Convocatoria de ayudas de Proyectos de Investigación Fundamental no orientada

# TECHNICAL ANNEX FOR TYPE A or B PROJECTS

1. SUMMARY OF THE PROPOSAL (the summary must be also filled in Spanish)

PROJECT TITLE: Comprehensive Probabilistic Approach for Seismic Risk Evaluation in Spain (CoPASRE)

PRINCIPAL INVESTIGATOR: Martha Liliana Carreño T.


SUMMARY
(brief and precise, outlining only the most relevant topics and the proposed objectives):

The general objective of the proposed project is the development of a beyond the state-of-the-art methodological framework and probabilistic modelling methods for seismic hazard and risk assessment and disaster risk management composed of tools for the evaluation and communication of risk derived from seismic hazard in Spain. The project is conceptually oriented to facilitate decision making and to incorporate a comprehensive approach to disaster risk management. The generic approach will be the basis of a second step, in which different methods will be used to identify and measure particular features of risk in a more comprehensive way than the current models. The methodological framework will define the major characteristics and pillars of seismic risk assessment taking into account collateral hazards triggered by earthquakes. Due to the stochastic aspects of the natural, built and social environments, uncertainties are an intrinsic part of any attempt to estimate risk and are also present in the methods and models used to qualify or quantify it. As a result, uncertainties will explicitly be evaluated, providing a measure of the confidence level of estimates. The project will provide an open-source and open-architecture probabilistic risk modelling platform, built upon a sequence of modules, to quantify potential losses arising from seismic events. As such, this integrated software platform will be developed as a value-added outcome of the project and document will be delivered for future functionality design considerations. It will therefore help strengthen prevention and risk mitigation for improved disaster risk management in Spain.

TITULO DEL PROYECTO: Enfoque integral y probabilista para la evaluación del riesgo sísmico en España


RESUMEN
(breve y preciso, exponiendo sólo los aspectos más relevantes y los objetivos propuestos):

El objetivo general del proyecto propuesto es el desarrollo, más allá del estado del arte, de un marco metodológico y métodos de modelización probabilista para la evaluación de la amenazas y riesgo sísmicos y la gestión del riesgo de desastres compuestos por herramientas para la evaluación y comunicación del riesgo derivado de la amenaza sísmica en España. El proyecto está conceptualmente orientado a facilitar la toma de decisiones y a incorporar un enfoque integral a la gestión del riesgo de desastre. Este enfoque será la base de una segunda fase, en la que se utilizarán diferentes métodos para identificar y medir las características del riesgo de una manera más amplia que los modelos actuales. El marco metodológico definirá las características principales y los pilares para una evaluación del riesgo sismico teniendo en cuenta las amenazas colaterales que pueden ser provocadas por los terremotos. Debido a los aspectos estocásticos de los entornos naturales y construidos, las incertidumbres son una parte intrínseca de cualquier intento de evaluación de riesgos y están presentes en los métodos y modelos utilizados para calificarlo o cuantificarlo. Como resultado, la incertidumbre se evaluará de forma explícita, proporcionando una medida del nivel de confianza de las estimaciones. El proyecto desarrollará una plataforma de modelos probabilistas de código y arquitectura abiertos, construida como una secuencia de módulos, para cuantificar las posibles pérdidas derivadas de eventos sísmicos. Para complementar esta plataforma se desarrollará un documento sobre su diseño y futura funcionalidad. Con esto se ayudará a fortalecer la prevención y mitigación de riesgo para la mejorar la gestión del riesgo de desastres en España.

2. INTRODUCTION
(maximum 5 pages)

## 2.1. Aim of the project

This project is proposed in the frame of the "Subprograma de Proyectos de Investigación Fundamental no orientada" for the class A of projects (for young researchers) in the area of Civil Engineering and Architechture (Ingeniería Civil y Arquitectura, ICI).
The purpose of the project is to develop a methodological framework and approach for probabilistic risk assessment taking into account not only methods based on seismic hazard but also collateral hazards triggered by earthquakes such as liquefaction, landslides and tsunamis. The development of this project will be according to the state-of-the-art disaster risk conceptual evolution but will be also based on beyond state-of-the-art probabilistic risk modelling worldwide.
The project is conceptually oriented to facilitate decision making and to incorporate a comprehensive approach to disaster risk management. The generic methodological framework and methods developed will refine existing methodologies in ways that capture the influences of seismic hazard and risk. The generic approach will be the basis of a second step, in which different methods will be used to identify and measure particular features of the seismic risk in a more comprehensive way than the current models.
The methodological framework will define the major characteristics and pillars of the seismic risk assessment taking into account collateral hazards wich can be triggered by earthquakes. Due to the stochastic aspects of the natural, built and social environments, uncertainties are an intrinsic part of any attempt to estimate risk and are also present in the methods and models used to qualify or quantify it. As a result, uncertainties will explicitly be evaluated.
The project will take into account the diversity of different approaches. It will review and compare them and then provide a generic methodological framework for multi-hazard and risk assessment. Based on the identification of gaps in the theory of current approaches, a common language will be developed in order to clarify exactly what comprehensive disaster risk assessment means. This will build a bridge between different disciplinary approaches. Past projects on seismic hazard, vulnerability and risk in which the Risk Management Group of CIMNE was involved, like the European Commission projects RISK-EU, LESSLOSS, RAMFLOOD or MOVE, and the Spanish Government projects EVASIS, Habitat 2030 or SEDUREC, will be taken into account and the major contributions and shortcomings of these projects will be analysed. The application of risk concepts and methodological frameworks used worldwide will be carefully examined; among them, the Global Earthquake Model (GEM), and other multi-hazard initiatives such as the FEMA's HAZUS, and the Central American Probabilistic Risk Assessment project, promoted by the World Bank, Inter-American Development Bank and the UN-ISDR will be considered.

## 2.2. Background and the state of the art of the scientific knowledge

Disaster risk is defined as the probability of future damage and loss associated with the occurrence of a combination of different environmental hazards where levels and types of loss are determined by the levels of exposure and vulnerability of society. Risk is the result of the interactions in time and space of probable physical events with exposed vulnerable elements of the social and environmental systems. It is in the latency of risk that the opportunity for risk prevention, mitigation and transfer exists, employing diverse adaptation or disaster risk management principles, strategies and instruments. Disaster risk management may be defined as a social process that searches to reduce, predict and control disaster risk drivers in a development framework, by means of the design and implementation of appropriate policies, strategies, instruments and mechanisms (Cardona and Barbat 2000).

On the other hand, the concept of hazard is used to refer a latent threat or proneness that can be expressed as the potential occurrence of natural, socio-natural or anthropogenic events that may have physical, social, economic and environmental impact in a given area and over a certain period of time. A natural hazard means the potential occurrence of an extreme event from the internal or external geodynamics or a hydro-meteorological event that may cause severe effects to exposed and vulnerable elements (Cardona 2009).

Several complexities of hazards and risks have been revealed at the world scale in past disasters, particularly in the earthquakes of Kobe (1995), Marmara (1999) and Sichuan (2008), where concatenated fires, liquefaction and landslides occurred; or in the Indian Ocean earthquake-tsunami-floods (2004). These and other disasters in the world have illustrated that disaster risk assessment based on a single hazard may neglect important effects and damage, mainly when the likelihood exist to trigger other hazardous events. In other words, it is not only important to consider conjoint and cascading hazards but also the possibility of concatenated propagation effects, functional impacts on lifelines, industry and interdependent infrastructure.

During the second half of the twentieth century, when technological advances contributed enormously to the knowledge of natural hazards, it was commonplace to define risk as the estimation of the possible occurrence of a physical phenomenon. This definition of risk is still commonplace among some specialists that study phenomena such as earthquakes, landslides, floods and storms. In the 1970's, and even in the 1980's, the occurrence probability of an earthquake was usually considered as synonymous with estimating seismic risk. Towards the end of the 1980's and particularly in the 1990's the concepts of seismic hazard started to be more frequently used to refer to what was previously termed as seismic risk. The 'risk transfer' approach employed by insurers favoured the consolidation of a new paradigm as regards risk assessment, security and trustworthiness of systems. This approach was clearly established in the report published on Natural Disasters and Vulnerability Analysis by the Office of the United Nations Disaster Relief Coordinator (UNDRO) and UNESCO in 1980, as the product of an expert meeting held in July 1979 whose objective was the unification of disaster related definitions. This report included the definitions of natural hazard, *H*, vulnerability, *V*, elements at risk, *E*, specific risk, *S*, and risk, *R*. From this perspective, risk may be defined as:

$$R = E \cdot S = E \cdot H \cdot V \text{ (given that } S = H \cdot V) \quad (1)$$

Now then, whilst essentially maintaining this conceptual framework, during the Institute for Earthquake Engineering and Engineering Seismology meeting held in 1985 in Skopje (Former Yugoslav Republic of Macedonia), Cardona proposed the suppression of the variable related to the exposure, because it is implicit in the notion of vulnerability. In other words, one cannot be 'vulnerable' unless one is 'exposed'. Originally, this formulation was presented by Fournier d'Albe (1985), Petrovsky and Milutinoviç (1986) and later by Coburn and Spence (1992). The expression of risk as a function of hazard and vulnerability that is now widely accepted in the technical and scientific fields, and increasingly in the social and environmental sciences, was formulated as follows:

$$R_{ie} \mid_t = f\left(H_i, V_e\right) \mid_t \quad (2)$$

This signifies that once the hazard or threat, $H_i$, is known (expressed as the probability that an event with an intensity greater or equal to *i* will appear during a period of exposition *t*), and the vulnerability, $V_e$, is also known (understood as the intrinsic predisposition of an element *e*, to be affected or to be susceptible to damage with the occurrence of an event with an intensity *i*), the risk, $R_{ie}$, is expressed as the probability of loss to the element as a result of the occurrence of an event with an intensity greater or equal to *i*. That is to say, risk, in general, may be understood as the probability of loss during a given period of time *t* (Cardona 1985, 1986).

The development of the concept of risk in the applied and physical sciences commenced with the modern development of probability theory. In this context, the concept of probability had quasi-

deterministic overtones, where probability scores were influenced by a lack of knowledge of the hazard or, in other words, epistemic uncertainty. This can, in principle, be overcome by more experimentation and learning exercise. But the need to formulate statistical physics in order to study certain complex phenomenon has introduced a component of irreducible uncertainty, which has been called aleatory uncertainty or inherent randomness. These two types of uncertainty reflect the duality that underlies the concept of probability, and therefore of risk. At present some other analytical theories are related to the uncertainty: the theory of fuzzy sets, the theory of possibility, and the theory of evidence (Kikuchi and Pursula 1998).

The frequency of extreme events is particularly low and, hence, very limited historical data are available. Considering the possibility of future highly destructive events, risk estimation has to focus on probabilistic models which can use the limited available information to best predict future scenarios and consider the high uncertainty involved in the analysis. Therefore, risk assessments need to be prospective, anticipating scientifically credible events that might happen in the future. Earth and applied science bases have been used to develop prediction models which permit to assess risk of loss as a result of extreme hazard events. Since large uncertainties are inherent in models with regard to event severity and frequency characteristics, in addition to consequent losses caused by such events, risk models are based on probabilistic formulations that incorporate this uncertainty into the risk assessment.

At present, risk assessment is the result of the evolution from early days of insurance to computer-based catastrophe modelling using advanced information technology and geographic information systems (GIS) for mapping. With the ability to store and manage vast amount of information, GIS became an ideal environment for conducting easier and more cost-effective hazard and loss studies (Grossi and Kunreuther 2005). Since the end of 1980's a set of risk modelling firms such as AIR Worldwide, Risk Management Solutions and EQECAT have led the industry of probabilistic risk modelling with their proprietary models. Overall they are considered "black boxes" but in any case they have been developed based on the contributions of the Professors Luis Esteva and C. Allin Cornell in 1960's and the subsequent inputs mainly of Robert Whitman, George Housner and Robin McGuire, where the seismic risk has been understood from the probabilistic point of view as the "convolution" of hazard and vulnerability of exposed elements. At present, all computer-based models for probabilistic risk assessment encompass software modules for the treatment of hazard, exposure, vulnerability and risk.

The first public domain probabilistic hazard risk model was "Hazards U.S." (HAZUS), developed by the Government of United States and labelled as an open source model. The goal of FEMA was to create a methodology that was the "standard national loss methodology for assessing losses from natural hazards" (FEMA, 2002). In 2004 it was relabelled as HAZUS-MH, the first public domain multi-hazard probabilistic methodology that integrates the earthquake module with new modules to estimating potential losses from wind and flood (riverine and costal) hazards (Grossi and Kunreuther 2005). A probabilistic approach to risk assessment is the most appropriate way to handle the abundant sources of uncertainty inherent in all natural hazards related phenomena (Woo 1999). The following probabilistic risk measures are at present very useful to develop a disaster risk model:

*Loss Exceedance Curve, LEC*, represents the annual frequency with which a loss will be exceeded. This is a very important risk measure for disaster risk managers, since it estimates the amount of funds required to meet risk management objectives when it is expressed in monetary units.

*Probable Maximum Loss, PML*, represents the loss amount for a given annual exceedance frequency, or its inverse, the return period. Depending on risk tolerance, the risk manager may decide to manage for losses up to a certain return period.

*Aggregated Average Annual Loss, AAL*, is the expected loss per year. Computationally, AAL is the sum of products of event expected losses and event annual occurrence probabilities for all stochastic events considered in the loss model. In probabilistic terms, AAL is the mathematical expectation of the annual loss for all values at risk. In addition, the AAL per exposed element is very important; i.e. results of the AAL are given for each of the values at risk described in the exposure databases. Results are given in such a way that they can be easily analysed in GIS systems.

These probabilistic metrics may provide an appropriate approach for commensurability of risk results obtained from different multiple hazards. They are also useful both for probabilistic as well as deterministic risk analyses. Disaster management and vulnerability reduction need in many cases probabilistic information from deterministic specified hazard scenarios, considering some historical or future specific events. In other words, a probabilistic risk model may also estimate results of risk from one or a set of simultaneous collateral hazards according to the risk management needs (e.g. a disaster scenario for the formulation of an emergency response plan). In any case, risk managers need to become familiarised with the underlying assumptions of the probabilistic models and understand the implications and limitations of their output in order to utilize the results effectively.

## 2.3. Essential references


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3. OBJETIVES
(maximum 2 pages)

υ 3.1 Describe the reasons to present this proposal and the initial hypothesis which support its objectives (maximum 20 lanes)

Disaster risk reduction relative to hazards of different origin is a major challenge for the regions and citizens of Spain and Europe.
Although in Spain there are institutions and specialists in diverse techno-scientific disciplines such as, seismology, geology, geophysics, etc. they are not necessarily familiar with the interdisciplinary developments for rigorous risk assessment. Most performed studies are only hazard assessments, many of which have been mistakenly referred to as 'risk evaluations' focused only on natural processes and without proper attention to the vulnerability of the exposed elements.
The use of GIS without an appropriate modelling foundation has led to the production of maps that remain essentially descriptive. Probabilistic assessment of seismic risk allows for the calculation of average annual losses or evaluations of probable maximum loss that must be faced. So, even when certain decisions could rely on approximations, there remain limits on the scope and effectiveness of such decisions that ultimately will require a probabilistic approach to risk.
In summary, Spain suffers a certain lack of seismic risk evaluations with a comprehensive analytical methodology adjusted for each of the local, sub-national and national levels. Little suitable information for rigorous assessments is available for Spain and the existing risk studies are dispersed geographically and in time without systematic updating. There is the need for an adequate frame of reference from which each region can design and adopt standards, can control quality and can develop suitable seismic risk evaluations for planning.

υ 3.2. Indicate the background and previous results of your group or the results of other groups that support the initial hypothesis

Past projects have performed important methodological developments and the proposed project will take into account the diversity of different approaches. It will review and compare them and then provide a generic methodological framework for seismic hazard and risk assessment. Based on the identification of gaps in the theory of current approaches. A common language will be developed in order to clarify exactly what comprehensive disaster risk assessment means. This will build a bridge between different disciplinary approaches.
It will take into account past projects on hazards and risks in Europe and Spain, such as:

RISK-EU: An advanced approach earthquake-Risk scenarios, with application to different European Towns. Ref: ENVK4-2000-00513. European commission, Vth Framework Programme. (01/02/2001 - 31/03/2004)
LESSLOSS: Risk mitigation for earthquakes and landslides. Ref: GOCE-CT-2003-505448. European commission, VIth Framework Programme. ( 01/09/2004 - 31/08/2007)
RAMFLOOD: Decision support system for risk assessment and management of floods. Ref: IST-2001-37581. European commission, Vth Framework Programme. (01/10/2002 - 30/09/2003)
EVASIS: Desarrollo y aplicación de procedimientos avanzados para la evaluación de la vulnerabilidad y del riesgo sísmico de estructuras. Ref: REN2002-03365. MINISTERIO DE CIENCIA Y TECNOLOGIA.Plan Nacional I+D (2000-2003). (01/10/2002 - 30/09/2005)
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It will analyse the major contributions and shortcomings of these projects. It will consider the applicability of risk concepts and methodological frameworks used in other regions or worldwide; for example the Global Earthquake Model (GEM), and other multi-hazard initiatives such as the FEMA's HAZUS, and

the Central American Probabilistic Risk Assessment project, promoted by the World Bank, Inter-American Development Bank and the UN-ISDR.

υ 3.3. Describe briefly the objectives of the project.

The objectives of this project are focused on the necessity of having a scientific-technic understanding of the disaster risk and disaster risk management in order to support an efficient decision making on prevention and mitigation of the socio-economic lossess due to disasters triggered by seismic hazards.
The main objective of the proposed project is *to provide an improved probabilistic methodological framework and new methods for the assessment of seismic risk in Spain. Advanced tools for disaster risk management decision-making are incorporated in a value-added open source integrated software platform for seismic risk assessment and disaster risk management applications*. Unlike the existing risk models, the risk metrics which will be used in the project will provide the disaster risk managers with essential aggregated risk information required for disaster risk prevention and mitigation applications.

Concrete scientific and technical objectives:

The probabilistic methodological framework which is proposed will employ an integrated, comprehensive approach helping and guiding seismic risk mitigation and decision making. The methods developed in the project and tested in selected spatial contexts will improve knowledge, models, and integration strategies for disaster risk management in Spain. The specific objectives of the project are:
*Objective 1:* To harmonise existing models and frameworks of risk assessment within a new generic methodological framework that will provide general guidance on what disaster risk encompasses in the Spanish natural and socio-natural hazards context.
*Objective 2:* To develop a beyond state-of-the-art methods to measure seismic risk in a more comprehensive way. This goal can be achieved by taking into account the different elements defined in the existing methodologies –e.g. probabilistic, deterministic, GIS, indicators– and complexities revealed at the world scale in disasters.
*Objective 3:* Another crucial goal is to link the development of methods to different cascading phenomena; i.e. earthquake, landslides, tsunamis, in different scales and landforms, such as mountains and coastal regions.
*Objective 4*: To develop new techniques in order to generate seismic-hazard scenarios and risk information that can be tested and linked to risk mitigation applications for decision-making taking into account interdisciplinary perspectives.
*Objective 5:* To design the methods and level of risk analysis to support risk reduction, public and private investments, emergency management, and financial risk transfer strategies through the development of cost-benefit analysis, land use planning tools, incorporating indicators of risk, risk retention and transfer evaluations, early warning and on-line loss assessment mechanisms.
*Objective 6:* To develop an open-source and open-architecture software platform for seismic hazard and risk modelling that takes into account various cascading hazards and which will have many practical uses in urban and regional planning and in the mapping of risks.

RESEARCH GROUP

In the work plan, reference will be made to the members of the research group using the numbering which appears in the following lists.

Researchers of the International Center for Numerical Methods in Engineering, CIMNE, Barcelona, Spain

1. Martha Liliana Carreño T., Doctor in Earthquake Engineering and Structural Dynamics, *"Profesor Asociado"* of the UPC
2. Alex H. Barbat, Professor of the UPC
3. Mabel Marulanda, Doctorate student in the Structural Analisys programme of the UPC

All these researchers are members of the Risk Management Group of CIMNE.

Researchers from other institutions (Investigadores de otras entidades) involved in the project

4. Omar Dario Cardona, Doctor in Earthquake Engineering and Structural Dynamics, Professor of the Universidad Nacional de Colombia, Manizales.
5. Jairo Andres Valvárcel T., Doctorate student in the Earthquake Engineering and Structural Dynamics programme of the UPC, Department of Geotechnical Engineering and Geo-Sciences, UPC.

These researchers, which belonging to institutions differente from CIMNE, are also members of the Risk Management Group of CIMNE.

New research personnel to be incorporatred in the Risk Management Group of CIMNE requested with charge to the project

In this proposal we request for funding for hiring two specialists by CIMNE which are named in the proposal *specialist 1* and *specialist 2*. At the same time, we request two scholarship holders which are named in the proposal *grantee 1* and *grantee 2*.

6. Specialist 1: Will participate in the methological development for hazard and risk evaluation in a probabilistic way.
7. Specialist 2: Will participate in the methological development of assessment methods for collateral risk assessment in a probabilistic way.
8. Grantee 1: Will suport the development of the software platform, and will be specially involved in the development of the hazard evaluation tools.The Grantee 1 will be enrolled in a Doctorate Program of the Technical University of Catalonia (UPC) adequate for the scientifical and technical activity he will perform.
9. Grantee2: Will suport the development of the software platform, and it will be specially involve in the risk evaluation tools. The Grantee 2 will be enrolled in a Doctorate Program of the Technical University of Catalonia (UPC) adequate for the scientifical and technical activity he will perform.

The six objectives of the project described before will be addressed within the overall strategy of the work plan which encompasses five Work Tasks (WT) which also outline the systematic phases of the

project. Within the first phase of the project, the existing gaps in current seismic-hazard risk assessment methodologies will be reviewed as well as the requirements of exposure and vulnerability data and the need of probabilistic risk metrics. This first activity of the project corresponds to WT 1. This will provide criteria and recommendations for the conceptualisation of the new methodological framework for seismic-hazard risk assessment in Spain, which will be the base for the formulation of new different hazard and risk methods.
The building of a new generic methodology adapting, enhancing, designing new seismic hazard and risk assessment methods both for risk assessment for collateral triggered hazards and the application of new methods to evaluate risk are the two core components of WT 2. The hazards related to this methodology will be earthquake-tsunami, earthquake-landslides,and earthquake-liquefaction.
The case studies will be defined during the progress of the project according to the existent and available information. case studies will be tested in Spain. These elements are the key components of WT 3.
WT 4 will develop and use risk mitigation/adaptation methods based on the results of the new methods for seismic risk assessment considering collateral hazards. The application methods and case studies could be the cost-benefit analysis of mitigation/adaptation measures and retrofitting; the development of structures of risk retention and transfer (insurance) for financial protection; and the development of risk communication tools based on holistic approaches using risk indicators. Disaster risk management case studies will be tested with regard to their applicability in Spain to describe how to use the risk results in decision-making processes.
In WT 5, the integration of an open source and open architecture software platform for seismic hazard/risk assessment and for disaster risk management will be performed and a document for future functionality and design considerations will be also developed. On the other hand, based on the testing and refinement of the methods in the case studies and on the integration of the software platform for probabilistic risk assessment, the dissemination of the interim results and, at the end, of the new methodological framework and of the methods for seismic risk assessment will be performed.

In the following, the work tasks will be described in detail and the members of the research group which will be involved in their development will be indicated.

## WORK TASKS OF THE PROJECT

### WT 1. Identification of gaps in the existing models and conceptual framework development

*Purpose*
Analysis and identification of gaps in existing probabilistic models and conceptual methodological frameworks for multi-hazard and risk assessment.

### Description of work

a) Review of existing seismic risk assessment methods to evaluate the potential collateral integrated approaches.
This activity encompasses the detailed literature review and the identification of the theoretical, conceptual and practical gaps of the existing methodologies to be used. (1) Seismic hazard approaches; (2) Tsunami hazard; (3) Landslides hazard;.

b) Definition of data requirements for exposure treatment, classification of assets and vulnerability curves standardization.
This activity involves the characterization and standardization of exposed elements and development of a standardized methodology for creating vulnerability curves.

c) Probabilistic and non-probabilistic risk metrics required for collateral hazards triggered by earthquakes and risk models.
This activity encompasses the fitness of metrics based on the loss exceedance probability curve, and the fitness of parametric variables and indicators used in GIS systems.

*Objectives addressed:* 1
*Duration:* Month 1 to 10
*Milestone 1.* Review and analysis of gaps in existing risk assessment approaches and methods, data/metrics requirements (month 10)
*Involved personnel:* 2, 3, 5, 6, 7, 8, 9.

## WT 2. Building new methodology and new methods both for earthquake and collateral risk assessment

*Objective*
Building new methodological framework adapting, enhancing, designing new hazard and risk assessment methods both for earthquake and collateral risk assessment in Spain.

### Description of work

The new methodological framework will be a beyond state-of-the-art probabilistic approach for seismic hazard and risk assessment methods. It will need a generic conceptual framework, metrics and visualisation techniques useful to develop collateral hazard analysis and disaster risk evaluations taking into account collateral effects and damage on complex, interdependent systems. This phase will encompass the following sub-activities: (1) Develop a toolbox of statistical functions that are found adequate for describing connections, vulnerability, damage probability, uncertainty parameters. These statistical functions shall be representative for typical natural and society processes, and shall be inter-connectable so that the endpoint (the loss function) engulfs all processes in a statistically and mathematically consistent way; (2) Estimate uncertainties (random and epistemic) to all processes; (3) Establish the mathematical and statistical framework that allows incorporating all the above functions so that final losses can be computed through a process where median, mean and confidence parameters for the losses are computed. This must be done consistently with respect to processing uncertainty parameters at each level; (4) Provide back-track analysis tools that can identify the most decisive and least decisive vulnerabilities for the estimated loss.

*Objectives addressed:* 1, 2, 3, 4.
*Duration:* Month 7 to 15
*Milestone 2.* Methodological framework (month 15).
*Deliverable 1.* Methodological framework document for seismic hazard/risk assessment (month 15).
*Involved personnel:*. 1, 3, 4, 5, 6, 7, 8, 9.

## WT3. Testing and refinement of seismic hazard risk assessment models through case studies

*Objective*
Testing and refinement of disaster risk assessment methods, with special emphasis on the collateral effects, through case studies.

### Description of work

The purpose of the case studies is to test the generic methodological framework developed before as well as to examine the potential and applicability of the different seismic hazard and risk assessment methods proposed for each case study. The illustrative case studies which will be performed will be defined during the progress of the project according to the existent and available information. This phase will encompass the following aspects: (1) testing and application of the methods in carefully selected test-beds; (2) review of the applicability and availability of data in different case studies; (3) review of the workload and time estimated to utilise the methods; (4) study of the limitations and applicability of the different methods in the case studies taking into account different hazard types, spatial scales and landscapes; and (6) refinement of the methods applied using the obtained results.

*Objectives addressed:* 3, 4
*Duration:* Month 16 to 25
*Milestone 3.* Testing and refinement of seismic hazard risk assessment methods (month 25).
*Involved personnel:* 2, 3, 4, 6, 7, 8, 9.

### WT 4. Development and testing of disaster risk management applications through case studies

*Objective*
The purpose of these complementary case studies is to perform illustrative tests of disaster risk prevention and mitigation techniques. The intention is to illustrate how the seismic hazard and risk results can be used for decision-making and risk reduction planning and how the assessment outcomes can be used from an interdisciplinary perspective to improve overall disaster risk management.

#### Description of work

In this phase, some of the following possible analyses will be considered:

- Cost-benefit analysis of risk mitigation measures and retrofitting.
- Holistic approach of seismic risk evaluation based on indicators for risk communication.
- Development of structures of risk retention and transfer (insurance) for financial protection.

*Objectives addressed:* 4, 5
*Duration:* Month 26 to 33.
*Milestone 4.* Testing and refinement of derived disaster risk management techniques (month 33).
*Deliverable 2.* Description of seismic hazard and risk assessment and disaster risk management illustrative case studies (month 33).
*Involved personnel:* 1, 4, 5, 6, 7, 8, 9.

### WT 5. Integration of a software platform for seismic-hazard/risk assessment and risk management

*Objective*
Integration of a software platform for seismic-hazard/risk assessment and for disaster risk management, based on selected hazard, vulnerability, risk and application modules.

#### Description of work

a) Seismic-hazard and risk assessment open architecture and open source computer platform.

The methodological framework and the different methods will be tested in terms of their applicability in case studies. This activity will encompass the development and the releasing of an integrated software platform of public domain for the practical assessment of risk to seismic hazard in Spain. This will provide an overview of the main research results and will include the procedures for the different assessment methods recommended in order to measure seismic hazard/risk in different contexts of collateral hazards in the Spanish environment. It will outline the different methods and techniques. Unlike the existing risk assessment models, the risk metrics of this new computer-based seismic-hazard risk model will provide the disaster risk managers with essential "aggregated" risk information required to improve disaster risk prevention and mitigation applications. This "living instrument" will permit the development, in the future, of additional hazard and risk modules and new disaster risk management applications useful for different regions in Spain.

b) Document for future functionality and design considerations

This document will review the use of Open Source GIS software. Among others relevant considerations that will be taken into account, this document will include: descriptions on specifications freely available to users, use of existing open standards, explicit inputs and outputs of the computational components, aggregation principles for working at multiple scales, risk visualization methods, linking the tools to Open Source GIS software.

*Objectives addressed:* 6
*Duration:* Month 11 to 35.
*Milestone 5.* Software platform for seismic-hazard and risk assessment (month 35). Involve WT1 to WT4.
*Deliverable 3.* Integrated seismic-hazard and risk assessment open source/architecture software platform (month 36).
*Involved personnel:* 2, 3, 6, 7, 8, 9.

4.1 CHRONOGRAM MODEL (EXAMPLE)

This chronogram must indicate the persons involved in the project, including those contracted with project funds.
Underline the name of the person responsible of each task.

| Tasks | Centre | Persons | First Year (*) | Second Year (*) | Third Year (*) |
|---|---|---|---|---|---|
| WT 1. Identification of gaps in existing models and conceptual framework development | CIMNE | A. Barbat, M. Marulanda J. Valcárcel, Specialist 1, Specialist 2, Grantee 1, Grantee 2 | X\|X\|X\|X\|X\|X\|X\|X\|X\| \| | \| \| \| \| \| \| \| \| \| \| | \| \| \| \| \| \| \| \| \| \| |
| WT 2. Building new methodology and new methods both for earthquake and collateral risk assessment | CIMNE | M. Carreño, O. Cardona, M. Marulanda, J. Valcárcel, Specialist 1, Specialist 2 Grantee 1, Grantee 2 | \| \| \| \| \| \|X\|X\|X\|X\|X\|X | X\|X\|X\| \| \| \| \| \| \| \| | \| \| \| \| \| \| \| \| \| \| |
| WT 3. Testing and refinement of seismic hazard risk assessment models through case studies | CIMNE | A. Barbat, O. Cardona, M. Marulanda, Specialist 1, Specialist 2 Grantee 1, Grantee 2 | \| \| \| \| \| \| \| \| \| \| \| | \| \| \|X\|X\|X\|X\|X\|X\|X\|X\|X | X\| \| \| \| \| \| \| \| \| \| |
| WT 4. Development and testing of disaster risk management applications through case studies | CIMNE | M. Carreño, O. Cardona, J. Valcárcel, Specialist 1, Specialist 2, Grantee 1, Grantee 2 | \| \| \| \| \| \| \| \| \| \| \| | \| \| \| \| \| \| \| \| \| \| \| | \|X\|X\|X\|X\|X\|X\|X\| \| |
| WT 5. Integration of a software platform for seismic hazard/risk assessment and risk management | CIMNE | A. Barbat, M. Marulanda, Specialist 1, Specialist 2 Grantee 1, Grantee 2 | \| \| \| \| \| \| \| \| \|X\|X | X\|X\|X\|X\|X\|X\|X\|X\|X\|X\| | X\|X\|X\|X\|X\|X\|X\|X\|X\|X\| |

(*) Mark an X inside the corresponding boxes (months)

## 5. BENEFITS DERIVED FROM THE PROJECT, DIFFUSION AND EXPLOTATION OF RESULTS

The project will have three types of benefits:

*Scientific and technical benefits:* The programme of work envisaged under the proposed project is designed to throw light on the difficult and elusive concept of risk in the contexts of seismic-hazard in Spanish regions and cities. First, it will develop a generic methodology framework and specific research instruments designed to identify, characterise and measure seismic hazard risk in Spain. Second, it will tackle the common elements of disaster risk by means of different illustrative examples for Spain. Finally, the project will create and disseminate methods and procedures that will be directly useful in the efforts to reduce the seismic risk in Spain by developing an open source and open architecture integrated standard software platform for multi-hazard and risk assessment. This important outcome of the project will provide new risk assessment methodologies and tools for identifying risk areas allowing prioritizing between mitigation/adaptation measures.
*Economic benefits:* The institutions which are involved in the disaster risk management tasks, at national and local levels, in Spain, can find useful support in the tools and results of the project for the decision making process on risk reduction and mitigation. The software platform which will be an essential product of the project will be useful for formulating policy, directing development, designing protection measures, allocating funds, consulting stakeholders, and encouraging informed public debate on safety and security in Spain. The project will also provide a better support for the management of the seismic hazard in Spain.
*Training benefits:* This is a proposal of high training level; the research group has long tradition and experience on training scientific personnel. The staff of the Risk Management Group of CIMNE directed more than 25 Doctoral Theses, while other 10 are in course. The requested grantees will be enrolled in Doctorate Programs of the Technical University of Catalonia (UPC) and will benefit from a carefull, high level direction.

The diffusion of the project results will be made in three ways:

*Scientific diffusion*: The project involves scientific and technical development of high level, and the diffusion of these results, in journals and conferences, is an important objective for the research group. Scientific and policy papers on the research conducted under the proposed project will be published, disseminating new methods and results in international journals, such as *Earthquake Engineering and Structural Dynamics; Journal of Earthquake Engineering; Natural Hazards; Earthquake Spectra; Disasters: The Journal of Disaster Studies, Policy and Management, Structure and Infrastructure Engineering* or other indexed journals. The members of the research group will also present their results in special conference sessions and in electronic form. At the end of the project, CIMNE will publish a monograph that will be "The book of the project". It will be useful to consolidate the dissemination of the project methods and results with the scientific community and disaster risk management decision-makers.
*Institutional diffusion*: Some institutions can be particularly interested in the results of the project. Among them, we can list the following:

- Civil Protection Service of Spain (Dirección General de Protección Civil de España), Civil Protection Service of the different Authonomic Regions of Spain and of different Municipalities.
- Instituto Geográfico Nacional
- Instituto Geológico de Cataluña.

Social diffusion: The above mentioned institutions can be also a diffusion way for the project results to the general population who is the final beneficiary of this research.

6. BACKGROUND OF THE GROUP
(In the case of a coordinated project the topics 6. and 6.1. must be filled by each partner)
(maximum 2 pages)

The International Centre for Numerical Methods in Engineering (CIMNE, http://www.cimne.com/) is a research organization in Barcelona, Spain. CIMNE was created in 1987 as a Consortium between the Catalan Government (Generalitat de Catalunya) and the Technical University of Catalonia (UPC – Universitat Politècnica de Catalunya). CIMNE is an autonomous RTD centre focusing in promoting and fostering advances in the development and application of numerical methods and computational techniques for the solution of engineering problems in an international context.

The activities of CIMNE are organised in the following departments:

RTD Department. CIMNE carries out various research and development activities in the field of numerical methods and its applications and has participated in more than 900 RTD projects in different areas of science and engineering in cooperation with many enterprises and organizations worldwide. CIMNE has taken part in some 150 projects of EC programmes and has acted as coordinator in 40 of these projects.

Publications Department. CIMNE publishes books, monographs, scientific publications and technical reports in the field of computational methods in engineering and applied sciences. CIMNE has published some 1200 titles since 1987. Additionally CIMNE researchers publish some 40 papers per year in international journals indexed in the Science Citation Index of the ISI. CIMNE also publishes software codes resulting from the research activity. Some codes are used for teaching purposes. Others are used as the basis for producing commercial software packages by companies. CIMNE has produced the following industrial codes since 1987 in the following sectors: sheet stamping (Stampack) and casting (Vulcan) marketed by Quantech ATZ S.A.; structural analysis (RamSeries) and fluid dynamics (Tdyn) marketed by Compass Ingeniería y Sistemas S.A. The pre and postprocessing system GiD (www.gidhome.com) developed by CIMNE received the IST Award of the EC and City of Barcelona Award in 2002. GiD has some 50.000 users worldwide.

Congress Department. CIMNE has specialized in the organization of international conferences. Some 85 conferences have been organised worldwide by the Congress Department of CIMNE since 1987.

Training Department. CIMNE organises courses and seminars in the field of numerical methods in engineering. CIMNE runs since 1989 the Master Course on Numerical Methods in Engineering and since 2007 the Erasmus Mundus Master Course on Computational Mechanics. Both degrees are awarded by UPC. In addition some 45 Ph.D. students develop their research in CIMNE towards a Ph.D under the supervision of CIMNE and UPC scientists.

Spin-off Companies. CIMNE has promoted the creation of some 9 spin-off companies in different areas such as Quantech ATZ S.A. (industrial forming processes), Structuralia S.A. (e-training in the civil engineering sector), Compass Ingeniería y Sistemas S.A. (civil and naval engineering sectors), Build Air S. A. (inflatable and textile structures), Ingenia AIE (aerospace engineering), Sensoria S.A. (wireless sensor network in engineering), NHIT S.L. (RTD consultants), etc. CIMNE is a shareholder in Structuralia, Compass and Ingenia.

Administrative Department. CIMNE has a staff of some 20 persons specialized in the management of RTD projects and the administration of finances. Currently some 110 RTD projects are being carried out at CIMNE, 41 of which are EC supported projects.

CIMNE employs some 180 scientists and engineers from different technical fields and nationalities specialised in the development and of numerical methods to a wide class of engineering problems. The research activities of CIMNE cover the development of innovative constitutive models for composite materials and structures,

new numerical methods for non linear analysis and safety studies of structures, shape optimization in structural and fluid dynamic problems, computational fluid dynamics studies for both external and internal flow problems and numerical simulation of material deformation and forming processes for the manufacturing industry, mesh generation and visualization interfaces, casting and thermal process, stochastic optimization as well as program parallelization and distributed (grid) computing techniques and, as an important activity, the risk assessment and management.

In the last twenty years, CIMNE has taken part in over 900 RTD projects with over 200 companies and organizations. Some 150 of these projects have received EC support through FP3-7 programmes. CIMNE has been the coordinator of some 30 EC funded projects (including a cluster of projects in the FP5 IST programme). The outcome of the research is recorded in over 1200 scientific publications, technical reports and educational software codes published by CIMNE. CIMNE has also successfully organized some 400 courses and seminars and around 80 international conferences. CIMNE has also specialized in the development of decision support systems integrating Artificial Intelligence models based on the Monte Carlo method, Neural Networks and IT tools such as wireless sensor networks and user friendly interfaces for finite element based simulation software. CIMNE received one of the 2002 IST Awards for a new software product named GiD [GiD 2003] for pre-processing analysis data and the visualization of numerical results from engineering computations (see www.gidhome.com). Also, in 2003 CIMNE received the City of Barcelona Award in Technological Research for the development of GID system “an innovative and easy graphic interface for modelization and visualization of numerical simulations results”.

The Risk Management Group of CIMNE made important contributions to vulnerability and risk studies in Spain, Europe and Latin-America. In this sense, the developments performed by its researchers on the vulnerability framework and on the holistic risk approach, as well as in developing and using indicators and indices, probabilistic modelling of hazards, in the development of urban risk scenarios, in the economic evaluations for risk transfer and financial protection, in the management of uncertainties by means of Monte Carlo tests, among others, are well known in the scientific community. This group of CIMNE has been involved in European projects such as SERGISAI, VAB, RISK-UE, RAMFLOOD, LESSLOSS and MOVE of the 7th EC Framework Programme and the Specific Programme Cooperation, but also in the Program of Indicators of Risk and Risk Management in the Americas (2002-2004) and its update (2009), and in the development and application of the Mega-cities Indicator System in Manila. At national level, members of the proponent group participated in the project EVASIS (REN2002-03365/RIES) of the Spanish MEC, whose main result were physical seismic risk scenarios for the city of Barcelona, in HABITAT 2030 and in SEDUREC. The team participates in important projects in the field of disaster risk evaluation and management funded by the World Bank, the Inter-American Development Bank and the International Strategy for Disaster Reduction of United Nations (UN-ISDR). At present, CIMNE, together with other partners, is developing the most important open source risk model in Latin American and Caribbean region. The Central American Probabilistic Risk Assessment is, at present, a project for hazard and risk analyses taking into hurricanes, floods, storm- surges, landslides, earthquakes, tsunami and volcanoes.

In order to provide an integrated software platform for seismic-hazard/risk assessment, visualization, mapping (GIS), and disaster risk management, the research group of the project incorporates a worldwide recognized expert from the National University of Colombia (Universidad Nacional de Colombia sede Manizales) that has been involved in the development of similar modules for various specific hazards. This aspect will enhance and make use of the new software modules together with the other members of the research group in a challenging research cooperation. He will be also involved in the definition of the conceptual framework of the project in the development of risk assessment models, in which he is expert.

6.2 PUBLIC AND PRIVATE GRANTED PROJECTS AND CONTRACTS OF THE RESEARCH GROUP
Indicate the project and contract grants during the last 5 years (2004-2008) (national, regional or international)
Include the grants for projects under evaluation

| Title of the project or contract | Relationship with this proposal (1) | Principal Investigator | Budget EUROS | Funding agency and project reference | Project period (2) |
|---|---|---|---|---|---|
| Desarrollo y aplicación de procedimientos avanzados para la evaluación de la vulnerabilidad y del riesgo sísmico de estructuras (EVASIS) | 2 | Alex Barbat | 77.050€ | Mº DE CIENCIA Y TECNOLOGÍA REN2002-03365 | 01/10/2002 30/09/2005 C |
| Methods for the Improvement of Vulnerability Assessment in Europe - MOVE | 1 | (Alex Barbat and Martha Liliana Carreño from the CIMNE group) | 2,083,427 € (166,520€ CIMNE) | European Commission. 7th EC Framework Programme and the Specific Programme Cooperation | 2008-2011 C |
| Design and Implementation of an Integrated Disaster Risk Management Plan - Risk Indicators and Flood Risk Evaluation for Guyana | 2 | Martha Liliana Carreño | US$305,751 | Banco Inter-Americano de Desarrollo | 01/11/2010 01/11/2011 C |
| Technical assistance to design a risk financial protection strategy, a speciic financialinstrument and a policy recommendation for urban wather and sanitation utilities in Perú | 1 | Alex Barbat | US$169,665 | Banco Mundial | 20/09/2010 20/05/2011 C |
| Central America Probabilistic Risk Assessment: Nicaragua and Costa Rica | 1 | Alex Barbat and Martha Liliana Carreño | US$ 699,933 | Banco Mundial | 2008-2009 C |
| Central America Probabilistic Risk Assessment for Belize, El Salvador and Guatemala | 1 | Martha Liliana Carreño | US$930,000 | Banco Mundial / Banco Inter-Americano de Desarrollo | 15/12/2008-30/06/2010 C |
| Central America Probabilistic Risk Assessment for Honduras | 1 | Martha Liliana Carreño | US$349,989 | Banco Inter-Americano de Desarrollo/Banco Mundial | 10/03/2009 - 10/09/10 C |
| Country specific risk evaluation (Bolivia, Guatemala, Jamaica y Perú) | 1 | Martha Liliana Carreño and Alex Barbat | US $400,000 | Banco Inter-Americano de Desarrollo | 07/07/2008 30/04/2009 C |

| | | | | | |
|---|---|---|---|---|---|
| Aplicación y actualización indicadores de riesgo y gestión de riesgos | 1 | Martha Liliana Carreño | US$ 600,000 | Banco Inter-Americano de Desarrollo | 27/10/2008-31/07/2009 C |
| HABITAT: Desarrollo de nuevas tecnologías en "materiales y procesos de fabricación de componentes" orientados a su integración en edificios | 2 | Alex Barbar | 47,600€ | MEC-MINISTERIO DE EDUCACIÓN Y CIENCIA. PSE-380000-2008-002 PS-380000-2005-11 | 2007 |
| SEDUREC: Seguridad y durabilidad de estructuras de construcción | 3 | Eugenio Oñate | 1.260.000 € | MEC-MINISTERIO DE EDUCACIÓN Y CIENCIA. CSD2006-00060 | 2006-2011 (C) |

(1) Write 0, 1, 2 or 3 according to: 0 = Similar project; 1 = Very related; 2 = Low related; 3 = Unrelated.
(2) Write C or S if the project has been funded or it is under evaluation, respectively.

## 7. TRAINING CAPACITY OF THE PROJECT AND THE GROUP
## (In the case of Coordinated Projects this issue must be filled by each partner)

This title must be filled only in case of a positive answer to the corresponding question in the application form.
Justify that the group is able to receive fellow students (from the Suprograma de Formación de Investigadores) associated to this project and describe the training capacity of the group. In the case of coordinated projects, each subproject requesting a FPI fellowship must fill this issue.

Note that all necessary personnel costs should be included in the total budget requested. The available number of FPI fellowships is limited, and they will be granted to selected projects as a function of their final qualification and the training capacity of the groups.

The experts who constitute the Risk Management Group of CIMNE made important contributions to seismic vulnerability and risk studies and already collaborated in many other important risk evaluation projects but they also directed more than 25 Doctoral Theses. They will bring in the proposed project their special expertise as, for example, on methods for disaster risk management taking into account engineering, cultural and land use issues, and for better validation and evaluation of the metrics and methods developed. This will be useful for the other members of the group. In order to avoid a situation in which each member works mainly on a specific disciplinary approach, there will be continuous exchanges among them, as well as initiatives to test the applicability of different methods by more than one member. This will ensure that there are appropriate synergies, and that the specific potential to combine and integrate various disciplinary approaches will be realised. Moreover, new knowledge on how to measure seismic hazard risk at sub-national and local levels in Spain will be generated. The group which proposes the project is well balanced in terms of the integration of different specific expertises on risk evaluation.

On the other hand, the experts involved in the project have a high capacity of transmitting their broad knowledge and experience in different areas related to the hazard, vulnerability and risk evaluation and management to members of the Risk Management Group of CIMNE which we expect to incorporate with charge to the proposed project.

At the same time, the proposed project has a high training capacity in the field of probabilistic hazard and risk evaluation and their representation in a platform using GIS tools, from which the newer members which will be incorporated, that is, the two requested FPI fellowship holders, will benefit. The training will also involve the modelization for different natural hazards. The Risk Management Research Group of CIMNE has long tradition and experience on training scientific personnel and, therefore, the requested grantees will be enrolled in Doctorate Programs of the Technical University of Catalonia (UPC) and, consequently, they will participate in several specialized courses in the field of the developments which will be made in the project according to the necesities and interests of the project and the research group.They will receive training in areas such as risk modelling and disaster risk management. They will also participate in the development of the case studies.