GEM Technical Report 2010-1

GEM1 Executive Summary

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www.globalquakemodel.org

1 GEM1 Executive Summary

1.1 Goals of GEM1

The Global Earthquake Model (GEM) is a public/private partnership initiated and approved by the Global Science Forum of the Organisation for Economic Co-operation and Development (OECD-GSF). GEM aims to provide uniform, independent standards to calculate and communicate earthquake risk worldwide. With committed backing from academia, governments, and industry, GEM will contribute to improved modelling of earthquake risk worldwide. More information is available on the GEM website: www.globalquakemodel.org.

As a first step in developing a global earthquake model, a focused pilot project named GEM1 was launched to generate GEM's first products and develop GEM's initial IT infrastructure. GEM1 formally started in January 2009 and ended on March 31st 2010, whilst ETH Zurich was appointed as the coordinator, with EUCENTRE (Italy), GFZ (Germany), NORSAR (Norway) and the USGS (USA) as contributing partners (and a number of other institutions and individuals, named in the companion reports, also provided models, data and feedback). The main objective of GEM1 was that it would provide a basis upon which the future development of the full GEM computing environment and product set could be built. The aim as spelled out in the GEM1 implementation plan was to largely use existing tools and datasets in hazard and risk, connected through a unified IT infrastructure. The GEM1 deliverables are therefore to be considered 'proof-of-concept' rather than final products, hence any resulting outputs should be conceived as conceptual only and are thus not suitable for application. This report briefly summarizes the achievements of GEM1.

1.2 Financial overview

A maximum budget of 2.2M Euro was allocated to GEM1, whilst the actual total expenses were 1.73M Euro, of which 212k Euro were dispersed directly through the GEM Foundation to the USGS, while the rest was managed through ETHZ. The GEM1 team of scientists and IT experts[1] consisted of 25 individuals, many of them giving their time to GEM1 as a matching contribution. A breakdown of the budget into recipients and focus area is shown in Figure 1.1. The GEM Secretariat reviewed and approved the detailed accounting of GEM1.

In several areas, GEM1 spent less than foreseen in the implementation plan:

- Only 50k Euro were spent for software and data, instead of the budgeted 350k. Contrary to expectations, there was only a very limited need to support software modification or data preparation, which were made available at no cost to GEM1.
- GFZ Potsdam was not able to hire staff as fast as hoped for and consequently used about 200k Euro less than the budgeted 300k Euro. A part of that saving was early on re-allocated to NORSAR scientists working on risk.
- The subcontract on Evaluation and Testing foreseen at 60k Euro was not implemented, because it was decided that the "models" being developed in GEM1 (in particular for what concerned hazard) would be available too late for meaningful testing.

[1] www.globalquakemodel.org/node/149

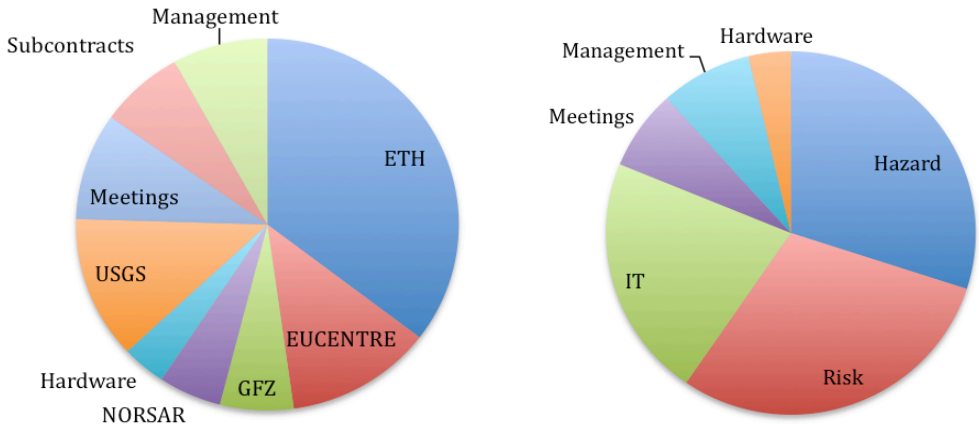

Figure 1.1 Breakdown of the GEM1 budget allocation by recipient (left) and task (right).

1.3 GEM1 Deliverables

The technical achievements of GEM1 have been summarised in a series of 10 reports, 6 internal GEM1 reports presented in Table 1 and 4 GEM1 external reports presented in Table 2, which have been produced following the detailed reviews of an initial set of reports by the Model Advisory Group (MAG), a group of experts[2] in seismic hazard and risk modelling that convened twice during the duration of GEM1. The major goal of each report is to provide a summary of the activities that have been performed within GEM1 to the informed technical community. The reports are currently available from the following link: www.globalquakemodel.org/node/747

Table 1.1 List of the GEM1 Report Series

No.	*Title*	*Authors*
1	*GEM1 Executive Summary*	
2	*GEM1 Hazard: Overview of PSHA software*	*Danciu L., Pagani M., Monelli D., Wiemer S.*
3	*GEM1 Hazard: Description of input models, calculation engine and main results*	*Pagani M., Crowley H., Danciu L., Wiemer S., Monelli D., Field E. H.*
4	*"Best Practices" for Using Macroseismic Intensity and Ground Motion Intensity Conversion Equations for Hazard and Loss Models in GEM1*	*Cua, G., Wald, D. J., Allen, T. I., Garcia, D., Worden, C.B, Gerstenberger, M., Lin, K., and Marano, K.*
5	*GEM1 Seismic Risk Report*	*Part 1: Crowley H., Colombi M, Crempien J., Erduran E., Lopez M., Liu H., Mayfield M., Milanesi M.* *Part 2: Crowley H., Cerisara A., Jaiswal K., Keller N., Luco N., Pagani M., Porter K., Silva V., Wald D., Wyss B.*
6	*OpenGEM System Design Document*	*Krishnamurthy R., Euchner F., Mömke A., Roland S., Kästli P*

[2] John Adams (Geological Survey of Canada), Ezio Faccioli (Politecnico di Milano, Italy), Ned Field (USGS), Mengtan Gao (CEA, China), Gottfried Grünthal (GFZ, Germany), Dirk Hollnack (Munich Re, Germany), Andrew King (GNS, New Zealand), Mario Ordaz (UNAM, Mexico), Mark Petersen (USGS), John Schneider (GeoScience Australia), Kunihiko Shimazaki (University of Tokyo, Japan), Paul Sommerville (URS Corporation, USA), Mark Stirling (GNS, New Zealand).

Table 1.2 List of the GEM1 External Reports

No.	*Title*	*Authors*
E1	*Selection of Ground Motion Prediction Equations for GEM1*	*Douglas J., Faccioli E., Cotton F. and Cauzzi C.*
E2	*Earthquake Model for the European-Mediterranean Region for the Purpose of GEM1*	*Grünthal G., Arvidsson R., Bosse Ch.*
E3	*Data Interchange Formats for the Global Earthquake Model*	*Porter K. and Scawthorn C.*
E4	*User Needs Assessment for the Global Earthquake Model (GEM)*	*Porter K. and Scawthorn C.*

The second major deliverable of GEM1 was the OpenGEM application and portal, however this portal is not currently accessible due to a number of technical modifications that are currently being carried out following an IT Review, that was held in Zurich in June 2010[3].

1.3.1 Hazard Reports

The major achievements in the hazard domain carried out by the core GEM1 team (at ETH Zurich and USGS) are described in Reports 2 and 3 of the GEM1 Series.

- The hazard team investigated 10 existing PSHA codes for their features and performance. Several diagnostic test bed applications that allowed for the quantitative comparison of calculation results were implemented. Based on this review, which highlighted the potential of OpenSHA due to its modularity and platform independence along with its ability to compute hazard for both simple and complex models (and on other existing benchmarking studies that had been carried out using hazard codes), the GEM1 team opted to use OpenSHA as the basis for the OpenGEM hazard engine, and to provide additional developments to this code.
- GEM1 collected 17 national or regional hazard models, and one global model based on a smoothed seismicity approach. All models - parsed into a common data structure - provided an accurate state-of-the-art of available hazard inputs worldwide and an almost complete coverage of the globe, though there are some missing regions in the Caribbean, the area around Papua-New Guinea and the Pacific Islands.
- Based on these models, and assuming a simplified global approach to ground-motion prediction equations (GMPE's), a first global probabilistic seismic hazard map has been computed. While mainly being presented as a proof-of-concept, it allows for an assessment of the state-of-the-art in PSHA around the globe.
- The USGS model for the USA – a sophisticated nationwide PSHA input model – was chosen as a feasibility test of the GEM1 hazard engine. The hazard engine used and further developed in GEM1 (OpenSHA) was able to fully re-create this model, which was another compelling reason to select this code.
- The hazard team also developed a preliminary interface to risk calculations, through both hazard curves and a scenario "ground motion field" calculator that takes into account spatial correlation.
- The GEM1 hazard team introduced a first version standard format for the exchange of hazard models. The XML-based format and data model, that has been termed shaML, is an important step towards the efficient sharing of hazard information.

In addition, Report 4 reviewed equations that directly predict intensity (Intensity Prediction Equations, ICEs) and that convert ground motion values to intensity (ground-motion-to-intensity conversion equations, GMICEs). This study is of particular need to allow seismic risk studies to be carried out both in terms of engineering-based ground-motion parameters (GMPs) and macroseismic intensity. The review addresses uncertainties in the predicted intensity in addition to the median predicted value. The methodology includes evaluation of the predictions of candidate models against data in evaluating GMPEs, IPEs and MICEs. Selection of the preferred models (currently only for active tectonic regions) is based in part on the performance of the models in predicting the data.

[3] See www.globalquakemodel.org/node/928 for the report from the IT review.

The GEM1 core hazard team's achievements described above have been supported by 2 hazard reports produced through external contracts:

- Report E1 was developed under contract during the early stages of GEM1 with the objective of recommending a suite of GMPEs (including a weighting scheme for the logic tree) to be used for all of the 17 national or regional hazard models as a function of the tectonic regime. A MAG subgroup undertook a review of these recommendations following their November meeting and some alternative; for completeness sake, these recommendations are attached at the end of the original report.
- Report E2 describes a regional model for Europe that has been applied directly in GEM1. It contains 435 sources which are specified with M_{max}, depth, a-values (at M_w = 3.8) and b-values for application in the Gutenberg Richter equation. It is a very high level description of a very detailed model and an example of the type of regional model to be expected from GEM's Regional Programmes.

The activities of GEM1 have thus ensured that global PSHA models (including logic trees) will have a standard format that can be directly input into a hazard engine for global hazard calculations comprising hazard curves, hazard maps and disaggregation output for both engineering-based GMPs and macroseismic intensity. The current focus on hazard in GEM is on the development of the following 5 global components by international consortia of experts[4] which will need to be combined into global PSHA input model(s) under the coordination of the Executive Committee member for Hazard:

- Global Historical Catalogue and Database;
- Global Instrumental Seismic Catalogue;
- Global Active Fault and Seismic Source Database;
- Global Geodetic Strain Rate Model;
- Global Ground-Motion Prediction Equations (GMPEs).

This coordination will be carried out in close collaboration with the GEM Model Facility[5], that will now also have the task of further developing the hazard engine (and integrating it with the risk engine for end-to-end calculations), producing tools for processing the data from the global components and for producing PSHA input models, which will be of particular benefit to the Regional Programmes.

1.3.2 Risk Report

The major GEM1 achievements in the risk domain, as reported in Report 5, are:

- A critical review and application of 9 existing risk software codes was undertaken. From this evaluation, and considering the features of GEM's mission, the GEM1 Risk team formulated a list of attributes for the GEM risk engine:
  - Open-source software, community development platform;
  - Platform-independent;
  - Modular (object-oriented language);
  - Flexible (multi-hazard);
  - Expandable (in terms of methodologies employed);
  - Scalable.
- Based on the MAG feedback received in November 2009, the risk team initiated the development of a GEM1 risk engine, an object-oriented code that fulfils the aforementioned criteria and aimed to be compatible with the GEM1 hazard engine (OpenSHA). The main 'classes' of the engine are 'asset' and 'vulnerability' following the

[4] www.globalquakemodel.org/node/840

[5] www.globalquakemodel.org/node/980

design principles of OpenRisk[6]. Vulnerability can be described as the probability distribution of loss given an intensity measure level (IML), where the distribution of mean loss with IML can be discrete or continuous, though at present only the former distribution has been implemented.

- The OpenRisk developers provided useful recommendations on data interchange formats through an external contract, many of which were used in the risk engine (see GEM Technical Report E3).
- A critical review of available global vulnerability and exposure databases was performed. This review also provided important input for setting up the Risk Global Component Requests for Proposals.
- In close collaboration with the hazard team, selected scenario and probabilistic test applications were implemented using the GEM1 risk engine as a proof of concept of the global capabilities and flexibility of the engine. These included preliminary global risk maps, based on the USGS PAGER[7] empirical vulnerability approach and databases.
- The preliminary interfaces for risk calculations from the hazard engine were designed together with the GEM1 hazard team.
- A web-based user interface based on existing open source software for presenting risk output was designed and rapidly prototyped (see Figure 1.2).

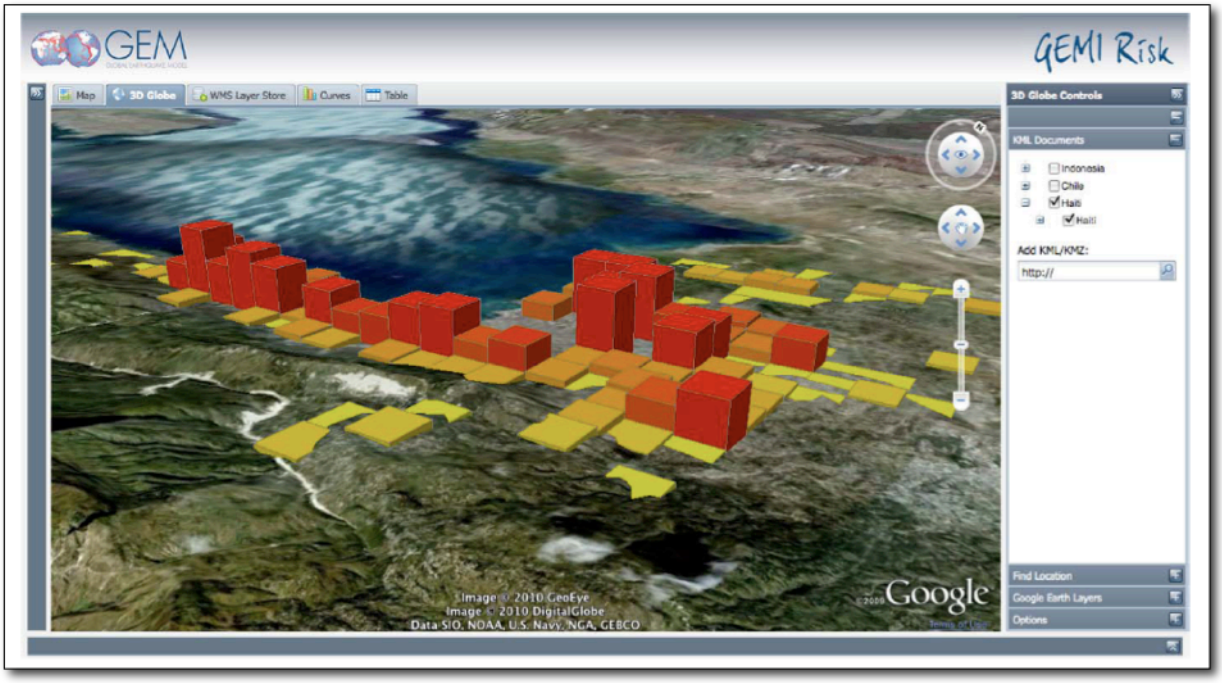

Figure 1.2 Prototype risk results visualisation platform showing loss ratios for a deterministic scenario in Haiti

The activities of GEM1 risk have thus ensured that global (but also regional and urban) vulnerability and exposure models can be input into a risk engine for global loss calculations considering both deterministic and probabilistic events (though currently without considering spatial correlation of the ground-motion variability). The current focus on risk in GEM is on the development of the following 5 global components by international consortia of experts[8] which will need to be integrated for global risk calculations under the coordination of the Executive Committee member for Risk:

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6 www.risk-agora.org

7 http://earthquake.usgs.gov/earthquakes/pager

8 www.globalquakemodel.org/node/842

- GEM Ontology and Taxonomy
- Global Earthquake Consequences Database
- Global Exposure Database
- Global Vulnerability Estimation Methods
- Inventory Data Capture Tools

This integration will be carried out in close collaboration with the GEM Model Facility, that will now also have the task of further developing the integrated hazard and risk engine (and in particular ensuring that portfolio analysis for a number of assets, including spatial correlation of the ground-motion residuals, is implemented within the engine, as recommended by the MAG).

1.3.3 IT Report

The name OpenGEM has been chosen for the computational infrastructure of GEM. During GEM1, a multi-tier IT architecture was designed to meet the foreseen requirements in terms of accessibility, flexibility, availability and scalability (see Report 6). In Figure1.3 the transformation from today's state-of-the-art in terms of hazard and risk IT to the OpenGEM system is presented; this outlines the main objectives of the OpenGEM system.

objectives of the OpenGEM system.

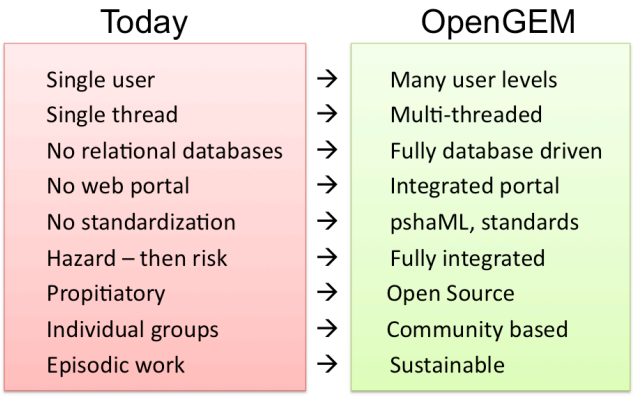

Figure 1.3 Illustration of the differences between today's state-of-the-art in seismic hazard and risk calculations as compared to the approached promoted by OpenGEM.

GEM1 implemented a proof-of-concept version of the OpenGEM system, providing the base architecture and end-to-end functionality for a limited number of use cases. A snapshot of the OpenGEM portal, through which these use cases can be demonstrated, is shown in Figure 1.4. For this purpose, the GEM1 team acquired and configured hardware consisting of four 32 node SUN workstations.

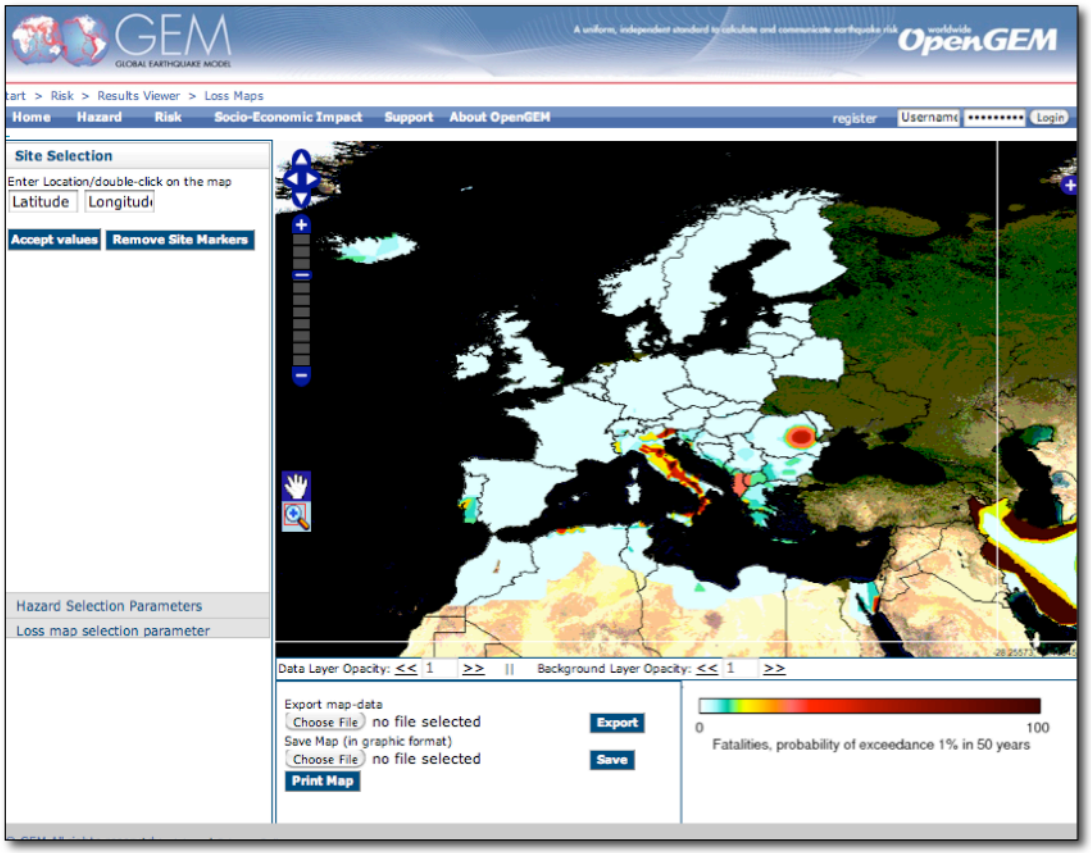

Figure 1.4 OpenGEM portal view of the hazard results for Europe.

The OpenGEM system design was reviewed by a team of 17 IT experts in June 2010 and the review was published online[9]. Report 6 has not been revised following this review as it aims to present a faithful description of the work undertaken during GEM1. On the other hand, the review report provides a description of the future directions that the IT development at the Model Facility were recommended to take, and have already begun to implement. These include the need for tighter prioritisation of the user stories of the OpenGEM system (which will be undertaken by the Executive Committee members), implementation of the features of open source development practice (noting that the OpenGEM computational engine will be open source from January 2011), further consideration of the use of portlet technology, redesign of the database system, amongst others.

1.4 General Achievements of GEM1

A number of additional general GEM1 achievements are noteworthy:

- GEM1 successfully initiated the process of the Model Advisory Group (MAG). The two meetings of the MAG that reviewed GEM1 in November 2009 and April 2010 demonstrated eloquently the need for such a community review and buy in of the GEM components.
- GEM1 hired and trained an international team of experts on hazard, risk and IT.

9 www.globalquakemodel.org/node/928

- By working closely aligned with the European Regional Programme SHARE and the Middle East Regional Programme EMME, GEM1 initiated the interaction and synergies between the GEM model infrastructure and regional programmes (e.g. see Report E2).
- GEM1 conducted a web based User Needs Assessment (see Report E4), which aimed to address the question of *Who* the users of GEM will be, and *What* their needs are. In order to address these questions, a User Survey was conducted, consisting of 17 questions each in English, Spanish, Chinese, Hindi and Japanese. The survey was accessed over 800 times from over 74 countries, with over 400 completed responses.
- The GEM1 process allowed for the definition of the GEM Model Facility (GEM MF), its mandate, potential users and required budgets. The GEM MF, located at ETH Zurich, is operational since April 2010.