# SUSTAINABLE MANAGEMENT OF NATURAL HAZARDS IN THE REGION OF SOUTH-EAST ASIA AND SOUTH ASIA

M. H. Faber, A. Kos, B. Becker, M. Kaufmann, P. Stamp, K. Seeland, A. Grün.
Swiss Federal Institute of Technology
ETH-Hönggerberg, 8093-Zürich, Switzerland.
faber@ibk.baug.ethz.ch

S.L. Ranamukhaarachchi, G.P. Shivakoti, L. Samarakoon, O. Shipin
Asian Institute of Technology (AIT), Thailand
ranamuka@ait.ac.th

and Loy Rego
Asian Disaster Preparedness Centre (ADPC), Thailand.
loyrego@adpc.net

**ABSTRACT:** Following the devastating consequences of the Banda Aceh with the Earthquake followed by the tsunami in the Indian Ocean on December 26, 2004, focus has been directed towards the high vulnerability and low robustness of the affected societies, infrastructure and natural resources in regard to natural hazards.
A proposal for an ETH (Swiss Federal Institute of Technology) lead project in partnership with AIT (the Asian Institute of Technology) and ADPC (the Asian Disaster Prevention Centre) is presented. The aim of the project is on a medium to long term to improve the basis for sustainable management of risk due to natural hazards through improved decision support tools, improved understanding of the risks, knowledge dissemination and education. A risk management framework is proposed considering three distinct decision situations namely, before, during and after the event of a natural hazard. Use of the risk management framework is envisaged to provide decision support for decision makers at international, national, regional as well as municipal levels. Furthermore the decision support tool may also greatly enhance education and training as it facilitates that the consequences of various risk management strategies may be quantified and compared.

The focus of the project is directed towards two different exposure conditions, namely hazard conditions relevant for coastal regions and conditions relevant for inland regions. The first mentioned regions are typically exposed to more rapidly evolving event of natural hazards such as tsunamis and floods whereas the inland regions may be more exposed to e.g. climatic changes and short sighted land use.

The proposed risk assessment framework takes basis in a newly developed approach to risk assessment where a given system such as e.g. a larger geographical region is assessed by consideration of the exposure (hazard) to the system, the vulnerability (immediate damage due to a hazard) of the system and the robustness (indirect and/or delayed consequences due to the immediate damage) of the system. The concept of risk indicators in conjunction with Bayesian Probabilistic Networks (BPN's) is applied for the assessment of risks and for the optimization of strategies to risk management. The risk indicators are descriptors characterizing a given geographical area in regard to the prevailing exposure condition, vulnerability and robustness. Typical indicators are related to e.g. geographical conditions, population density, distance to various potential sources of natural hazards, type of buildings, existence of life-line facilities of various sorts, soil conditions and land utilization. To facilitate the management of the significant amount of data required for the risk management it is envisaged to develop a GIS based platform for the decision support tool. This will also greatly enhance the potential of the developed tool for educational purposes. Of utmost importance for the proposed framework is to ensure that especially the interaction between immediate direct damages due to natural hazards and indirect consequences to the affected societies are taken properly into account. This includes the longer term effects of damages to agricultural assets, production facilities and lifeline systems as included in the modelling of the robustness. Management of natural hazards has to be seen in the light of this interaction and thus calls for the strategic planning of land use as one of the most significant factors in sustainable risk management.

## 1. INTRODUCTION

Following the devastating immediate consequences of the tsunami in the Indian Ocean on December 26, 2004, increased focus has been directed towards the effective management of risks due to natural hazards. Whereas it is generally accepted that any society subjected to events of natural hazards might be severely affected by the corresponding consequences in terms of loss of lives, economical losses and damage to environmental qualities, it is only recently appreciated that developed societies and developing societies are affected rather differently to

events of natural hazards and that the efficient and sustainable management of risks must take these differences into account.

Developing societies have in many ways not yet reached a state where economical means, in the same proportion as in developed societies, can be directed to activities of societal consolidation, i.e. for the purpose of safeguarding the individuals of society, the environmental qualities and the societal infra-structure. Therefore for such societies natural hazards often have particularly pronounced immediate as well as delayed effects. The immediate effects may be especially severe as a consequence of the need in developing societies to utilize all available land for commercial activities; i.e. pursuing activities in land zones of high exposures to natural hazards without the sufficient economical resources to safeguard the activities. The delayed effects may be especially significant due to the lack of economical buffer resources and sufficient capacity of societal infra-structure to sustain the immediate consequences at a level which facilitates continued societal developments. In the case of slow hazards as induced by a-biotic stresses, like drought, it is often more difficult to discern between immediate and delayed risks. But in essence the societal limitations in resource poor countries are the same, though the long term damages can be quite high when the society reacts too late.

The continued positive development of developing societies is highly dependent on:

- Efficient and sustainable allocation of limited available resources for management of risks
- Education, training and research in the area of risk assessment and risk management

It is expedient that efficient approaches and tools are developed to support society and societal decision makers at all levels in achieving these objectives. Focus should not be directed entirely to events of immediate public interest such as Tsunamis, earthquakes and volcanic eruptions, but should consider all hazards which are relevant for a given geographical location, also the more unnoticeable slowly evolving hazards of e.g. climatic change. Moreover, risk management should be seen as being more than just efficient strategies for emergency aid, rescue and evacuation, namely all the different aspects of risk management and decision making - prior to, during and after events of natural hazards, including improved information, education and collaborative research.

The objective of the present project is to enhance sustainable management of risks due to natural hazards in the region of South-East Asia and South Asia. The regional focus facilitates the efficient utilization of the experiences and knowledge represented by the project team, however, the developed framework and approaches are generic and can be adapted for other developing societies in different geographical regions.

The project which in some ways has a highly general approach and a wide scope is envisaged to provide an overarching framework not only for the specific activities planned within the project, outlined in the subsequent, but also for other project activities pursued by other project groups. The structure is illustrated in Figure 1. All projects aiming to enhance risk management and sustainable land use in the region of South-East Asia and South Asia can benefit from bringing together their ideas, research results, tools and insights, the result being a more efficient use of funds and a broader impact of efforts.

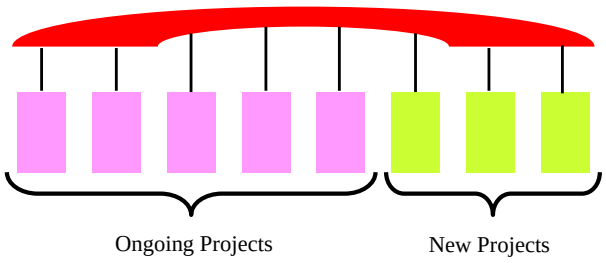


**Figure 1 Illustration of the overarching nature of the proposed project aiming to provide a platform for not only the activities in the present project but also those of other past, ongoing and future projects.**

## 2. OBJECTIVE AND AIMS OF THE PROJECT

The objective of the project will be achieved through a targeted effort to reach the following aims (see also Figure 2):

- Provide aid in supporting decisions for the management of risks due to natural hazards with a special view to the long term reduction of the vulnerability as well as the long term increase of robustness/resilience of natural resources.
- Provide a decision support system for international organizations to identify for what purposes they may provide financial support to reduce risks and improve long terms living standards most efficiently.
- Support through research and development of tools the needs and priorities identified by disaster risk reduction practitioners in communities, community organizations, and local and national governments.
- Perform educational activities improving the general knowledge in the region of South-East Asia and South Asia in regard to a holistic approach to management of risks due to natural hazards and the sustainable long term management of natural resources.
- Develop new and strengthen existing scientific collaborations with universities in the region and universities abroad.
- Reach out wherever suitable to network in synergy with existing and new programs of similar focus.
- Provide an overarching framework for other projects with similar aims such that coordination and exchange of knowledge and data may be enhanced and synergy achieved through joined efforts.


**Figure 2 Illustration of aims of the proposed project.**

The aims of the project will be reached through five different types of activities, namely:

- Indicator based risk assessment
- GIS modeling and risk mapping
- Capacity building
- Project management and dissemination strategy
- Demonstration projects

The five different activities are interrelated in the project as illustrated in Figure 3.

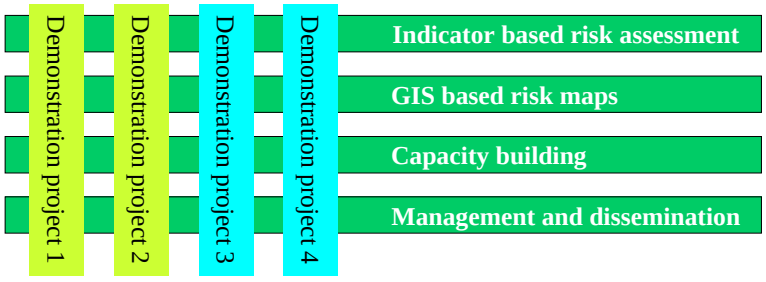


**Figure 3 Illustration of envisaged project activities.**

The horizontal activities in Figure 3 are thematic cross-going activities including methodology, tools and capacity building. The vertical activities relate to the implementation of the developed methodology, tools and schemes for capacity building on specific geographical locations – the demonstration projects.

The scope for the activities is:

- **Indicator based risk assessment** - develop a generic risk management framework for the efficient management of risks due to natural hazards with a special focus on the sustainable long term management of natural resources. The framework shall accommodate for the inclusion of information of special relevance for the assessment of risks – the risk indicators.

- **GIS modeling and risk maps** – to model input and output relations between hazards and resulting risks by means of a geographic information system platform. The platform shall serve as the data management support in the project as well as to enhance modeling and results presentations. Finally GIS based hazard and risk maps will form specific output from the project as a means in the planning of land use.

- **Capacity building** – setting up programs for teaching and other educational activities for the purpose of capacity building in the region of South-East Asia and South Asia. Teaching as well as students exchange shall be coordinated with the other activities of the project such as to provide a living framework where students and teachers may interrelate with the ongoing research and developments. Taking basis in the indicator based risks assessment framework and the developed GIS-models an interactive scenario based teaching platform is developed. The students and decision makers at various levels will be exposed to real life risk management problems (scenarios) and learn about the relevant aspects of risk management and the significance of prevention, mitigation, vulnerability and robustness (resilience).

- **Project management and dissemination strategy** - development of guidelines to allow and facilitate and effective and efficient collaboration and exchange of data and tools between different projects under the overarching project proposal. Elaboration of a dissemination strategy will be made in order to make the results available to decision makers at different levels and to the affected societies and communities.

- **Demonstration projects** - application of the developed framework and decision support tools at specific locations in the region of South-East Asia and South Asia. It is envisaged that two different types of demonstration projects will be conducted one type at an inland location (with main hazard being a-biotic stress) and one type at a coastal location (with main hazard being Tsunami). It is stressed that the risk assessments will be multi-hazard oriented and that the perspective taken is from a decision making view point but at various levels covering legal authorities at different levels down to smaller societies and communities.

## 3. WORKING THESIS AND APPROACH

The theoretical framework for the approach to risk management in the project takes its basis in recent developments in the area of risk based decision making as described in e.g. Faber and Maes [1]. In the following the core activities in establishing the components of the project are briefly outlined.

### 3.1 The risk management approach

The approach taken for the risk management will address risk management in three different situations, namely prior to, during and after the event of a natural hazard. For each of these different decision situations the risk management framework will be able to provide support for decision makers at different societal levels in regard to how available, possibly limited societal resources may be allocated most efficiently to manage the prevailing risks with a special view to sustainability.

Initially the main emphasis will be directed to one type of suddenly occurring hazards – Tsunamis, and one type of a slowly progressing hazard by a-biotic stresses. This direction of focus aims to provide a basis for the illustration of how the general risk management framework may be applied for the consideration of specific and principally different types of hazards. At a later state this scope will be broadened to consider all relevant hazards in the region of South-East Asia and South Asia.

In the risk assessment envisaged in the demonstration projects, however, all relevant interrelations between different hazards and the related processes are taken into account.

Two regions in Thailand and Sri Lanka will be selected for the trial applications of the developed risk assessment approach. Thereby the risk assessments will be performed for regions where the main hazards are Tsunamis and regions where the main hazards are a-biotic stresses in both countries and facilitate the consideration of field data from these regions.

The risk assessments are performed with the aim of enhancing decision making. Therefore the perspective of the decision maker is taken as basis for the approach. However, decision makers at different levels (regional, municipal, communities, etc.) and their special problems will be considered.

In the assessment of risks all dimensions of societal assets will be taken into account including the individuals of society, the qualities of the environment and the economy. Sustainability has a high focus in the present project; special consideration is given to possible long term consequences of decision making on the qualities of the environment. This includes also the important interrelation between risks and agricultural land use.

For a given geographical area the framework will provide an assessment of the risks considering all hazards which are relevant for that particular area. Risks include risks due to potential loss of lives (on both a short and a long term perspective), damages to the qualities of the environment (e.g. loss of arable land, loss of drinking water, pollution) as well as economical losses due to damages on the built environment and societal infra-structure (housing, road way systems, dams, electricity supply, bridges, etc).

A main feature in the proposed framework will be the utilization of risk indicators, i.e. any observable quantity which contains information about the risk. Indicators may be visually observable through site visits, observable from building and construction drawings as well as from aerial and satellite photos. The framework will thus be generically adaptable to a given geographical area simply by specifying the risk indicators which are specific for a given area. To facilitate this, a new risk assessment framework will be utilized, see Faber and Maes [1], which describes a system subject to risk assessment by means of the relevant hazard exposures, the vulnerability for any combination of exposures and the robustness/resilience for any given state of damage of the system. The risk indicators will be identified for these three different types of system descriptors specifically, see also Figure 4.

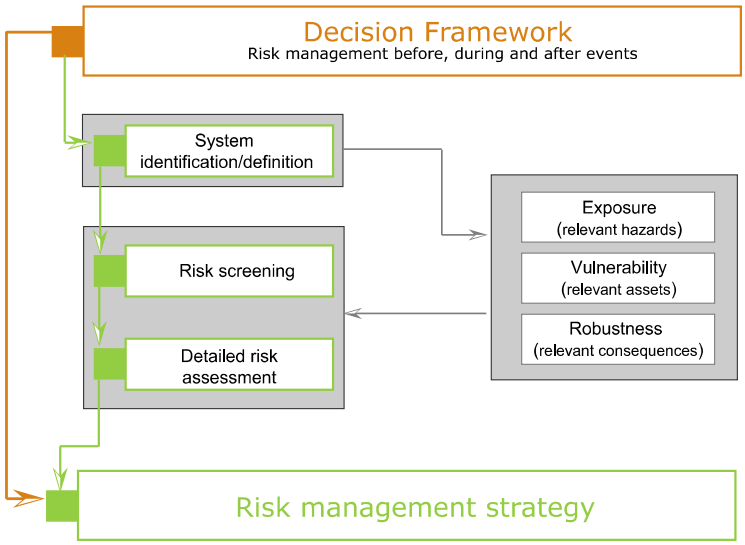


**Figure 4 The risk management framework and its constituents.**

Finally risk indicators will be identified which are applicable at different levels of detail or scale. Crude risk management may thereby be possible which is relevant for e.g. a large geographical region or as a first estimate for a smaller geographical region - using less precise risk indicators. Use of more precise indicators typically corresponds to the application of a smaller scale in the risk assessment. This in turn facilitates a more precise assessment of risks but is also associated with larger efforts in the collection and processing of data. The approach indicated in Figure 4 is shortly explained in the following.

### 3.2 Risk management framework

The issue of concern here is to develop the theoretical framework and the decision support tool for the integral management of risks due to natural hazards with emphasis on the reduction of vulnerability and an enhancement of robustness of exposed natural resources. The framework will be formulated such that it facilitates the risk management for larger geographical areas or regions. The framework will be based on the Bayesian decision theory (already developed under the Merci project utilizing Bayesian Probabilistic Networks (BPN's), see Bayraktarli et al. [2] and the Merci project [3]) and will utilize the concept of risk indicators to facilitate the application of the decision support tool for areas with different characteristics in regard to exposure conditions, vulnerabilities and robustness' (see later). Typical indicators will be related to the geographical conditions, the density of population, the distance to various potential natural hazard event, type of buildings, the existence of life-line facilities of various sorts, the soil conditions and the land utilization of the area, etc, etc. It is important to realize that different indicators will be relevant for the different decision situations, i.e. before, during and after natural hazard events.

### 3.3 Risk screening

Generally a risk screening serves to identify the issues which are not of concern, i.e. a most basic exercise to identify the system to be considered in the decision analysis. A workshop with the purpose to conduct a risk screening would thus ensure that the project is relevant in regard to the demand or need of the societies of the affected region.

The starting point for a risk screening is an inventory in regard to assets and relevant exposures. This inventory should take basis in a graphical information system as well as records on consequences of previous events of natural hazards.

It is important that the risk screening is performed jointly by experts covering the whole spectrum of aspects of importance for a risk assessment. These include experts on the process understanding of the various exposures (e.g. earthquake, tsunamis, floods, volcanic eruptions, fires, erosion, droughts, etc), experts on the assessment of the vulnerability (the immediate damage for a given exposure event) of different types of assets as well as experts on the assessment of the robustness for given exposures and given vulnerabilities. The robustness represents the ability of the considered system to sustain the immediate damage and plays a significant role for the tremendous follow up consequences due to hazards, e.g. loss of drinking water, damaged sanitation systems, spread of decease, missing hospital treatment capacity, destruction of crops, loss of arable land, etc.
Finally the risk screening also serves to identify the more precisely the need for decision support of the various official institutions responsible for or involved in natural hazards preparedness, mitigation, rescue and educational activities.

Within the proposed project it is suggested to perform the risk screening as one of the very first activities. The risk screening could be performed in the form of a workshop with the participation of scientists from the project team and other experts and national representatives from the affected region. The result of the workshop would be a clear definition of the precise scope for the project in regard to considered exposures, vulnerabilities and aspects of robustness to be considered. Furthermore, the workshop would identify which participants from the affected region would participate in the various tasks of the project and thereby also define the topic/sub-project on which individual research groups and Ph.D. students would be working on at the universities and institutes represented by the project team.

### 3.4 Detailed risk assessment

The detailed risk assessment consists of a quantitative assessment of the risks for persons, economy and environment with a special focus on the natural resources. As mentioned in the foregoing Bayesian Probabilistic Nets will be applied for the quantification of risks. A similar approach has been successfully applied in other risk management projects considering e.g. earthquake exposures, see e.g. Straub [4] is illustrated in Figure 5.

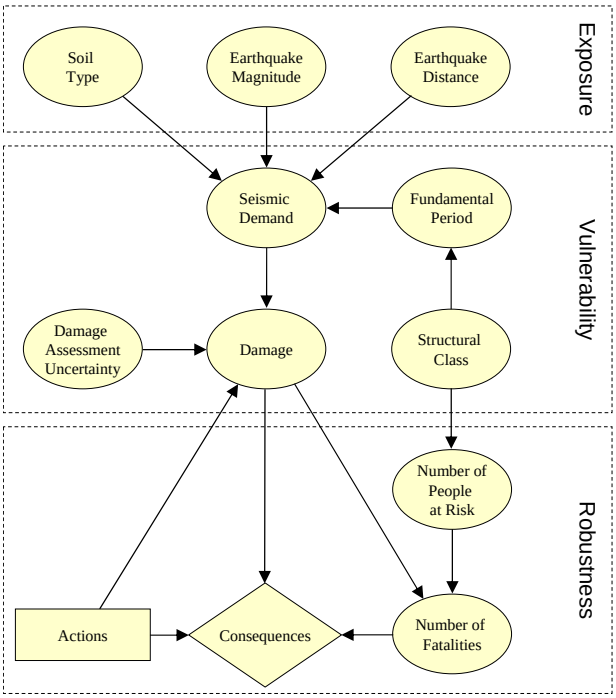


**Figure 5 Illustration of the application of Bayesian Probabilistic Nets in indicator based risk assessments.**

The risks are assessed by considering the main descriptors representative of a given area namely, the exposures, the vulnerabilities and the robustness'. In the detailed risk assessment the risks will be quantified using a generic approach taking basis in indicators related to exposure, vulnerability and robustness'. Furthermore the efficiency of various actions for controlling and reducing risks will be assessed, again logically divided into activities reducing exposure, reducing vulnerability and improving robustness. These activities must include factors that reflect the interrelation between misuse of natural resources, increased societal vulnerability and reduced societal robustness.

### 3.5 Exposure modeling

A central activity in the project is to model the exposures in regard to natural hazards. All relevant natural hazards will be considered for a given region, including e.g. suddenly occurring events such as floods and earthquakes but also more slowly evolving events such as a-biotic stresses which can lead to permanent or long term soil degradation. For tsunamis the modeling concerns e.g. the assessment of the annual probability of tsunami waves of different height and energy contents for different locations. To undertake such a modeling and to represent such models in a simplified generic indicator based format necessitates a thorough understanding of the physical processes generating the exposures and the uncertainties influencing them. A possible approach to this is given in Schubert et al. [5].

### 3.6 Vulnerability assessment

As mentioned in the foregoing the vulnerability is a measure of the immediate damage for a given exposure. The vulnerability for a geographical location with buildings could thus be quantified in terms of the number of buildings failing or damaged as a consequence of a given exposure event. The vulnerability is, however, not just related to assets like buildings but also assets such as people, qualities of the environment, life-lines and arable land.

An important task in the risk assessment is to be able to quantify the vulnerability for the different relevant types of assets and to identify the various indicators containing information about this. Again for buildings, the indicators could be the type of building, the type of foundation, the year of construction, etc.

Another task of significance is to identify measures or actions of risk reduction which would reduce the vulnerability of the different assets. It is in this category, e.g. a tsunami warning system belongs, however, also actions such as strengthening of structures, construction of protective structures and the implementation of evacuation strategies are to be considered. Moreover, the sustainable long term management of natural resources will be implemented as a decisive tool to reduce the vulnerability and increase the robustness of society. Finally in this activity also the effectiveness of the relevant vulnerability reducing measures has to be assessed.

### 3.7 Robustness assessment

The robustness is related to the ability of the exposed system to absorb the consequences of the immediate damage. In this way the robustness can be assessed through the indirect consequences for given damage and given exposure. It is important that all relevant indirect consequences are taken into account and to ensure this requires a significant insight into the social characteristics of the areas considered. Among indirect consequences should be counted the event and effects of loss of drinking water, damaged or loss of sanitation systems, exhausted medical systems, loss of crops, etc.

Again it is important to identify the indicators containing information about the robustness as this information facilitates a generic application of the developed models for the representation of the robustness for a given damage and given exposure for a specific area.

As for the vulnerability different actions will be identified by which the robustness may be improved. This task also necessitates a significant insight into the mechanism generating the indirect consequences. Robustness may e.g. be ensured by introducing redundancy in life-line systems, by devising and training efficient disaster preparedness plans and by the sustainable management of all natural resources. Finally in this activity also the effectiveness of the relevant robustness improving measures has to be assessed.

### 3.8 Risk management strategy

Based on the detailed risk assessment utilizing the indicator based modeling of the exposure, vulnerability and robustness strategies may be identified for the optimal management of risks which are relevant for a given area or region. It is envisaged that this activity will be highly facilitated by a decision support tool which is programmed into an appropriate software product. A Geographical Information System (GIS) platform will integrate all information relevant for the management of risks – and thereby form a basis for the development of strategies for risk management and also form a unique foundation for education where students as well as decision makers may learn how different actions will affect the risk in different ways. The platform will also provide a research platform for the consistent collection of real world data regarding indicators of risk.

As illustrated in Figure 6 the indicators will be assessed such that these indicators are related to the models of the real world which form the basis for the risk assessments, i.e. the exposure, the vulnerability and the robustness/resilience of the considered system. Finally, the risk as assessed from the models and related to the real world through the indicators may be managed by means of various actions of risk reduction.

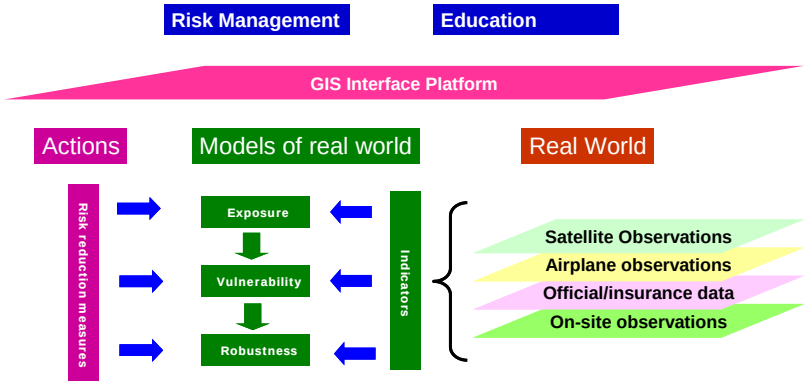


**Figure 6 Illustration of the constituents of the integral project.**

The technical activities will serve as the vehicle for achieving the educational and research collaboration aims of the project. It is therefore suggested that the project will be conducted in the form of one joint interdisciplinary project with the participation of several individually managed research groups.

### 3.9 Capacity building

A major part of the project will consist of a capacity building, knowledge transfer and student exchange program with selected partners The main activities involve 1) Scenario based blended learning, 2) Graduate student workshops and seminars and 3) Graduate student exchange.
Capacity building will target undergraduate and graduate level students, where a number of courses will be offered by participating institutes (and possibly other sponsoring scientific organizations) on selected topics of relevance for the workshops and the problem framework in general. Courses will principally use a scenario-based blended learning didactic represented by a number of thematic modules. The modules will be part of an online learning environment that will be integrated with the proposed risk management platform. Several of the scenario based modules may also be adapted for training of professionals responsible for hazard and risk management.
Joint workshops and seminars between participating institutes will be conducted in turn within 1-½ year intervals at different universities or institutes in the region of South-East Asia and South Asia. At the workshops the results achieved from the project will be presented and act as a major knowledge transfer component of the project. Additionally, the joint workshops and seminars will serve to identify students at Masters or PhD level who merit a support for further qualification in joint inter-university exchange programs or in direct exchange programs within one university. These students will play a major role in strengthening relevant research work within the project at regional institutions. In addition to the extent considered feasible after the initiation of the project students from the participating research organizations and universities from the region of South-East Asia and South Asia could be offered an exchange program.

## 4. ACKNOWLEDGEMENTS

Professor Said Irandoust, the president of AIT, Dr. Suvit Yodmani, the Director General of ADPC and Professor Olaf Kübler, the president of ETH are greatly acknowledged for their support in the initiation of the joint project. NIDECO is warmly acknowledged for economical support in connection with the first joint workshop and for managing the administrative issues of the project. Last but not least the significant support in making the project come through from a large number of researchers in South East Asia, South Asia, ETH, AIT and ADPC is highly appreciated.

## 5. OUTLOOK

The joint project as outlined in the foregoing is still in its early phases. The real work is just now taking form and the future will show to what degree the project will be successful and make an impact towards a more efficient management of natural hazards in the region of South East Asia and South Asia. However, one thing is clear; the initiative which has been taken is a step in the right direction. Many other good initiatives have also been taken from other sides. Project already have or are being formulated at present with scopes which are very compatible with the scope of the present project. What is important in order to achieve the larges possible benefit of these and present project is that we all aim for synergy, exchanging ideas, research results and data and at the same time reducing redundant and parallel work.
The present project is aiming to provide a platform for collaborations between presently running as well as project which will be initiated in the future. It is the outspoken wish from all participants of the present project that such collaborations will be realized and in this spirit we invite all with an interest to participate, support or in other ways to contribute to the project to take contact.

## 6. REFERENCES

[1] Faber, M.H. and Maes, M.A. (2005). On Applied Engineering Decision Making for Society. Proceedings of the 12th IFIP WG7.5 Working Conference on Reliability and Optimization of Structural Systems, Aalborg, May 22-25, 2005.
[2] Bayraktarli, Y.Y., Ulfkjaer, J.-P., Yazgan, U. and Faber, M.H. (2005). On the Application of Bayesian Probabilistic Networks for Earthquake Risk Management. Proceedings ICOSSAR2005, 9th International Conference on Structural Safety and Reliability, Rome, June 19-23, 2005, pp. 3505-3512.

[3] The Merci Project, Web site: http://www.merci.ethz.ch/.

[4] Straub, D. (2005). Natural hazards Risk Assessment using Bayesian Networks. Proceedings ICOSSAR2005, 9th International Conference on Structural Safety and Reliability, Rome, June 19-23, 2005, pp. 2509-2516.

[5] Schubert, M., Straub, D., Faber, M.H. (2005). Reliability of rock fall protection galleries – A case study with a special focus on the uncertainty modeling. Proceedings ICOSSAR2005, 9th International Conference on Structural Safety and Reliability, Rome, June 19-23, 2005, pp. 1333-1340.