Regional RiskScape: A Multi-Hazard Loss Modelling Tool

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EXTENDED ABSTRACT

The management and mitigation of natural hazards and the response to disasters has become increasingly important for local and national authorities in the last decade. Geological hazards are an ever present danger in New Zealand, which straddles the Pacific and Australian crustal plates. The frequency of severe weather-related events is increasing, not only because of global warming, but people also tend to be more vulnerable especially when attracted to settle in areas which are inherently at risk from natural hazards such as the coast or flood plains. These potential perils require tools and decision support systems that facilitate the analysis and comparison of risks from different hazards. Current national scientific and engineering knowledge is combined to develop a powerful software program called RiskScape for analyzing potential impacts from various hazards in New Zealand. At present it covers five natural hazards: earthquake shaking, volcanic ashfall, river floods, wind storms and tsunami.

The prime goal is to develop an easy-to-use decision-support tool that converts hazard exposure information into likely consequences for a region, such as damages and replacement costs, casualties, disruption and number of people affected. Consequences for each region presented in a common platform across all natural hazards can then form the basis of prudent planning and prioritized risk-mitigation measures that link directly to the severity of the risks

The development of Regional RiskScape New Zealand has been underway for three years of its four year development phase. The paper will describe the status quo of the development and will also address problems and areas where further work is required.

1. INTRODUCTION

New Zealanders are exposed to a wide variety of natural hazards. The extremes of weather and geological forces that create its unique character also present many hazards, including earthquakes, volcanic eruptions, tsunamis, storms, floods and landslides. River flooding is the most frequent and costly peril in New Zealand (Smart 2006, Te Ara 2007), but at longer return periods, earthquakes and tsunami can produce substantial damage and loss of life e.g., 1931 Hawkes Bay earthquake. Further, the consequences of all weather-related hazard events are likely to be compounded by the effects of global warming. In particular, the major increases in risk will be in coastal areas (due to sea-level rise and associated intensification of waves and storms) and river/urban inundation (due to intensification of rainfall) (NIWA, 2007).

Increasingly, emergency managers and planners are demanding more quantitative information on possible consequences and the risks associated with different hazards (Blong 2003, Durham 2003, Grünthal et al. 2006) to be in a position to compare the impacts across the different hazards before making investment decisions on risk reduction for their region. For example, a recent overview of the national tsunami risk has estimated that the potential for casualties and damage is higher than the national earthquake risk given the same exceedance probability (Berryman 2005)

In the past, risk management has been mostly reactive. RiskScape is a new tool, being developed jointly by the National Institute of Water and Atmospheric Research Ltd (NIWA) and the Institute of Geological and Nuclear Sciences (GNS Science), which aims to simulate regional scenarios in advance, and produce estimates of damage in dollars and likely casualties (Bell & King 2006, Schmidt et al 2007). It provides informative support for decision makers.

2. RISKSCAPE FRAMEWORK

The prime goal is to produce an easy-to-use decision-support tool that converts hazard exposure information into likely consequences for a region, such as damage and replacement costs, casualties, disruption and number of people affected. Consequences for each region presented in a common platform across all natural hazards can then form the basis of prudent planning and prioritized risk-mitigation measures that link directly to the severity of the risks (Schmidt et al 2007).

RiskScape works by running through a sequence of steps. First off, the zone of influence of a particular hazard needs to be ascertained and its local intensity and recurrence interval established. Then the impact of events of various intensities can be calculated by overlaying the hazard exposure for each event over built-environment inventories and demographic profiles of the people exposed to such event (i.e. the receptors).

A critical factor in estimating losses from potential hazards is information or inventories about all material and non-material aspects that may be impacted by the hazard. Thus, a comprehensive inventory of assets and people is the backbone of a loss-modelling tool. It provides critical input to several stages of the risk calculation (see Figure 1). Dealing with different types of hazards and numerous assets and land uses (e.g., agriculture) requires a huge amount of information, particularly about the characteristics of the assets at risk e.g., construction characteristics of buildings, routes for utilities such as water supply, sewerage, road and power, demographic and business information. A comprehensive national database on building and infrastructure attributes does not exist in New Zealand. Whilst existing building valuation databases are a useful starting point, providing a few basic attributes, during the development phase of RiskScape different ways are being tested to find the best approach to estimating some of these attributes where the data doesn't exist. However, there are still various attributes, e.g. building floor height, which is relevant to flood water damage to buildings, about which no handy information exists. Thus, extensive field surveys have also undertaken and new techniques such as satellite imagery or laser-scanning (LiDAR) used to get the necessary information about the elements at risk. For people, data from the 5-yearly census, provides a nationally consistent and reliable dataset for a meshblock (an area with about 20-30 houses).

Hazard modelling is the second major cornerstone of the RiskScape tool. To associate the hazard intensity with an individual asset, high resolution models are necessary. Use is made of sophisticated computer models that simulate the hazard (e.g. the flow of floodwaters over floodplains or streets; tsunami overland flow, volcanic ash dispersion and settlement). Some verification can be done against past recorded events to help tune the models. RiskScape also has the ability to import directly the hazard exposure fields (e.g. flood depths and flow velocity, wind gust strengths) from previous studies or to compute these hazard fields internally, which is done for earthquake shaking and volcanic ashfall. To allow the end-user to analyze and compare the risks and consequences from different hazards, a probabilistic approach is used. However, particular scenarios or historic events can also be simulated.

The third cornerstone is the fragility/loss module, where the RiskScape framework assesses how much damage would occur for a particular building or piece of infrastructure. Vulnerability or fragility curves are the most common way to estimate hazard-related damages because there is usually a correlation between monetary losses, the damage state and the hazard intensity. However, understanding these correlations and associated uncertainties for the range of building and infrastructure characteristics present in New Zealand is one of the major challenges of the RiskScape project.

But the risks are much wider than those of direct damage to our built environment. RiskScape is also being developed to include impacts on people and society, initially addressing the risk of casualties or injuries and potential number of people affected. The economic effects caused by a major disaster can be significant depending on where the boundaries of the analysis are drawn. If a national perspective is taken, the economic effect of the lost gross domestic product (GDP) would normally be small. However, if the analysis is confined to the affected area, the economic effects can be severe, although some sectors like the construction/building sector often benefit. Hence, RiskScape will not only focus on direct damage to our built environment but also addresses the impact on people's lives and indirect damages. That provides planners and emergency managers with a comprehensive and detailed overview of possible consequences and enables them to prepare and develop mitigation strategies in due time.

Conceptually, this process from hazard to risk is relatively straight forward, but application to real-world situations is problematic, with inherent difficulties in obtaining and linking good-quality inventory and demographic datasets and comparing hazards with vastly different recurrence intervals and source mechanisms. These challenges are being met by the development of a Regional RiskScape Model.

The key principles built into the RiskScape system are:

- Primarily intended for applying to regions (e.g., New Zealand has 15 regions based around river catchments);
- Usable by emergency managers and planners who may have little knowledge of the science and engineering aspects of natural hazards;
- Develop the computational "engine" using open-source software with limited GIS-like capability to avoid expensive licensing arrangements, but still provide input/output processing on a GIS platform;
- Designed as stand-alone software to be functional during a major hazard event and not be reliant on a server.
- Capability to implement external asset databases, models or loss curves. This provides the end-user with flexibility to implement RiskScape into their existing environment rather than being forced to switch to a completely new system.
- Results on the consequences (damage, disruption, casualties) will primarily be produced for aggregated areas (e.g., census meshblocks 30–50 houses or district council areas). Computations at the individual building or infrastructure scale would be restricted to owners of the inventory data.
- Where possible provide truly comparable losses & casualties from different natural hazards for specified exceedance probabilities (or return periods), as well as the ability to simulate losses from historic or prescribed scenarios;
- Ability to import directly the modelled hazard exposure fields from previous runs of sophisticated dynamic models (that may take several hours to run) or to compute these fields internally where simpler attenuation models are possible e.g., earthquake shaking;
- Concerted effort to track uncertainties at all stages of the processing that turns a hazard exposure into losses;
- Working alongside regional and local government partners over the 4-year project to provide a fit-for-purpose tool that is practically useful in risk-reduction decision making;
- Fast computational system that enables the system to also be used during a major hazard event as it unfolds or as a simulated exercise by emergency managers.

The overall concept of the Regional RiskScape system is shown in Figure 1.

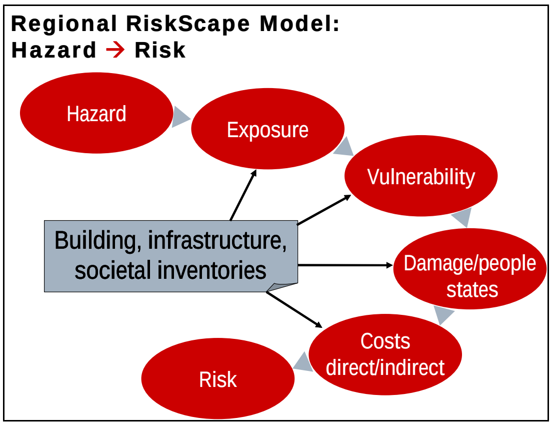

Figure 1. Flowchart of main modules of the Regional RiskScape tool.

For the initial development phase (4 years), we are trialling the system with three regional/local government partners (centred on Westport, Napier & Hastings, Christchurch) which cascade up by an order of magnitude in population. The initial natural hazards being considered are: earthquake, volcanic ash-fall, local and distant tsunami, storms (wind only), and river flooding. However, the software design allows other hazard modules to be added later.

To aid emergency planning and response RiskScape has been developed to ensure it is compatible and usable with as many end-users as possible. The system is stand-alone with the computational engine developed using open-source software to avoid expensive licence arrangements. Since the majority of possible end-users already use well established GIS software, RiskScape has been developed to allow import and export of data into any existing GIS platform. However, the tool will have basic GIS functionality and allows the end-user to conduct a range of analysis such as filtering the results e.g.

where are the areas with more than 25% damage to buildings.

3. APPLICATION OF THE RISKSCAPE SYSTEM

The RiskScape System is built on a modular modelling framework. New hazard, asset, or loss modules can be seamlessly integrated into the running system as new modules (Figure 3). A RiskScape module specification and module builder interfaces have been developed to facilitate this task.

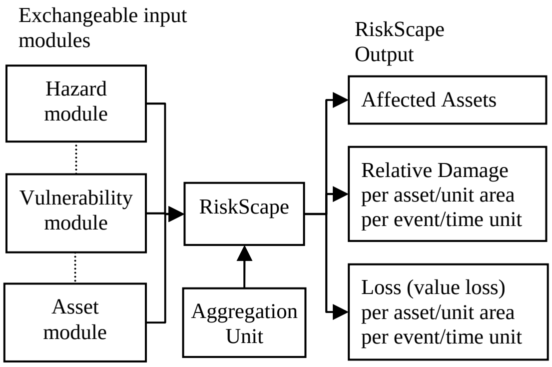

Figure 3. Components and outputs of the RiskScape system.

The RiskScape user interface guides through a series of sequential risk modelling steps:

1. Choose hazard.
   User selects a hazard type, currently implemented: earthquake, storm, flood, tsunami, volcanic ashfall.

2. Choose hazard model.
   User selects a particular hazard model, implemented for selected hazard type.

3. Define model parameters.
   The Interface queries hazard parameters specific to the selected hazard model, eg. earthquake depth and magnitude, and subsequently displays the selected hazard scenario (Figure 3).

4. Select assets and aggregations.
   The Interface offers assets that are under threat from defined hazard scenario. Aggregations are optional spatial units (for example authority boundaries) for displaying losses on a spatially aggregated level.

5. Select fragility function.
   The user can select a fragility function (= loss model available for the selected combination of hazard and asset.)

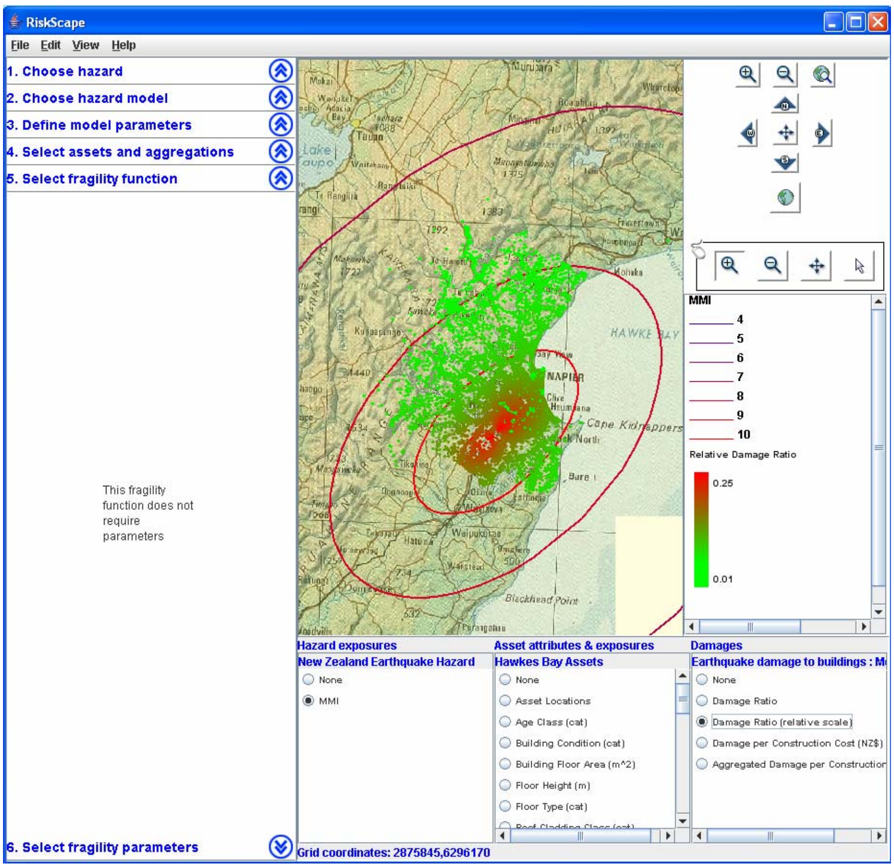

Figure 2: Example of a simple earthquake scenario applied to buildings in the Hawkes Bay region

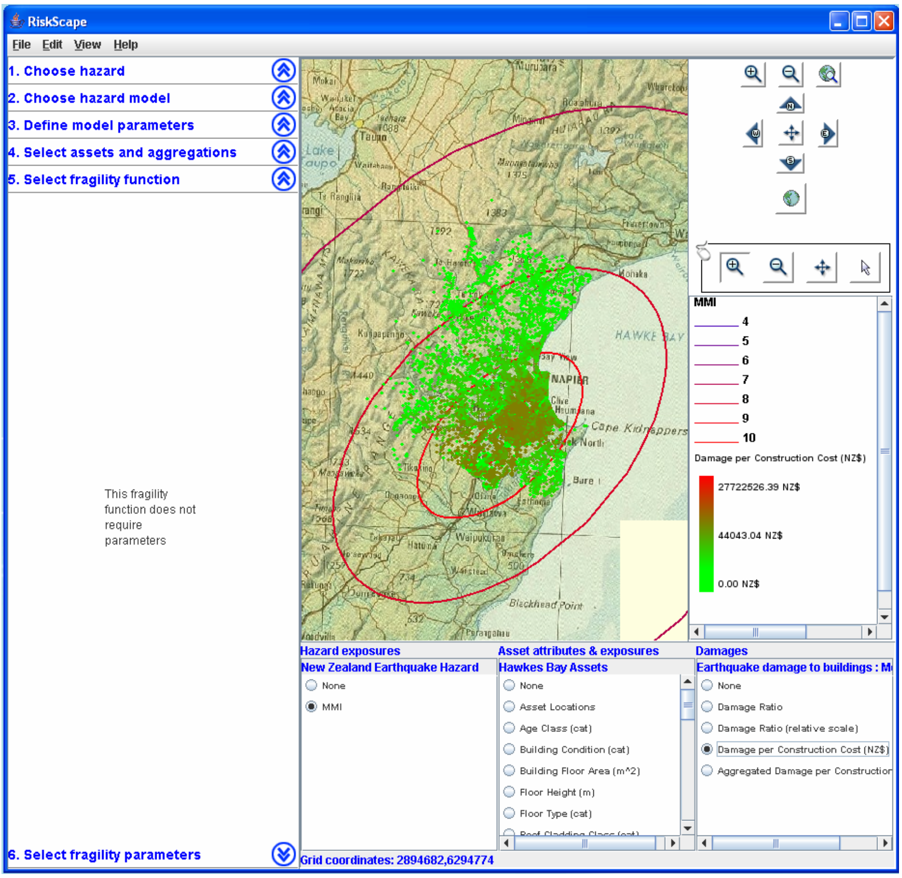

Figure 4: Map of expected building losses from the earthquake scenario

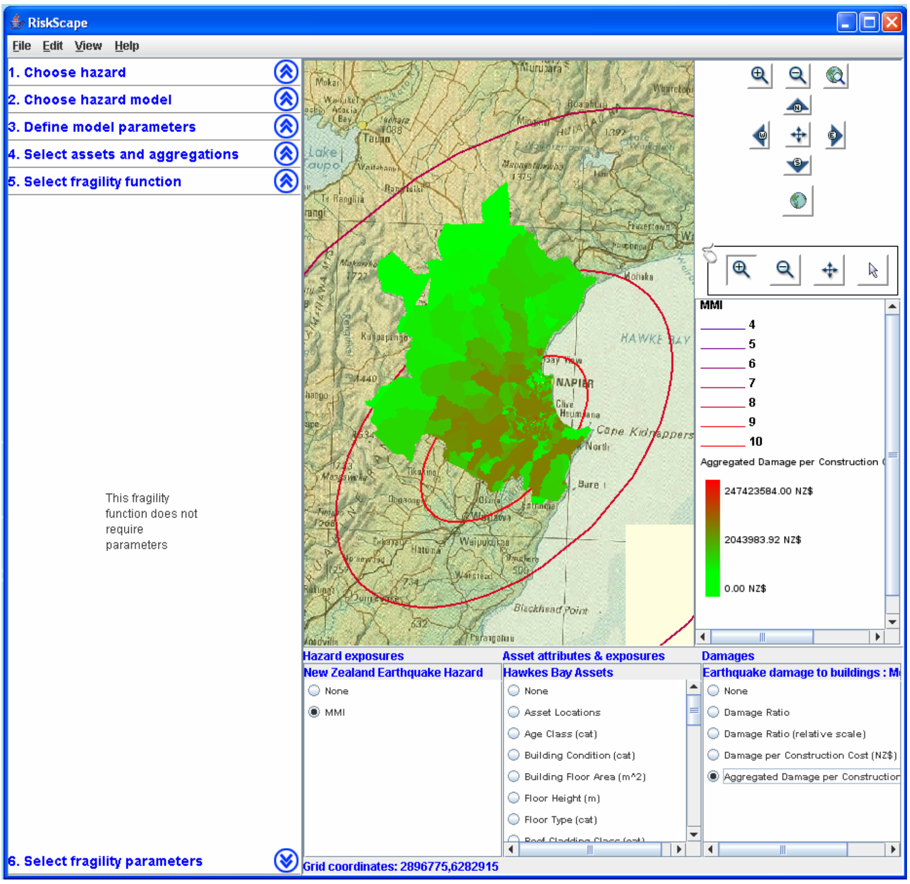

Figure 5: Building losses from the defined earthquake scenario aggregated on a meshblock level

Once hazards, assets, aggregations, and fragility functions have been selected, the system computes damage ratio (Figure 3) and expected losses on an asset and aggregation level (Figures 4 and 5).

4. ISSUES AND CHALLENGES

The project was launched in 2004, the first prototype released to our partners in July 2006 and an operational version is expected for winter 2008 which can then be applied in other areas of New Zealand. After 3 years into the project, several issues have emerged that provide some challenges to the development and implementation of a quantitative risk assessment tool:

- Access and availability of building and infrastructure inventory data that has sufficient parameters to assign fragility classes and hence fragility curves and damage states for each natural hazard. An example is the lack of ground-floor elevations for buildings to assess flood and tsunami damage and roof type and % openings data for wind damage. At this stage we have calibrated a floor height relationship using building age classes as a surrogate based on field sampling surveys;

- Accurate modelling of the hazard exposure is a crucial step in the process, particularly for topographically-steered hazards such as floods and tsunami and to a lesser extent wind. A critical element of successful modelling in this context is the availability of accurate coastal and floodplain topography such as LiDAR (airborne laser scanning) or satellite radar altimetry;

- Each hazard sector uses different ways to communicate risk, probability and uncertainty, so we have an ongoing need to work with our partners to ensure they have results from RiskScape that are appropriate for their intended use in decision making;

- Acceptance of the results including the inherent uncertainties (no matter how grim) by the end users and a means by which they can be assisted in getting public and political buy-in for appropriate and cost-effective risk mitigation measures e.g. the cost-benefit may be higher for earthquake-proofing a critical bridge than adding more height to a stopbank (levee) in a particular area to reduce flood risk (or vice versa);

- Ongoing maintenance of hazard exposure models & inventory datasets as changes in the built environment occur and revised updates on climate-change projections become available.

5. OUTLOOK

The Regional RiskScape decision-support tool has been through a 3-year development phase. Much has been achieved in firming up the concepts and undertaking preliminary software development through the cooperative effort of two institutes working together. Field experience in sampling building attributes relevant to a wide range of natural hazards has been invaluable in assessing the minimum information required, complemented with the use of more-readily-available surrogates such as building age where possible. Key progress steps now are: a) to use preliminary results of Regional RiskScape to demonstrate to and consult with local/regional government and infrastructure/utility agencies involved in hazard management about how to best streamline the tool and its outputs to suit their requirements; and b) then to proceed to fine-tune and operationalize the tool in the remaining year.

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