Decision support system for landslide risk management in a geographical area with high risk for natural disasters – terrarisc

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Abstract: *The project will provide a technical solution for assessment of environmental parameters needed in landslide risk management using advanced technologies that will allow:*

- *acquisition of data concerning the underground water level (sensors installed inside caissons),specific environmental parameters, data regarding relatival displacement of fitted terrestrial bench-marks (sensors for relatival displacement) ;*
- *transmission of field data through wireless communication to a risk management center;*
- *modeling and simulation for natural disasters risk assessment;*
- *control and observation of risk factors regarding landslides, based on an advanced decision-support system using GIS technologies and business intelligence;*
- *complex analysis of masive historic data and meteo and seismic forecasts, in order to identify the evolution trend (during given time periods) and foresee the risk of landslide and also to identify on a map critical areas;*
- *automatic reporting about parameters evolution due to increased alarm/emergency quota;*
- *interactive facilities for creating alarming strategies (actions, tasks, priorities) and generating emergency plans;*
- *automatic alerting via Internet according to an emergency plan;*
- *presenting information (text, maps) to action group members both on fixed (PC) and mobile devices (PDA, mobile phone).*

***Keywords**: natural disasters, hazard, vulnerability, risk*

1. Introduction

Natural disasters, also known as hazards, cause huge damages every year, directly affecting the social and economical development and also taking away human lives.
Hazard means the probability of a human/environment harmful phenomenon to occur during a certain period of time. *Vulnerability* indicates the level of damage caused by a certain phenomenon to humans and their assets. *Risk* means the probability of the humans and of

their assets to be harmed by a phenomenon of a certain size. *The elements on risk* are the population, the properties, communications, economical objectives in an area.

The global cost of natural disasters has grown over 800% in the last four decades being connected to an increasing vulnerability of the population living in high risk areas.

Landslides are disasters that destroy villages and towns, damage roads, railways, farm fields and have negative effects on every person that lives in the affected area and generally on society. The causes of these hazards are climate changes, seismic activity, but also incontrollable human activities like abusive land deforestation (not followed by coherent financially supported reforestation strategies) .

In Romania there was no firm legislation in this field at the beginning of the economical transition, therefore the environment conditions have taken a turn for the worst and intensified the impact of natural hazards over the society. The problem of environmental damages due to human activities with devastating consequences must be seriously tackled since Romania wants to be part of the European Union in the nearest future.

Environment protection problems focus on identifying the causes of natural disasters, preventing possible damages, globaly approaching the effects on short/long term socio-economical development.

The major objectives of the local administrations are the environmental problems and natural disasters risk. The knowledge about this phenomenon only allows authorities to take proper preventing methods, to decrease the negative effects and to reconstruct damaged areas. The complexity of this domain enforces a serious research of hazards, vulnerability and risk as well as a constant education of the population. Advanced technologies can make a good support for taking decisions about the observation of environment parameters, alerts and risk management.

Today the legislation regarding preventing and diminishing disasters was adopted and it only waits for concrete actions in this direction.

The TERRARISC project aims at having a part in this national effort by creating an intelligent decision-support system to evaluate real–time environment parameters needed in landslide risk management and by offering complex S/T control and observation services, using advanced technologies (automatic field-data acquiring systems, wireless communication, relational databases, integrated analysis of a large amount of historic data – Business Inteligence, modelling and forecast technologies, GIS, mobile devices for operative activities coordination).

The project started on November 2005 and end on June 2008. The complex research-development tasks to be solved in the project will be established by a consortium made of: ITC-SA and IPA SA (research-development institutions), Bucharest University – The Faculty of Geology and Geophysics (internationally creditable high-education institute) and SSI Bucovina (research-development company in the pilot area – Suceava). The system will be installed in Suceava City Hall. Divers technologies need to be used and also experimental evaluations and probabilistic modeling of landslide evolution involved to accomplish its tasks.

2. The selection of pilot area for TERRARISC project

For TERRARISC project monitoring there were selected the following two pilot areas:

- the N-E slope of Suceava city;
- the northern slope of the Throne Fortress of Suceava.

2.1 The N-E slope of Suceava city

General presentation. The N-E slope of Suceava city is represented by the junction slope between the superior platform of the town and inferior platform of Suceava river and it is appearing as a monocline with a fall on North-East side, having an inclination of about 250-350 meters length and having about 2 kilometers in width on level line.

Landslide and interventions in the area. The N-E slope was in the line of time (1910-1911, 1930-1940, 1965), and in the present, the Suceava city area affected mostly by landslide. The ridge of Suceava city platform (the contact line between the flat portion and junction slope) has a steep aspect, favoring as much as detachment of portions after vertical fissures, and as collapse and transport on slope, with material disintegration and forming of mudflow (a very conspicuous phenomenon in the rainy periods).

In the area, in time, there have been made consolidation and retaining works (deep drainage works – caissons with radial vibrato drill drainage – but also for vertical retaining and systematization), obtaining partial landslide stabilizations. The landslide reactivation in the autumn of year 2001 affected an area of Zamca superior platform level (on NV-SE direction, on about 100-150 meters width) and determined fissures on retaining works, affecting even residences situated in recent consolidated area.

Zamca landslide base

Affected house in recent consolidated area

The importance of the area for the local community. If the plateau hosts the civic center of Suceava city (the administrative, social, cultural edifices have a great weight here) and the terrace of Suceava hosts the industrial platform, the slopes insure the ground for link facilities between the town and industry. Thus, on the slopes there are placed the channels of communication between the city and the industry area, the DN2 and DN29 highways, the energy and telecommunication networks, thermal pipes, as well as buildings series with streets network and afferent services (the later have a share of 15-20% of the whole city).

2.2 The northern side of the Throne Fortress of Suceava

General presentation. Geomorphologically, the placement is located on the edge of a high plateau, separated from the Suceava city plateau by the Targului Brook valley. The Fortress Plateau has quotas about 333 mdMB, being able to be correlated with the average terrace from the central area of Suceava city, which has approximately 340 mdMB quotas. The Fortress Plateau continues surveying to Ipotesti (with an artificial separation represented by the eastern side of the defense ditch), being similar to the structural surface of the Fortress

– Ipotesti – Bosanci cuesta. On the Throne Fortress of Suceava plateau, two quasi-plane level steps are distinguished, differentiated by 3-5 meters between them. The northern slope of the Fortress is represented by the steep of Fortress – Ipotesti – Bosanci cuesta, which has big inclinations towards N and N-V, of 32°-40°.

Landslides and interventions in the area boundaries. The area of the northern slope of the Fortress has been affected in time by a series of sliding and falling, at this time the external wall is missing on a portion of about 60 meters. The slope morphology, with three inclination levels and the escarpments from the basis of the median third of the slope, certifies this. Also, the vegetation existing on the northern slope has frequent deviations from the vertical. The northern external wall of the enclosure was being placed probably on the ridge of the fallen slope, at about 12-15 meters from the present ridge.

Main split in the reconstructed vault

Recent splits in the N-E tower

The importance of the area for the local, national and worldwide community. Being located at the east side of Suceava city, the Throne Fortress is a foundation of voivode Petru I Musat, mentioned even since 1388. It has of over 10 meters height and 4 meters width.

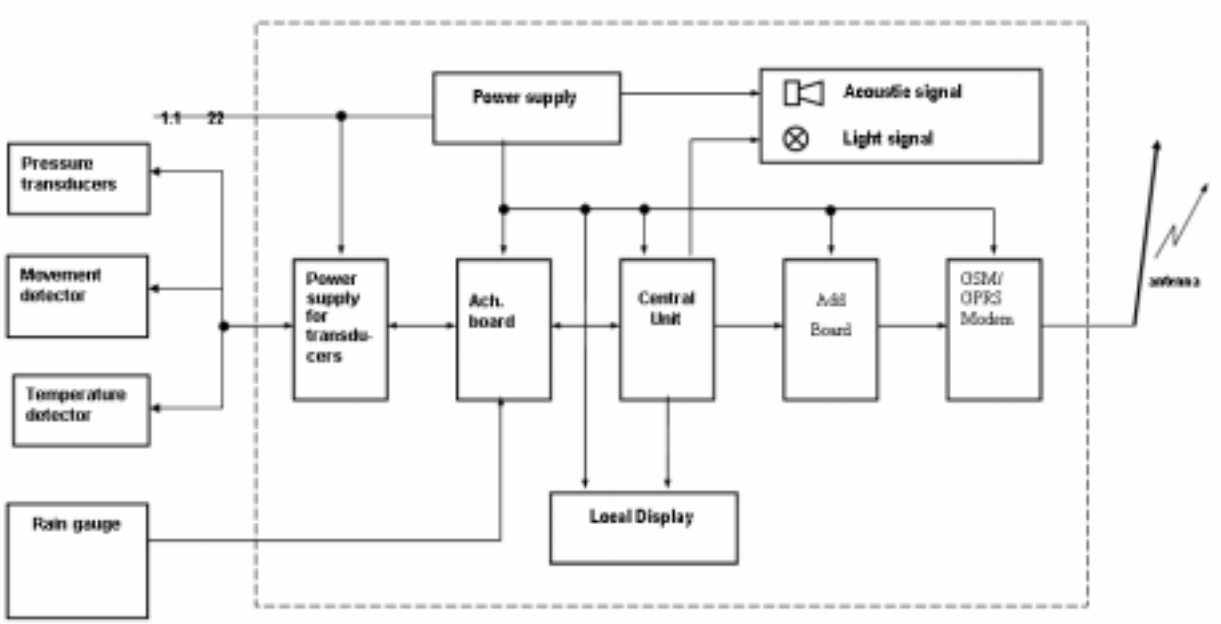
3. TERRARISC - System presentation

TERRARISC project will elaborate an intelligent decisional support solution for real time evaluation of the environmental parameters in landslide risk management.
The system will integrate technologies regarding:

- On-line environmental parameters capture
- wireless communication
- Relational Data Based System
- Business Intelligence
- Data Mining and Pattern recognition, simulation techniques based on theory of probability in order to obtain landslide models
- GIS systems
- Mobile access devices

The intelligent system for management will be based on GIS (Geographical Information System) technologies and advanced IT platforms, which will provide the decisional workflow.

Next diagram present the system infrastructure from the monitoring point:



Local echipament – block diagram

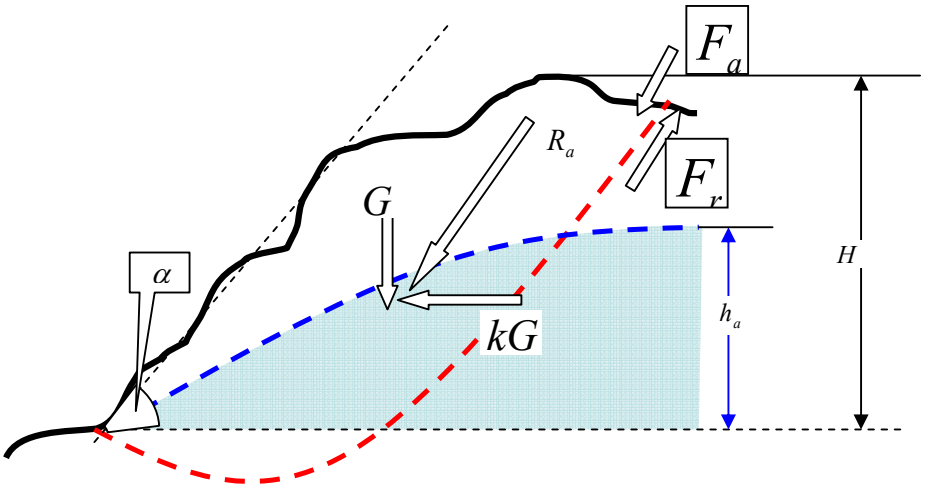
4. Curent execution stage and the future Project objectives

TERRARISC started with a scientifical Study for establishing the necessities of observing and on-line evaluating areal environment parameters respecting european requires and the capacity of advanced technologies to support landslide risk management.

Probabilistic models for modelling and simulation of landslides was elaborated conforming with the critical surface characteristic features and its space-temporal variation, identified during the visits in the two pilot areas.

We shall use two chategories of models:

- probabilistic models (Markov Chains) for probabilistic evaluation of time series based on environment parameters provided by the on-line monitoring system;
- quasi-probabilistic models for slide probabilities evaluation .



The main forces in the assumption of rotational landslides

The entries in the modelling/simulation of slope stability cause outputs used in warning and forecast services.

Functional model for the landslide risk management decision-support system was designed in June 2006: functional structure, arhitecture design for the landslide risk management (information) system and also software solution (database structure, types of on-line services to be offered with the help of the new technology).

The future objectives will be:

- Constructing a real-time data acquiring, analysis and decision-support technological platform for on-line observation of environment parameters and intelligent landslide risk management;
- Creating the GIS support for analysis (hazard map and risk map of the area in study according to the methodological norms from the Government Decision no. 447-10 April 2003)
- Elaborating an advanced landslide evolution forecast and assessment solution using:
  - experimental studies based on real data collections, software analysis integrated environments (Business Intelligence) and pattern-recognition for landslide evolution
  - probabilistic methods
- Constructing landslide risk management services
- Real-time reporting for decision factors and for the population, on fixed and mobile devices.

5. Expected results

We expect a significant result that implies developing the technological support for online observation of environmental parameters, illustrating the evaluation and prognosis of the risk to landslides. The project is based on a modern and complex data acquisition system, wireless communications, GIS technologies and integrated software environments (Business Intelligence) which will perform data mining over real, historical information and probabilistic simulation methods.

The **expected results** are the following:

- functionality remote control of the surveillance devices installed in high risk land slide areas;
- permanent monitoring of landslides, through online interpretation of data captured from the movement transducers and level sensors of the ground water;
- creating digital maps with specific thematic layers for a hazardous area;
- using GIS technology in order to create risk and hazard maps;
- a relational database with specific content in order to manage the sliding risk within the pilot area;
- developing software tools for risk managers so they can create alarming and civil protection strategies;
- controlling and coordinating the evacuation activities - through real time access facility for population (on mobile devices).

6. Expected benefits

The expected benefits are the following:

- decrease vulnerability of areas threatened by land slides;
- locating the vulnerable areas, where normal variation range of the parameters is exceeded, and presenting them on digital maps;
- estimation of sliding periods, based on experimental studies and probabilistic modeling, presenting the evolution on digital maps and evolution diagrams;
- generating alerts in concordance with the alarming procedures;
- online informing and citizens education regarding the effects of destroying the ecosystems and the measures that must be taken in case of natural disaster;
- environment protection and lasting development of high risk land slide areas;
- national monitoring systems could be integrated within the European Informatics System regarding alarming strategies in hazardous situations.

Return of investments in landslides risk management can be on long term, but postponing these investments can have catastrophic individually, locally, regionally and even nation-wide effects.

7. Economical and social effects:

- decrease of material damage through prevention and evacuation coordination measures decreases the number of casualties in crisis situations
- improve people's health in the high risk areas through reduction of stress
- reduce high risk habitats by implementing environment protection measures

The results of this project will be also used within other high risk landslides areas, and will be integrated within an nation-wide network for environmental monitoring, evaluation and prediction of natural disasters.
Developing this project will ensure the necessary experience in order to implement new projects within the European 7th Framework Program.

8. Conclusions

The key for avoiding the risk is knowledge and decision. The risk can be accepted, unaccepted, tolerable or intolerable. The decision is to be taken upon the unaccepted and intolerable risk.

This project has from the very beginning the support of the Suceava authorities, interested in intelligent administration of the risk of the hill where Throne Fortress of Suceava was built and the northeast slope landslides. This consortium has elements in fundamental and applicative research regarding the shaping and the prediction and also in equipments for acquiring environmental parameters, analysis, alarming and coordination of the activities for evacuation and goods and human lives salvaging.

We can say that we can offer a solution based on self-research, conforming to the needs of the zone that can be tested at the beneficiary with minimum configuration. Further costs, due to the expand of the monitored zone, will be supported by other finances.

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