risk types with confidence. As well as risk characteristics insurance data includes understanding specific parameters such as: cover vs value, deductible levels, cover selection (company culture), claims settlement regime, repair strategies (replacement in kind or upgraded), and the economic environment (including post event inflation).

Earthquake damage vulnerabilities and damage ratios remain the most critical element in loss assessment applications. Essentially there is limited **real data** upon which to base these parameters. It is only in the last decade that earnest attempts have been made to secure and research data. David Dowrick and colleagues from IGNS have carried out rigorous work [7, - contains other references] determining damage ratios from New Zealand earthquakes. However given the limited number of events and specific inventories it is prudent to allow for inter-event variability, and also to consider other international data, in establishing damage ratios for use in New Zealand studies. Invariably there are limitations in all loss data currently available, particularly insurance loss data, and considerable earthquake engineering judgement is necessary for particular applications. A cautious approach to the transferability of data from one location to another is essential. Exposure characteristics and earthquake source characteristic differ.

Data is very much lacking on business interruption and overall societal losses. Estimates are made, often based on generic data, but it is difficult to estimate total costs, eg, the total cost of the Bay Bridge collapse following the Loma Prieta earthquake and the motorway bridge collapses in the Northridge earthquakes resulted in costs for alternative transport use which can only be estimated after the events.

CONFIDENCE LEVELS

With methodology model development, application of GIS and other computer systems, supported by data collection and analysis, use of quantified data refined to higher resolution and applied more comprehensively, loss assessments can be used with more confidence.

HOWEVER, recent experience in the USA sounds a note of warning despite the development having progressed markedly in the last 10 years. Insurance loss processes gained credibility following the 1989 Loma Prieta earthquake where estimates were consistent with actual losses, (US$900 mill. estimated vs US$920 mill. actual insured loss). Subsequently, estimates initially seriously underestimated losses following the 1994 Northridge earthquake. Estimates made in the days following the event were in the range of 1.5 to 2.2 billion US dollars, whereas the final insured loss was of the order of US$12.5 billion. While hindsight review identified valid reasons for the 6 to 8 fold inconsistency, future work needs to be shown to be more credible. Sources of Northridge inconsistency included;

- Earthquake magnitude (6.6 - 6.7) determination
- Attenuation (thrust fault giving higher intensities than strike slip faults, and the hanging wall higher intensities than the footwall).
- Unexpected damage/loss levels to steel frame buildings.
- Water losses from sprinkler damage.
- Extent of non structural damage losses.
- Losses to appurtenances, swimming pools, retaining walls, paving.
- Extensive underinsurance

Assumed average deductible levels.

Experience also shows that using modern models it is often difficult to replicate losses from previous events.

The words of Karl Steinbrugge, (Professor Emeritus of Structural Engineering University Of California Berkeley, recognised expert in insurance loss estimation, consultant with USGS and other US government agencies, Past President Seismological Society of America and EERI, [15], are still relevant. "Reasonable monetary loss estimation methods are available from a number of sources, albeit with results which may differ widely. The user company may wonder about these discrepancies, since the practitioners are often engineers and scientists who understand earthquakes and computers. -- Therefore their results "must be correct". First and foremost, loss estimation is by no means an exact science, rather a combination of art and science. The art exists in the experience plus judgement capabilities of the consultant, or underwriter, or loss control person. There is a growing trend to the provision and application of computer systems which have some 'judgement' decisions built in and are tending to be used by personnel who do not have the experienced based judgement capabilities. Considerable quality assurance has to be applied in these situations".

APPLICATIONS

The aim of earthquake loss assessment is to determine how structures and infrastructure will fare under earthquake conditions, to establish loss distributions and costs allowing for probabilities of the event and damage levels. The loss - probability relationship provides the basis of risk management provisions by arrangements to enable business and service continuity and to offset the financial loss. The processes can be extended to enable financial risk of ruin analysis, again on a probabilistic basis, to establish the business solvency using dynamic simulation methods incorporating the range of values for the respective variables. BUT model sophistication is again dependent on the quality of quantified data.

Loss assessment applications usually result in an exceeding probability relationship as shown in the curve of Figure 5.

Applications of loss and risk management processes have been made in community loss assessments, emergency management planning, utility service provision, asset management, district planning, and insurance management for both Government and private business. Applications of standard regional loss models are being made in the USA under Federal financial support, [11]. Newer applications are moving toward 'real time' situations for emergency management, government and insurance activities following an event. An advanced application in actual prototype form is the post earthquake control of gas supplies in Tokyo, [12], [13].

A measure of progress over the decade since the Edgecumbe Earthquake may be seen in the conference sequence sponsored by the NZ Earthquake Commission:

"Information Needs Of the Earthquake Insurance Industry in New Zealand", Christchurch, November 1989.

"Seminar on Methodologies For Calculating MPL's", Auckland, July 1991

"Wellington After The Quake - The Challenge of Rebuilding Cities", Wellington, July 1995.

"After The Disaster - Finding, Managing and Sharing People and Information", Wellington, November 1996.

Next, perhaps the Commission may consider something like 'construction resources for recovery'?

An interesting reference [14] indicates that quantified analysis shows that fittings and furniture are sources of earthquake danger, living rooms and kitchens are unsafe, and that the "smallest room" and bathroom appear to be safer places at least in Japanese households.

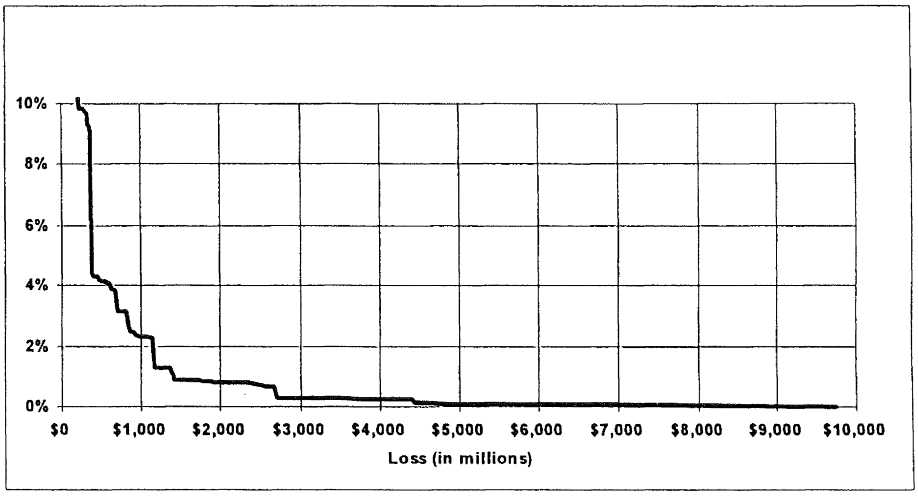

FIGURE 5: The Exceeding Probability curve shows the annual probability of exceeding specific levels of loss.

Hazard and risk information has been made public and incorporated into district plans. There is some uncertainty in the minds of local government officials regarding the publishing of this information with concerns at effects on land values and public and political reaction. Porirua City published hazard data in their District Plan in 1995. There have been few queries, The more serious queries were resolved by the Council and land owner working together on site specific surveys and reports prepared by consultants. It is often a matter of resolving where ground forms actually change (mapping accuracy), using alternative forms of construction and particular provisions to mitigate the hazard threat. Japanese land values are extremely high and land ownership represents a great part of Japanese personal and commercial wealth. Resale land values are seen as critical to the economy. Local Government authorities in the Tokyo region have undertaken earthquake/land/hazard studies and categorised the land into hazard zones of earthquake effects including ground shaking, ground deformation by landslip and liquefaction, fire, and flood (stopbank damage). There was political argument as to whether such information should be published based on perceived social and economic effects. Some local governments are still holding such information as confidential, but the Tokyo Metropolitan Government published it's "Area Vulnerable Assessment of Earthquakes" (1993) without significant consequences. Hence concerns at publishing earthquake hazard data are generally unfounded and citizens and interested parties can work on a factual basis in future planning.

FUTURE DIRECTIONS AND DEVELOPMENT

Loss assessment is a complex integrated model involving analysis of many and varied factors. Hence there is a need for ongoing development in data resolution, expansion and quality for all elements of loss assessment work. Even inventory data which appears to be directly measurable is lacking because of the means and expense to count and classify risks. Providing an accurate portfolio of residential buildings for Earthquake Commission purposes has difficulties. This appears to be a universal problem, [9] [10]. "Compiling a detailed structural inventory is often the most difficult and expensive step in an earthquake risk analysis. --- attributes including location, lateral load resistance, size, functional use ---are needed to estimate repair or replacement cost, loss of use of the facility, and casualties."

Data upon which to base damage ratios is scarce. The insurance industry may wish to set up damage and insurance recording methodologies prior to the next event in order to secure accurate data useful for extracting the loss information important for their future use.

The current good work in hazard identification and quantification needs to continue.

CONCLUSION

Society exposure to disaster risk appears to be greater than previously recognised with exponential increases shown over recent years. The rise in risk and disaster loss has displaced homeowners, disrupted business, disrupted insurance markets, and strained Government resources internationally. We have to evaluate ways for reducing disaster losses based on quantified and confident risk management methods. Despite some good progress over the last decade key information is still required in respect to the nature of catastrophe risk and the likely effects.

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