XTREME LOSS SOLUTIONS

X L S

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A Methodology to estimate Insurance Losses from Earthquakes

XTREME LOSS SOLUTIONS White Paper

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Abstract

This document reviews the methodology implemented in the XLS software system to estimate insurance losses from earthquakes. The objective is to provide academics, regulatory bodies and risk carriers with a theoretical perspective on best the practice principles to model these losses.

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TABLE OF CONTENTS

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AUDIENCE

This draft White Paper is intended for academics, regulatory bodies, actuaries/actuarial analysts and CFO's. Academics will find this paper useful in obtaining more insight into the practical implementation of earthquake loss estimation theory in the Insurance Industry. This paper will assist regulatory bodies in setting standards for earthquake models used by Risk Carriers in their Internal Financial Condition Reporting models. This paper will give actuaries/actuarial analysts and CFO's more insight into the theoretical principles of modeling insurance losses from earthquakes.

EXECUTIVE SUMMARY

The current state of the art in countries where risk models are not used is for Risk Carriers and especially Reinsurers to estimate earthquake losses by applying a percentage to total sums insured in a CRESTA zone as a 1 in 100 year reference loss. Statistical probability distributions such as a Simple Pareto curve are then used to extrapolate earthquake losses to longer return periods. In South Africa, the percentages of total sums insured per CRESTA zone are mainly provided by 2 sources:

- EQECat, a European company that specializes in the modeling of catastrophe risk and
- General market views, such as 2.5% of total sums insured in CRESTA zone 6 (Johannesburg) for the 1 in 100 year event.

To date there is no documentation readily available that explains the methodology or data used by these sources. Also the percentages do not appear to be regularly updated. This renders the validity of the earthquake loss estimates from these sources questionable.

A recent survey conducted by the author in conjunction with Guy Carpenter Reinsurance Brokers on Financial Condition Reporting yielded the following results:

1. 100% of the respondents aim to build an Internal model, indicating an overwhelming requirement for such a model.
2. On average, respondents opted for earthquakes as the natural peril which has the biggest impact on the capital requirement.
3. 99% of respondents opted for a detailed catastrophe model instead of a simplified catastrophe model as explained in the first paragraph of this section.

Therefore the general view of the Insurance Industry is that a detailed Earthquake loss model is needed for poignant Financial Condition Reporting.

Detailed earthquake modeling now has been made more accessible than ever by four new developments: The ability to integrate different specialist information systems, increased computer calculation speed, the improvement of Insurance Administration Systems and the development of geographical information.

XREME LOSS SOLUTIONS has developed software that will enable practitioners in the Insurance Industry to develop detailed and transparent earthquake loss models unique to each Risk Carrier's business profile. The software encourages the use of expert opinions at various stages of the model construction and makes it easy for the practitioner to implement this expert knowledge into their model.

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BACKGROUND & DEFINITIONS

In 2001 Hannover Re in conjunction with the Council of Geoscience did a publication on seismic risk in South Africa. The table below is an abstract of the key results from the publication; and shows the mean annual damage ratio to property as a result of earthquakes for various cities:

City	Mean annual damage ratio
Cape Town	1.08%
Johannesburg	0.63%
Pretoria	0.31%
Durban	0.50%
Bloemfontein	0.31%
Benoni	2.13%

A premium rate is the premium divided by the sum insured or estimated maximum loss of the risk. Premium rates charged by Insurers for Property business in general varies between 0.2% to 0.25% per annum depending on the market cycle and various rating factors. If one considers the above results in conjunction with current property premium rates, property business may be written at a major loss in the long-term.

It is the author's opinion that if gross property claims of South African Insurers are analyzed by cause of loss over the full term of available loss data, losses from earthquakes will be negligible. Underwriters and management of Insurance Companies may very well argue that the mean annual damage ratios shown are too conservative and unrealistic. One key difference between comparing actual earthquake loss history with the quoted mean annual damage ratios, is that time periods of the 2 assessments are very different. Insurance Companies may have at most 10 to 15 years of historical loss data to analyze; whereas the quoted mean annual damage ratios are calculated over thousands of simulated annual earthquake loss scenarios. As Insurance Companies collect loss data over longer periods of time, it becomes more likely that larger and more devastating earthquakes will become part of the loss data, thereby increasing the long-term mean annual cost of claims from earthquakes above current levels.

These issues indicate significant differences in opinions of seismic risk between insurance market practitioners and seismic experts. It is the author's view that the difference in opinions can be breached or reduced by introducing a modelling platform which combines the expertise of seismic experts with the irreplaceable input of actuarial practitioners in a balanced format which allows complete financial control of the seismic model.

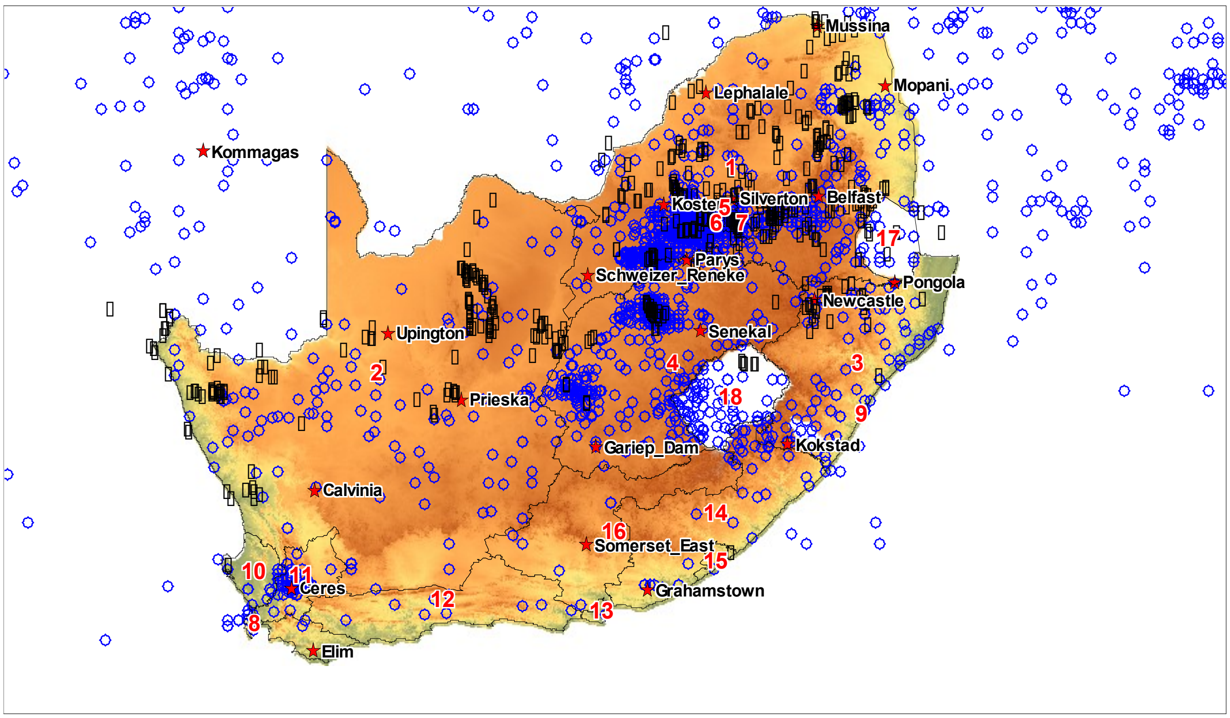
The paper which follows has the following key objectives:

- To disclose a methodology and assumptions of earthquake insurance loss modeling
- To highlight the key features of a practical detailed earthquake model for the purposes of an Internal Financial Condition Reporting model.
- To show how the two can be integrated without increasing risk or reducing the oversight of actuarial specialists.

KEY FEATURES OF A PRACTICAL DETAILED EARTHQUAKE MODEL

Geographical Risk Areas

The map below shows the locations of historical earthquakes (as blue circles), mines (A's) and the seismological stations (stars) in South Africa.



The following observations could be made from the map:

- Certain geographical areas are more exposed to seismic events than other. Therefore to create a realistic model for earthquakes; geographical risk areas have to be created.
- There is a strong correlation between seismic events and mining activity. From the map it seems quite easy to create risk areas where there is mining activity due to the clustering of events.
- Areas exposed to natural seismic activity can also be easily identified such as Ceres, Eastern Free State and Southern Kwa-zulu Natal.
- There are also areas where the location of earthquakes seems to be completely random. Therefore a realistic model must be able to simulate/generate earthquake epicenters randomly within defined risk areas. It must also be borne in mind that these risk areas can be irregular polygons; and as such the model must be able to simulate random locations within these unique risk areas.

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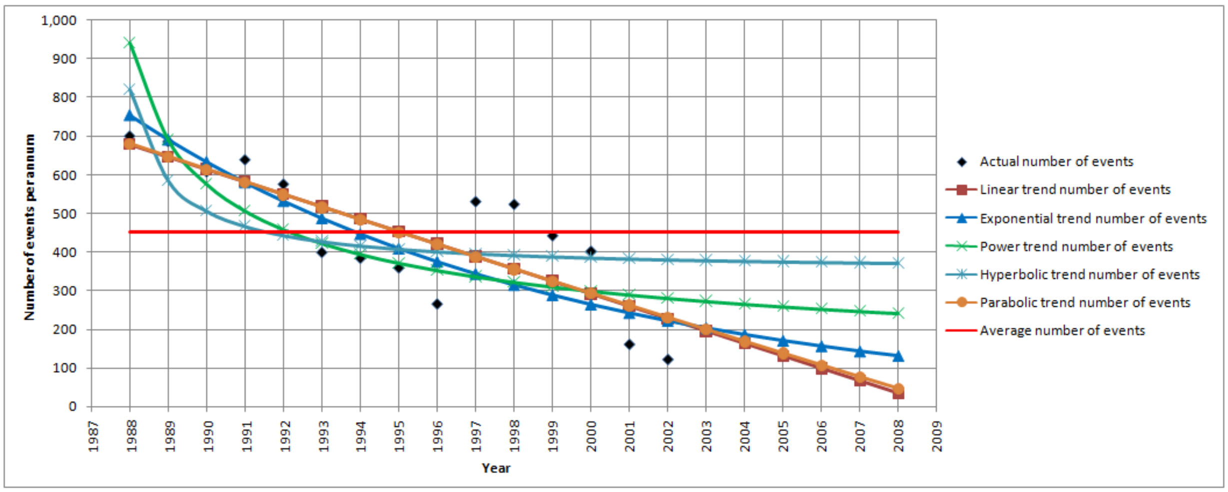
The ideal practical model must enable practitioners to draw their own risk areas based on their views but also allow them to integrate risk areas based on expert opinions.

Trends in the number of earthquakes per annum

A detailed model needs to project the trends in the number of earthquakes over time. The graph below is a good example of how the number of earthquakes in a risk area can change over time.



The red line presents the average number of earthquakes per annum ignoring any trends. The black dots presenting the actual observations show a decreasing trend over time. The listed trend curves can assist practitioners in formulating assumptions for the number of earthquakes in future years.

Ignoring trends in the number of earthquakes over time can result in significant over or under estimation of the number of earthquakes per annum as shown in the graph above.

Probability distributions for the number of earthquakes per annum

The above graph shows that no trend curve explains all the variation in the number of earthquakes from one year to the next. Therefore statistical probability distributions are required to quantify potential volatility around the expected number of earthquakes.

The Seismological Series produced by the Council of Geoscience shows a significant number of earthquakes in South Africa each year. The availability of significant volumes of earthquake frequency data validates the fitting of statistical distributions to data. It must be noted that the vast majority of earthquakes each year in South Africa are small in Richter Scale Magnitude and cannot be felt. This data still remains valuable as a basis from which the annual number of earthquakes can be modeled.

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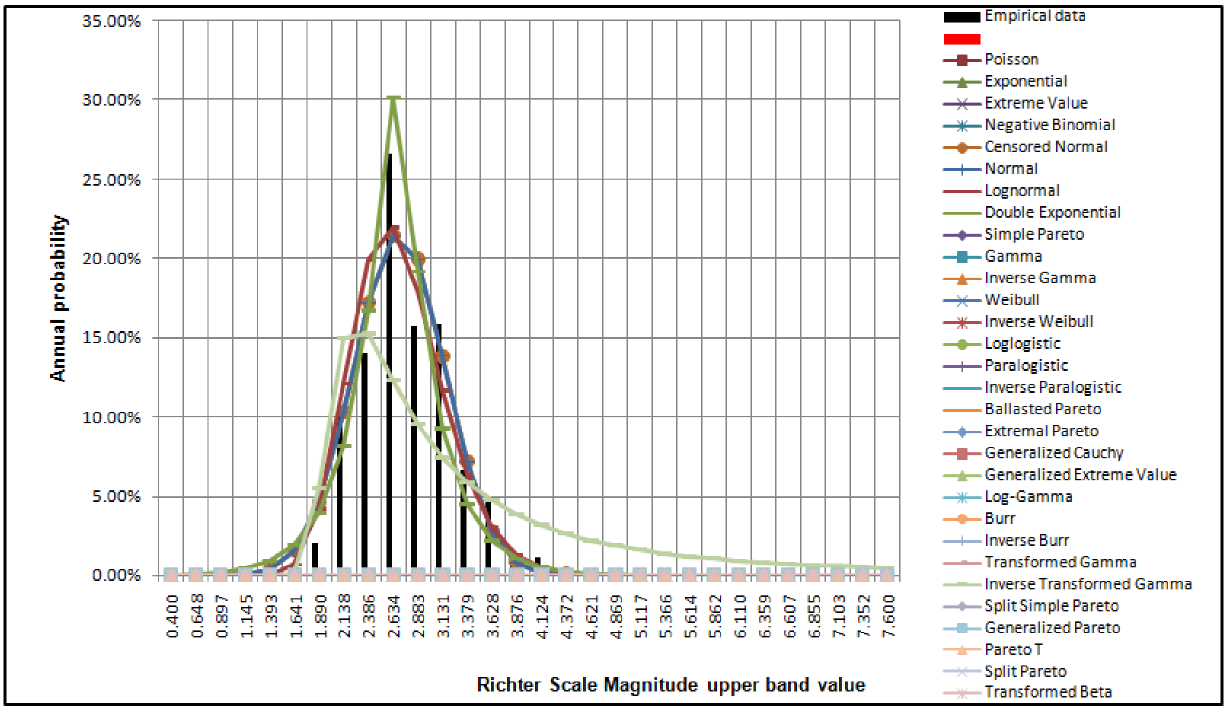
Increasing computer processing speed makes it possible for practitioners to fit many statistical probability distributions to frequency data within a short period of time. The fitment of many statistical distributions assists the practitioner in making more informed decisions when selecting a probability distribution to represent the volatility in actual observed frequency data.

The author proposes the method of maximum log-likelihood for the estimation of parameters of statistical distributions, since it is consistent with actuarial industry standards. A detailed model must allow the practitioner to define a user defined probability distribution if they are of the opinion that a standard probability distribution is not appropriate for the problem.

Probability distributions for the Richter Scale Magnitudes of earthquakes

The graph below shows the actual and fitted annual probability of Richter Scale magnitudes within a risk area.



A detailed earthquake model should allow practitioners to fit many statistical probability distributions to Richter Scale magnitude data. The statistical distribution that best fits the data can be used to extrapolate to larger more devastating earthquakes. As with frequency distributions, we recommend the method of maximum log-likelihood to estimate the parameters of fitted magnitude distributions.

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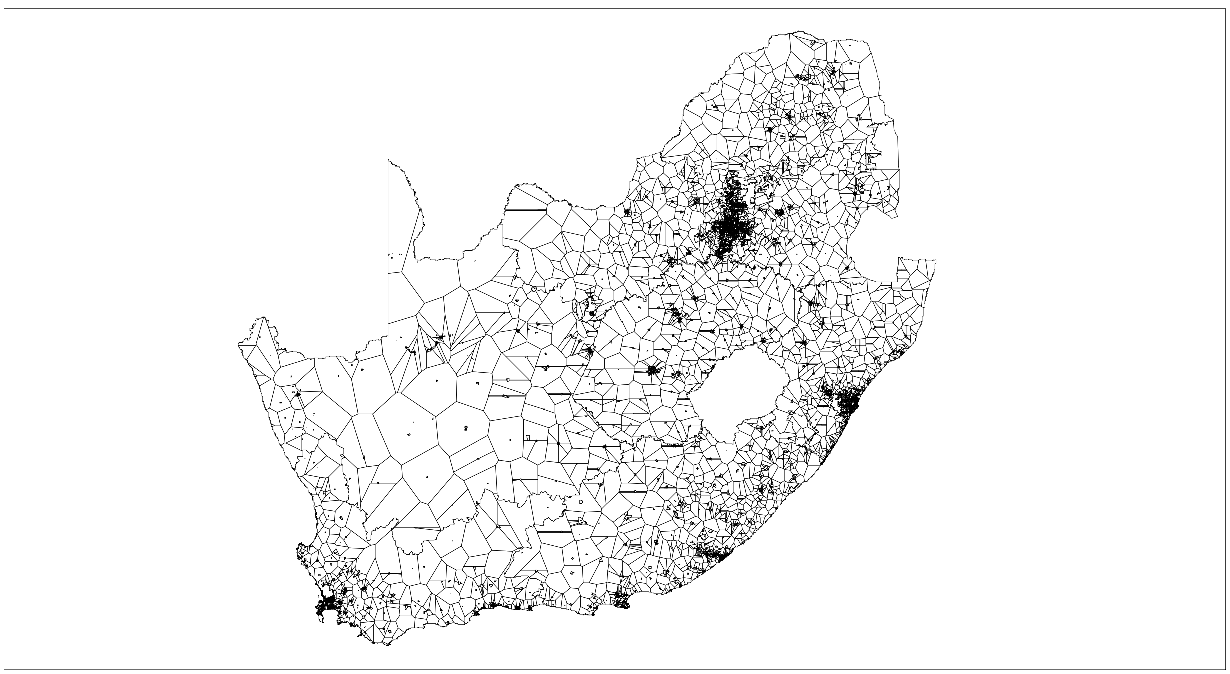
Analysis of magnitude data showed that maximum log-likelihood parameters of the best fit distributions do change if fitments are done from one year to the next. Therefore a detailed earthquake model must allow for parameter uncertainty and parameter correlation for Magnitude probability distributions. As with frequency distributions, the practitioner must be able to define a user probability distribution if a standard statistical distribution is not appropriate for the problem at hand.

Exposure data

In order to calculate damage to insured risks, the distance between the earthquake epicenter and the exposure location must first be calculated. Most insurers will at least capture the postal code of insured risks, since the postal code is required to generate CRESTA zone accumulation reports for reinsurers. Longitude and Latitude coordinates of the midpoints of postal code areas are available from companies specializing in geographical information. The simulation of longitude and latitude coordinates of an earthquake epicenter and the availability of midpoint coordinates of postal codes makes it possible to approximate the distances between an earthquake and all the risks within an insurer's portfolio.

Practical difficulties will arise if earthquake loss estimation goes to a more detailed level such as street addresses. Street addresses are generally optional free text fields on insurer's administration systems, therefore the data may not exist for many risks or many typing errors may occur. If one considers the vast distances over which earthquakes can damage exposure and the small areas of postal codes then the difference between loss assessment at street level and postal code level is likely to be small. The practical difficulties of street level loss assessment outweigh any loss in accuracy of postal code loss assessment.

The map below shows the level of detail of postal code areas in South Africa.



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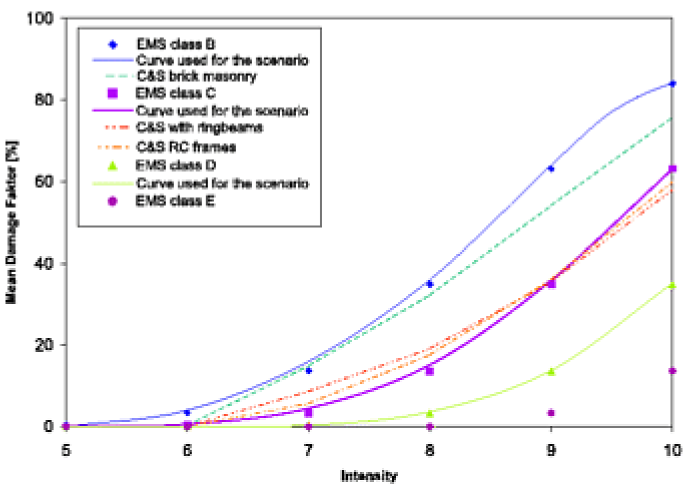
Postal code areas are quite detailed in highly condensed exposure areas such as Gauteng, Durban and Cape Town. A detailed earthquake model should have the capability to match longitude and latitude coordinates of postal codes to the exposure data.

Importing risk items line by line into the model will allow the practitioner to calculate retained and ceded earthquake losses accurately when varying the retention amount on Surplus Share reinsurance contracts. The retained loss by the insurer and ceded loss to the reinsurer on a Surplus contract both depend on the sum insured of the risk in relation to the retention amount, hence detailed per risk exposure information is a necessity.

It is preferable to base earthquake loss calculations on sum insured values of risks instead of estimated maximum loss (EML) values. The full value (i.e. the sum insured) of risks could be damaged by an earthquake. Using the EML values in earthquake loss calculations could result in significant under-estimation of losses.

Organizations in the USA have performed in-depth analysis on actual earthquake damage to various types of properties. The result of this analysis was a set of vulnerability curves for various types of property. The graph below is a general example of such vulnerability curves. The curve shows the mean damage factor percentage for various Modified Mercalli Scale Intensities.



The existence of these curves makes it possible to quantify earthquake damage to specific types of properties more accurately. Therefore exposure information should include data fields that describe the risk. Examples of such data fields are class of business, type of risk or source of business. Classes of business are for example property, motor and engineering. Type of risk can be for example personal lines or commercial lines. Source of business can also assist the practitioner in understanding the type of risk. For example certain underwriting managers writing business on behalf of insurers may specialize in underwriting a specific type of risk such as hotels or factories.

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Practitioners may want to project earthquake losses over a future defined time period. Therefore the current exposure profile needs to be adjusted to reflect the expected profile over the modeled time period. A detailed earthquake model needs to allow practitioners to make assumptions about future expected premium income and premium rates to project exposure profiles over future time periods. The result is a more realistic assessment of earthquake losses over future time periods.

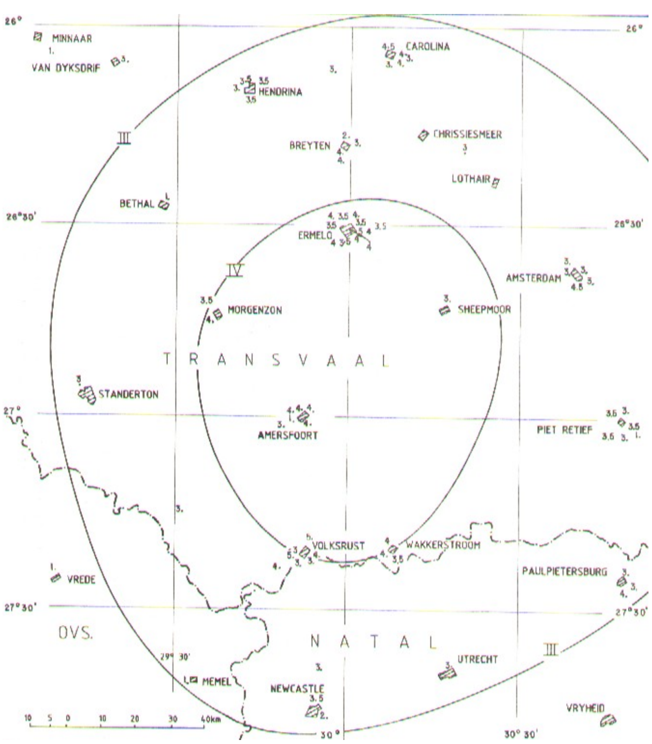
Modified Mercalli Scale Intensity Attenuation equations

The Modified Mercalli (MM) Scale is a subjective measurement of the Intensity of an earthquake. This measurement is done by seismologists after the event by talking to people and observing the damage in the affected area. An MMI attenuation equation predicts the MM Intensity at a geographical point and has the following general mathematical relationship:

$I - I_0 = A + B \times M + C \times D + E \times Ln(D)$, where:

I = Intensity at the geographical point
I_0 = Intensity at the epicenter. Intensity at the epicenter is a linear function of magnitude and can be calculated by rewriting the Richter formula.
A, B, C, E = constants
M = Richter scale magnitude
D = distance between geographical point and earthquake epicenter

The constants in the above expression can be estimated from isoseismal map data. The map below is an example of an actual isoseismal map for a historical event courtesy of the Council of Geoscience.



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We recommend minimizing the sum of squared errors to estimate the constants A, B, C and E. The sum of squared errors (SSE) is:

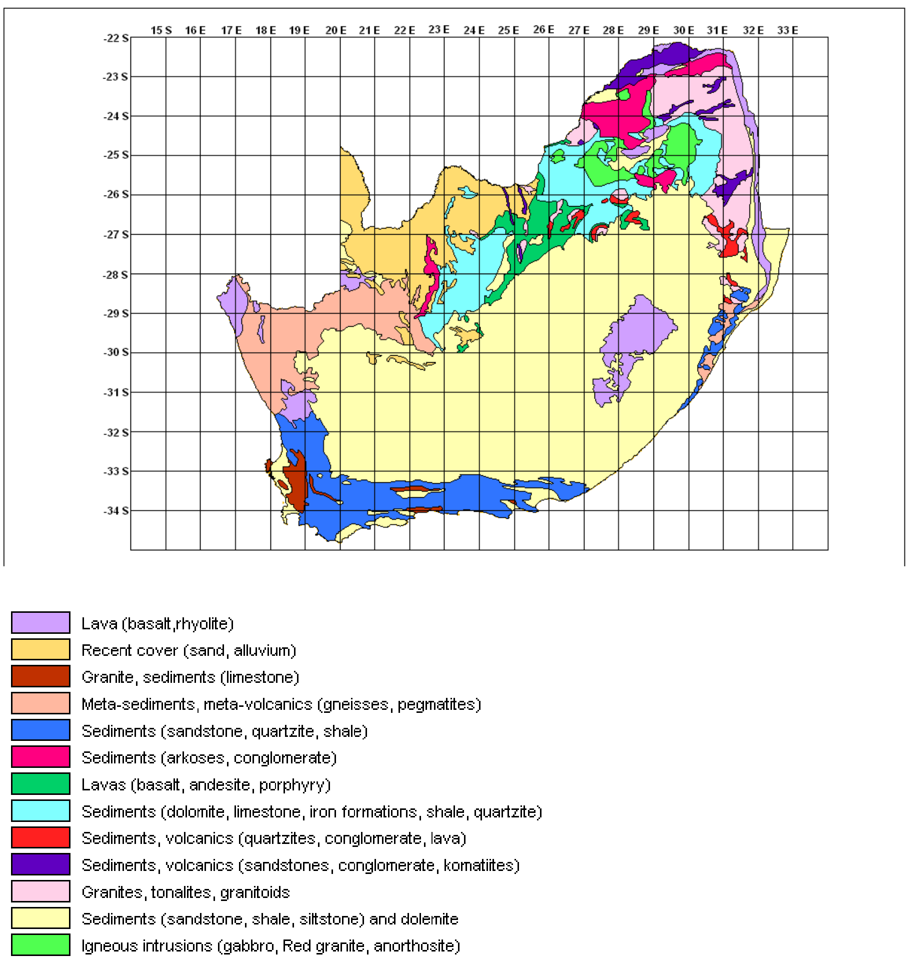
$\sum$ (Actual MM Intensity – Fitted MM Intensity) ^{2}

The summation is over all observations in the isoseismal data set. A detailed earthquake model should allow practitioners to fit MM Intensity attenuation models to isoseismal data combined with the flexibility to integrate expert opinions on appropriate parameter values.

Another key factor that affects the MM Intensity experienced at a geographical point is the geological structure underlying the geographical point.

Geological structure areas

Ground shaking as a result of an earthquake will vary between different types of rock or sediment. Soft sand will shake more than solid rock in the event of an earthquake. As a result geological structures underlying risk locations have to be considered in the loss assessment since more or less shaking will result in more or less damage. Below is summarized geology map of South Africa.



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Geographical information systems can be used to extract isoseismal data points within each geological structure area. A MM Intensity attenuation model can then be fitted to extracted isoseismal data for each geological structure area.

Another factor that will affect the MM Intensity of a geographical point within a geological structure area is the series of geological structure areas through which the seismic wave travels before reaching that point. Isoseismal Map data in South Africa is limited and reflects MM Intensity as seismic waves travel through different geological structures. To identify the impact of each geological structure through which the seismic wave travels before reaching one MM Intensity observation will have practical difficulties due to a lack of data. A different MM Intensity model is fitted to each geological structure area.

The MM Intensity experienced at different points within a particular geological structure area will be affected by other geological structure areas. These other geological structure areas lie between the earthquake epicenters and the particular geological structure area considered. Therefore MM Intensity models for geological structure areas reflect the impact of other geological structure areas on the arriving intensity of seismic waves.

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Vulnerability curves

As explained under the exposure section, vulnerability curves graph damage ratios against MM Intensity. Vulnerability curves do exist for many different types of properties. A detailed earthquake model should include these vulnerability curves and allow the practitioner to link different business segments to the appropriate vulnerability curves. Business segments are unique combinations of classes of business, type of risk and source of business descriptions in exposure data.

The nature of business segments will vary widely from one risk carrier to the next. Therefore it is impossible to determine a standard set of vulnerability curves that will be appropriate for the business segments of all risk carriers. We recommend that practitioners be allowed to adjust standard model vulnerability curves linked to particular business segments to reflect the unique nature of the business segment. If adjustments are made, the practitioner should provide valid reasons. An example of vulnerability curve adjustment maybe where a “High rise building” curve is used for property sums insured above a certain value and a “Medium or low rise building” curve for lower property sums insured.

Analysis of actual earthquake damage has shown that damage to similar type of buildings subject to the same MM Intensity can vary. Therefore vulnerability curves used in detailed earthquake modeling should include a statistical distribution at each MM Intensity level to capture variation in damage. Interpolation can be used to estimate damage ratio probability distributions at non-integer MM Intensity levels.

Demand inflation

Demand inflation occurs when there is a sudden increase in demand of a product (such as tiles or paint) with a shortage in supply. Hurricane Katrina in the US is a typical example of a catastrophe event resulting in a demand inflation affect on resulting insurance claims. A detailed earthquake model should therefore include a demand inflation affect once total event losses exceed a certain percentage of exposure. The demand inflation affect should also increase as total events losses as a percentage of exposure increases. It is our opinion that this relationship should be non-linear.

Reinsurance Contracts

To make a realistic assessment of a risk carrier’s retained earthquake losses, reinsurance (retrocession for reinsurers) contracts have to be included in the loss assessment. A flexible detailed earthquake model should allow practitioners to link business segments to actual or new reinsurance contracts. The practitioner should also be able create inurances (order of reinsurance cover) between actual or new reinsurance contracts.

For proportional reinsurance contracts (Quota Share or Surplus) event limits have to be considered in retained and ceded loss calculations. Detailed risk by risk sum insured information must be stored in the model in order to accurately calculate ceded and retained earthquake losses after Surplus contracts. Surplus contracts are more complex to handle in an earthquake model since the percentage of the risk retained and ceded depends on the sum insured in relation to surplus retention.

The number of reinstatements has to be considered in the calculation of ceded and retained losses under Catastrophe XL contracts. The ideal earthquake model should include a reinsurance default risk assessment per participating reinsurer.

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Simulation module or engine

Insurance losses from earthquakes are driven by several complex processes as outlined in the previous sections of this document. Many processes are subject to some degree of volatility or uncertainty. To understand the complexity of the processes involved in earthquake loss estimation and the uncertainty of loss outcomes, several thousands of possible earthquake loss outcomes have to be quantified. This can be done using a simulation module or engine.

A simulation process also allows practitioners to attach probabilities to earthquake loss outcomes, which is indirectly a requirement of Financial Condition Reporting. We have implemented a simulation module which includes the following processes and features:

- Simulates at least 10,000 annual earthquake loss scenarios.
- Simulates the annual number of earthquakes per risk area from fitted statistical or user defined probability distributions.
- If a standard statistical distribution is selected to model Richter scale Magnitude, it simulates the parameter values of the standard distribution with consideration of parameter correlations.
- Simulates Richter scale magnitudes per risk area from fitted statistical or user defined probability distributions given the simulated annual number of earthquakes and simulated parameter values. Ignore any further calculations if the simulated Richter scale magnitude is less than 5. Earthquakes greater than 5 are defined as significant.
- Simulates the longitude and latitude epicenter coordinates for each significant simulated earthquake in each risk area.
- Calculates the distance between the centroid (midpoint) coordinates of each postal code in the exposure data set and each significant simulated earthquake in each risk area.
- Identifes the geographical structure area in which each postal code in the exposure data set is located. The appropriate fitted MM Intensity attenuation equation can then be allocated to each postal code.
- Calculates the MM Intensity at each postal code in the exposure data set using the fitted MM Intensity attenuation equation for each significant simulated earthquake in each risk area.
- Calculates the adjustment factor for each MM Intensity calculation to allow for a smooth progression in MM Intensity as the seismic wave moves incrementally from one geological structure area to another.
- Identifies the business segment of each individual risk in the exposure data set and the vulnerability curve linked to each business segment.
- Identifies the individual risks at each postal code from the exposure data set.
- Calculates the interpolated mean damage ratio and standard deviation in damage ratio from linked vulnerability curves for each risk in the exposure data set, for each simulated significant earthquake.
- Calculates the parameters of the damage ratio probability distribution using the mean and standard deviation interpolated above.
- Simulates a damage ratio from the probability distribution now calculated for each risk in the exposure data set, for each simulated significant earthquake.
- Calculates the gross earthquake loss to each risk for each significant earthquake.
- Calculates the ceded and retained earthquake loss under each reinsurance contract for each risk for each significant simulated earthquake.

- Sums all retained losses and ceded losses to each reinsurance contract over all risks for each significant simulated earthquake.
- Saves the resultant data into a table for reporting and model output purposes.

Scenario testing

In addition to the above, scenario testing allows practitioners to calculate a distribution of earthquake losses from one earthquake with a defined Richter scale magnitude and epicenter. This will give the practitioner an indication if the assumptions underlying the detailed earthquake model are reasonable or whether the assumptions should be reviewed. It is also a useful tool to assess what the loss will be to the risk carrier should a large historical earthquake (such as the Ceres earthquake in 1969) occur today.

Model output

A detailed earthquake model should produce the following reports as cumulative probability distributions, probability of exceeding or return periods:

- Number of ceded earthquake loss events per annum
- Number of ceded earthquake loss events per annum to each defined reinsurance contract
- Earthquake loss amount per event to each defined business segment and all business segments combined gross of all reinsurance
- Earthquake loss amount per event to each defined business segment and all business segments combined net of all proportional reinsurance
- Earthquake loss amount per event to each defined business segment and all business segments combined net of all proportional and non-proportional reinsurance
- Earthquake loss amount per event per annum to each defined business segment and all business segments combined net of all proportional reinsurance
- Ceded earthquake loss amount per event per annum to each defined reinsurance contract and all reinsurance contracts combined
- Ceded earthquake loss amount per event to each defined reinsurance contract and all reinsurance contracts combined
- Correlation matrix of earthquake loss amounts between various business segments gross of all reinsurance
- Correlation matrix of ceded earthquake loss amounts between various reinsurance contracts

The model should also show earthquake losses as value at risk (percentile) or tail value at risk reports.

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