Consequence-based decision making tools to support natural hazard risk mitigation and management: evidences of needs following the Canterbury (NZ) Earthquake sequence 2010-2011, and initial activities of an open source software development Consortium

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ABSTRACT: Effective risk mitigation and post-disaster recovery depends upon the efficient allocation of scarce resources through good decision-making. The Canterbury Earthquake sequence 2010-2011 in New Zealand highlighted the need for decision support tools to inform and support, among others, decisions on: 1) damage assessment, recovery and resilience enhancement of impacted infrastructures; 2) the management of temporary housing in the short and long-term; 3) the reconstruction planning at the urban-level. First, the paper reports and analyses the aforementioned requirements, based on the perspectives of the stakeholders and key agencies involved in the same decision making processes. Secondly, the paper presents the idea of an open source solution for consequence based decision-making tools to be developed by, and to be made available worldwide to stakeholders involved in natural hazard risk mitigation and management processes. To reach this goal, the "Multi-Hazard Assessment, Response, and Planning" (M-HARP) global, open source consortium was established with members from multiple countries. The activities of the M-HARP Consortium, summarized in the paper, include: 1) the further development of existing open-source modelling tools (e.g. MAEviz, EQvis) along with the necessary IT framework and infrastructure to support them; 2) the development of additional applications and modules to address specific aspects of risk assessment and mitigation, post-disaster response and recovery for multiple-hazards; 3) desired strategic partnership and collaboration with other, appropriate initiatives worldwide (e.g. GEM, RiskScape).

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1 INTRODUCTION

Effective risk mitigation and post-disaster recovery depends upon the efficient allocation of scarce resources through good decision-making. The problem is that making good decisions depends on understanding many complex problems and their interrelationships. Despite the numerous global and regional initiatives to create platforms/tools aiming to support the understanding, management and mitigation of seismic risk, on the one hand, and to enhance post-disaster and recovery decision-making across various sectors, on the other hand, the Canterbury Earthquake sequence 2010-2011 in New Zealand highlighted, once again, that none of the existing platforms/tools are either accessible and/or readable usable by emergency managers and post-disaster recovery decision makers.

A global, open source consortium, under the name of "Multi-Hazard Assessment, Response, and

Planning” (M-HARP) was established to support a pro-active development and implementation of tools and platform able to inform and support natural-hazards risk mitigation and post-disaster recovery and reconstruction. Based on the perspectives of the stakeholders and key agencies involved in the post Canterbury (New Zealand) Earthquake sequence 2010-2011 recovery processes, the paper reports in Section 2 on needs and requirements for decision making support tools. Section 3 of the paper provides few examples (an exhaustive and critical overview is out of the scope of this paper) of global and national initiatives and technologies for open and non-open source platforms/tools that aim to support the understanding, managing and mitigation of seismic risk and to enhance recovery decision-making across various sectors. The idea of the M-HARP open source solution for consequence based decision-making tools, is presented in Section 4.

2 CONSEQUENCE-BASED DECISION MAKING TOOLS: EVIDENCES OF NEEDS FOLLOWING THE CANTERBURY EARTHQUAKE SEQUENCE

Christchurch, the second largest city in New Zealand, and the nearby Wamakariri District Council, WDC, have been seriously affected by the Canterbury Earthquake sequence, that included: September 4, 2010 Darfield earthquake (Mw=7.1); February 22, 2011 Christchurch earthquake (Mw=6.3), along with an impressive number of M>4 aftershocks including June 13, 2011 Mw=6.0 event. The Canterbury Earthquake sequence 2010-2011 in New Zealand highlighted the need for decision support tools to inform and support, among others, decision on: 1) damage assessment, recovery and resilience enhancement of impacted infrastructures; 2) the management of temporary housing in the short and long-term; 3) the reconstruction planning at urban-level. These needs are shortly summarised in the following sub-sections.

2.1 Damage assessment, recovery and resilience enhancement of impacted structure and infrastructures

The devastating Canterbury Earthquake sequence 2010-2011 caused widespread damage to the built environment, heavily affecting structures, infrastructures and networked utility systems. The Natural Hazard Research Platform (NHRP) of New Zealand funded various projects to support and inform the decision making process during the recovery phase. Among few others, the “Recovery of Lifelines” project was established and funded by the NHRP to support the recovery of lifelines in the Canterbury Region. The project aimed to inform and to help meeting the short-term operational needs of lifeline utilities by facilitating the accessibility to lifelines of available know-how and by connecting them with the national and international research community.

As part of the project specific short-term recovery needs from the lifelines utilities were collected (Giovinazzi and Wilson 2012), many of them can be related and summarised in term of the need for tools/procedures to support:

- the assessment and analysis of the physical and functional impact of the earthquakes on the lifelines’s components and systems;
- the assessment of the residual and future functionality of affected components;
- the prediction/estimate of the expected performance and risk for alternative repair and/or reconstruction strategies in the event of aftershocks and/or future earthquake events;
- the reporting/documenting and archiving of the lessons learned.

All the possible support, under the difficult circumstances and constraints imposed by the post-earthquake recovery climate, was provided to the lifelines utilities (Giovinazzi 2012a) and several initiatives were advanced, including: 1) promoting the use of Geographical Information System, GIS, for evaluating the performance of different underground pipe materials (analysis of pipe performance for WDC water network and for Christchurch wastewater network are reported in Knight et al. 2012 and Brooks & Craigie 2012); 2) promoting the use and showing the potentialities of MAEviz for analysing the damage occurred to structure and infrastructures and for evaluating alternative reconstruction scenarios (application of MAEviz to analyse the damage occurred to the building in

Christchurch Central Business District and to the bridges respectively are reported in Lin et al. 2012 and Brando et al. 2012, Figure 1a); 3) proposing innovative solutions to speed-up and automatized the damage assessment of underground pipes (Figure 1b, McHenry and Lee 2012).

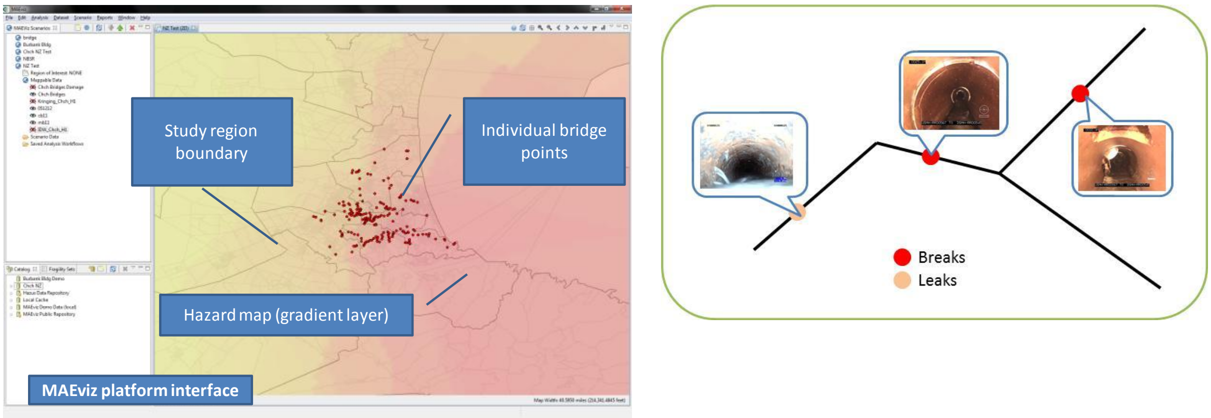


Figure 1. Application of MAEviz to support damage assessment and analysis of networked infrastructures following Christchurch Earthquake: a) MAEviz analysis framework, with Christchurch area unit boundaries, bridge points overlaied to 22nd February 2011 gound motion map; b) proposal for "Automated Detection of Cracks and Leaks in Buried Pipeline" and automatic geocoding in MAEviz (McHenry and Lee 2012).

Longer-term recovery and reconstruction needs for decision support-tools were collected directly leasing with the Stronger Christchurch Infrastructure Rebuild Team (SCIRT) that is currently responsible for rebuilding the horizontal infrastructure in Christchurch. The SCIRT alliance, formed few months after the 2011 February Earthquake, is a partnership between Christchurch City Council (CCC), Canterbury Earthquake Recovery Authority (CERA), New Zealand Transport Authority (NZTA) along with four contracting companies. For the sake of an example SCIRT is considering different possible options repair and reconstruction of the heavily affected wastewater network, including: 1) like-for-like (e.g. keeping the existing system and repairing/substituting damaged components); 2) modified-gravity system (e.g. keep existing steep grade and use new pipe materials and modern construction or enhance gravity by steepening grades); 3) adopt pressure sewer/grinder pump system; 4) adopt vacuum-system.

SCIRT was looking for a method and/or existing platforms/tools:

- to measure and compare the increased seismic resilience possibly offered by the different aforementioned wastewater network rebuilding options.

To support SCIRT decision-making process toward the seismic resilience enhancement of Christchurch wastewater network a team composed by University of Canterbury and international experts engaged with SCIRT (Liu et al. 2013) bringing, firstly a great contribution in term of available know-how, lesson-learnt and best practices from recent earthquakes worldwide, in particular Kobe and Northridge. Secondly, the team discussed with SCIRT the potentialities and limitations of existing seismic risk assessment tools, allowing for probabilistic and scenario analysis simulations, and the several definitions available in literature for lifelines resilience to natural hazards were discussed. It was found that none of the existing platform/tool was readably usable to immediately support the SCIRT decision-making process targeting the resilience enhancement of horizontal infrastructures in Christchurch.

2.2 Assessing and managing post-earthquake housing needs

Post-disaster temporary housing programs have often demonstrated the inability to fulfil socio-economic needs of displaced population in addition to being overly expensive (Bolin 1982; Comerio 1997; Johnson 2007). Similar shortcomings have affected the management of temporary housing issues following the Darfield 2010 and Christchurch 2011 earthquakes (Giovinazzi and Stevenson 2011, Giovinazzi et. al 2012a) including: 1) lack of preparedness and pre-planning; 2) lack of data and models to estimate/predict the displaced population and the internal and external population migration; 3) lack of coordination/communication and information sharing capabilities among the involved agencies; 4) temporary housing solutions unable to meet and satisfy expectations and needs of the displaced populations.

The Canterbury experience, enforced once more the need for robust and structured methods and tools to plan for and to better manage post-disaster temporary housing issues, by supporting:

- the pre-disaster planning for temporary housing;
- the assessment of post-disaster temporary housing needs during both the emergency management and the recovery phases;
- the assessment of benefits and shortcoming of alternative strategies and solutions for temporary housing.

The authors of the paper engaged with key stakeholders involved on the management of the still on-going and unresolved response to housing needs following the Canterbury Earthquake sequence 2010-2011. In particular, following explicit interest and request from the Canterbury Earthquake Temporary Accommodation Service (CETAS) the authors are testing and investigating the feasibility of implementing in Christchurch existing tools that might have potentialities to inform and support post-earthquake housing needs, in particular: 1) the “Temporary Housing Module” included in MAEviz, an open-source software developed by the Mid-America Earthquake Centre, MEA, in cooperation with the National Center for Supercomputing Applications, NCSA, at the University of Illinois (see Section 4); 2) and the Community-Based Housing Response Pool, CHRP an automated data acquisition module enabling involved agencies to qualify and quantify the socioeconomic needs of displaced families (El- Anwar and Chen 2012).

The availability of on field collected data from Canterbury earthquake and the connection and collaboration of key stakeholders and decision-makers provide a unique opportunity for the advancement of the on-going research on models to estimate/predict post-earthquake displaced population and housing needs (Chang et al. 2009; FEMA 2007; Wringht and Johnston 2010). On-going research at University of Canterbury, in collaboration with GNS Science, MAE and NCSA – University of Illinois, EPICentre - University College London, University of Washington and REM UME Graduate School - University of Pavia, Italy, is, in particular looking at: 1) testing/calibrating and enhancing the aforementioned predictive models based on Canterbury earthquake data and observations; 2) including/reflecting in the aforementioned models factors that have proved in Canterbury to heavily influence households need and decision to move to alternative accommodation including: physical impact on structure and infrastructures; social, economic, ethnical and cultural factors; adopted public policies on shelter-use and shelter costs; latent accommodation resilience, such as thresholds of “willingness to stay” and liveability when staying with family and friends; social acceptability of different forms of temporary housing; 3) defining a method focused on New Zealand reality and culture (existing models might include parameters and criteria US-cultural specific). Preliminary results on the first point above are reported in Melos-Santos (2012).

2.3 **Reconstruction planning at urban-level**

The Canterbury Earthquake Recovery Authority, CERA recognised that maximising the positive potential, and minimising negative impacts of the many decisions required to achieve recovery and reconstruction across Greater Christchurch was a critical aspect of its activity. CERA recognised the need for tools/platforms that could inform and support its decision making process, by providing, among others:

- support for the data gathering and archiving of relevant information and data;
- processing capability to analyse data and evidences and convert them into know-how applicable to anticipate and solve recovery problems;
- optimisation capabilities to support efficient prioritisation, allocation and coordination of

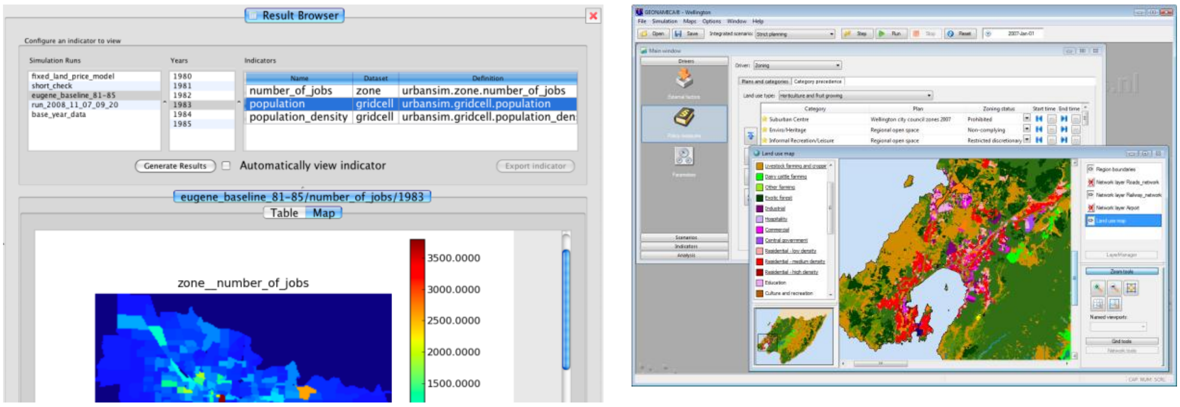
scarce resources;

- compelling visualisation components (GIS based) to allow for the visual articulation and presentation of findings/results;
- ability to integrate components of urban planning (e.g. land use, population growth, structure, infrastructures, utilities, social services and agencies,) and modelling capabilities to test the impact of different scenarios on public safety, sustainability, environment; and
- support the synchronising among sectors and agencies to build a consolidated and joint understanding of the positive potential, and latent negative impacts of alternative decisions.

Giovinazzi (2012b) provided an overview of existing urban planning and urban growing predicting tools, designed to assist planners public and communities, in general in: 1) integrating their land use, transportation, and environmental planning efforts; 2) determine impacts of possible future planning, and assess public policies related to planning options; 3) experience their community and future changes via compelling visualization components, including 3D view. The analysed tools/platforms were either the result of multi-collaborative multi-million research projects or software produced, maintained and distributed by private companies. Few of them used grid-based cellular automata (CA) approach integrated with regional socioeconomic models. Others were desktop-based systems, often extensions of ArcGIS. Only one of the analyzed tools was open-source (Figure 2a).

From the analysis it was concluded that existing urban planning urban growing predicting tools have great potentials to effectively support post-disaster recovery planning process offering modeling (e.g. test of alternative scenarios at multiple scales), prediction, design, visualization, support to effective collaboration and dissemination of results capabilities. However it was noticed that none of the existing urban planning and urban growing predicting tools was tailored and readably usable for handling and analyzing post-disaster issues and/or for assessing the benefits of including disaster mitigation options while planning the recovery and reconstruction at urban level. Furthermore it was highlighted that existing tools included and used models and indicators calibrated on the USA reality and/or USA specific.

It is worth highlighting that following the Canterbury Earthquakes sequence the Ministry of Business, Innovation and Employment, MBIE in NZ, funded a four-year multi-agency collaborative research project "Economics of Resilient Infrastructures" to develop economic models able to capture the impact to the economy caused by infrastructure failure and to provide information on the process of recovery over time and space. The models will become an integral part of an innovative and NZ specific planning tool "Integrated Scenario Explorer, ISE" (Figure 2b) in course of development as part of an on-going collaborative policy-science research programme funded by the same MBIE (research programmes: "Sustainable Pathways" 2003-9; "Sustainable Pathways 2" 2009-2015; "Creating Futures" 2006-10).



Name	Dataset	Definition
number_of_jobs	zone	urbansim.zone.number_of_jobs
population	gridcell	urbansim.gridcell.population
population_density	gridcell	urbansim.gridcell.population_den

Figure 2. Planning tools for supporting urban and regional development: a) The Open Platform for Urban Simulation (http://www.urbansim.org); b) The Integrated Scenarios Explorer "ISE" (*photo courtesy:* Garry McDonald and Ir Hedwig van Delden).

3 EXAMPLES OF GLOBAL AND NATIONAL INITIATIVES AND TECHNOLOGIES

The demand created by earthquake catastrophes has led to a number of global and regional initiatives aiming to understand, manage and mitigate seismic risk and to create platforms/tools to enhance decision-making in risk management across various sectors.

Among other, relevant initiatives in this sense include:

- CAPRA, Central American Probabilistic Risk Assessment, operated by the World Bank;
- OpenSHA issued by the University of Southern California;
- RiskScape from New Zealand operated by GNS science;
- Global Earthquake Model, GEM operated by the GEM consortium in Europe;
- MAEviz and its regional applications (e.g. EQvis).

There are also a number of software packages approaching specific regional topics like ELER (Earthquake Loss Estimation Routine)[1] in Turkey or SAFER (Seismic eArly warning For EuRope)[2] by GFZ Potsdam with attractive specific applications. A critical and exhaustive review of platforms/tools to support and enhance decision-making in seismic risk management is out of the scope of the paper. Just The character of the existing tools can be described briefly as follow:

3.1 CAPRA, Central American Probabilistic Risk Assessment[3]

CAPRA is a disaster risk information platform for use in decision-making. With the World Bank in the background, it aims at situations relevant on global scale. Several applications are provided including only partly finished multi-hazard approaches. It allows accounting at the same time for the effects of different correlated hazards, as for example in case of hurricane analysis, it also includes wind and flood effects. A code has built-in visualisation tools to view the exposed building stock, the hazard, the economic loss per building and the total loss for the entire area of study. Output files are provided as shape files but also in other formats like xml, dbf, shx.

It does not compute directly the hazard but requires the user to input a specific standardised hazard file, which includes a collection of stochastic scenarios associated to a specific annual frequency of occurrence, the intensity distribution and the variability across the region of interest for each scenario. General application is still difficult because the offered solution on the internet does not provide all the necessary files described in the tutorial.

3.2 OpenSHA[4]

OpenSHA includes several desktop Java applications for seismic hazard calculation. As an open source project OpenSHA welcomes any additional involvement and contributions. Source files are available for download from the website. The initiative is limited only to seismic hazard analysis. Maps and data output files can be downloaded from a web-server. It is an easy-to-use user-friendly tool with a very good tutorial available.

3.3 RiskScape[5]

This software, limited to application in New Zealand, provides a very detailed scientific background and includes the analysis of multi-hazards risk for the built-environment, the waterways and the

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[1] http://www.koeri.boun.edu.tr/depremmuh/eski/

[2] http://www.saferproject.net/index.htm

[3] http://www.ecapra.org/

[4] http://www.opensha.org/

[5] http://www.riskscape.org.nz/

agricultural lands. The built environment assets include structures, infrastructures, and networked infrastructures, namely electrical and communication networks, road networks, potable water, wastewater and storm-water networks. A licence is required to run the software, which, at the time being, it can be difficult to get.

3.4 **Open Quake engine from Global Earthquake Model, GEM, Consortium**

The Open Quake engine currently developed by the GEM consortium (release foreseen for the end of 2014) is an open source application written in Python and Java for calculation of seismic hazard and risk at varying scales of resolution, from global to local. It makes use of a number of other independent, open source projects such as OpenSHA (refer to above description) used as a foundation for the seismic hazard component of the engine, as well as Celery and RabbitMQ. Currently only a development version is released without user interfaces. It claims to it will include a large number of features which sound extremely ambitious. The application in practice will need to be tested.

3.5 **EQvis**

EQvis is based on the MAEviz development and has added a number of features desired by various user-groups. Among them are a fragility manager for typical European application, the addition of a multi-criteria decision support tool for the socio-economic loss computation and various applications introducing time (i.e. the development of the distribution of a toxic cloud considering meteorological forecasts). Its development is based on MAEviz. After testing all available packages, the EQvis team found MAEviz to be the most complete and generally applicable open source software and made the decision to build EQvis on the MAEviz framework.

4 THE OPEN SOURCE CONSORTIUM “MHARP”: MULTIPLE HAZARD ASSESSMENT, RESPONSE, AND PLANNING

In order to overcome the challenges identified in Section 3 and meet the needs described in Section 2, we have established the open source consortium, “M-HARP” (Multi-Hazard Assessment, Response, and Planning). MHARP aims to further develop existing platform/application/modelling-tools (e.g. MAEviz, EQvis, etc.) as well as the necessary IT-infrastructure to support the cyberinfrastructure of those tools and systems. It is the objective of the Consortium to encourage the development of cyberinfrastructure, including additional applications/models, that: 1) fit on the IT-infrastructure; 2) integrate with the existing application models; and 3) provide for a more valuable, robust environment for decision makers (and researchers) in risk assessment, response and recovery, and planning for natural hazards. It will be open to developers and users on a global scale. The entire broader community working on risk or on its specific elements is invited to join this initiative.

The goal is to help building resilient and sustainable communities in all regions of the world by providing pro-active concepts and tools for supporting the planning and response to natural hazards.

The fields of application, originally devoted to earthquake engineering, will be widened to all natural hazards on the one side, and to application of different sectors of our societies. Priorities will still be put on the management of natural hazards but applications in the health, utility, power and supply sector are anticipated. Last but not least, the application functional ease of use as a planning tool for urban and regional development will be supported.

4.1 Background

The Mid-America Earthquake Center (MAE Center) is one of three national earthquake engineering centers in the United States, established by the National Science Foundation (NSF Award No. EEC-9701785). While headquartered at the University of Illinois at Urbana Champaign, MAE comprised a partnership between nine different universities. In 2001, a task-specific partnership was formed between the MAE Center and the world-class computational technology center, National Center for Supercomputing Applications (NCSA), with the goal of producing an information technology framework that could serve as a platform to support the various components of the center’s core activities.

In 2002, the partnership produced MAEviz, version 1.0 of a seismic visualization and analysis system. Over the years, a growing set of functional requirements and a broader vision became clear. In 2006, the system was re-architected by a larger team of developers, with MAEviz version 2.0 designed as a cyberinfrastructure platform to support a more general hazard research and risk assessment and decision support framework. The vision was to be able to more easily incorporate the ideas and expertise from researchers across multiple institutions, and integrate new and existing tools into the system where the different tools, models, and data sets could be flexible components of a customize-able, integrated whole. In order to provide a flexible, modular environment with broad extensibility, the underlying platform is built on the open source Eclipse Rich Client Platform (RCP) framework. RCP provides an extension mechanism to define extension points where developers can add new software modules called plug-ins (Eclipse Foundation, 2013). The framework uses these extension points and this extensibility by plug-ins to support different analysis types, base geometries, data sets, data mappings, GIS schemas, locations, metadata, repository types, units, etc. For example, if a new algorithm exists to generate liquefaction data, the modular nature of the system's workflow allows it to easily be added to the software so that analyses that take liquefaction data as inputs can use the output of the new algorithm. Users can also customize the ways in which certain algorithms in the system function. For instance, instead of using the default mapping of fragilities to buildings, users can provide not only their own mapping file but also their own fragilities. This can lead to more accurate results in cases where a fragility study has been done for a specific structure.

Many risk assessment tools and platforms exist today; however, most of them lack the flexibility to easily add new algorithms or extend their base features due to a combination of architecture and/or closed-source licensing policies. Our reliance on an open-source business model combined with its modular, extensible architecture address many of the issues that limit the utility of other analysis tools, and provide a potentially revolutionary capability to enable sophisticated risk analysis around the globe.

Since version 2.0, we've been helping a number of different groups around the world implement the system. In the three year period from March 1, 2009, there were 1195 downloads of the system. Several of the groups around the world have been adding new functions and improvements. Notably, the Vienna Consulting Group (VCE) in Austria, led by Dr. Helmut Wenzel, has added significant extensions to the system, through EQvis (a European application for industrial risk by the IRIS Project). MAEviz (Version 3.1.1) with these extensions formed the basis for a customized European application of an innovative emergency management system. This hybrid system was successfully demonstrated in a large civil protection exercise in Hungary in 2011 involving more than 500 emergency responders and combining and successfully managing multiple emergency scenarios.

4.2 Moving Forward

Based on discussions with several user groups around the world, and a common desire to learn from and leverage these other groups, we recently formed M-HARP, a global, open source consortium with the idea of sharing data and new technology and models with each other, further expanding the system functions in multi-hazard assessment and response, and growing the consortium to include new regional implementations and new expertise (e.g. socio-economic, urban planning, etc.). In a comprehensive 2009 study comparing open source earthquake loss assessment packages, the MAEviz system was recognized as the best available production quality Earthquake Loss Estimation (ELE) software package (Daniell, 2009). Daniell envisioned that, by combining MAEviz with other ELE software packages such as SAFER, EQSIM, CAPRA, and EQRM a holistic ELE system will be obtained. The M-HARP consortium agrees with Daniell's vision. As a starting point, the MAEviz system, with the modifications and extensions from EQvis, form the initial baseline technology for the M-HARP consortium. Existing modifications, tools and improvements from other partners will serve as the initial contributions to be reviewed, tested, modified (as needed), and incorporated into the M-HARP system. Current partners include well known researchers and research institutes, high profile engineering firms, and groups responsible for advising national agencies on hazard assessment and planning from the US, China, Lebanon, Austria, Trinidad, Jamaica, South Korea, New Zealand, and

England.

For a consortium structure and organization, we are borrowing heavily from existing highly successful open source consortium models, using the Apache Foundation and the Eclipse Foundation as the key examples. As we formalize and document the processes and policies for accepting, testing, and managing contributions within the organization, we will make the consortium and its products and support services more publically available; at that point, we expect that this group will be ready to grow significantly. Similar to other successful open source consortia, there will be processes for identifying areas of development needs, processes for accepting and reviewing technical contributions, and processes for distributing products, resources, and documents to the broader community. People and institutions providing contributions to the system will receive clear and visible credit for their contributions.

4.2.1Planned Features and Resources

Planned consortium development efforts shall seek to provide:

- IT-infrastructure that will allow storage, data management, and computations using large data sets;
- Referenced hazard maps on global scale;
- A comprehensive catalogue of fragilities of all elements at risk;
- A multi-factor decision support system for socio economic consequence computation;
- An on-line access to risk computation modules;
- Various specific applications for any region of particular interest;
- Specific applications for each of the concerned sectors;
- Various requirements defined by the community shall be assessed and implemented.

Part of the consortium's efforts will be devoted to collection of data comprising hazard maps on global scale (collaboration with other initiatives like GEM will be encouraged). Goals include a global catalogue of fragility functions that will be made available and properly enlarged and maintained. An opportunity to entree any structure into the system through an online form will be offered. This information and on-line service shall be used to compute vulnerability information as much as will be reasonable. Risk computation will be performed and the results will be offered, relative to the sufficient information that will be available for any specific case. New and additional features will be defined and elaborated by the community.

5 **CONCLUSIONS**

The M-HARP open source, consequence based decision-support tools will be developed by, and made freely available, worldwide to stakeholders involved in natural hazard risk mitigation and management processes. In order to develop a system that is applicable on a global scale to complex situations and regions, and useable by all concerned user-groups, it is necessary to introduce enhanced user friendliness in combination with considerable computation power. A major development step is necessary to integrate and transform existing expert driven systems into a user-friendly application platform. The challenge to be faced will be to produce open source software that can be operated not only by specific experts, but also by a wider range of user-groups. This requires a user-friendly and tolerant application. It further requires large databases and functions to allow scenarios in previously not considered regions with limited data stock. Simple and free licenses, and high quality but easy to read tutorials will be required.

New Zealand can make a major contribution and can greatly benefit from supporting and participating in the M-HARP Consortium. Through appropriate collaborations with individuals, with specific institutions, and with other risk assessment and hazard framework system organizations, the M-HARP project will look to support:

1) innovative IT solutions to enhance inter-agency flows of information, communication and coordination, and to support decision making to create interfaces that are faster to learn, more efficient to use, and more subjectively satisfying;

2) enhancement of optimisations and multi-criteria models within multi-hazard risk assessment and risk-estimation tools to more-effectively support decision-making;

3) testing the feasibility of inclusion of the aforementioned methods/tools within other risk assessment and hazard framework systems such as RiskScape.

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