GEM
GLOBAL EARTHQUAKE MODEL

Uniform and open standards to calculate and communicate earthquake risk worldwide

Global Earthquake Model

Report 2009/2010 Second Edition

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An OECD Global Science Forum Initiative

Working Together on Global Earthquake Risk Assessment

We write this letter almost halfway through GEM's five-year first build-up programme, preparing ourselves for the third Outreach Meeting, which this time round will take place in Beijing, China. There, the Socio-Economic Impact Global Component approved activities will for the first time be presented, including plans for the development of a toolbox of methods for assessment of the impact of earthquakes on economy and society, and thus effectively implying that all three core scientific modules of GEM (Hazard, Risk, SEI) will at last be fully operative.

Indeed, hundreds of individuals, supported by the wider (technical) community are now developing databases, approaches, models and tools on hazard, vulnerability, exposure and socio-economic impact. At the same time the development of GEM's innovative, web-based platform OpenGEM, as well as its underlying OpenQuake calculating engine, continues to advance steadily and surely. Workshops around the globe have been and continue to be organised, to describe the capabilities of the software and how it may be readily downloaded, contributed to, tried, and tested. The tragic events in New Zealand and Japan have again demonstrated the importance of improving globally our data and tools for risk assessment and risk reduction, but have also proven how effective risk reduction measures can be established when scientific advancements are adequately transposed into construction standards.

We invite you to read through this report, including the highlights section, so as to learn more about all the ongoing developments, the individuals and teams behind them and the open collaborative/participatory process in which GEM continues to operate, involving an as wide as possible community of scientists, developers, contributors and stakeholders.

On the above note, a word of thanks seems appropriate here. To everyone that has been part of GEM from the start, and of course to those that continue to join and share their expertise, provide their support and donate their time and data, we express our deepest appreciation and gratitude.

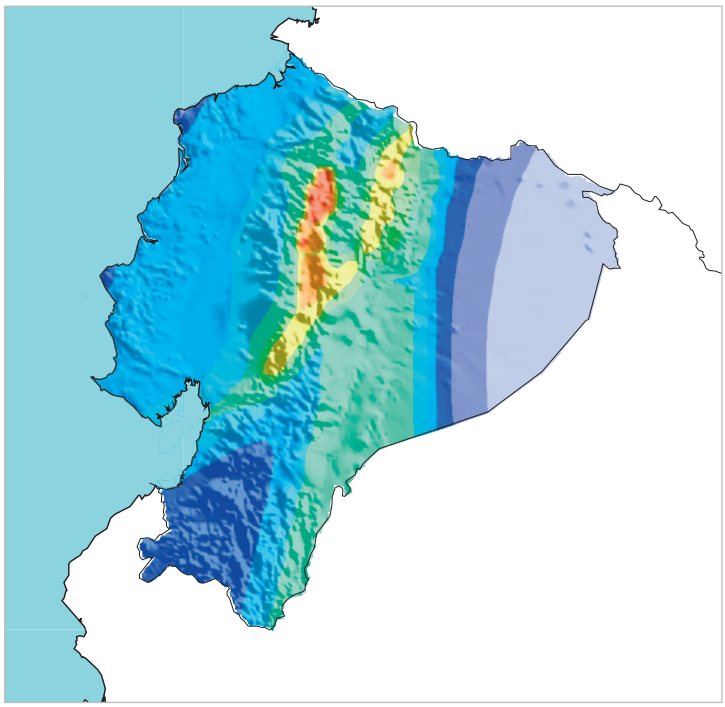
And for those who are not involved in the GEM initiative yet: we need you to come on board, and help us in the process of learning and improving models and approaches being used around the world. Indeed, we firmly believe that countries cannot stay in isolation; we need a set of open software tools to explore modelling alternatives as well as a trans-national dialogue to discuss and vet the different ideas and approaches and develop uniform standards. Then, those working in disaster management can provide feedback on the usability of the output produced, and decision-makers in public and private sectors in all regions of the world will have access to state-of-the-art tools that they trust and can actually use.

We hope we can count you in, so that we can work together at having a lasting impact on seismic risk assessment, and thus mitigation, worldwide.

Anselm Smolka
Chairman GEM Foundation

Rui Pinho
Secretary General GEM Foundation

Highlights



First applications of the OpenQuake software

The open source OpenQuake software for seismic hazard and risk assessment is already being used in various ways around the globe. Notwithstanding the fact that the current version of the software still is a 'developer' release, the code is stable and can already execute reliable hazard and risk calculations. That is the reason why the Instituto di Geofisica of Ecuardor asked GEM to work together on developing the country's new seismic hazard maps, using OpenQuake. An example of preliminary maps produced so far is shown here. Furthermore, collaborations with the EMME and SHARE Regional Programmes have led to valuable lessons and improvements on both sides and produced results that will be used to visualise the work the Programmes carry out. Read more on the application of OpenQuake on page 28.

Regional Programmes moving forward

After a series of meetings and workshops taking place in all continents over the past years and many efforts from advocates in those regions, we now see the start-up of quite a few Regional Programmes being realised. In May 2011 large workshops took place in the Caribbean and Morocco with the view to set up Regional Programmes, the Earthquake Model of Central Asia (EMCA) programme will have its first local gathering in June 2011, and a new workshop is planned for the region of South-East Asia/Pacific gathering local experts in Indonesia in July 2011. With ongoing regions collaboration has intensified over the past years leading to synergies and essential knowledge exchanges.

GEM's community is continuously growing. More and more entities and individuals are getting involved in this effort, which strengthtens the activities being undertaken. GEM currently features sixteen public-private funding partners and six notable associate organisations. There are more than 50 institutions involved in global activities, and over a100 on a regional scale. More than 100 international experts have been involved in (peer) reviewing GEM-related activities so far. We interact actively with stakeholders ranging from emergency response organisations to government officials and the media, and we report on latest developments through the website and newsletter, which are followed by thousands of individuals in 98 countries. Outreach Meetings provide a platform for new and known stakeholders to learn and discuss about GEM and its various aspects. Consult page 14 for an overview of this collaborative global effort.

A global collaborative effort

Who knows better than the experts themselves how to build a global instrumental catalogue for the world that is as uniform as possible, or how to capture data from satellite imagery? More than 200 experts and professionals in their fields are working on 10 essential global components in the fields of hazard and risk. Cutting-edge technology and the latest advances in science are being used for the development of open databases, tools and uniform approaches. Already a first beta-version of a GEM building taxonomy has been produced and the demo-version of a tool for the uploading of faults into the global fault database is almost ready. Read more on the work of international consortia for development of the global components on pages 20 to 24.

State-of-the-art Science

Debate and discussion are key to GEM so as to develop tools and models that are supported by the community and therefore actually used. International meetings are therefore held on a regular basis. This picture was taken at meetings held in London for discussion of Testing and Evaluation for GEM, OpenQuake, Macroseismic Intensity and Financial Modelling. A joint meeting in Zurich in February 2011 united representatives of three Regional Pogrammes with those of two Hazard Global Components, members of the TAP Working Group on Hazard Integration and Assembling, and members of the Model Facility. Interaction between global components and regional programmes, and with the community at large, is essential also on a more continuous basis however; an open online collaboration platform will therefore be released in the summer of 2011.

Discussion and debate

1/
Mission and Goals

1.1 The Need

Over half a million people died in the last decade due to earthquakes, most of these in the developing world, where risk is increasing due to rapid population growth and urbanisation. Recent earthquakes, such as the ones occuring in Japan and New Zealand, painfully reminded the world of the destructive impact of seismic events and the importance of having reliable earthquake risk information availlable. However, in many earthquake-prone regions no risk models or advanced tools exist to provide such information, and even where they do exist, they are often inaccessible, due to their proprietary nature or complex user-interface. Also there are no agreed global standards for risk assessment, which are critical for effective and unambiguous communication of seismic risk. Reliable, uniform and consistent risk estimates for the entire globe constitute critical input for increasing risk awareness and the undertaking of mitigating action. Such information is an essential puzzle-piece for minimizing loss of life, property damage and social and economic disruption due to earthquakes, by supporting decisions and actions that may lead to better building codes and construction, land use planning for sustainable development, improved emergency response, protection of critical infrastructures and greater access to insurance.

There is a need for such earthquake risk information to become accessible to a wide spectrum of organisations and individuals around the globe. This need has been underlined by a call from the Global Science Forum of the Organisation for Economic Cooperation and Development (OECD) for the development of open-source risk assessment tools, and has been confirmed by a variety of institutions, the scientific community and the public at large. In response to the needs outlined above, the GEM initiative aims to establish uniform, open standards to calculate and communicate earthquake risk worldwide, by developing a global earthquake risk model and ensuring it has understandable and customised interfaces that support the needs and capabilities of GEM's multitude of stakeholders.

1.2 Mission and Vision

GEM's mission is to **engage a global community in the design, development and deployment of state-of-the-art models and tools for earthquake risk assessment worldwide.**

As mentioned above, OECD's Global Science Forum created the opportunity for an initiative to leverage (scientific) knowledge on earthquake risk for the benefit of society, worldwide. What GEM envisions and is working on, is therefore the bringing together of state-of-the-art science, cutting-edge technology and national, regional, international organisations as well as individuals, in a global collaborative effort that will have a lasting impact on seismic risk assessment.

- Only by operating at a global scale will it be possible to create synergy and share knowledge and approaches for assessment that will improve our understanding. Global collaboration is also needed to enlarge datasets, especially for those areas where such information is currently hardly available. Furthermore, undertaking a global effort is essential for the involvement of as much of the community as possible, in order to create standards and databases that are accepted and used by a maximum number of experts. Such standards, in turn, will allow for comparisons between areas and regions, which will facilitate decision-making on a global scale for many types of public and private actors.
- Involvement of a wide community ensures that the model and tools are being developed and deployed collaboratively, in a transparent way and facilitated by open debate so as to serve a wide range of stakeholders. Knowledge and expertise are shared in the open, so that others can build upon it. In this way, GEM hopes to build authority and to include ever-more individuals, organisations and governments, to support continuous improvement of the model and its applications for expert and non-expert users, in particular for all those working or deciding on risk mitigation.

By functioning as a true collaborative effort, GEM is hence building a state-of-the-art and dynamic model for the assessment of seismic risk worldwide, featuring not only the computation of the probability of earthquakes occurring and inducing damage to buildings and houses, but also methods and tools for analysing impacts of earthquakes on economy and society.

1.3 Strategy

A first global-owned version of GEM's seismic risk model will become available at the end of 2013. Users across the globe will from then on be able to access the model, databases and tools through GEM's risk assessment platform OpenGEM, allowing them not only to perform hazard, vulnerability, risk and socio-economic impact analyses, but also to collaborate and exchange data, results and opinions amongst each other.

Continuous development

Although the suite that will become available in 2013 already constitutes a sound platform, it will continuously need to evolve. GEM aims for the global earthquake risk model to cover the entire globe as uniformly as possible and to use models that incorporate the latest logic-tree approaches, however in five years time it will not be possible to incorporate all the data effectively available, nor cover all the countries in the world in a uniform way. During its first Working Programme (2009-2013) GEM will hence create tools and standardised methods for obtaining and analysing data, and GEM collaborators/affiliated researchers will use these tools to begin the process of assembling the needed datasets, hereby producing data coverage for the world that is more uniform and complete than before. It is believed and hoped however that by developing GEM in a collaborative way and by building a global platform that is flexible enough to incorporate new developments and datasets, other researchers, agencies and institutions will adopt and enhance the tools GEM is developing, and will thus help in populating the datasets, developing applications for new stakeholder groups, and export the model to other natural hazards.

Global buy-in and regional collaboration

Involvement of experts and professionals from all regions in the world is essential to creating a model that is 'owned' by the global community. Collaborative development of GEM's models and tools means discussing and debating methodologies, best practices and approaches, and finding solutions to account for regional differences. In addition to having consortia composed of various international institutions and individuals work on the main components of the model, interaction between global and regional experts is facilitated in many ways. Large international technical review meetings are for example organised twice a year in various parts of the world, involving representatives of the various GEM components and projects, boards, participants and stakeholders.

Science and technology in the open

Open standards and open methods of communication are important characteristics of the model; not only to allow for transparent insight into risk, but also to permit a wide community to use and improve it. GEM has therefore committed itself to developing its software and tools in the open, so that the code is accessible at any point in time. GEM will also render tools available that support collaborative development and involvement in the development process, so that step-by-step an open body of knowledge on earthquake risk assessment is created.

1.4 Long-term Outlook and Sustainability

GEM clearly envisages continuing its operations well beyond the initial five-years timeframe needed to develop the first version of the OpenGEM platform and set-up of mechanisms for continuous collaboration and development. Requests for proposals will be released for further development of components of the model, to complement the continuous updating of the data and standards, by means of application of the toolkit and interfaces available in OpenGEM. An important part of GEM's activities will be focused on promoting the tools and models and supporting their use, through technology transfer in all regions of the world. Necessary funds are envisaged to arrive from further private sponsoring, government adhesion fees, collaborations with other initiatives and possible fees for use of OpenGEM through high-performance (cloud) computing.

2/
A Global Earthquake Risk Model

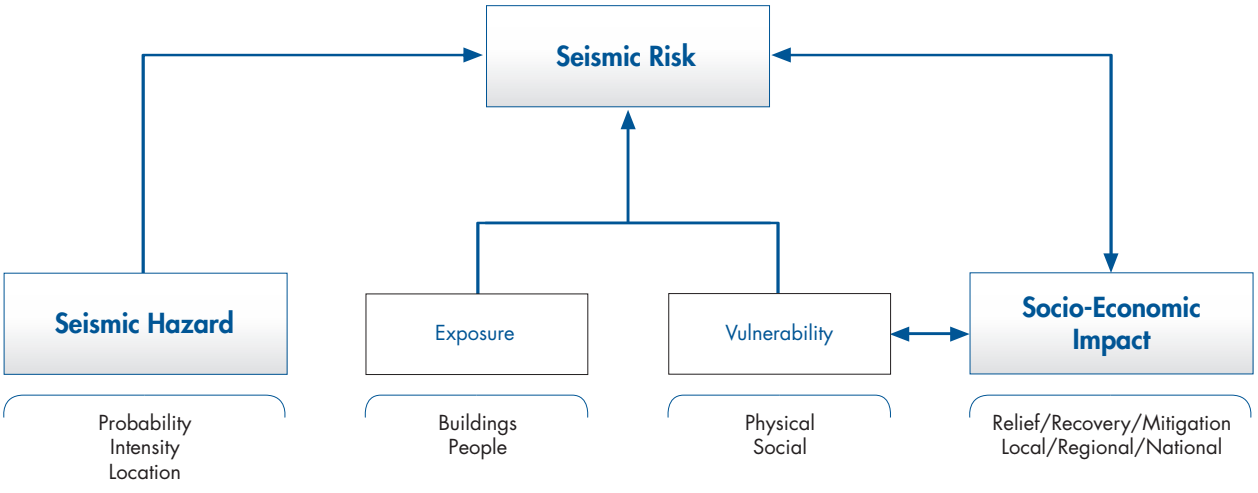
In light of earthquakes such as the ones that struck China (Sichuan) in 2008, Haiti in 2010 and Japan (Tohoku) in 2011, one could ask how a computer model is going to contribute to reducing the risk many people are still facing. A model however is the basis for all common understanding and a starting point for individual action and political decision-making on risk mitigation. With a model, local communities will be able to run or consult earthquake scenarios and see what is the risk they are facing over a period of 10 or 50 years, for instance. Homeowners and businesses will have tools available, such as portfolio and cost-benefit analysis, that can support them in choosing between alternative risk reduction strategies. GEM is therefore determined to build a model that serves all such needs of the community at large. The global earthquake risk model can be characterised as follows:

- It will not only cover seismic hazard, but extend also to risk and include socio-economic impact;
- It will cover as much as possible the entire globe;
- It shall be public-owned;
- It will be developed by the community;
- It will be transparent (i.e. provide insight into the databases and the methods used);
- It will use harmonised standards and methodology;
- It will be modular, flexible and expandable;
- It will attempt to serve the needs of various types of users and beneficiaries.

2.1 Scientific Modules

Three scientific modules form the core of GEM's model; Seismic Hazard, Seismic Risk and Socio-Economic Impact. The modules are developed independently, but will be connected and subsequently integrated into one model for seismic risk analysis and exploration. The image below represents a conceptual model of how the core modules are linked together.

Within GEM seismic risk is defined as a function of seismic hazard (the probability of levels of ground shaking, resulting from earthquakes, within a given time span), physical vulnerability (the probability of loss given a level of ground shaking), and exposure (the elements at risk, mainly buildings, critical infrastructure and humans). Risk hence tells us something about the extent of loss (damage, fatalities, casualties) that can be expected in a given location in the world. Risk can therefore be high in an area without significant probabilities of ground shaking, because it has an older, more vulnerable and densely populated building stock, and lower in an area with high levels of seismicity but with well constructed structures that are sparsely inhabited. Earthquakes however have an impact that goes beyond physical damage or casualties. Earthquakes can severely damage the economy and influence society and social well-being. Therefore, GEM's global earthquake risk model will include methods (models, indicators, tools) for analysis and evaluation of the impacts of earthquakes on local and global scales, that will comprise measures for social vulnerability. Insight into earthquake effects over time will support decisions on short-term needs after an event (relief, shelter), medium-term needs (recovery and reconstruction) and long term needs related to policies and activities aimed at risk mitigation.



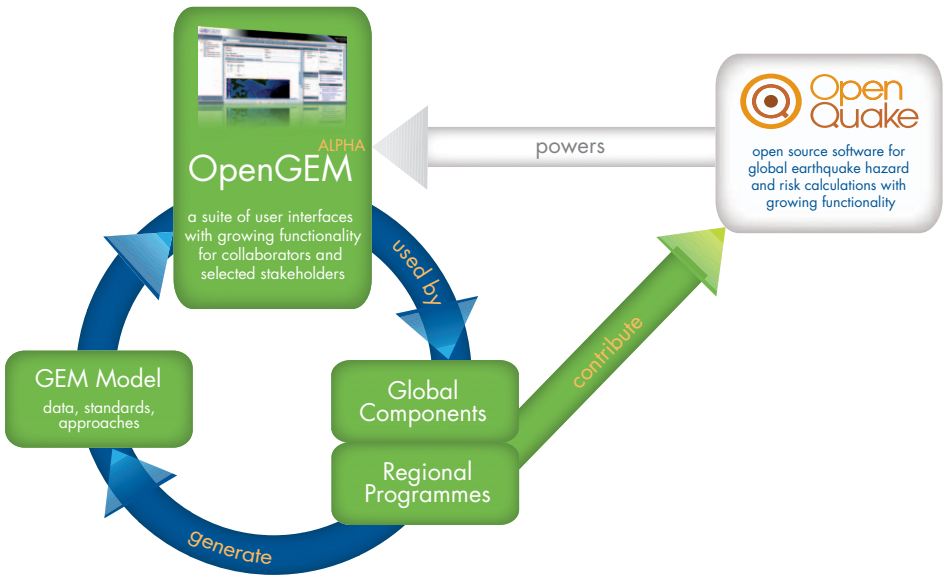
2.2 Construction of the Model

GEM believes that a global model can only be built in full cooperation with the community, and in this way become authoritative because it is trusted and believed in. Development of the model is therefore mostly carried out by the community, both on global and regional scales. Thousands of experts and professionals of more than 150 insitutions carry out research, work on consistent methods and tools, and discuss standards and best practices. This strong community-based characteristic ensures also that developments on the forefronts of scientific and engineering knowledge as well as IT processes and infrastructure are being integrated into the model.

The global earthquake model is being constructed by means of various 'building blocks'. The first building block was the GEM1 pilot project, which ended in March 2010 and delivered a proof-of-concept in terms of preliminary global hazard and risk calculations, and an initial model-building infrastructure. Development of the global earthquake risk model is now based on the efforts of the Global Components, Regional Programmes and the Model Facility, and in a later stage also the Testing and Evaluation Facility.

The Model Facility is developing the IT architecture that enables global risk calculations and communication of output through user-interfaces; its efforts are mainly focused on development of the OpenQuake software that empowers seismic risk calculations, and of the OpenGEM risk assessment platform. Global Components constitute the scientific core of the model, and comprise global datasets, methods, models, standards and tools related to seismic hazard, risk and socio-economic impact. GEM Regional Programmes are independently-run projects that are carried out under the GEM umbrella in conformance with GEM standards and goals.

The illustration below demonstrates the interaction between these main building blocks in this first build-up phase of GEM: the Global Components, in interaction with the Regional Programmes, develop the GEM model, which is the basis of the OpenGEM platform. The OpenGEM platform is the web-based point of entry to access a harmonised suite that includes databases, models, model building tools, calculation tools, assessment tools and much more. The OpenGEM platform is powered by the open-source OpenQuake software, which is being enhanced through interaction with the Global Component projects and the Regional Programmes. The latter in turn use the tools being developed as part of the OpenGEM suite to develop and enhance the databases and models they are working on.

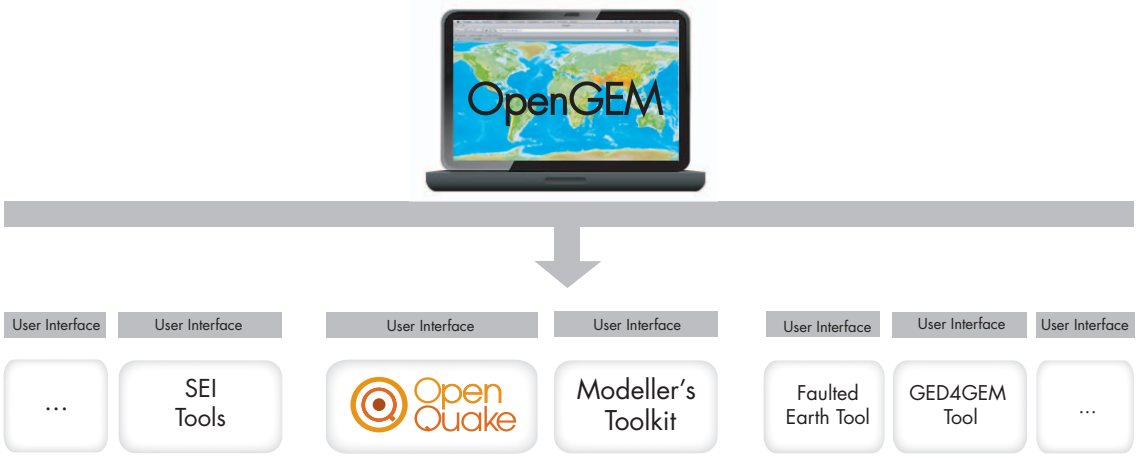


International consortia, involving reputable institutions from around the globe and the best international and local experts in their field, are working on the development of the global components, in interaction with the regional and global community. The selected consortia responded to open calls for proposals, which are subject to public commentary and revision before official release. Consortia are selected only after a thorough peer-review process by several international experts, as well as GEM's Scientific Board. Consortia receive funding from GEM to carry out their activities, but often also contribute in-kind resources. The value of what they produce within the scope of the Global Component projects will extend beyond GEM; the products and deliverables will benefit the community and scientific development at large.

Nearly 10M Euro has been made available for a total of 12 Global Components projects that are deemed essential input to the model. Ten projects, comprising over 200 individuals, on Hazard and Risk issues have started already and two are being prepared: one on Socio-Economic Impact and a new Hazard component. New Requests for Proposals are released from time to time in order to fill essential research gaps. The projects that are to lead to state-of-the-art and homogenised databases, methods and tools, are described in more detail in section 5.1.2 of this report.

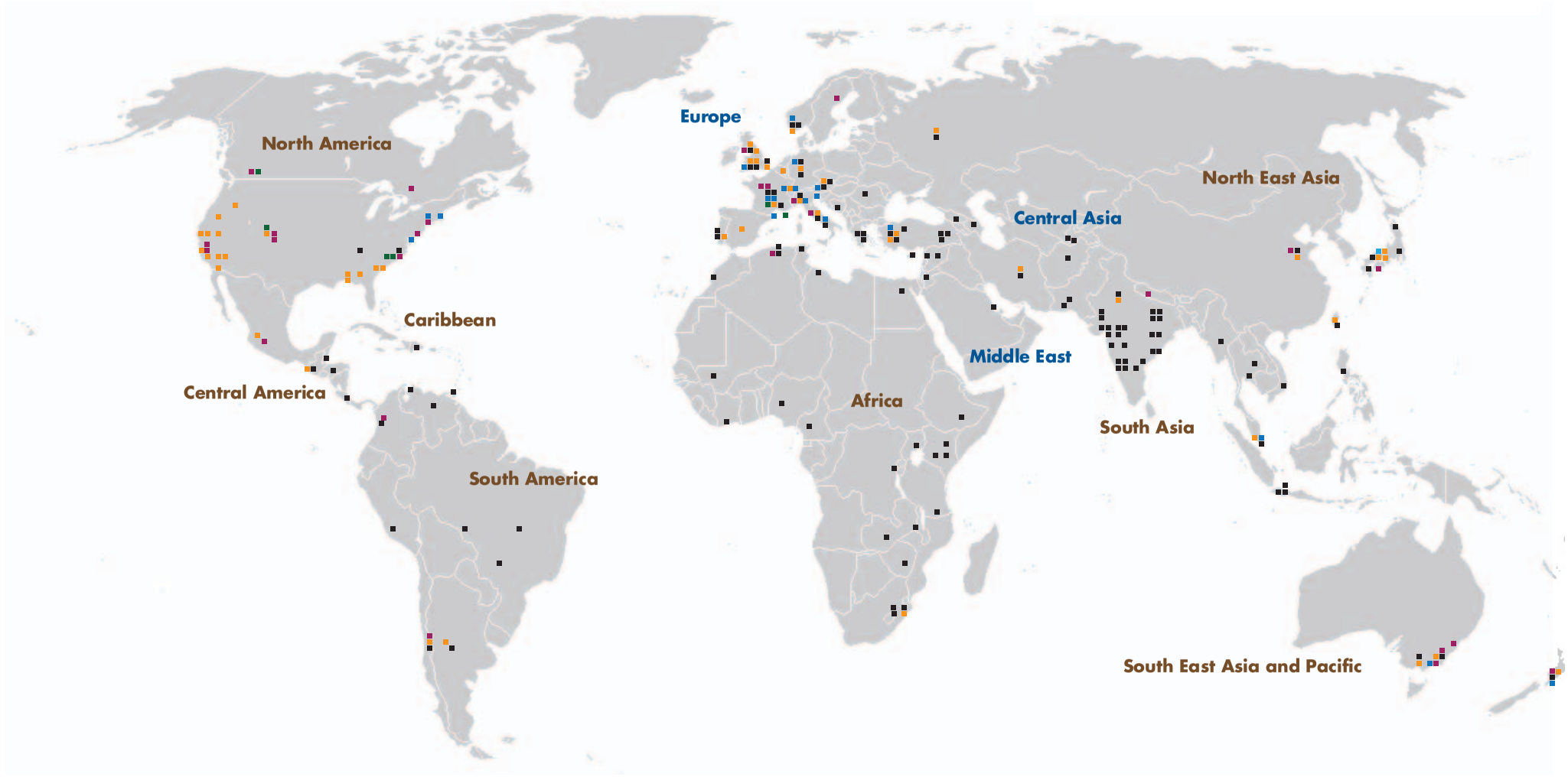
Development of a global model can only be done with full involvement of local experts and professionals from all parts of the world. Global Component consortia hence need Regional Programmes to provide feedback on the standards and data, considering applicability in each given region. GEM Regional Programmes are independently-run projects that are carried out under the GEM umbrella in conformance with GEM standards and goals. Some are set up as dedicated bottom-up projects; in other occasions collaboration is sought with ongoing projects. GEM Regional Programmes involve local institutions and experts from as many of the countries of the region as possible. Besides providing feedback on the global components, they deliver essential contributions in the form of more detailed local data and will serve as a starting point for technology transfer. Collaborations are ongoing with organisations and institutions in all parts of the world to link up with current programmes, or set up new ones. For an overview of the current situation, please consult section 5.1.3.

The OpenGEM risk assessment platform is the main output of GEM's first five-year programme and should be perceived as a suite of (connected) tools, models and databases. OpenGEM is being developed by GEM's Model Facility, in close interaction with a number of specialist organisations and the wider community. From 2013 onwards, OpenGEM will allow users with different levels of expertise to assess seismic risk information on local, national and regional scale. Users will be able to access pre-calculated output, such as maps, curves, tables and indices, but can also discuss about them through the GEM user network. Users with more advanced expertise will be able to compute hazard and risk themselves and analyse impacts of earthquakes on society and economy. They will also be able use their own data if they so wish. The OpenGEM platform will be powered by the open source OpenQuake software, that computes seismic hazard, seismic risk and the socio-economic impact of earthquakes. Development of the OpenQuake software is driven by the scientific team of the Model Facility in collaboration with the IT development team, but takes place in the open (using a public-code repository, and test-driven development), to allow other organisations and individuals to use the software, and improve the code even further. OpenQuake is being developed with the Agile development philosophy, where requirements and solutions continually evolve through collaboration between the scientists and the developers. Such a development strategy is ideal for an initiative like GEM where there are unknown or evolving requirements, and where a large amount of research and development is still required. OpenQuake has time-based releases, meaning that each 3-6 months a new version is released which includes enhanced and/or new features.



The OpenGEM Risk Assessment Platform will be a single access-point for a suite of tools, databases and applications that are being developed

In addition to OpenQuake, the Model Facility is also working on other components of the OpenGEM suite, such as tools for development of input models (a Modeller's Toolkit) and tools for uploading/adding data to the global databases being developed as part of the Global Component projects. Each of these has its own user-interface, which are currently being developed, and in 2013 the components will be hence combined to form OpenGEM, as a single-access point, which the above depicts. Demo user interfaces of OpenQuake and the Modeller's Toolkit will be ready in the summer of 2011, to support technology transfer and early adoption.



GEM: a global collaborative effort

3/
Serving User Needs

GEM is going through a continual user-needs assessment effort, to ensure that the software and applications that are being developed meet the needs of stakeholders, both users with advanced and basic knowledge of earthquake risk, and beneficiaries, the people and organisations that might not wish to use the OpenGEM risk assessment platform, or have no direct access to internet.

A user needs assessment has been carried out among expert users, to understand their needs with regard to OpenGEM, in order to support their work in the fields of hazard and risk assessment. Collaboration with Regional Programmes furthermore leads to concrete input on how OpenGEM and the OpenQuake software can be improved to support their needs and those of their collaborators working on earthquake hazard and risk assessment around the globe.

Through continuous discussion and collaboration with partners in GEM's network that deploy local, national or regional programmes related to risk mitigation and risk management, GEM seeks to shape its model and interfaces to support their needs and to see whether specific applications can be built on top of the model. There is a specific programme being carried out aimed at understanding the needs of community leaders when it comes to earthquake risk management (Beneficiaries Needs research). Ten target communies have been chosen in which ten earthquake risk 'advocates' working in local governments, schools, local business, etc., will be interviewed: Padang and Bandung (Indonesia), Istanbul and Ankara (Turkey), Lima and Pisco (Peru), Thimpu (Bhutan), Guwahti (India), San Francisco (US) and Christchurch (New Zealand). The study will provide recommendations on what these individuals/organisations need in order to support earthquake risk management, which individuals or groups are most likely to use GEM tools, how GEM can best communicate its information so that it is readily usable by its non-expert beneficiaries and how future advocates could be trained to use GEM's tools.

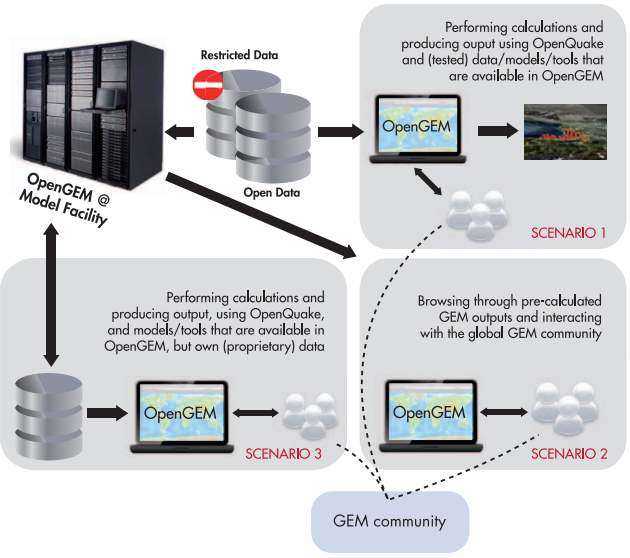
3.1 Prospective Users

GEM's model and platform are envisaged to support many types of users, both from private and public sectors, non governmental organisations, international bodies, but also individuals in earthquake prone areas. There are many possible applications of the model and below we provide a number of examples that demonstrate how different stakeholders might use OpenGEM, in some cases together with their own input data.

- A country's Minister of Economy would like to find out how the average household income is affected by a possible earthquake, in the short, medium and long term.
- A civil protection department would like to see the expected distribution of damage and fatalities within an urban area for a selected scenario earthquake for emergency management planning.
- An international agency would like to compare relative earthquake risk for the areas they operate in (over 2 continents).
- A company would like to gain insight in the effect of possible earthquake scenarios on the gross domestic product (GDP) of the countries in which it has operations.
- A risk manager of a multinational would like to get a global overview of the risk of the various production sites of his/her company.
- An urban planner would like to calculate risk maps within a given region for a given building typology in order to identify the areas of a large city with higher levels of risk.
- A reinsurer or global primary insurer would like to calculate the average annual loss and probable maximum loss to a portfolio of buildings (based on their own input exposure data).
- A geophysicist would like to calculate the expected seismic motion on bedrock for a given location, in order to define the reference motion needed for site effect analysis.
- A geologist would like to carry out a new tectonic analysis in proximity of a dam, and would like to download data on active faults as a starting point for his/her study.
- An engineer who is working on the design of a bridge located in a zone with seismic activity, would like to obtain uniform hazard spectra at different return periods for different performance limit states.
- A university researcher would like to access the OpenGEM platform as an expert user in order to produce his/her own PSHA input model using the Modeller's Toolkit, and run hazard calculations with OpenQuake.
- An individual would like to understand how hazardous the area is, where (s)he is planning to buy a house.

3.2 Using the Model

GEM's risk assessment platform (OpenGEM) will have many different types of users, with different levels of expertise and data, and different restrictions on this data, and the IT architecture and user interfaces should therefore be capable of supporting this. OpenGEM is therefore developed as an expandable, modular and dynamic suite. There are different scenarios thus of how OpenGEM will and can be used. Here we describe three main scenarios, but because of the flexiblity of GEM's IT architecture, many different kinds of use cases can be addressed by OpenGEM. The image starts from the Model Facility which hosts the servers for computation of data, and will in the future also dispose of 'cloud' services to allow multiple calculations to run at the same time. The Model Facility also stores data in a safe environment. Only data that has been provided by its owners as open data can be directly accessed by users. Computations however both use restricted and open data provided to GEM. A series of pre-calculated outputs will be available to support risk assessment for users with various levels of background knowledge and expertise. Users are connected to each other and can share their user experiences and opinions.



GEM has already started to develop ideas on what the interface could look like, with several desired characteristics having been defined: the interface should be user-friendly and should have interactive (web 2.0) features, catering for sharing and interaction within the GEM user community. Most likely there will be basic and more advanced interfaces, allowing users with different levels of (background) knowledge to find the tools and applications that fit their needs. An advanced interface is envisaged to include settings allowing users to explore hazard and risk under different assumptions and make calculations based on GEM or their own data. Such an interface will also include tools for data (input) preparation, data upload, and a number of applications that are built upon the model. A basic interface might allow a user to consult output (maps, graphs, etc.) calculated by GEM or by expert-users, but also have access to practical applications, for example related to the house/surroundings where one lives.

3.3 Promote and Support Use of the Global Earthquake Model

Making individuals and organisations familiar with OpenGEM and with the OpenQuake software is essential for adoption. Transfer of technologies and explanation of the use of approaches/models to local scientists and professionals is therefore already integral part of regional workshops. In the future standardised (online) training modules and workshop series will cater for in-depth explanation of the software, the tools and their capabilities. GEM envisages such activities mainly taking place in areas where use of risk assessment tools and software is currently less common. Design of such activities will be linked to the outcomes of the beneficaries needs research, in order to develop trainings that effectively promote use of the model and tools to support earthquake risk mitigation. Open development of OpenQuake and the suite of tools that will constitute OpenGEM, provides interested stakeholders with insight into the capabilities and allows them to indicate where the software and tools could be improved. Developers and expert users can find tools and manuals in Github, the open source development environment that has been adopted.

The web-interface that OpenGEM will have, allows users to link-up with others for data and idea sharing, and is expected to create an active user community around OpenGEM. This not only ensures long-term sustainability of data, software and tools, but also promotes employment of the model. Individual help-functions and manuals will naturally be an essential ingredient of the platform. GEM furthermore foresees presentations, workshops and (online) trainings taking place in which OpenGEM is promoted and explained to selected stakeholder groups. Specific attention will be given to non-expert users. Promotion of the model will become an integral part of outreach activities and much of it will be done in collaboration with GEM's partners.

In section 5.2.4 it is explained how the OpenQuake software, the calculation 'engine' is already is being used. Other current output are technical reports that are available on the website, and for the coming years it is foreseen that deliverables and other interim products, but also underlying discussions, are as much as possible shared with the community at large.

4/
A Public-Private Partnership

The realisation of the global earthquake model is a collaborative public-private endeavour, and GEM is therefore structured as a partnership between country governments, private organisations, research institutions, international organizations, global risk initiatives, professionals associations, NGOs and individuals. Partnering up with governmental, non-governmental, international and private organisations is essential for meeting user needs and ensuring that the risk information coming out of GEM is suitable for use by a wide audience. Moreover, participation of individuals and institutions worldwide ensures that the model is owned by a global community and reflects its needs and knowledge. This wide range of partners also underlines the nature of the GEM effort - a politically, scientifically and commercially independent undertaking.

4.1 Participants

GEM's participants are those partners that formally take part in the GEM Foundation and make the GEM effort possible due to their financial contribution and/or guidance.
Public participants are country governments that adhere to GEM and contribute financially, and are of primary relevance to ensure that the model meets governments' needs and that the standards GEM produces are incorporated in national policies.
Private participants are private organisations that play a major role in making the model possible due to both their financial contribution as well as their guidance in ensuring the model meets (private industry) end-user needs.
Associate participants, typically international and intergovernmental organisations, are important to GEM both for sharing their experiences/data with GEM as well as contributing to GEM's worldwide outreach efforts and ensuring that the model's output will meet the needs of risk mitigation initiatives worldwide. They do not necessarily contribute financially to the effort.

GEM's participants have ensured three-quarters of the funds necessary for GEM's first five-year programme, and negotiations with many prospective participants are ongoing. Interest in joining GEM is substantial, which underlines the recognition for this unprecedented initiative and highlights its financial sustainability. Countries that formally adhere to GEM have a seat on GEM's Governing Board. In order to adhere to GEM countries pay an annual fee, which is based on their Gross annual amount of Expenditure on Research & Development (GERD). In addition to the 9 countries that have committed to GEM already, negotiations with another 15 potential public participants are currently ongoing. Discussions are also ongoing with a number of corporations in various sectors; private organisations can become a private participant in GEM and sponsor the effort through three different types of sponsor collaborations: platinum, gold and silver. A fourth category of private participants are the Founders. These are the five organisations (Munich Re, Zurich Financial, AIR Worldwide, Willis and Eucentre) that have been supporting the effort ever since the beginning and have a seat on the Governing Board. Platinum sponsors may also request a seat on the Governing Board. GEM has so far welcomed six authoritative international organisations to its Governing Board as associate participants.

4.2 Contributors

From the image on page 14 it becomes clear that GEM has many contributors around the globe who are involved in the development of GEM. Already more than 50 institutions collaborate with GEM on global activities whilst in the various regions another 100 institutions are connected to GEM; either through individual experts or groups.

4.3 GEM Foundation

The non-profit GEM Foundation, based in Pavia, Italy, is the legal entity driving the GEM initiative. The various bodies it consists of are set out below. For names of current members of these bodies, visit www.globalquakemodel.org/organisation.

Governing Board

The Governing Board is the body through which decisions on all matters relating to GEM are taken. The board is comprised of representatives of all the participants that make up the GEM Foundation; Public and Private Participants have voting rights and Associate Participants take part as non-voting members. The Secretary General takes part, with non-voting rights, in all Governing Board meetings, serving also as its executive secretary.

Scientific Board

The Scientific Board is the body through which the global scientific strategy of the GEM Foundation and corresponding implementation is monitored, reviewed, advised and guided. It provides the Governing Board with proposals on all matters related to the implementation of the work programme. The Scientific Board is made up of not more than 20 international experts selected by the Governing Board, with proven expertise on GEM Foundation-related scientific fields (hazard, vulnerability, risk, social-economic impact, and IT), experience on running large collaborative efforts, wide-ranging international connections, demonstrated capacity to secure significant contributions of data and work. They may also be representatives of international scientific associations. The membership features a duration of 2 years, renewable.

Board of Auditors

The Board of Auditors is the body through which auditing of the accounting and administrative management of the GEM Foundation is carried out.

Secretary General

The Secretary General acts as the Chief Executive Officer of GEM and has the authority, within limits and guidelines decided by the Governing Board, and subject to the provisions of the GEM Statute, to administer funds and enter into contracts and agreements on behalf of GEM. The Secretary General also has the authority to take operative decisions and measures on scientific matters, in accordance with the provisions of the GEM Statute.

Secretariat

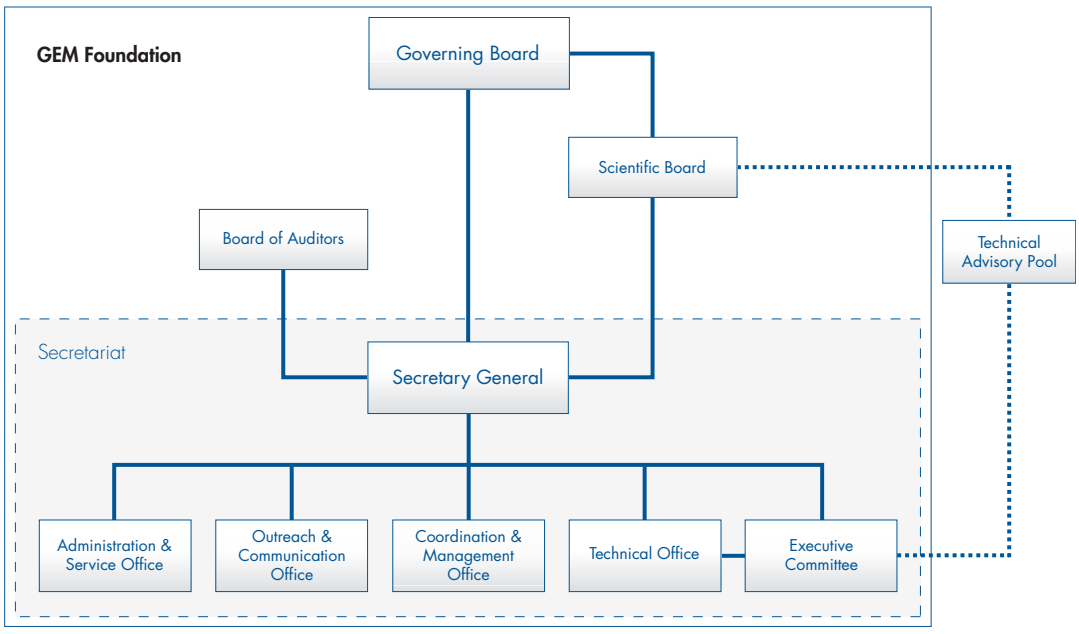
The Secretariat is responsible for executing all technical management, administrative and supporting tasks as necessary to the achievement of GEM objectives. The Secretariat holds funding contributions and all assets of GEM. The four main activity groups of the Secretariat are Coordination & Management, Technical Office, Outreach & Communications, Administration & Services.

Executive Committee

The Executive Committee is the body through which the implementation of the technical activities is operationally coordinated and enforced within the GEM Secretariat; the committee links the work being carried out on global and regional levels, with model building efforts. There is a coordinator for each scientific area; Hazard, Risk and SEI and the committee furthermore comprises the manager of the Model Facility and the IT manager.

Technical Advisory Pool

The Technical Advisory Pool (TAP) is a large pool of experts covering all of GEM's knowledge domains, from which a number of splinter working groups is formed to review specific details of the project, as a function of the needs over the 5 years. The first splinter group, the Model Advisory Group (MAG), was created for the review of the GEM1 pilot project and recently a working group has been composed on Hazard Model Integration.



5/
Working Programme 2009-2013

GEM works according to five-year working programmes, of which the first started in 2009 and will result in the presentation of a first fully-featured version of the global earthquake model by the end of 2013.

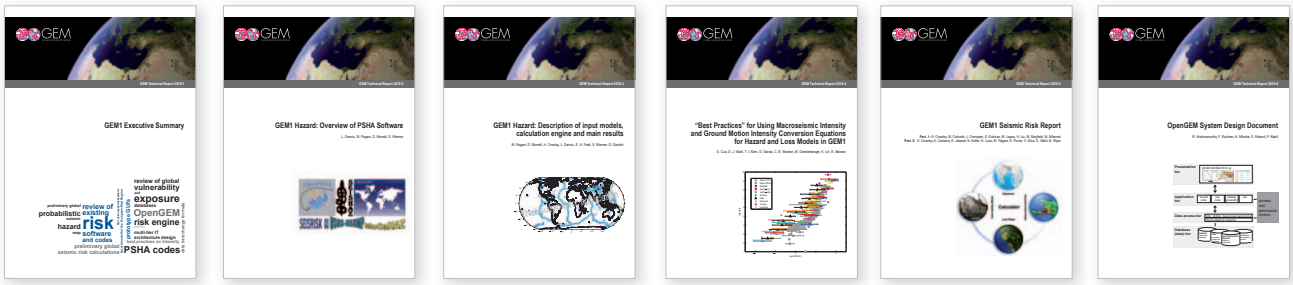
5.1 Construction of GEM

In what follows, an overview is given of the various building blocks that constitute the development of GEM, which at the same time provides an insight into the progress of GEM's first working programme.

5.1.1 GEM1

The GEM1 pilot project ran from January 2009 to March 2010, with the objective of laying a solid foundation for the subsequent development of the global earthquake risk model involving the Global Components and Regional Programmes. It was a test-case from various points of view, since there were numerous institutions from around the world involved and first tentative models and datasets were prepared to support (hazard and risk) calculations on a global scale. The GEM1 project started before the GEM Foundation was incorporated and had clear goals that were to be achieved in a narrow timeframe. The project focused around three areas: Hazard, Risk and IT. The five core institutions carrying out GEM1 were ETH Zürich, Eucentre Foundation, GFZ, NORSAR and the US Geological Survey; the project was led by ETH Zürich. An international team of experts on hazard, risk and IT was hence trained and hired, and succeeded in collaboratively reaching the goals that were set. In addition, several subcontracts were issued.

The main outcomes of the GEM1 project were proof-of-concept preliminary global hazard and risk calculations. A series of technical reports is available on the technical achievements of the project in the three main activity areas mentioned above. The reports can be downloaded from www.globalquakemodel.org/technical-reports/gem1. GEM1 furthermore led to the definition of the GEM Model Facility, whose mandate it is to undertake the development of the OpenGEM platform, and to enable and support all modelling developments related to the mission of GEM.



Technical reports summarize the main achievements of the GEM1 project

Other results worth noting are:

- 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.
- By being 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 Facility and Regional Programmes.
- 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.

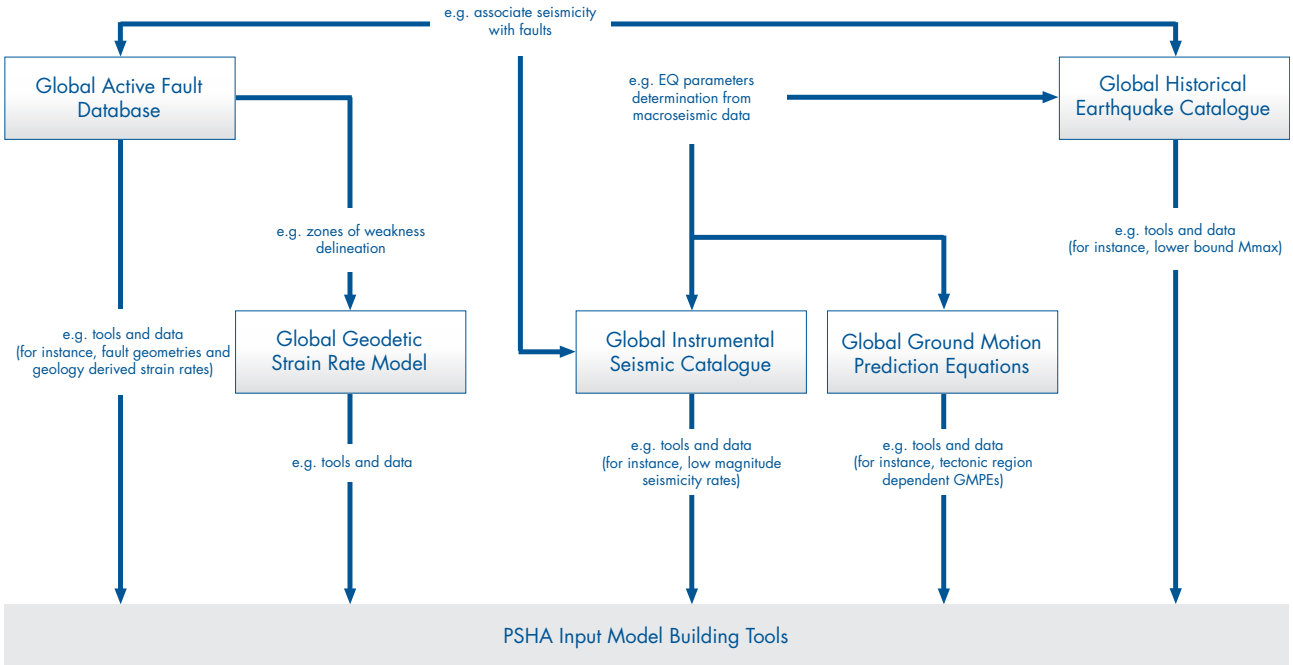
5.1.2 Global Components

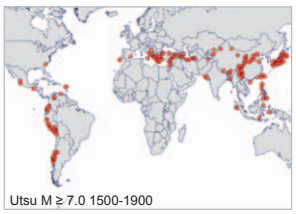
The task set out for the international consortia carrying out the Global Component (GC) projects is evidently very ambitious, and within the scope of GEM's first working programme it will not be possible for the global databases to be exhaustively populated, nor for all-inclusive tools to be developed. It is however critical that agreement on methods/standards is found, so as to build a solid foundation, and that collaborative tools are fully put in place, allowing users to continuously update and improve databases (and models). Work on five Hazard GCs has started and will be delivered in the spring of 2012. An RfP for a sixth component, on Site Effects, has been released in May 2011 and an Expression of Interest for activities to be carried out related to Macroseismic Intensity will lead to additional input to both GEM's Hazard and Risk Models. There are currently five Risk GCs, for which development started at the end of 2010 and will be finished in 2013. Work on the Socio-Economic GC will take off in the summer of 2011, with the goal to be finalised in 2 years. The total budget for development of the Global Component projects carried out by international consortia approaches 10 Million Euro.

Hazard Global Components

In the last decade, several earthquakes highlighted the still pressing need for reliable seismic hazard assessments in many parts of the world. An improvement of PSHA input models – and thus in computed results – can be achieved only by ameliorating its two main components: the one defining the earthquake occurrence on seismic sources and the one that given an earthquake rupture computes surrounding ground motion. In both cases, augmenting and homogenising the available data sets, introducing standardised procedures for data processing and calculations, and – mainly – making the best use of all the possible information available, are essential activities to be carried out. The activities have been currently divided into 6 global component projects, of which five are currently ongoing and the sixth will start in the fall of the 2011. The global component on seismicity will compile an instrumental seismic catalogue containing events occurred in the period 1900-2009, relocated following an homogenous procedure and with recomputed values of magnitude. This information will be complemented by an extensive database of active faults and a global parametric catalogue of historical earthquakes accompanied by an archive of historical earthquake studies. Crustal strain rate obtained from geodesy will be used as a proxy for earthquake potential. The inclusion of a geodetic strain rate model in GEM will help in assessing whether the estimated fault slip rates and earthquake activity rates are consistent with the strain accumulation measured from GPS. Tectonic dependent and harmonized ground motion prediction equations (GMPEs) are another fundamental ingredient for the computation of well-founded hazard results. Finally a project on site effects will complement the Hazard Module. The goal of this Global Component is to define a flexible, modular and scalable methodology to incorporate site-effects into probabilistic seismic hazard analysis, starting from the design and compilation of a database with parameters describing site conditions and the corresponding site response.

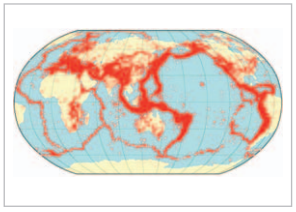
There is a clear interdependency between the five global components that are currently ongoing and together make up GEM's Hazard Module. They are described in further detail on page 21.





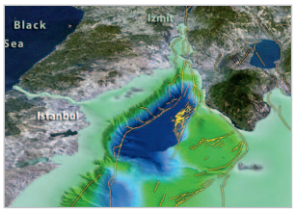
Global Earthquake History www.globalquakemodel.org/hazard-global-components/earthquake-history

An international consortium is working to build up a Global Earthquake History, based on existing regional initiatives and to support regional capacities yet to be developed. The consortium mainly considers earthquakes with M≥7.0 at minimum, in the time window 1000 to 1903. The project will produce a common set of definitions, strategies, standards, quality criteria and formats for the compilation of historical earthquake data. The main achievement will be a database of parametric entries, each referring to an individual study of an earthquake. Epistemic uncertainties will be emphasized rather than hidden, for the benefit of hazard assessments. An online resource will be developed [Global Archive of Historical Earthquake Studies] through which both reports and macroseismic datapoints can be uploaded, organised and made available to a wide public. The 2-year project is led by the Istituto Nazionale di Geofisica e Vulcolonogia (INGV) [Italy] and the British Geological Survey (BGS) [UK]. More than half of the work will be executed in cooperation with local researchers from various regions.



Global Instrumental Earthquake Catalogue www.globalquakemodel.org/hazard-global-components/instrumental-catalogue

The goal of this project is to compile a reference Global Instrumental Earthquake Catalogue (1900-2009) to be used by GEM for characterization of the spatial distribution of seismicity, the magnitude frequency relation and the maximum magnitude. The catalogue is being created using a uniform relocation procedure, and standard methods for assessing surface waves magnitude. More specifically, the consortium expects to deliver at the end of the project: 110 years of relocated earthquake hypocenters; recomputed Ms values for relocated events; Mw values based on seismic moment where possible (mainly 1980-2009) and proxy values in other cases using appropriate empirical relationships; a database with the above information and reference to original sources including scanned historical bulletin pages.The consortium consists of six international experts, backed up by their teams and institutions (IES Jaume Almera [Spain], Colorado University [US], GFZ Potsdam [Germany] and SISMOS [Italy]), and is led by the International Seismological Centre (ISC) [UK] in collaboration with the International Association of Seismology and Physics of the Earth's Interior (IASPEI). The project has a duration of 27 months.

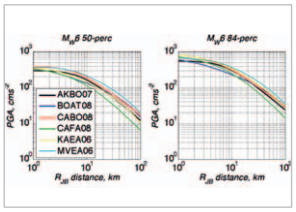


Global Active Faults and Seismic Source Database www.globalquakemodel.org/hazard-global-components/active-faults

The main task of the international consortium in this project is the compilation of a global database of active faults, that will also cover areas not covered before, building upon projects such as the 'Major Active Faults of the World' programme (1994-2004). In particular, the goals of the project, named 'GEM Faulted Earth', are to:

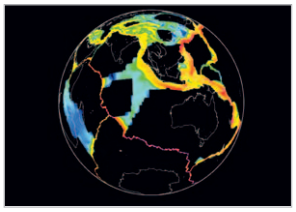
- Develop a commonly accepted flexible database standard for faults and seismic sources;
- Create an accurate and uniform inventory of the world's faults;
- Create a database of active faults and seismic sources;
- Create easy-to-use tools and assist in uploading of data to the database.

The project has a 2-year duration and is carried out by a consortium that includes a substantial number of international experts who are often linked to national institutions. GNS Science [New Zealand] is leading the effort, in collaboration with the Earth Observatory of Singapore (EOS), and the Universidad Nacional de San Luis [Argentina]. Local researchers are involved extensively in the project.



Global Ground Motion Prediction Equations www.globalquakemodel.org/hazard-global-components/ground-motion

The main goal of this project is the development of a harmonized suite of ground-motion prediction equations (GMPEs), built on the most recent advancements in the field. After definition of a consistent strategy for modelling ground motion, a global set of GMPEs will be derived. Regional experts involved in the project will subsequently compare observed data in their regions to those predicted by the shortlisted GMPEs to account for possible regional variances. The Pacific Earthquake Engineering Research Center (PEER) [USA] is leading this project, which furthermore features the active participation of 27 experts from all regions of the world, with combined GMPE knowledge covering almost the entire globe.



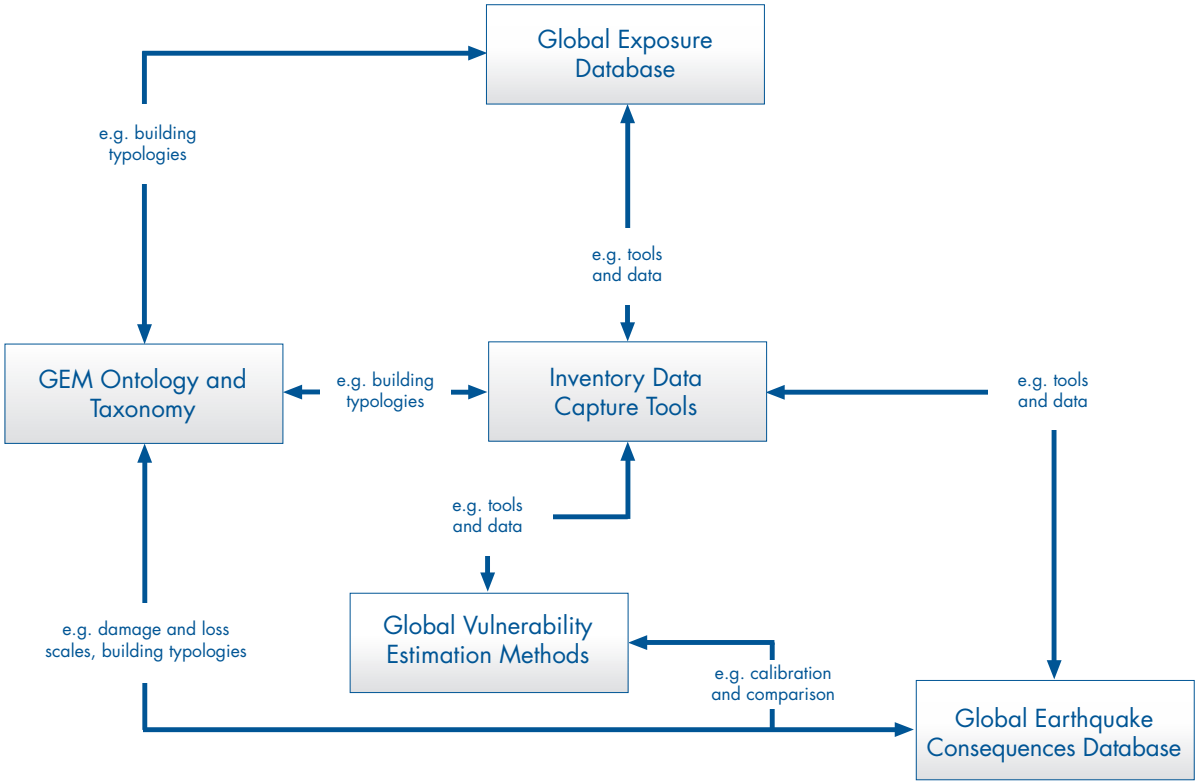
Global Geodetic Strain Rate Model www.globalquakemodel.org/hazard-global-components/geodetic-strain

The creation of a comprehensive and uniform model for geodetic strain rates is being pursued in this project, by means of critically reviewing all global and regional studies since 1994. The consortium will significantly update and improve the Global Strain Rate Model of 2004 which combines spherical cap motions of 25 assumed rigid plates/blocks with velocity gradient tensor fields in the plate boundary zones, and will also produce a uniform global GPS velocity database. The tasks within this 2-year project are carried out by international experts from the University of Nevada [US], the Ecole Normale Supérieure [France], the UCLA California [US]/China Earthquake Administration [P-R- China] and UNAVCO [US].

Risk Global Components

Five critical risk global components have been defined. As risk calculations are based on combining hazard with exposure and vulnerability, one of the main ingredients needed for the global earthquake risk model is a global exposure database. Currently no unified global database of building stock exists that can support global risk calculations. A global consequences database is the second ingredient of GEM's Risk Module. This open database will focus on collating detailed loss and damage data from past earthquakes, with an emphasis on proper data taxonomy and uniformity, and will provide a service for the future submission of such data. To ensure that these databases have a lasting value, inventory data capture tools will be developed that can enlarge the datasets, as our understanding of earthquake exposure and consequences changes, and as the building stock, population and other data itself changes. To deal with vulnerability, there is a need for tools to estimate vulnerability as accurately as possible. Over the past 10-20 years a number of different methods have been developed which are all valid, but there is no common standard on how to estimate vulnerability best. Surrounding all of this there is a need for a structured framework for risk assessment, an ontology & taxonomy, to support common understanding of earthquake risk and to support risk estimations on a global scale.

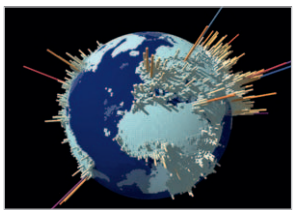
Continuous interaction between the consortia that are developing the components is of great importance, since they are closely intertwined, as can be seen in the figure below:



A short description of each of the components:

GEM Ontology and Taxonomy www.globalquakemodel.org/risk-global-components/ontology-taxonomy

This project foresees the development of a number of elements essential to the model. First of all, a technical communications and coordination programme is developed to support exchange of knowledge and opinions between various GEM collaborators, which can be sustained after GEM's first working programme. This programme is to support all other elements, such as definition of a set of concepts used in GEM and the relationship between them; a GEM ontology. Furthermore an initial GEM taxonomy is to be developed that can be sustained in the future (i.e. a classification of things in an ordered system that reflects their relation). The proposed O&T will be evaluated and tested extensively on applicability and utility for a broad spectrum of users. As a last task in the project, the consortium will develop a program for promoting and disseminating the GEM Ontology and Taxonomy globally. The Alliance for Global Open Risk Analysis (AGORA), DPRI [Japan], PEER [US] and the World Housing Encyclopeadia/EERI are the institutions that carry out this 3-year project.

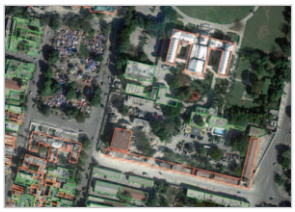


Global Exposure Database www.globalquakemodel.org/risk-global-components/exposure-database

This project, named GED4GEM, has as its main goal to develop an open homogenized database of global building stock and population distribution, containing the spatial, structural, and occupancy-related information necessary for damage, loss and human casualty (estimation) models to be deployed in GEM. The consortium builds on existing databases and publications at first and then collects and integrates other population and building stock data for at least the first level of sub-national boundaries for all countries. The consortium will devise and document a systematic and flexible approach for global application. Finally, an open data development environment will be created for future modification and improvement of the database. The partners making up the consortium are: University of Pavia [Italy], CIESIN-Columbia University [US], China Earthquake Administration - Institute for Earth Sciences [P.R. China], China Earthquake Administration - Institute for Geophysics [P.R. China], ImageCat [US], Joint Research Centre [EU], the GOU of UN-HABITAT and USGS [US]. The project has a 3-year duration.

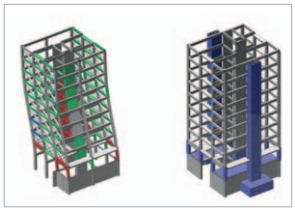
Global Earthquake Consequences Database www.globalquakemodel.org/risk-global-components/consequence-database

The aim of this project is to create a structure to assemble and to store earthquake consequence data in a web-accessible way. Data to include comprise building damage, damage to lifelines and other infrastructure, ground failure, human casualties, social disruption, and financial and economic loss. The database will serve to inform users on consequences from past events, as a benchmarking tool for analytical loss models and to support the development of tools to create vulnerability data appropriate to specific countries, structures, or building classes. Preparation of an interface enabling impact damage from future earthquakes to be captured and uploaded to the database is also part of this project, named GEMECD. The consortium is led by CAR Ltd [UK] and also includes CRED [Belgium], Evaluación de Riesgos Naturales - America Latina (ERN-AL), GNS Science [New Zealand], KOERI [Turkey], Kyoto University [Japan], Munich Re [Germany], SPA Risk and USGS [US]. The project has a 3-year duration.



Inventory Data Capture Tools www.globalquakemodel.org/risk-global-components/inventory-capture

This project has 2 main goals: a) to provide tools that will enable the capture and transfer of high-resolution inventory or damage data into either the Global Exposure Database (GED) or the Global Earthquake Consequences Database GECD), and b) to develop tools that can merge data collected using Remote Sensing with data acquired from Direct Observation. The tools developed within this component should provide the attributes needed to assign assets to specific vulnerability classes as input to the GED and should allow for collection of post-earthquake damage and impact data in a form suitable for transfer into the GECD. ImageCat leads the consortium, which is comprised furthermore of BGS [UK], CAR Ltd [UK], KIT/CEDIM [Germany], Nottingham University [UK], OpenGeo [US], Pavia University [Italy], SPA Risk, Stanford Univeristy [US] and WAPMERR [Switzerland]. This project will be carried out in 30 months.

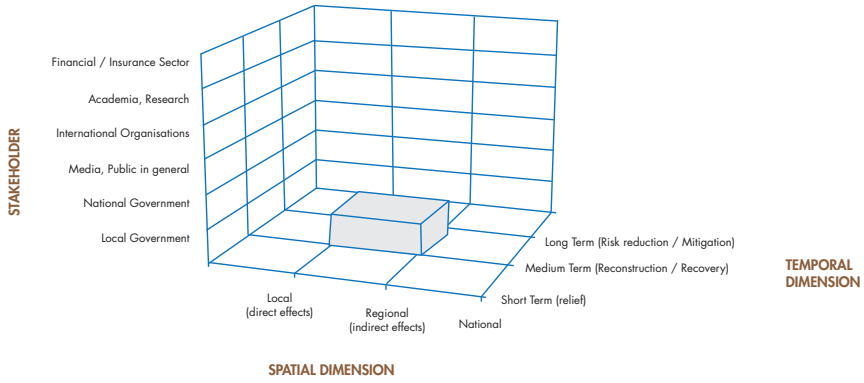


Global Vulnerability Estimation Methods www.globalquakemodel.org/risk-global-components/vulnerability-estimation

The aim of this project is to provide standards for vulnerability estimation (i.e. the estimation of building damage, both structural and non-structural, and associated social and economic loss) using a number of different methods (empirical, analytical, expert opinion) and a range of measures of ground-motion intensity. The consortium will furthermore propose default vulnerability estimations using the standard methods for all earthquake-risk countries/regions in order to allow a global risk assessment to be carried out. The methods will be demonstrated in detailed application to a particular region. The consortium, consisting of the University of Colorado [US], University of Chile [Chile], Geoscience Australia [Australia], EERI [US], Stanford University [UK], University College London [UK], University of Bath [UK], USGS [US] and Willis, will also propose methods to assess uncertainty. The project has a 3-year duration.

Socio-Economic Impact Global Component www.globalquakemodel.org/socio-economic-impact

The main objective of GEM's Socio-Economic Impact (SEI) Module is to provide the community with a set of methods for assessing, estimating and communicating impacts of earthquakes on society and economy. Development of the SEI Global Component is expected to lead to the development of an engine, which is envisioned as a toolbox that gathers a comprehensive set of models, metrics, data and tools. Such methods will include contemporary and traditional ones, used by social scientists, natural scientists and practitioners in areas such as economic analysis, risk assessment, mitigation, planning and decision-making. The toolbox will include methods that allow for analysis of effects on different timescales: short term (relief), medium term (reconstruction and recovery) and long term (risk reduction and mitigation). Methods should furthermore be applicable on different scales: local, regional and national, and they should serve diverse stakeholder groups, as the image on the next page displays. The exact choice of methods to include and of principles on how to organise them, will be defined together with the community.



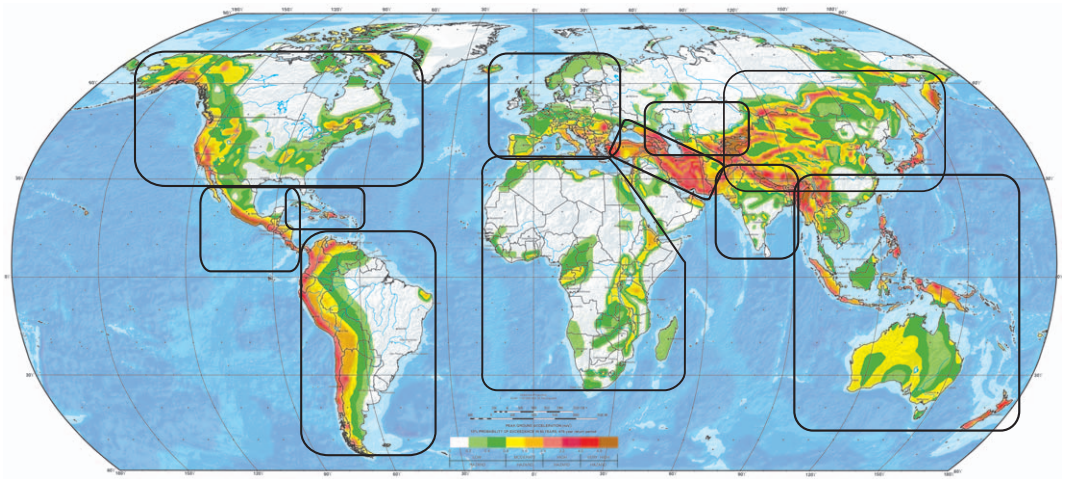
A Request for Proposals for GEM's SEI Global Component was released in December 2010 for international consortia to respond to. Before this release, GEM provided the community the opportunity to provide comments on the draft RfP, by means of a 2-month public commentary process. Three challenging proposals were received and in June 2011 GEM's Governing Board will decide which group of international experts and organisations will be awarded the project. The consortium is therefore expected to start its work in the summer of 2011.

The Social and Economic Impact engine, or SEI-component of OpenQuake, is to be constructed following a two-track approach: in the first track, the consortium awarded with the project shall generate a framework for organizing methods for social and economic impact analysis, which will result in the toolbox referred to in the previous paragraph. In the second track, the consortium shall generate methods that will populate the toolbox. Within the SEI Module, in addition to the work the consortium will undertake for the SEI Global Component, collaborators of GEM's Model Facility will work on innovative solutions to improve the knowledge about the linkages between natural events, the economy and the society.

5.1.3 Regional Programmes

Involvement of all regions of the globe is critical for development of a global model. Collaboration with regions preferably takes place through Regional Programmes, independently-run regional projects that are carried out in conformance with GEM standards and goals, involving local institutions and experts, and are focused on hazard, vulnerability, exposure or socio-economic impact or a combination of these. In collaboration with the regions, the GEM Secretariat organises meetings and workshops aimed at contributing to the kick-starting and setting-up of Regional Programmes and assists in coordination/ management efforts. Interaction between Global Components and Regional Programmes is facilated through (joint) meetings and online interaction mechanisms.

Since 2010 GEM also provides financial support for the introduction of Operations Managers in regions where other sources of funding are not available, such as North Africa, sub-Saharan Africa, South America and the Caribbean. Page 25 provides an overview of current activities in the various regions.



GEM envisages one or more Regional Programmes to be(come) operational in these regions

Europe

GEM is linked to three independent European programmes: SHARE, SYNER-G and NERA. SHARE is focused on seismic hazard harmonization in Europe. SYNER-G aims to develop a unified methodology and tools for systemic vulnerability assessment in Europe. NERA is aimed at creation of a European research infrastructure for risk assessment and mitigation. Especially with the SHARE programme there is close interaction and collaboration, focused around OpenQuake. In the last two years the GEM Model Facility participated in several SHARE workshops and was actively involved in the creation of the SHARE PSHA input model. Representatives of the GEM TAP Working Group on Hazard Integration and Assembling also attended some of these workshops.

Middle East

GEM is closely linked to the EMME project; the Earthquake Model for the Middle-East. The project currently covers Iran, Turkey, Jordan, Pakistan, Lebanon, Syria, Georgia, Azerbaijan and Armenia and has workpackages on hazard, risk and loss assessment, but also on city scenarios such as Mashad (Iran), Karachi (Pakistan) and Zarqa (Jordan). In various recent workshops and meetings, the project coordinators and collaborators of the GEM Model Facility have worked to implement OpenQuake for various areas in the region.

Central Asia

The EMCA programme, Earthquake Model for Central Asia, has been operative since the spring of 2011. EMCA is managed by GFZ Potsdam and aims at cross-border assessment of seismic hazard and risk in Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan), by working together with institutions and experts in the region.

Caribbean

In the Caribbean, a large kick-off workshop was held in May 2011, hosted by the University of the West Indies, with a view to start the Regional Programme in the region. The workshop featured participation of over 70 individuals (experts and stakeholders) and led to the formation of a number of working groups, which will soon start.

Africa

The framework for a GEM Regional Programme is put in place, combining the sub-regions of sub-Saharan and North Africa. Currently collaborators are working on a pan-African proposal, looking for sub-regional Operations Managers to support the programme and are coordinating the deployment of activities in their sub-region. A workshop is to be held at the end of May 2011 in Morocco to define start-up of activities in North Africa.

South Asia

A GEM Regional Programme for the region, focused on hazard, vulnerability and risk has been defined after a number of workshops which involved a large number of institutions, mainly from India. Currently support funds are being sought, to be followed by an effort to involve neighbouring countries in the endeavour.

South-East Asia / Pacific

A regional workshop was held in 2010, involving representatives from almost all countries in the region, who confirmed their commitment to jointly work on earthquake hazard and risk (see picture). A new workshop focused on hazard modelling is planned for July 2011.

South America

An Interim Manager initiated the creation of a network in the region. In collaboration with CERESIS and several South American risk experts, one or two Operations Managers will be selected and activities started.

Central America

GEM cooperates with the CAPRA (Central America Probabilistic Risk Assessment) programme deployed by the World Bank in the region and has made good contacts with other programmes, such as RESIS II, and individual experts.

North-East Asia

A large workshop and several meetings are to be held in June 2011 for definition of one or more Regional Programmes in the region, involving countries such as the People's Republic of China, Japan, Korea and Mongolia.

5.1.5 GEM Model Facility

The mandate of GEM's Model Facility (MF) is to undertake the development of the OpenGEM platform (and its underlying OpenQuake software) that will integrate hazard, risk, and socio-economic impact assessment tools and data and provide these to the community, and to enable and support all modelling developments. Its main tasks are therefore to:

- Lead the development of OpenQuake as an open source, web-mountable integrated software service that will include hazard, risk and SEI engines and a modellers' toolkit;
- Manage the dedicated computing infrastructure as well as access to distributed computing facilities to provide the capability to compute, analyse and communicate global harmonised hazard, risk and socio-economic impact estimates;
- Develop, provide access to, and maintain the OpenGEM web-based service for accessing the engine, tools, data and models, as well as GEM precomputed results;
- Support model building developments arising from Regional Programmes, Global Components, and other third parties;
- Support the interaction between OpenGEM and its contributors and user community.

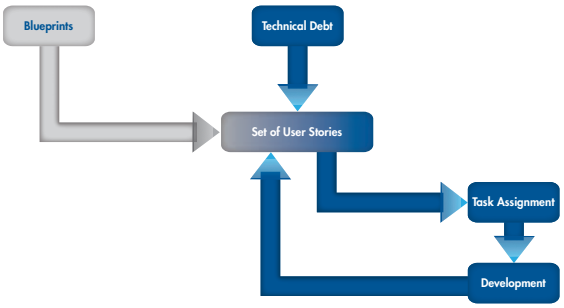
From July 2010 the Model Facility became fully operational as a joint project between ETH Zurich and the GEM Secretariat in Pavia, and a new open source strategy for developing GEM's IT was implemented.

Methodology

Open source development has a number of requirements which go beyond the simple release of source code, and have the advantage of improving community engagement, providing free labor, and ultimately leading to better software:

- Release of source code with an open source license;
- Use of a public code repository where code changes can be viewed by "outsiders", that can track the code development, provide bug patches etc.;
- An open process of discussion (through open mailing lists, an IRC channel);
- A policy for open, consensus-based, decision-making.

OpenQuake and the other components of the OpenGEM suite are being developed following all of these practices. Furthermore, development follows the Agile philosophy, as was explained in section 2.2. The Scientists, which in the case of OpenQuake are the Executive Committee members of GEM for hazard, risk and socio-economic impact and their collaborators, define the high level goals which are documented in BluePrints and hosted on the OpenQuake project Wiki. The BluePrints are then tackled through a number of Sprints, which are 2-3 week short, iterative development cycles with fixed priorities that cannot be changed during the Sprint. An example of a BluePrint would be the description of a feature that allows users to produce magnitude-distance-epsilon and geographic disaggregation plots. These BluePrints are split up into a number of user stories, where each story is an actionable amount of work, which should take a maximum of 2 days for a developer to complete. The science team prepares a number of user stories before a Sprints begins, and these tasks are assigned to the developers during Sprint Planning. Pivotal Tracker is a tool that the team uses to manage user stories, prioritise, assign tasks to developers, and check the velocity of the team. At the end of the Sprint the developers demo their code to the science team, and the whole team undertakes Retrospective, which requires each individual to identify things they liked about the Sprint and things they would change. This is also an opportunity for the team to identify what tasks have been completed and which remain to be carried forward to the next Sprint, or to be postponed, should a change in priorities be required.



The code is hosted on GitHub, a web-based hosting service for software development projects that use the Git revision control system, which is distributed rather than centralized. The benefit of having a distributed revision control system is that any interested developer can work on a private or shared branch (offline or online), and can submit a "merge proposal" in order to have their code (or "patch") integrated into the Master code (following a review by the core developers). Such a framework means that the development can scale to thousands of developers and it thus further supports community engagement.

A final important characteristic of OpenQuake and related pieces of codes, concerns the use of Test-Driven Development (TDD) and Continuous Integration. TDD requires all developers to first write the code that will test their patches. All code is reviewed by at least one of the core developers before being merged to the Master, which then leads to a full run of end-to-end tests, which is known as Continuous Integration.

OpenQuake

OpenQuake has been discussed in various sections already, but here we describe it in further detail. OpenQuake is a state-of-the-art, open source software that is mainly written in the Python programming language, for calculating seismic hazard and risk at any scale. It makes use of a number of other, independent, open source projects such as OpenSHA. OpenQuake is a unique software for a number of reasons:

- It combines deterministic and probabilistic hazard and risk calculations within a single software;
- The development is "open source", and takes place on a public repository that encourages collaboration on a single code base (through a distributed version control system);
- All input and output follow an evolving data interchange format called NRML (Natural hazards Risk Markup Language);
- The code is engineered in such a way that it can be used on a single processor laptop as well as on a cloud of computers.

OpenQuake builds on work carried out in the GEM1 pilot project. As part of that effort, a number of existing hazard and risk software applications was reviewed, which allowed the main scientific requirements of OpenQuake to be specified. A close collaboration with the OpenSHA team at the US Geological Survey and the University of Southern California was also initiated during GEM1, which ensured that OpenQuake had a state-of-the-art basis for the hazard code. In June 2010 the IT infrastructure design made during GEM1 were reviewed by a team of 17 experts and recommendations were made on the future steps necessary to ensure GEM would produce the open source, community based software and model that had been part of the vision of the OECD's Global Science Forum since it launched the GEM initiative in 2006. From July 2010, development of OpenQuake took a sprint, and from January 2011 it became an open source project, allowing a wider community of developers and experts to contribute to development of the code.

The version of OpenQuake that was released at the moment of writing (0.3) is a 'developer' release without a user interface (though this is currently under development), but for those that are not put off by preparing ASCII input files and running calculations through the command line, it can currently be used for a number of seismic hazard and risk analyses.

Seismic Hazard

The hazard component of OpenQuake leverages on OpenSHA, an open source, Java-based platform for conducting Seismic Hazard Analysis (SHA) (www.opensha.org). OpenQuake computes hazard following two different approaches: one termed Classical Probabilistic Seismic Hazard Analysis (PSHA) and a second one based on the stochastic simulation of earthquake activity and of the shaking produced by each event. The main outputs that the software can currently produce, given an input source zone model and set of ground-motion prediction equations (GMPE), include:

- Hazard curves (curves providing probabilities of exceedance in a given time span for given values of a ground motion parameter);
- Hazard maps (maps describing the geographic distribution of values of a ground motion parameter with a fixed probability of exceedance in a given time span);
- Stochastic Event Set (a set of earthquake ruptures in a given time span obtained through random sampling of a seismic source model);
- Sets of Ground-Motion Fields (each ground-motion field describes the ground-motion shaking values for a set of sites computed considering an earthquake rupture and a GMPE, and spatial correlation of the intra-event residuals of the latter).

Future developments will expand the capabilities to include uniform hazard spectra and magnitude-distance-epsilon and geographic disaggregation.

Seismic Risk

OpenQuake calculates seismic risk using three different calculators: the Classical PSHA-Based Risk Calculator, the Probabilistic Event-Based Risk Calculator and the Deterministic Event-Based Risk Calculator. All three calculators require the same input in terms of vulnerability functions (currently modeled as discrete functions describing the probabilistic distribution of loss, given a level of ground shaking) and exposure data (e.g. geographical distribution of values of given building typologies). Version 0.3 provides the following main outputs:

- Loss exceedance curves (loss versus probability of exceedance in a given time span, both for single assets and aggregated losses for multiple assets);
- Conditional loss maps describing the geographical distribution of values of loss with a fixed probability of exceedance in a given time span;
- Mean loss maps describing the geographic distribution of mean loss within a given time span;
- Loss statistics per event or across all events (mean loss, standard deviation of loss etc.).

Future developments will allow damage maps to be produced, describing the geographical distribution of mean number/area/percentage of damage at a given limit state for a given deterministic event.

Socio-Economic Impact

Version 0.3 of OpenQuake does not have any implemented features related to socio-economic impact, but will in the near future include a benefit-cost ratio calculator following the model of OpenRisk (www.risk-agora.org) and a Dynamic Population Estimation Model calculator that can forecast or hindcast changes in population in a given region over time, also taking into account the impact from earthquakes. Other features will be discussed and developed as soon as a consortium is awarded the global component project.

Further information for both potential developers and users can be found on http//openquake.org. The Scientists are currently developing an OpenQuake Book that will describe the mechanics behind the scientific calculations, and an OpenQuake Manual that will help users to prepare configuration files, will describe the NRML format in more detail and will include a number of tutorials and tests. Interested developers can get involved in the development of OpenQuake, whilst potential users are encouraged to install the software, run tests, submit bugs, review and comment on the documentation and BluePrints.

OpenQuake application

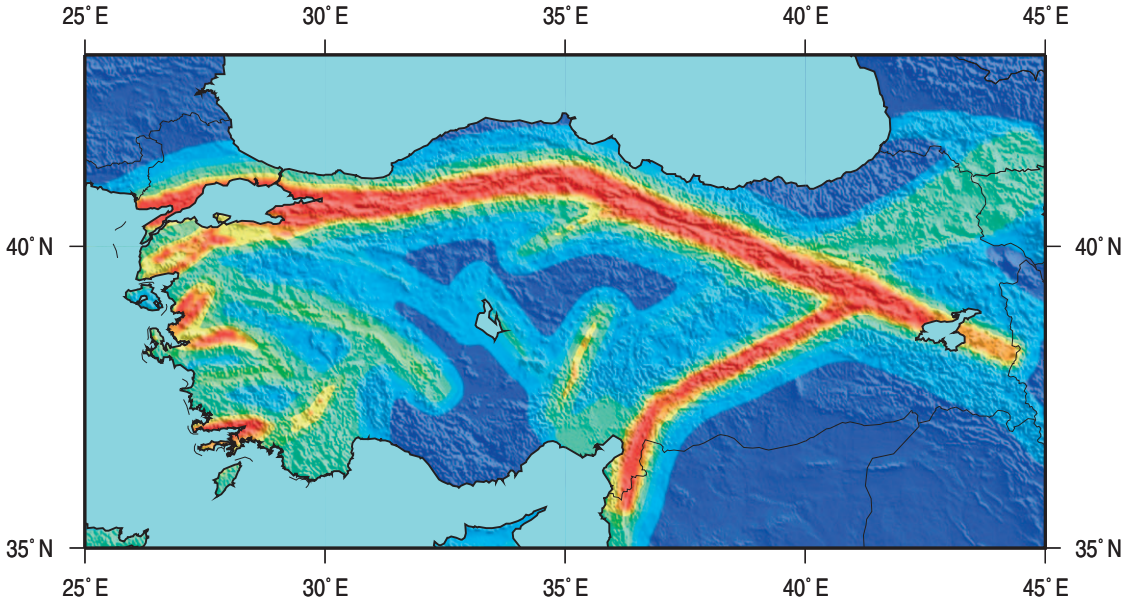
Over the course of the past two years, the Model Facility started several collaborations with Regional and National Programmes. And, as the Highlight displayed, OpenQuake is already used through such collaborations. Discussions are ongoing for more collaborations in 2011.

EMME (Middle East)

The Model Facility has been working closely with the EMME Regional Programme on the application of OpenQuake for hazard and loss calculations in the region. An OpenQuake workshop between the Model Facility and KOERI took place in April 2011 and OpenQuake was demonstrated and installed on a number of local machines. Configuration files for the calculations and a number of input files in the NRML format for the PSHA input model, vulnerability functions, and the building and population inventory are currently being prepared to allow a number of preliminary calculations to be carried out:

- Hazard curves and maps for the whole of Turkey using a logic tree structure for a number of spectral ordinates for 475 and 2500 year return periods;
- Deterministic event-based ground-motion field calculations using the fault rupture of the 1999 Kocaeli earthquake (M=7.4) and a hypothetical fault rupture close to Istanbul (M=7.5);
- Loss maps in terms of cost of repair and ratio of cost of repair to cost of replacement for the aforementioned deterministic events considering local building inventory and empirical vulnerability models provided by KOERI.

The preliminary hazard map of Turkey produced with OpenQuake (May 2011) is displayed below, representing the first results of the collaboration between EMME and the GEM Model Facility. The map will be the basis for further analyses.



SHARE (Europe)

The Model Facility Team has been working with scientists involved in the programme for Seismic Hazard Harmonization in Europe. The collaboration has so far mainly focused on two areas: 1) The implementation of a number of Ground Motion

Prediction Equations (GMPEs) in OpenQuake, and 2) The development of a number of new OpenQuake features, such as area sources accounting for seismicity depth distribution, new branching levels of the logic tree structure accounting for specific types of epistemic uncertainties (e.g. variability of the Gutenberg-Richter a and b values) and area sources with borders impermeable to ruptures.

Instituto Geofisico (Ecuador) - IRD (ISTerre France)
The GEM Model Facility is working with the Istituto Geofisico de Quito in Ecuador and the Institut de Recherche pour le Développement (IRD) from France on the new seismic hazard maps of Ecuador. In addition to providing technical support for OpenQuake, the MF team explained how to create the NRML data exchange file which is needed to describe the PSHA input model. The Model Facility ran preliminary calculations on its in-house cluster, but OpenQuake was also installed on a computer at IRD o favour and solicit the interaction with the Model Facility preliminary testing of the models and the implementation of sensitivity studies. This has led to preliminary seismic hazard maps for different source models, shallow crust, interface and intraslab using a variety of GMPEs, which will contribute to increased hazard awareness and will possibly also be used for other applications.

5.1.5 Testing and Evaluation Facility

A Testing and Evaluation (T&E) facility is being set up in Potsdam Germany, as part of the collaboration between Germany and GEM. A T&E planning meeting was held in March 2011 to define the mandate and scope of the facility in further detail. In the meeting it was decided that the T&E Facility will focus on prospective testing, whereas the Model Facility will take care of retrospective testing, where past data is used to test the models as they are being built. The facility will work on three main areas: 1) testing of the seismic rate model, 2) prediction of ground motions and hazard, 3) testing of risk forecasts.

5.1.6 GEM Secretariat

The activities of the Secretariat can be split up into 4 main categories: Coordination & Management, Technical Office, Outreach & Communication, Administration and Services. A brief description of their tasks to date is provided below.

Coordination and Management
GEM's coordination and management team defines rules and regulations for the GEM Foundation, such as financial guidelines, contracts and organisational procedures, and is on a constant basis involved in discussions with possible new participants both from public and private sectors. Nine countries formally adhered to GEM, of which Norway, Australia and New Zealand are the latest arrivals, and FM Global and Hannover Re decided to become a Platinum Sponsor. As GEM aims to produce innovative, user-intuitive, but in particular open source software, background research into software licences and legal issues is another essential task within this activity area.
GEM's management organises and coordinates the Governing Board and international progress assessment meetings, which take place twice a year. Collaborators participate on a regular basis in international conferences and workshops; such as for the design and enhancement of Regional Programmes around the globe (e.g. meetings in India, Kenya, Peru, Singapore, etc). Organisation of these and other international meetings is a key element to support the community effort, creating an environment for consensus building and further dissemination of GEM's goals and activities. Negotiation with international consortia for the global component projects is another task that is carried out within this area, as is carefully hiring new staff and collaborators that have the capacity and drive to make GEM a success.

Technical Office
One of the principal tasks of the technical office is to organise and oversee the development, release and review of calls for proposals for the Global Components, the subsequent coordination of the work carried out by the Global Components and linking that to developments in Regional Programmes. The technical office also coordinates the activities of international peer reviewers and keeps a close contact with the Scientific Board.

With the start of the Model Facility, collaborators of the technical office became involved in development of OpenQuake. From that moment, the Executive Committee also came into force. This body, through which the implementation of technical activities is operationally coordinated and enforced, became the coordinating committee of the technical office. The technical office furthermore facilitates technical collaboration with other organisations and initiatives.

A news-item appeared on the website of Nature on June 3rd 2010; informing the public about the initiative and latest developments is important for the collaborative effort that GEM is.

Outreach and Communications

Outreach and communication is an integral part of the GEM effort, as (active) involvement of the community is indispensable for GEM's success. Whenever and wherever possible, GEM creates and uses opportunities to inform the (technical) community and direct stakeholders about GEM, through presentations at conferences, through selected media releases, through articles in technical magazines and by means of an appealing website.Essential materials to support such dissemination activities are developed and improved, such as brochures and profile sketches. A number of tools have also been developed to keep the community informed. There is a bi-monthly e-newsletter to which currently around 2000 individuals are subscribed. As on average 2500 people access the website per month, it is kept well up-to-date and news are posted on the homepage to allow individuals to follow GEM through an RSS feed. A unique occasion for informing the community and at the same time providing a platform for discussion is the annual Outreach Meeting. Both in 2009 and 2010 such meetings were organized, involving between 100-250 individuals from 40+ countries discussing all main aspects related to GEM. Providing the community with a platform for discussion and/or feedback is essential for a global collaborative effort. A discussion forum has therefore been integrated into the website, as has an online commenting system for the community to provide feedback on draft RfPs. For GEM's technical community there are also dedicated announcements and technical reports being produced to share interim results and lessons learned. Finally, supporting user needs assessments and collaboration with GEM's Model Facility on OpenGEM user interface(s) and user interaction is also part of Outreach and Communication.

The GEM Outreach Meeting 2010 was part of the Understanding Risk Forum, organised by the The World Bank and GFDRR, together with GEM and others.

Administration and Services

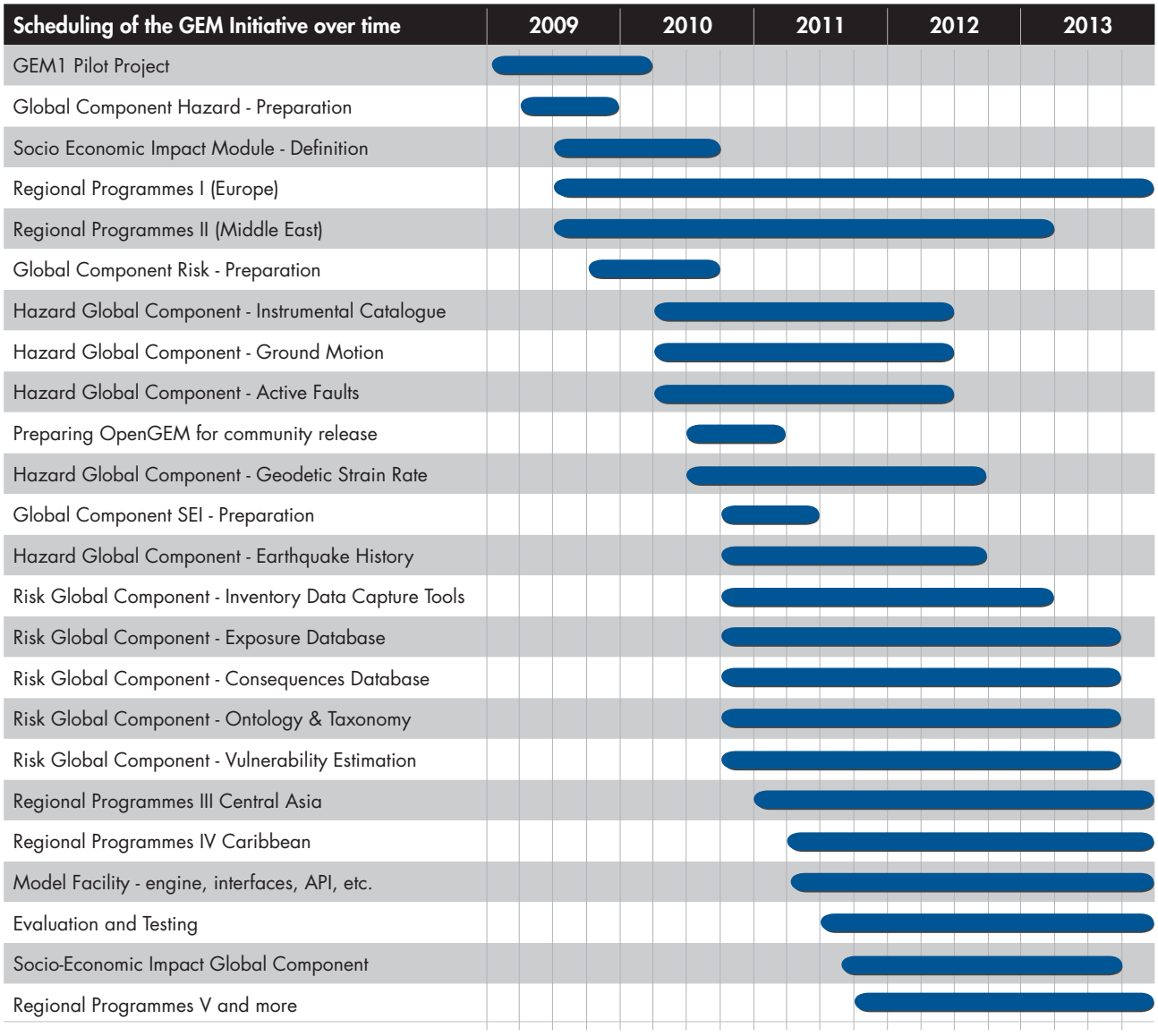
Administration and services activities are aimed at supporting the GEM Foundation in logistics, accounting, contracts and services, including the organisation of meeting and workshops all over the globe, travels, etc. A streamlined administration of all GEM's orders and invoices, outgoing and incoming funds is one of the other core tasks of the Administration and Services department. An external auditing exercise underlined GEM's reliable and organised administration as well as clear procedures.

5.2 Milestones and Scheduling

In order to accomplish GEM's ambitious working plan, a number of Milestones have been defined for the period between 2009 and 2013, which support the programme's management and measurement of progress.

March 2009	Establishment of GEM as a legal entity
March 2010	Proof-of-concept hazard and risk calculations (GEM1)
April 2010	Start of Hazard Global Component Activities
April 2010	Conclusion of a first User Needs Assessment Exercise
October 2010	Start of Risk Global Component Activities
December 2010	Start of a project on GEM's beneficiaries' needs
January 2011	Release of a sandbox version of the OpenGEM risk engine (OpenQuake)
June 2011	Demo versions available of OpenQuake, including User-Interfaces
July 2011	Start SEI Global Component activities
September 2011	Regional Programmes defined in at least 5 major areas of the world
December 2012	All funds secured for the five-year working programme
December 2013	Public release of the first version of GEM's global seismic risk model

The figure below provides an overview of how the various components and activities, which are to lead to a first fully-featured version of the global earthquake model, are scheduled over time.



5.3 Financial Overview

Building a first version of the global earthquake model will take five years (2009 – 2013) and will cost 35 Million Euro; a budget that includes independently-run Regional Programmes, which are discussed in paragraph 5.3.2. A projection of the expenditure and revenue for the years 2009-2013 is provided below for all components directly funded by GEM; i.e. GEM Global.

5.3.1 GEM Global

The table below visualises a breakdown of the budget for the main components of the GEM effort:

- The main scientific modules: Seismic Hazard, Seismic Risk and Socio-Economic Impact
- IT and Infrastructure: both the development of the IT architecture as the supporting infrastructure for computation
- Evaluation and testing: vetting and testing of the global earthquake risk model before its release
- Interaction for the design and deployment of Regional Programmes
- Outreach and communication
- Coordination and management
- Administration, supporting services and facilities

Expenditure (in Euro)	2009	2010	2011	2012	2013	
Seismic Hazard	525,000	1,600,000	850,000	425,000	200,000	**3,600,000**
Seismic Risk	525,000	1,750,000	1,650,000	1,650,000	925,000	**6,500,000**
Socio-Economic Impact	35,000	165,000	550,000	350,000	300,000	**1,400,000**
IT and Infrastructure	400,000	1,300,000	1,500,000	1,500,000	1,400,000	**6,100,000**
Evaluation and Testing			200,000	250,000	250,000	**700,000**
Regional Programmes Interaction	45,000	100,000	100,000	100,000		**345,000**
Coordination	200,000	250,000	250,000	250,000	250,000	**1,200,000**
Outreach and Communication	225,000	300,000	380,000	400,000	425,000	**1,730,000**
Administration and Facilities	300,000	250,000	275,000	300,000	300,000	**1,425,000**
Total	**2,255,000**	**5,715,000**	**5,755,000**	**5,225,000**	**4,050,000**	**23,000,000**

This table represents the (anticipated) revenue of the GEM effort:

Revenue (in Euro)	2009	2010	2011	2012	2013	
Private Founders / Participants						
- Secured	2,900,000	2,898,544	2,898,544	2,898,544	2,000,000	13,595,632
- Prospective			600,000	900,000	900,000	2,400,000
Total	**2,900,000**	**2,898,544**	**3,498,544**	**3,798,544**	**2,900,000**	**15,995,632**
Public Participants						
- Secured	240,000	311,250	311,250	311,250	311,250	1,485,000
- Prospective		70,000	700,000	815,000	815,000	2,400,000
Total	**240,000**	**381,250**	**1,011,250**	**1,126,250**	**1,126,250**	**3,885,000**
In-Kind Contributions Global Components		**500,000**	**1,200,000**	**1,200,000**	**300,000**	**3,200,000**
Total	**3,140,000**	**3,779,794**	**5,709,794**	**6,124,794**	**4,326,250**	**23,080,632**

In-Kind Contributions

GEM is collaborating with a number of organsations and has several participants whose contributions are partly in-kind. This is the case for the institution that hosts the GEM Foundation, EUCENTRE, as well as many of the other institutions collaborating with GEM in the development of the Global Components, and who contribute part of their staff's time, as well as data and other input to the model building effort. It is estimated that between 20 and 25% of the total costs of the Hazard, Risk, SEI modules and the Model Facility is covered by the in-kind contribution of GEM's partners themselves.

Funding

The revenue projection demonstrates that between now and 2013, GEM needs to bring in another 2.4M Euro of private sponsor funds, to be coupled with the expected 2.4M Euro of public funding in order to cover the costs to be incurred in the completion of GEM's first working programme.

5.3.2 Regional Programmes

GEM does not administer Regional Programmes, providing only initial start-up support when and where pertinent. It has been estimated that a total minimum of 12M Euro is needed for regional programmes in Europe, the Middle East, Asia, Africa and Latin America. Each programme has its own funding and administration.

Currently, a total of 5.5M Euro is allocated for Regional Programmes in Europe and 2M Euro for the Regional Programme in the Middle-East; EMME. Public Participants Singapore, Australia and New Zealand have allocated 50% of their contributions to GEM for a regional programme in South-East Asia/the Pacific (the remaining 50% are destined for GEM Global and were thus incorporated in the revenue tables given above). The total in-kind contribution for this regional programme hence amounts to 460,000 Euro. Additional funding is being sought for the programme. 275,000 Euro (40%) of Germany's in-kind contribution has been allocated to the EMCA Regional Programme in Central Asia. Efforts to fund Regional Programmes in Africa, South Asia, the Caribbean and South America are ongoing.

5.3.3 Financial Statements 2010

In this section, a brief overview is provided of the overall finances of GEM Global for 2010, after which the financial flows of the GEM Foundation will be discussed in further detail. This section ends with explanations and a brief outlook for 2010.

GEM Global

The activities of the GEM Foundation, the GEM1 project, the Global Components and the Model Facility were part of the financial administration of the global GEM effort. The table on the next page provides an overview of the costs of the GEM initiative in 2010 and the revenue to cover those expenses.

Financial Overview GEM Global	2010	2009
Revenue		
Financial Contributions GEM Foundation	3,848,996.02	1,064,152.86
In-kind Contributions GEM Foundation	660,000.00	269,803.11
Financial Contributions GEM1		900,000.00
	4,508,996.02	**2,233,955.97**
Expenditure		
Seismic Hazard	1345,815.72	506,720.00
Seismic Risk	804,918.02	506,720.00
Socio-Economic Impact	216,368.37	34,059.18
IT and Infrastructure	861,828.55	387,520.00
Regional Programmes Interaction	14,201.08	35,527.84
Coordination and Management	617,527.70	168,483.18
Outreach and Communication	292,132.16	232,544.91
Administration, Services and Facilities	355,399.26	356,971.29
	4,508,190.87	**2,228,546.40**
Net result (in Euro)	**+805.15**	**+5,409.57**

GEM Foundation

GEM's financial statements represent the incoming and outgoing funds administered at the GEM Foundation, allocated to 2010, so as to provide transparency on all the ingoing and outgoing financial flows of the foundation.

GEM Foundation Expenses 2010

In 2010, the expenses of the GEM Foundation were related to the activities of the Secretariat, to the pilot project GEM1, the Model Facility and the Global Components. The costs of the Governing, Scientific and Auditors Board meetings are part of the costs of the Secretariat. The table below shows a breakdown of the total expenditure of the GEM Foundation for 2010:

	Coordination and Management	Administration and Services	Outreach and Communication	Technical Office	GEM1	Model Facility	Global Components	**Total**
Human Resources	279,052.61	54,294.55	58,404.25			119,187.26		**510,938.67**
Travel	17,199.07	688.52	6,501.17	51,947.14		28,296.26		**104,632.16**
Equipment			559.20	3,118.46				**3,677.66**
Consumables		3,038.38	84.00					**3,122.38**
Services	33,484.49	256,313.37	45,705.84	91,317.62	819,517.78	719,735.27	611,342.71	**2,577,417.08**
Workshops/Meetings	13,624.08		179,125.70	9,306.39		1,504.50		**203,560.67**
Executive Committee				294,171.96				**294,171.96**
Peer Review				18,474.00				**18,474.00**
Scientific Board				45,812.90				**45,812.90**
TAP/Review Meetings				196,333.72	92,816.15			**289,149.87**
RP Interaction	14,201.08							**14,201.08**
Other	216.00	41,064.44	1,752.00					**43,032.44**
Total (in Euro)	**357,777.33**	**355,399.26**	**292,132.16**	**710,482.19**	**912,333.93**	**868,723.29**	**611,342.71**	**4,108,190.87**

Explanation:

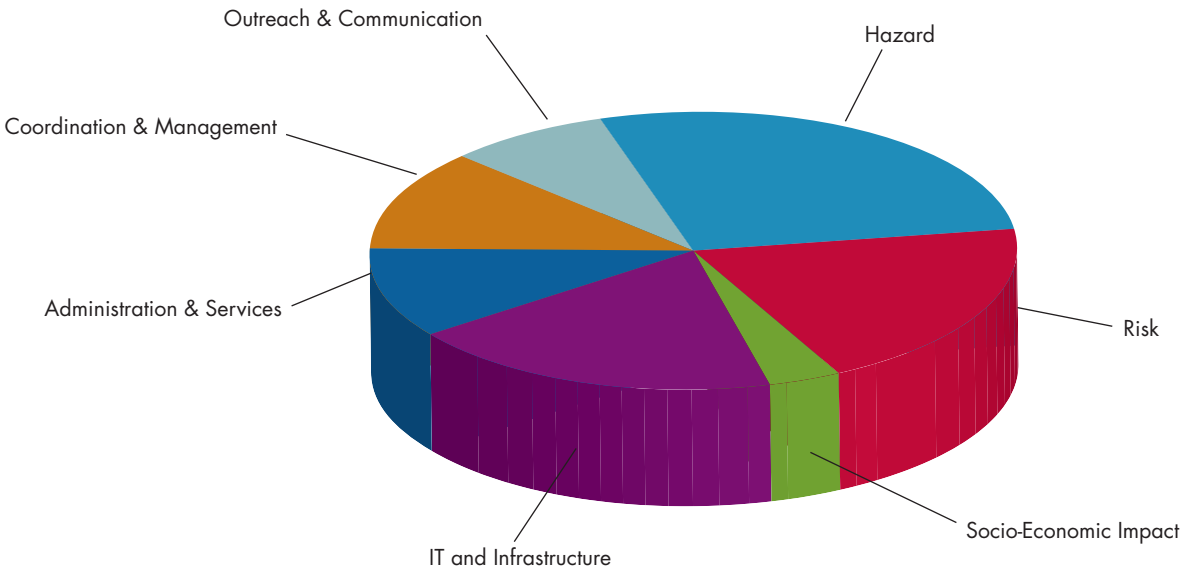
- Services Technical Office: this includes payments for the Benefciaries Needs research.
- Services GEM1: Payments to ETH, GFZ and USGS, partners in GEM1

- Services Model Facility: includes payments to ETH and external collaborators of the Model Facility.
- Workshops/Meetings Outreach & Communication: includes the annual outreach meeting.
- TAP/Review Technical Office: includes costs for the IT review of July 2010 and costs for the bi-annual review meeting of December 2010 in Singapore.
- Administration and Facilities: includes costs for office spaces, collaborator accomodation, etc.; these costs are covered by the Eucentre as in-kind contribution to GEM.

GEM Foundation Income 2010
This table provides an overview of the incoming funds allocated to 2010:

AIR Worldwide Private Participant Contributions	340,000.00
Australia Public Participant Contributions	56,250.00
Eucentre Private Participant Contributions	415,144.00
FM Global Private Participant Contributions	250,000.00
Hannover Re Private Participant Contributions	250,000.00
Germany Public Participant Contributions	343,750.00
Italy Public Participant Contributions	200,000.00
Munich Re Private Participant Contributions	840.499,15
Norway Public Participant Contributions	67,083.33
Singapore Public Participant Contributions	139,980.00
Switzerland Public Participant Contributions	102,056.21
Willis Private Participant Contributions	153,333.33
Zurich Private Participant Contributions	660,900.00
Total Income (in Euro)	**3,848,996.02**

Explanations and discussion
The first working programme of GEM (2009-2013), is financed with contributions of GEM's participants and collaborators. This refers to both financial and in-kind contributions. The total amount of necessary funding for GEM Global was calculated to be 23M Euro at the start of GEM's operations. After two years of operations, a total of over 6.7 million Euro has been spent. This seems slightly less than expected, however this is due to contracts that were finalised just after the financial administration of 2010 closed, and hence the trend is following budgeted totals. That total is divided over the main activity groups of GEM as follows:



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