An approach to assess suitable lands for disaster mitigation

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Abstract

This paper describes the goals, approaches, methods and results of the project ACDRS, Approaches and Criteria to Designate Relocation Sites for disaster prone areas. ACDRS was funded by the Urban and Rural Development Branch, Construction and Planning Agency of the Interior Ministry and is a part of the research program "Enhancing Innovation and Implementation of Disaster Reduction". ACDRS reviewed the relocation projects of the 921 Earthquake to identify key factors for successful relocations. Those factors were further developed as criteria and adopted the concept and advanced techniques in disaster risk management and GIS land suitability analysis to assess safety of lands for relocation and develop land-use strategies to meet disaster risk reduction and mitigation requirements. The results of the project include strategies and standard operating procedures for relocation development, in addition to assessments of safety of lands in disaster prone areas and their suitability of relocation purposes.
Keywords: disaster, uncertainty, vulnerability, risk analysis, suitability analysis.

1 Introduction

Experiences from the 921 Jiji Earthquake [1, 2] in Taiwan and devastating disasters worldwide give an important lesson that the time factor in disaster recovery and reconstruction management is critical. Rehabilitation, resettlement, relocation typically merge into a lengthy, complex process. Well-designed strategies and standard operating procedures (SOP) for relocation projects with commonly accepted, readily accessible relocation land assessments can significantly simplify and shortened the process. This is the underlying

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motivation of the project ACDRS, which stands for Approaches and Criteria to Designate Relocation Sites for disaster prone area. ACDRS was a project within the research program called "Enhancing Innovation and Implementation of Disaster Reduction" funded by Taiwan government in year 2008–2011.

Project ACDRS adopted the concept and advanced techniques in disaster risk management and GIS land suitability analysis to assess land safety for relocation and develop land-use strategies to meet disaster risk reduction and mitigation requirements. The project started with an initial risk analysis framework for assessing the safety of lands in disaster-prone areas and their suitability of relocation purposes. The framework was then enhanced during the project with a broad range of databases, including databases on debris flows, landslide and flood disasters databases, as well as 2009 National Land-use Census data.

Debris flow, landslide and flood risk maps of disaster-prone areas in Taiwan were generated based on four vulnerability measurements made of the areas by the project. The risk maps, presented later in the paper, enable the identification of villages in Taiwan with high risk of debris flows, landslides and floods. A hundred of the high risk villages were surveyed to collect further detail information at community scale for safe relocation sites designation purposes. The results of the project are integrated into a Virtual Relocation Land Reserved System (VRLRS). The system of databases, containing official land assessments and administrative standard operating procedures to get information on relocation sites, can provide rapid responses to requests for rehabilitation, resettlement or relocation lands for displaced disasters' victims.

Following this introduction, the remainder of the paper is organized as follows. Section 2 discusses factors of relocations that must be considered. Data on disaster risks acquired during map making process contains uncertainties that can degrade the quality of the resultant risk map. Section 3 presents the types of uncertainty and approaches taken to reduce them. Sections 4 and 5 present the results of the project, including VRLRS, sample disaster risk maps, and so on. Section 6 summarises the paper.

2 Factors of relocation

The objectives of post-disaster relocation [3, 4] can range from merely the restoration of communities and livelihood of people in them to stimulation of drastic changes that can improve rather than merely to restore pre-disaster living standard and social conditions. Our land assessment and risk analysis methods take into account of the primary objective of each relocation project as well as the six factors that can affect the chance of success of the project. The factors are presented here in two groups. The first three factors are institutional legislation, location safety, and financial feasibility. The second three factors are surviving victims' social and culture connections, economic vitality and awareness and willingness.

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2.1 Factors affecting planning and implementation of relocation projects

Planning, implementation and administration of every post-disaster relocation project depend directly on regulations and institutional procedures of authorities involved in relocation affairs, as well as location safety and finance feasibility. In most parts of the world, relocation projects typically face numerous regulations governing land use and constructions. For example, in Taiwan, lands for relocation must be in the “Residence” category. To get approval for changing the zoning category of a chosen land from non-residence category to residence category, a relocation project must deal with rigid regulations and lengthy procedures. Similarly, the project would be required to submit environment impact statements or evaluations in order to get construction licenses, if the chosen relocation site were in hillsides or environment sensitivity area. By providing GIS information on ecological and culture landscapes, disaster sensitivity maps, etc., our VRLRS aims to support the identification of lands unsuitable for relocation for these reasons.

Location safety is another important consideration. Our land assessment and risk analysis methods start by identifying low disaster risk regions from maps of potential debris flows by Soil and Water Conservation Bureau, potential flooding depths by Water Conservation Agency and potential landslide areas by the Central Geological Survey [5–7]. We then confirm the safety of lands for relocation within the low risk regions by field surveys.

Relocation projects must be financial feasibility. Published statistics showed that more than 50% of relocation-project failures resulted from financial issues. For this reason, cost of lands for relocation must be taken into account. In Taiwan, this means placing high priority on land owned by governments or state-owned enterprises.

2.2 Factors affecting the well-being of surviving disaster victims

Social and culture connections are important for all surviving disaster victims. It is a particularly important factor for indigenous peoples. Taiwan’s indigenous groups have long history living in Taiwan mountain area, which attributes to their identities and living styles. Past experiences show that it was difficult to preserve indigenous culture when the sites of relocation were far away from the original villages. Our relocation land assessment methods assume that the closer the relocation site is to the original village, the higher the chance for social and culture connections to be maintained or rebuilt. The methods also take into account the accessibility to original villages.

Disaster victims usually prefer reconstruction at the same place rather than relocation. It is more acceptable for them if the relocation sites are relatively advantageous in providing them with their former types of job and work. Our methods take into account this factor by giving higher weights to lands closer to agricultures and industries and to locations nearer to home lands of the victims.

Finally, land ownership, family and neighbour ties are among reasons for victims’ desire to remain, even when their homelands are badly damaged and reconstruction is more costly than relocation. The information provided by our

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methods and VRLRS aims to support the challenging tasks of raising the awareness and willingness of victims to be relocated.

3 Data uncertainty

The risk maps based on land assessment may differ from the current situation because of uncertainty in the data used to generate the maps [8]. There are three kinds of uncertainty:

- Uncertainty in time and space: A disaster is dynamic. In contrast, the relevant GIS information on it (e.g., the hazard potential map published by Water Resources Agency, Soil and Water Conservation Bureau and The Central Geological Survey) is based on data taken at specific times. Differences between available GIS information and the current situation include disaster location, time, scope of influence and so on.
- Uncertainty in scale: For different types of disaster and the spatial extent of the planning process, the scale of existing map data are very different, including accuracy and unit size. Due to such limitation, a map may not provide the information of accuracy required in the development stage.
- Uncertainty in subjective and objective views: This uncertainty is the difference from analysis results and the local opinions. The relocation site suggested by risk assessment may not meet disaster victims' requirement.

In order to reduce uncertainties, we included field survey as an integral part of land assessment and risk analysis methods. Specifically, major elements of fieldwork are local interviews and field research as well as surveys of disaster types and current vulnerabilities of the locations and the current settlement status on record. This work in high risk villages is a part of the validation process.

Using data and information acquired first hand by researchers from interviews and meetings with people in each assessed area has proven to an effective means to reduce data uncertainty. Our current and future work on reduction of data uncertainty is supported by the Academia Sinica project OpenISDM [9].

4 VRLRS: virtual relocation land reserved system

As stated earlier, VRLRS provides relocation project planners and administrators and disaster victims with ready access to data and information on relocation land assessments and regulations governing urban and non-urban land development. It also provides SOPs for planners and administrators so that they can easily follow relocation development guidelines, regulations and best practices. In this way, VRLRS can help them launch relocation projects for victim villages of debris flow, landslide and flood disasters in the shortest time. The GIS databases, web services and tools were prepared during disaster-free period, and are continuously updated and maintained. Thus the databases can also contribute to disaster prevention or risk reduction for disaster-prone communities.

Specifically, in fieldwork, details on environment of each selected villages were observed and examined. Based on the accuracy of information thus collected, development guidelines and regulations in checklist forms were suggested. The forms also provides links to environment safety evaluation reports, environment impact statement/analysis, water and soil conservation plans, engineering geological surveys, that are needed to get the development permissions. Again, compared with disaster relocation/reconstruction projects are much more complicated, with much higher time pressure, than regular development projects. For this reason, it is important to establish a simplify administration procedure to coordinate the dialogs between various authorities in levels of community, local and central governments. This is another kind of support provided by VRLRS.

VRLRS is based on lessons learned from experiences gained from the 2009 Morakot Typhoon and the 921 Earthquake homeland redevelopment [10]. The process consists of the following four stages:

1. Identify and designate: In this stage, official GIS disaster information databases are used to generate disaster risk maps of Taiwan, which identify villages prone to debris flows, landslide and floods. The risk index of each village is then calculated. The results are risk distribution maps for these types of disasters in Taiwan. The next section will provide an example.
2. Pre-assessment: The goal of this stage is to seek suitable relocation land for a specified high disaster risk village based on available GIS map resources. The assessment of land location follows the principle of finding “the nearest suitable safe place”. Hence the priorities of relocation sites are within the village, the township, and then the nearest suitable lands, in decreasing priority order.
3. Vulnerability and safety field survey: The aim of the survey is to confirm the accuracy of pre-assessment and to designate the boundary of relocation sites, for each site, the results have location facts from field survey, not second-hand GIS data.
4. Guidelines and regulations for relocation development: based on the results of field survey on land safety and suitability assessments, guidelines and regulations of each relocation site alternative are developed according to the legislation entitled or required. Format and forms of zoning maps and legislation tables were designed accordingly.

5 Land assessments and risk maps

This section provides examples to our results and contents of VRLRS, mentioned in the previous sections.

5.1 Disaster risk map

The hazard and risk maps of debris flow, landslides and flood were derived using the disaster susceptible maps by Water and Soil Conservation Bureau, the

Central Geological Survey and Water Resources Agency respectively, overlaying with vulnerability map of population, land-use, public utilities and public facilities, including transportation network.

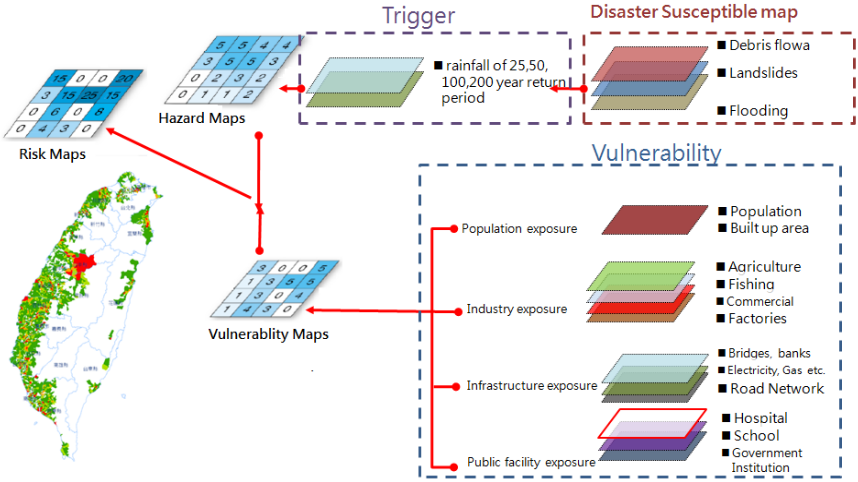

Figure 1: The debris flow risk map by villages.

The framework shown in Figure 1 explains how all the data come together in risk maps. The risk maps were further overlaid with village scheme map to obtain the complexity of disaster risks of each village and the worst risk value was selected to represent the disaster risk of the village. As an example, Figure 2 showed the spatial pattern of village debris-flow risk distribution, which indicates relative serious damage that local debris flows will cause to local villages.

5.2 Relocation land assessment

Based on the risk maps, top 100 high disaster risk villages were identified. Relocation land suitability analysis was applied to the 100 villages for the land assessment. The assessment, firstly, excluded the area under rigid developing controls of conservation or development-restricted zones by the 2nd overall review of Southern Regional Planning, considering the area is one of 19 environment sensitivity area. Secondly, settlement, industry, road network and public facility accessibilities were calculated spatially to illustrate the potential easiness of each land grid to access the village built environment. Figure 3 showed the map of the four accessibilities in the case of Xiaolin village. Figure 4 showed the process to present the accessibility map and the relocation site over Google Earth to examine topographic perspective of safety concerns, for example a table land is more resilient than valley land regarding to flood disasters.

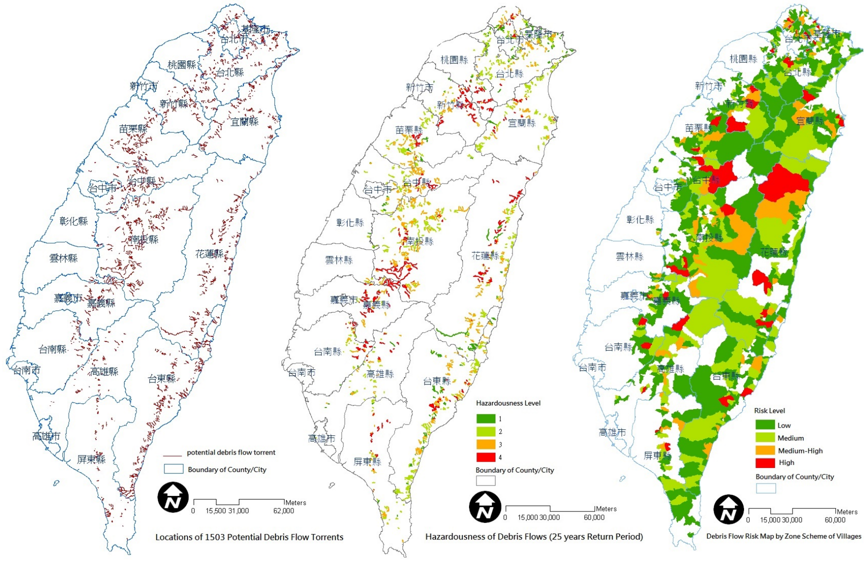

Figure 2: Series maps produces by debris-flow risk analysis.

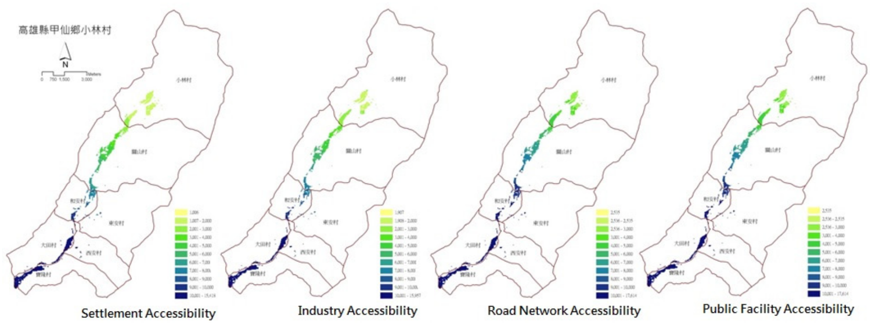

Figure 3: Accessibility map of relocation suitability assessment, Xiaolin village.

For the issue of data uncertainty and to confirm or to obtain the accuracy of the assessment at local community scale, a field survey on the type of disaster, the disaster affected area, the vulnerability of built environment and geological details was also designed [11, 12]. Figure 5 is an illustration of the geological map with the fact found during the field works.

Finally, profiles of relocation sites are produced. The comprehensive assessment lists contain the details of location in terms of X,Y coordinates, four accessibilities, land ownerships, land prices, land category, zoning regulation and land use are given.

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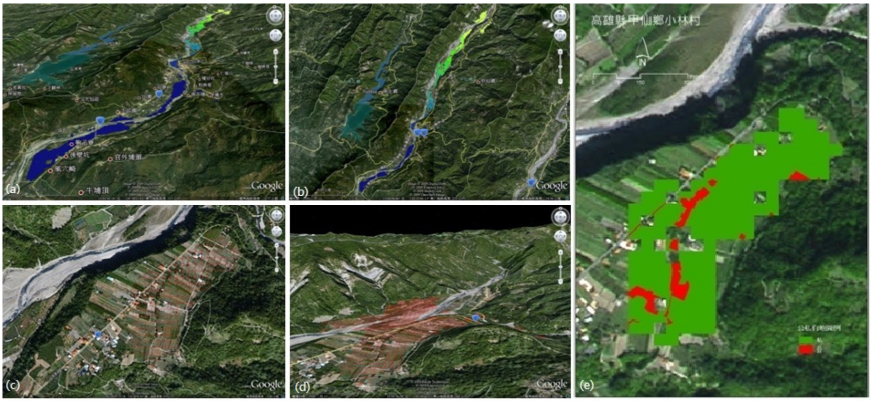

Figure 4: The accessibility map over Google Earth.

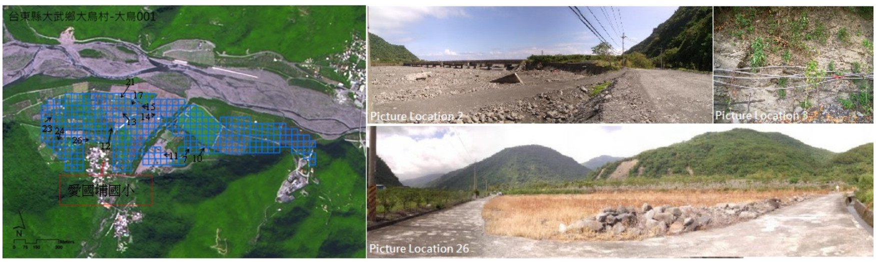

Figure 5: The geological map for field survey.

5.3 Web-GIS database

The presentation of the relocation land assessment information is also important [13, 14] in reducing the complexity of relocation projects for local authorities. Web-GIS technology is applied to meet the requirement that a platform to display the assessment data, information, pictures, imagines, documents etc. were established. Figure 6 is an illustration of the web-GIS platform. Figure 6(a) is the interface of the platform by Google Earth that provides as a geo-reference map engine to display disaster information as maps. Four types of maps can be queried, which are the map data used for assessing riskiness of villages, the hazardousness of villages, the riskiness of villages and the suggested relocation site for the top 100 riskiness villages. For the top 100 riskiness villages, the community level detail of environment dangerousness and suitability assessment for relocation by field investigation is also provided. Figure 6(b) is an example of Wulipu village's geological field investigation map, in which fragile geological spots are labelled with various illustrations. Besides, the profile of alternative relocation sites' information such as land ownership, land prices and land regulations etc. can also be queried.

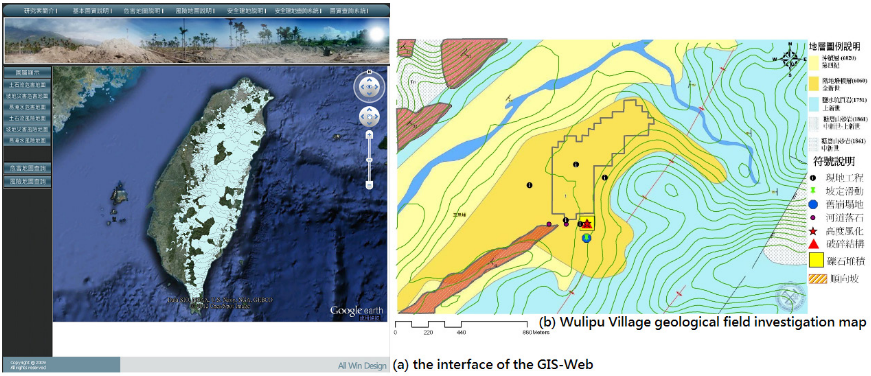

Figure 6: The Web-GIS platform.

6 Summary and future work

The virtual relocation land reserved system described in here is not just a land pre-assessment system; it is also a decision support system, as it provides relocation land assessments plus the SOP for relocation development projects. Such a SOP has four steps: (1) generate disaster risk maps and identify debris flow, landslides, flood prone villages in high risk area(s); (2) local land suitability analysis for relocation migration; (3) field survey to improve accuracy in safety and liveability assessments from village's perspectives; and (4) processes taken to conform to relocation guideline and regulation. The system allows relocation projects to follow the principle of "the nearest placement". In this way, it enables the projects to put the social and culture connectivity of affected disaster victims as one of the most important factors to consider in their choice of relocation site.

We note that from the viewpoint of disaster information uncertainty, disaster information in community level is particularly critical and vital for disaster prone communities. Official disaster decision support systems typically lack community level information. OpenISDM project is seeking IT solutions of issues of open disaster information resources, by which, the disaster information by private / individuals sectors can contribute to disaster prevention and mitigation. Our future study of using open data will focus on the uncertainty reduction, including the uncertainty characteristic of open data, measurement of the uncertainty, uncertainty reduction and efficiency assessment of the reduction processing.

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