MITIGATING NATURAL HAZARDS RISK TO INFRASTRUCTURE OPEN ANALYSIS TOOLS

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1. Introduction

Losses to infrastructure assets due to natural hazards are a heavy burden both on developing and developed countries. Recent statistics suggest that natural disaster risks to infrastructure are on an upward trend. Data from the EM-DAT[2)] and the Munich Re NatCatSERVICE[3)] suggest that the intensity and damage caused by natural disasters is rising as a result of the increase in human-induced vulnerabilities to the infrastructure assets and climatic uncertainties. According to data from the World Bank, during the 1990s, the cumulative loss of economic assets due to natural disasters is estimated at 2.5% of 2000 GDP for China, 5.2% for Bangladesh, and 15.6% for Nicaragua[4)]. Developing countries are very susceptible to the damages caused by natural disasters due to their limited capabilities to assess and mitigate the hazards. Left aside the direct damages caused by the natural hazards to the developing countries, indirect damages that can have long lasting negative effects on the regional and national economies such as diminish in employment capacity, disturbances on the trade balance, foreign indebtedness, damage or loss of natural resources, tourism, etc, are commonly observed[1)]. The effects of indirect damages are typically longer lasting and more difficult to alleviate. The loss from natural hazards affects network infrastructure (e.g., bridges, power transmission lines, roads, etc.) not designed for the impacts of earthquakes and floods. The building infrastructure is probably the most vulnerable asset class. The two major earthquakes in Turkey in 1999, for example, killed over 17,000 and damaged some 23,400 buildings.[4)].

Global development organizations that are concerned with the improvement of life standards and the reduction of poverty in the developing world, such as Multilateral Development Banks (MDB), invest in infrastructure projects in developing countries. The increasing amount of losses caused by natural hazards in the developing world has caused MDB's to view natural hazard risk mitigation from a new perspective. Traditionally, structures are designed per standard design code requirements.

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The main purpose of normal building design codes is not to eliminate all damage given a major natural hazard (e.g. an earthquake)[5)]. Rather, the code's purpose is to prevent major loss of life with significant damage being an acceptable consequence, if there are not a great number of casualties. The total loss, i.e. direct plus indirect losses such as business interruption, becomes very significant. As a result, the need arises for assessment of the loss that can be caused by natural hazards and ways to mitigate that loss. Currently, some methodologies for estimating natural hazard risk to infrastructures exist (e.g. HAZUS-MH), although they are limited to selected regions. What is lacking are broadly available tools for rapid and transparent estimation of natural hazard risk to infrastructures, that can provide mitigation solutions both at early stages of planning as well as in later stages of investment.

This paper presents an approach in developing user friendly computer based tools to be used at the early stages of planning for mitigating natural hazard risk to infrastructure. A global application recently developed is discussed as an example. The paper is organized as follows. In section 2, the approach in developing user friendly computer based tools that estimate the natural hazard risk to infrastructures is presented. In section 3, two open source software solutions that were developed with this approach are presented. Finally in section 4, concluding remarks and suggestions for future research are presented.

2. Open-Source Risk Software

Risk analysis is a crucial and necessary step towards understanding and mitigating natural hazard losses. Currently, risk analysis tools exist but are inflexible and not responsive to the user needs due to their lack in transparency (closed source - proprietary). In addition to that, global risk analysis tools are virtually inexistent. There is an emerging need for natural hazard risk analysis tools that can be developed rapidly and transparently and allow users to customize them to their best needs. Open risk analysis tools can provide both flexibility transparency and customizability to the users.

Open source/free software has been around since the early 1970’s. The open source software community created software that is reliable, inexpensive and transparent to the users. Open source software such as the GNU/Linux operating systems, the Apache Web Server, the Open Office, and the PostgreSQL relational database are increasingly gaining market share against their proprietary competitors. Open source refers to the software whose source code is made available to everyone to use or modify as needed, thus providing transparency. In contrast to that, proprietary (or closed source) software does not make the source code available to the users. The open source model allows collaboration of developers from all over the world thus enabling rapid development of software and fast effective elimination of programming bugs. In addition to that, the open source model harnesses the creativity of the global community of developers by allowing those that are truly interested in the development of specific software to participate. There are several papers in the literature that discuss the merits of open source software where the reader is referred to[6)-7)].

3. Case Studies

This section discusses two case studies.

(1) MIRISK - Mitigation Information and Risk Identification System

The Mitigation Information and Risk Identification System (MIRISK) was developed by the authors of this paper at Kyoto University. In summary, MIRISK provides information on natural hazards design guidelines, norms and good practices by allowing users to identify the natural hazards related to a development project, the typical vulnerabilities of each infrastructure and to recommend a normal design and mitigation plan for each infrastructure asset. MIRISK is designed to be a computer-based analytical guidance tool for infrastructure risk assessment and mitigation to aid the decision makers in reaching optimum decisions by helping them to consider natural hazards by (i) identifying natural hazards affecting a region, (ii) defining the kinds of infrastructure assets that make up typical development projects, (iii) describing the vulnerability of these assets to natural hazards, and how vulnerability can be reduced and (iv) analyzing the natural hazards and vulnerability data, to assess whether projects should follow normal design practices, or whether the cost of some enhanced design for natural hazards is justified by the benefits (of avoided losses).

In order for MIRISK to be able to serve several users at several locations conveniently and to be easily accessed and updated, it was decided to be build in a client-server environment. MIRISK comes with a comprehensible tabbed interface in order to facilitate ease of learning and convenience of use. For the making of MIRISK only Open Source software was used. The structure as well as screenshots of MIRISK in action can be seen in Figure 1.

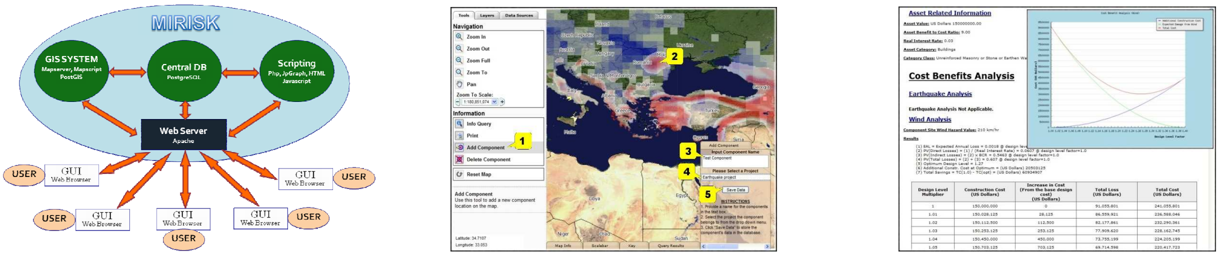


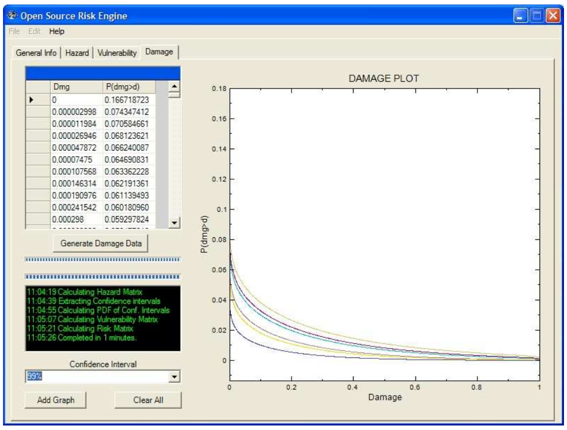
Figure 1: MIRISK structure (left), MIRISK GIS GUI (middle), MIRISK typical output (right)

MIRISK consists of several components. Central to MIRISK is a relational database which stores all the data needed for the deployment of the tool including geographical data, hazard description, asset vulnerabilities and mitigation data as well as data provided by the users to be used for a simple cost benefits assessment. In order to effectively provide natural hazard maps and other geographical information to the users to assist them in locating the site of a future project and identifying the hazards that exist at the site, a GIS system was designed which is closely integrated with the relational database and the other components of MIRISK. The graphical user interface (GUI) of MIRISK, the analysis module as well as data handling and calculation interfaces are deployed using Open Source scripting languages such as PHP, JavaScript and HTML. The scripting languages act as the glue that binds the components of MIRISK together. MIRISK resides at a web server and the users can access it by simply using their web browsers, such Firefox or Internet Explorer.

The analysis module of MIRISK aims to provide a quantitative estimate of incremental cost given project design level, cost of repair, duration of disruption, and benefit cost. The module provides general information on the costs of such ‘normal’ and ‘superior’ design and tabulates the overall costs and benefits for direct and indirect impacts such that the output could be used in a project planning document.

(2) OSRE - Open Source Risk Engine

The Open Source Risk Engine (OSRE) has been developed in Kyoto University, since 2005. It is currently in its third version. The purpose of OSRE is to develop a multi-hazards open-source software that can estimate the risk (damage)



of a particular site (object) given a hazard and the vulnerability with their associate probability distributions (i.e. confidence bounds). The original project team was made up of Christakis Mina, Masaki Higuchi, Koichiro Danno, Puay How Tion and guided by Professors Scawthorn, Kiyono and Ono. The main reason for choosing to disseminate the project as an Open Source software is to give access to engineers, programmers, researchers and educators from around the world to develop and enhance the program freely and keep it free for all to use. Using the Internet interested parties can read, redistribute, and modify the source of the software. The software becomes "alive" and keeps evolving "at a speed that, if one is used to the slow pace of conventional software development, seems astonishing". Figure 2 is a screenshot of OSRE output showing the damage curve with its confidence bounds

4. Conclusions and Future Research

In this paper, a new approach in developing user friendly computer based tools to be used at the early stages of planning for mitigating natural hazard risk to infrastructure was presented. The damage to infrastructure due to natural hazards is a heavy burden on a global scale. Risk analysis is a crucial and necessary step towards mitigating natural hazard losses. The current risk analysis tools are inflexible and not responsive to the user needs due to their lack in transparency. Open risk analysis tools that provide both flexibility and transparency are needed. In this paper two software applications that were developed using the open risk approach were presented. The open risk approach is currently at its early stages. In the near future a variety of open risk analysis tools will be required, utilizing more detailed data and thus requiring more researchers to be involved in the making process.

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