The Earthquake Commission's earthquake insurance loss model

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R.B. Shephard, D.D. Spurr, G.R. Walker

Seismic Consultants Ltd, Spurr Consulting, Aon Re Australia

ABSTRACT: The Earthquake Commission (EQC) has an integrated financial risk management computer system, called Minerva, which features facilities to monitor earthquake insurance exposures, to forecast claims numbers and amounts, and to investigate the financial sustainability of its operations.

This paper presents an overview of the Minerva earthquake loss risk modelling system: the system architecture, models and data used, outputs to assist portfolio management, outputs passed to the catastrophe response management systems, and outputs passed to the financial modelling system.

Minerva features an 'open model' with user options including attenuation, source and vulnerability models. Minerva can simulate the loss risk, and also simulate the financial performance of EQC in stochastic terms, over 10 years into the future.

Development of the earthquake loss component of Minerva raised a number of issues in relation to models and the data. These issues are discussed, including the sensitivity of the output of Minerva to them.

1 INTRODUCTION

1.1 *The Earthquake Commission*

This is a companion paper to that presented by David A Middleton, General Manager of the Earthquake Commission, titled "EQC's Use of Computer Modelling in a Catastrophe Response." Middleton (2002). In that paper the background, functions and operations of EQC is presented and so are only briefly summarised here.

EQC is a wholly owned Crown company, subject to a specific legislation, whose main function is to administer the scheme which insures homes and their contents against damage by earthquake and some other natural hazards. This insurance is automatically acquired with fire insurance. The cover is up to $100,000 plus gst for dwellings and $20,000 plus gst for contents, together with some land cover. This insurance is on a "first loss" basis, subject to $200 excess.

EQC comprises a core staff of 16 persons handling routine operations. Additional resources and services are out-sourced on demand to meet specialist requirements and high workloads such as claims after a large event. A critical requirement of EQC is to be able to pay claims quickly and fully under terms of the Act.

EQC's experience has shown, Middleton (2002), that computer tools could be critical for aspects of their operations and decision making.

2 CATASTROPHE INSURANCE LOSS AND FINANCIAL SYSTEM

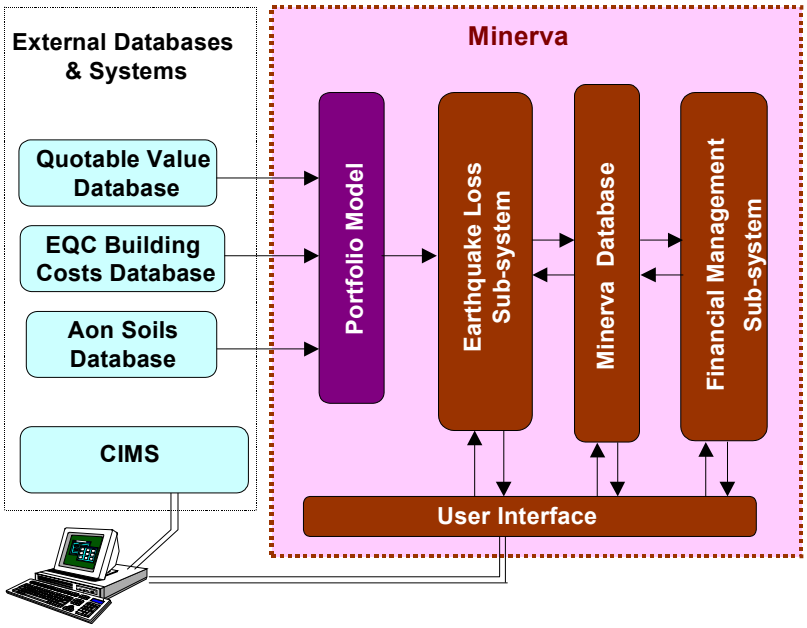
EQC have had an integrated insurance loss and financial risk management computer system, called Minerva, developed for them. Its primary purpose to enable EQC to manage the operation and finances of EQC in the most efficient and comprehensive manner possible, utilising state-of-art information technology. Minerva, and the Earthquake Loss and Financial Management sub-systems, utilises processes and models developed in-house by Aon, customised specifically to meet the needs of EQC.

The specific purposes of the system may be summarised as follows:

- Periodic monitoring of the exposure of EQC using both scenario modelling of specific earthquakes and probabilistic modelling of risk at national or regional level.
- With analyses based on probabilistic output on the earthquake loss risk over 10 years:
    - Detailed analysis of the sustainability of the Natural Disaster Fund and variable premium structures, deductibles, limits, investments and risk financing, while allowing for changes in economic variables such as interest rates, exchange rates, inflation, property growth and other economic indices.
    - Comparison of different risk financing options**,** i.e. the technical financial costs and benefits of different structures – including premiums, deductibles, limits, and investments.
- Estimation of claims numbers and losses to EQC following a major disaster, for use in their Claims Information Management System to establish the level of response required.

3 MINERVA - EARTHQUAKE LOSS AND FINANCIAL MANAGEMENT SYSTEM

The overall Minerva system architecture is shown in Figure 1 following:



The system comprises Portfolio input, separate Earthquake Loss (EQ) and Financial Management (FM) sub-systems with interconnecting Minerva Database(s), all operated by a common User Interface (UI) and Data Management system.

Currently there is a separate model for processing the portfolio data. This processes inventory data from the Quotable Value database for individual properties and their, together with the EQC Replacement Building Costs Database and an Aon Soils Database. Residential inventories with building characteristics, replacement costs and soils attributes are passed to Minerva for extraction of EQC's portfolio of exposures.

The User Interface controls the inputs/outputs and operations of both the EQ and FM Sub-systems. Minerva input/output data are stored in the Minerva Database from where they can be accessed by the sub-systems for processing and producing the internal and user outputs.

4 EARTHQUAKE LOSS SUB-SYSTEM

4.1.1 *System Description*

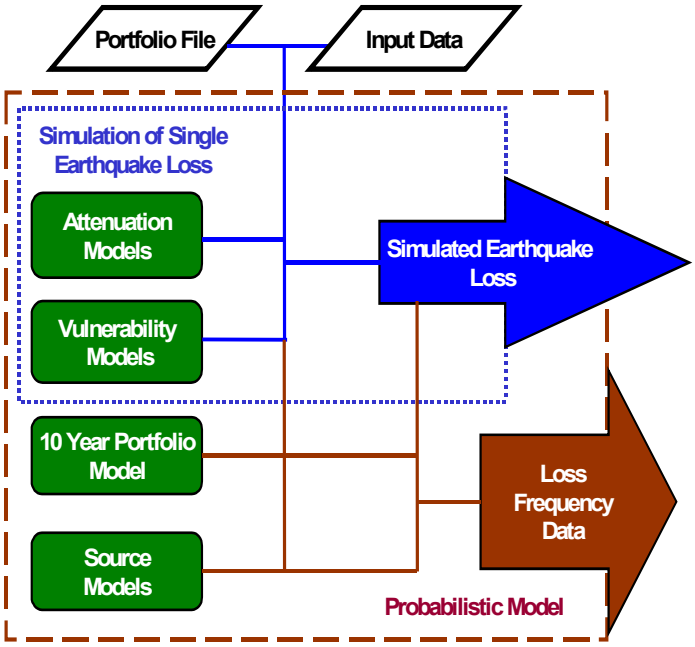
Development of the Aon earthquake loss model and its customisation for Minerva was undertaken by Dr David Spurr, a Wellington consultant, with assistance from Dr. Russell Kent, a consultant retained by Aon in the UK, and under the general supervision of Dr George Walker of Aon Re Australia.

The Earthquake Loss sub-system uses Geographical Information System (GIS) technology to simulate the geographic distributions of exposure and ground shaking in estimating the insurance losses to residential buildings and contents, and the portion of this accruing to EQC.

Property location, construction and value exposure data are accessed in details of every identified residential property in New Zealand. For Scenario and Probabilistic analyses, site exposures, shaking intensities and local geology are modelled on a uniform, square-celled grid covering the country. The size of the grid cell, which effects processing time, is selected by the user from four options between 0.5 km and 5 km.

Losses are initially calculated for each property based on grid cell shaking intensities, but taking account of the specific dwelling, appurtenant structure, and contents values, vulnerability characteristics and policy provisions applying for each property. Individual property losses and exposures are then aggregated to provide grid cell exposure and vulnerability estimates, which are stored for subsequent analysis undertaken at grid cell level

A schematic diagram of the Earthquake Loss sub system (Figure 2) follows:



Gross and net exposures are also separately aggregated at Area Unit, TA, Regional, and National level.

The source code of the executable program for the Earthquake Loss sub-system is written as a set of FORTRAN 95 subroutines that are compiled using Compaq Visual FORTRAN V6.5A. Communication with the rest of the Minerva system is between text files and the Minerva Database for input and output of data, managed by the Minerva System operating program. The system structure is modular and facilitates modifications and additions to take advantage of research developments.

Most models and data values used in the Earthquake Loss sub-system are variable subject to user selection.

4.1.2 *Attenuation Models*

The current version of Minerva incorporates five options as follows:

- Dowrick (1991) (MMI, zone model)
- Campbell (1997) (PGA / Spectra) / Youngs et al (1997) (Subduction model)
- Abrahamson and Silva (1997) (PGA / Spectra) / Youngs et al (1997) (Subduction model)
- Boore, Joyner & Fumal (1997) (PGA / Spectra, depth < 15km) / Youngs et al (1997) (Subduction model)
- Cousins, Zhou and Perrin (1999) (PGA / Spectra, M <7.4) / Youngs et al (1997) (Subduction model)

Attenuation models are used to determine the earthquake intensity for each portfolio grid cell from a specified earthquake.

The soil classification attached to each grid cell for use with the attenuation models is derived from a database of New Zealand surface soils. The soils database consists of digitised maps of surface soil characteristics relevant to earthquake attenuation. The surface soils characteristics were expressed in terms of 10 soil classifications. The attenuation models use different combinations of these classifications appropriate to their own systems of classification of local soil properties.

The attenuation models used do not themselves take account of soft soils. To overcome this Minerva includes a variable soft soil amplification factor based on the NEHRP recommendations for handling the soft soils.

4.2 *Scenario Earthquake Analysis*

For scenario analyses, ground motion intensities are calculated at each grid cell for a specified earthquake and attenuation model. The earthquake location, magnitude and fault characteristics may be input by selecting from a list of historical earthquakes, a list or map of faults with associated characteristic earthquakes, or may be input separately by the user.

4.3 *Earthquake Source Models:*

Earthquake source models are used for the probabilistic analysis of earthquake loss. These model the occurrence characteristics of earthquakes in terms of time, magnitude, location and depth. Two principal types of source model are embodied in the Earthquake Loss sub-system. One is a zone model, in which the country is divided into zones and uniform earthquake occurrence characteristics established for each zone. The other type models a combination of smoothed distributed seismicity based on historical data for smaller more common earthquakes, and fault based earthquakes using geological data on occurrence and magnitude characteristics

for the larger rare earthquakes. The discrete fault models use information on magnitude and return periods of selected faults. Uncertainties associated with magnitude are incorporated in the analysis. Three distributed models and three fault model options are currently available in Minerva.

The distributed earthquake models included are:

- Smith and Berryman zone model
- Aon Gaussian smoothing model
- Stock adaptive smoothing model

The distributed models use a 10km square grid for earthquake simulation. The Aon and Stock models simulate distributed seismicity with up to five 20km thick layers, and are intended to be used in conjunction with modelling specific fault sources.

The three fault source model options included are:

- IGNS 1998
- IGNS 2000
- Stock

The IGNS 1998 model is based on the fault data published in Stirling, Wesnousky and Berryman (1998). IGNS 2000 is based on the same fault traces, but using updated information on the return period and magnitudes of faults published in the EQC Research Report on New Zealand seismicity prepared by Stirling et al, (2000). The Stock fault model is a separate interpretation of the same list of faults by Christian Stock (2001).

The combined distributed and fault based models are regarded as more consistent with current knowledge. The Smith and Berryman zone model has been retained for reference purposes.

The probabilistic analysis can be undertaken for the whole of New Zealand or for exposures in selected regions.

4.4 *Building Damage Vulnerability Models*

Vulnerability models are used in conjunction with portfolio data and information on insurance coverage to estimate the characteristics of the total loss and net loss to EQC as a function of earthquake shaking intensity. They embody two sets of information. Firstly loss ratio tables provide the average loss as a ratio of the replacement or insured value for different types of property, including different building types and different earthquake intensities, expressed in terms of peak ground acceleration. The vulnerability relationships are transformed from loss data that were originally evaluated in terms of Modified Mercalli intensity values. Secondly Beta value tables provide information on the associated statistical distribution of loss for different average values of loss ratio. This distribution is needed to estimate EQC's share of the loss. A number of alternative vulnerability models are embodied in the model.

The calculations of net loss require information on the policy details such as caps, deductibles and coinsurance.

In the Minerva Earthquake Loss sub-system a loss table vulnerability relationship is established for each grid cell as a function of earthquake intensity. The loss table for each cell includes the aggregated losses of all properties enclosed by the cell. These are then used in conjunction with the calculated earthquake intensity at each cell obtained from the attenuation models for each soil type, to obtain the losses from a specified earthquake.

4.5 *10 year Exposure Portfolio*

For running the 10-year financial simulations, the Earthquake Loss sub-system also includes a

model for deriving the portfolio data for use in the 2nd and subsequent years. This is based on the input current portfolio file and user specified information on estimated inflation of property values, property refurbishment and extensions, and property growth.

5 EARTHQUAKE LOSS OUTPUTS

5.1 *Output Options.*

Minerva Earthquake Loss sub-system outputs include user-selected options as tabulations, charts and maps appropriate to the information. Outputs can be exported to Microsoft Excel and in Geographical Information System formats. Input assumptions and data can also be output.

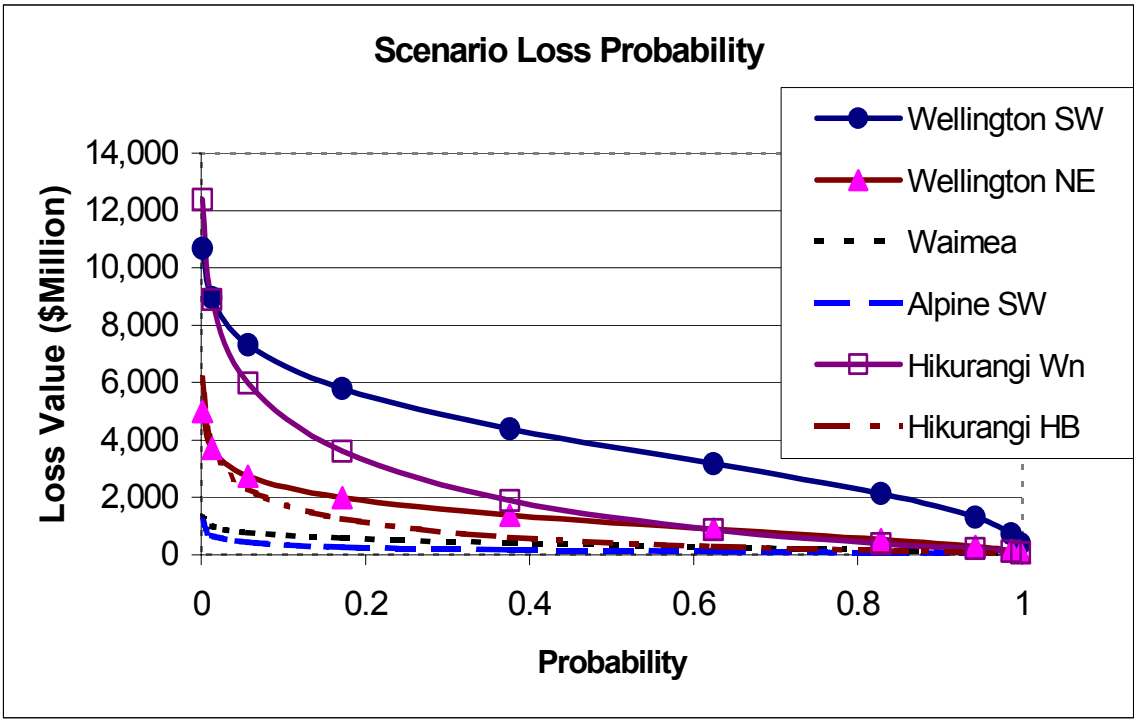
Analysis output options include:

- Scenario earthquake, as the loss mean value and probability distribution, and maps of exposure, properties, shaking intensity, claims amount and damage ratios.
- Loss probability, in terms events per year, return period and probability.
- Claims as tabulated claim numbers and value bands by locality, able to be aggregated by local authority and regions. Maps of randomly generated example sets of damaged properties. Summary claims data for use in the Claims Information Management System.
- Ten-year probability data for use in the Financial Management sub-system.

5.2 *Sample Outputs.*

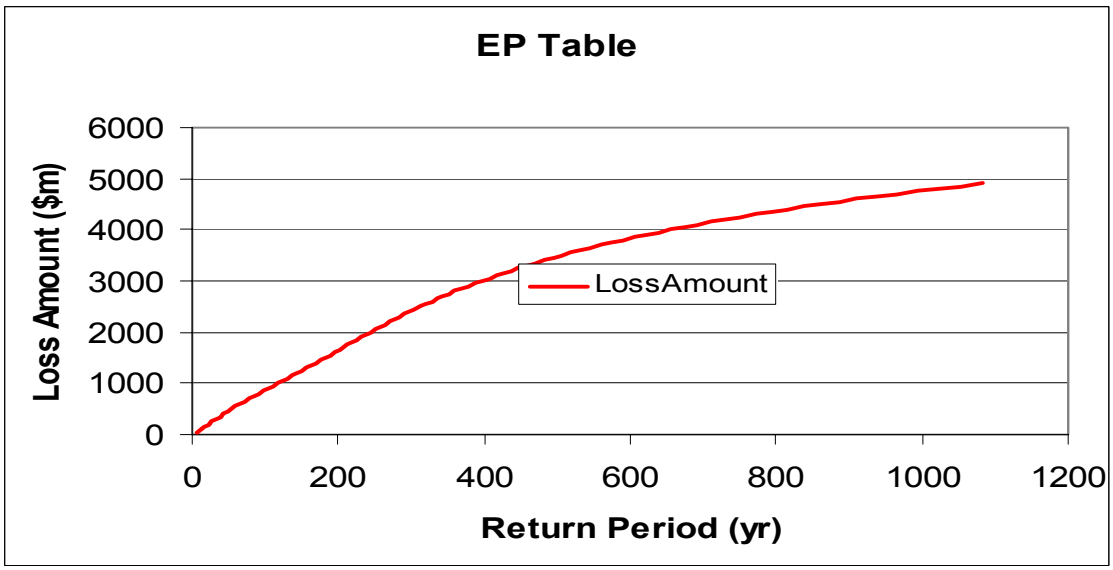
5.2.1 *EQC Scenario Losses*

Figure 3 shows a sample of earthquake scenarios expected losses forecast using Minerva:



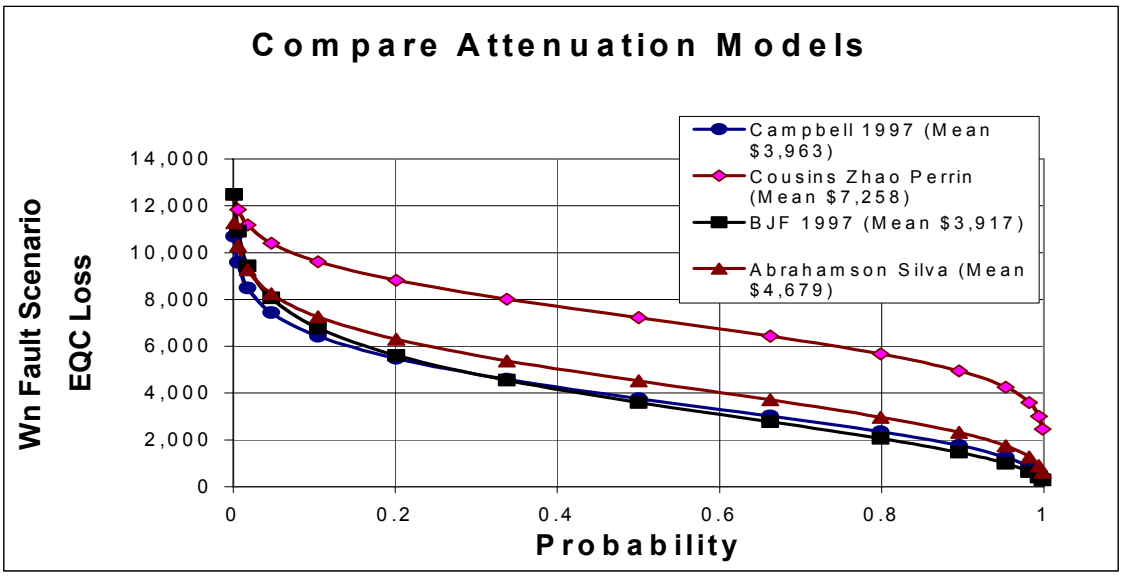
5.2.2 *Probabilistic EQC Earthquake Loss*

An example of the Loss Amount (expected value loss) and Return Period output (Figure 4):



5.2.3 *Variation of Scenario Loss With Attenuation Assumptions*

An example of the variation using alternative attenuation models (Figure 5):



Note the Range of losses according to attenuation Model. The "Cousins'" and "BJF" models are being used at the limits of their applicability. This loss variation is typical of using the possible ranges of variables for seismicity and vulnerability. The Campbell attenuation is the preferred option when taken with preferred seismicity and vulnerability model options.

6 CONCLUSIONS

The EQC 'Minerva' insurance loss and financial risk management computer system has been briefly described.

It is important to note that Minerva has been developed and customised specifically for the purpose of EQC's business. The processes and outputs of scenario loss, probabilistic loss,

claims estimates and data for financial management analyses are specific to EQC. Program logic has been developed to achieve efficiencies of data handling and run time for this purpose.

Note the situation when using (computer) models as expressed by Middleton (2002): "The organisation (EQC) is fully aware of the warning that it should not take the findings of models as conclusive – or as anything more than indicative -- . Or in another way " -- models replace the uncertainty of just not knowing with the uncertainty of having only a possible solution – or several possible and discrete solutions." This is a challenge facing EQC.

The development issue for assessing earthquake hazard insurance losses now is to establish assured criteria and data for Minerva modelling inputs, to make satisfactory selections and combinations of data and models, to narrow the probability range, and to give more confidence to outputs to enable operational and management decisions in EQC. At the same time extensions of Minerva to other natural hazards insured by EQC is to be developed.

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