(Section A: Planning Strategies and Design Concepts)

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Research and Practice on Disaster Prevention Planning in Villages based on Planning Support System

Overview: Potential public policies on spatial planning for sustainable urban forms A Case Study

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Abstract: Global geological hazards have brought huge losses, and the fast development in China is no exception. At present, China's hazard prevention and mitigation research and construction is mostly concentrated in the cities, while the rural, mountainous regions suffering the most serious damage and loss from geological hazards are neglected. In these areas, hazard prevention planning is missing or uses the city standard, lacking scientific analysis and theoretical support. Therefore, the study of disaster prevention and mitigation in remote regions is becoming more urgent. Existing studies on geological hazard prevention mainly focus on urban areas but ignore remote and rural areas where large numbers of people live. By drawing experience from disaster prevention and reduction in urban areas and incorporating effective scientific methods, this study aims to establish a planning support system for disaster mitigation to reduce the impact of disasters in rural areas on people and their property. The most significant contributions this research and practice offers is as follows. Firstly, the high-precision data of the villages, which is usually lacking and difficult to acquire, can easily and quickly be obtained by unmanned aerial vehicles (UVA) equipped with optical sensors and laser scanners. Secondly, combining high-precision data and the disaster evaluation model, geological disaster risk assessment technology has been developed for rural areas that addresses not only the natural factors but also human activities. Thirdly, based on disaster risk assessment technology, disaster prevention planning that has been constructed specifically for villages is more quantitative than before. Fourthly, with the application of a planning support system in disaster mitigation, a scientific and effective solution for disaster rescue can be achieved automatically. Lastly, this study selects a suitable area for implementation and demonstration, which can verify the feasibility and effectiveness of the system and enrich the knowledge base through a demonstration case. Based on the above research, a scientific hazard prevention strategy is put forward, which provides a scientific basis for decision-making and a support method for disaster prevention planning in villages.

1. INTRODUCTION

With rapid economic and social growth, the extent of geological hazard consequences increases yearly around the world (Hufschmidt, Crozier, & Glade, 2005). China has become the region with the highest frequency of geological disasters in the world according to the report released by the Emergence Events Database of the Global United Nations Development Programme (*Figure 1*). Statistics show that geological hazards leading to natural disasters are now the second leading cause of casualties in China, only after earthquakes (Peng & Wang, 2015), presenting a major challenge to the security of people's life and property. This situation is related to the specific geographical location and topography of China (Wu, Ren, & Niu, 2014).

Figure 1. The Influence of Natural Disasters Around The World by Emergence Events Database in 2010

According to statistics, 80% of casualties caused by natural disasters had were in rural areas; nearly 2 million houses have collapsed, with the majority in rural areas. Both the frequency of and loss from natural disasters in villages and towns are significantly higher than those in cities (M. Liu et al., 2015). In addition, most people live in villages in China, representing about 640 million according to 2013 census data. Most villages in China are located in mountainous areas with inconvenient transportation, relatively small economies and inadequate basic infrastructure. Compounding this problem, the development of disaster prevention planning in China is at a preliminary stage (H. Liu, Zeng, & Xu, 2014), and most of the research and disaster prevention and reduction construction has happened in city regions (McCall, 1998), meaning that the village regions, which are relatively more prone to the problems associated with geological disasters, are rarely involved. Therefore, the research of disaster prevention and control in villages and towns is particularly important and urgent.

Geological hazards are a type of natural hazard, defined by scientists as either the probability of a reasonably stable condition to change abruptly (Scheidegger, 1994) or as the probability of occurrence of a potentially damaging phenomenon within a given area and in a given period of time. The most common form of geological disasters are landslides, collapse, debris flow, and so on (Guzzetti et al., 1999).

As geological disasters have become more common, scholars and scientists around the world have increasingly taken to the study of disaster prevention and reduction (Liverman et al., 2001; McCall, 1998; Petro, Klukanova, & Kovacikova, 1997). From previous research, numerous studies have evaluated geological hazards and assessed geological hazard sensitivity or susceptibility (Lamelas et al., 2009; Muço et al., 2012). Those studies focused on the formation of geological disasters through relevant models, which led to the production of the prediction map for the probability of the occurrence of geological hazards (Fenton et al., 2014; Youssef et al., 2012). The recent trend is towards the development of warning systems (Ciampalini et al., 2015) and land utilization regulations aimed at minimizing the loss of lives and property damage without investing in long-term, costly projects for disaster prevention and reduction (Baban, 2009).

Compared to previous studies, this research investigates three novel aspects in the field. Firstly, the general terrain area for geological hazards is complex and basic data acquisition is difficult. In order to improve the accessibility and accuracy of basic data acquisition, this study uses unmanned aerial vehicles (UAV), equipped with optical sensors and laser scanners to obtain data. Secondly, the existing literature on disaster prevention and reduction is mainly concerned with urban regions (Bathrellos et al., 2012; Zhou & Zhao, 2013) and there has been little focus on villages and towns, despite its relatively greater urgency. Therefore, this study is aimed at the region of the villages and towns more prone to geological hazards. Lastly, a planning support system (PSS) has been used for disaster prevention and reduction in villages in this study. Studies show that planning support systems are mostly used for land use planning, assessment and planning of water resources and so on, where the application for disaster management and control is overlooked.

2. METHODOLOGY

"Define the problem, analyse the problem" has been the pattern of research of disaster prevention and mitigation in villages. *Figure 2* shows an overview of the content and methodology that is used in this study. The research process can be divided into three parts. In the problem definition phase, the main problems associated with disaster prevention and mitigation in villages are organised and summarised by collecting and analysing large amounts of material. For the main problems, specific techniques and methods have been used to analyse the cause of the problems and find solutions respectively in the last two phases. Four key technologies have been developed through the study flowchart, which can be described in detail as follows.

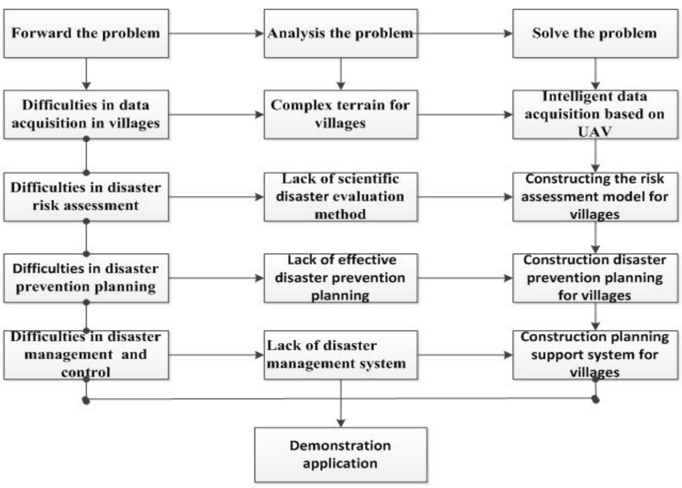

Figure 2. Flow Diagram of The Study

2.1 The intelligent acquisition and analysis technology of spatial data based on unmanned aerial vehicles

Unmanned aerial vehicles are a widely used efficient data gathering method. The unmanned aerial vehicle system (*Figure 3*) adopted in this research is composed of the following four parts, an Unmanned Aerial Vehicle (UAV) with a flight control system, a small digital camera, ground monitoring systems, and matched operating software. Route planning for the UAV was implemented using the TOPUAV plan (*Figure 4*), a professional route planning software. In order to ensure accuracy for the mosaic images, some technical indicators must be produced. First of all, adjacent photos must have at least 75% longitudinal overlap. Secondly, the adjoining flight line must have at least 50% lateral overlap. Furthermore, the image resolution of the lowest point in a flight block must greater than 0.2 m (*Figure 5* and *Figure 6*).

Figure 3. Electric Fixed-Wing UAV Platform

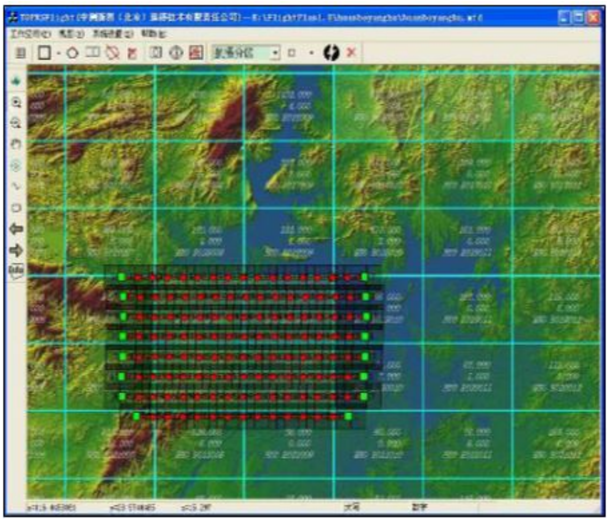

Figure 4. Route Plan Using TOPUAV Plan

Figure 5. UAV Route Planning of Case Area

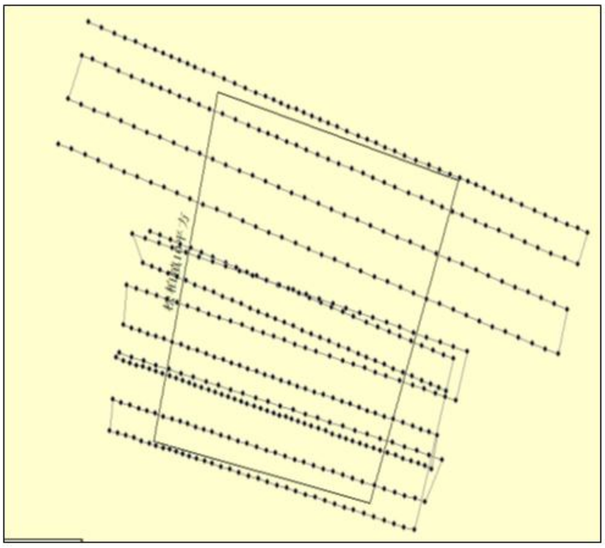

Figure 6. Ground Control Points Layout Scheme of The Case Study Area

The UAV platform used for data acquisition has a fixed-wing aerodynamic configuration. This UAV has the advantage of simple structure, it is light and strong. Ejection take-off can be achieved with a rubber band and landing by parachute, which means it can autonomously take off and land, reducing the requirements of the UAV operator. The UAV is highly flexible, can adapt to various complex conditions and can be quickly assembled in a short time. This UAV system is equipped with a digital camera system to obtain high resolution remote sensing images, which can provide the first remote sensing data for emergency mapping. The system can also be equipped with high-definition video capture equipment and a wireless digital image transmission system to rapidly capture comprehensive real-time video on the disaster or accident sites. Through the whole process of data acquisition and subsequent processing (*Figure 7*), the method can quickly access post-disaster terrain and ground object information, represented by the digital elevation model (DEM) and digital surface model (DSM). Therefore, this method has the characteristics of fast, flexible and efficient access to spatial information, especially in mountainous areas with complex terrain.

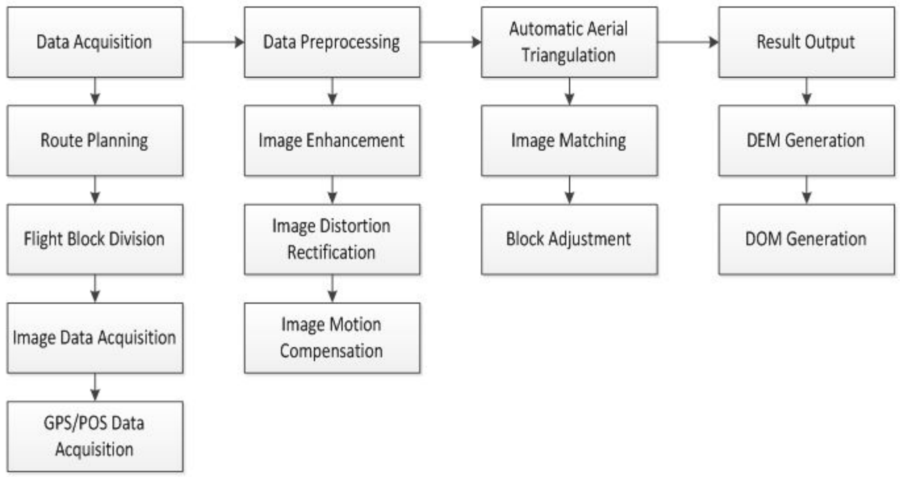

Figure 2. Geological Disaster Risk Assessment Technology in Villages

2.2 Geological disaster risk assessment technology in villages

High-precision data obtained by the UAV allows for new methods of studying the spatio-temporal distribution of geological disasters. This study investigated and summarised hazard-inducing factors from historical cases, including both factors from natural and human causes. Based on this data acquisition technology, multiple methods have been employed to quantify the risk of geological hazards. Those methods used to assess the risk of geological hazards have been detailed in *Table 1*. Unlike previous disaster evaluation, this research method has two significant aspects. First is the spatial autocorrelation analysis. In theory, geological hazards, as a kind of geographical data, exist in terrain that have a spatial dependence that has usually been overlooked. Therefore, Moran's I index has been adopted to determine the geological hazard's degree of spatial autocorrelation using GIS spatial analysis tools. Next is the application of the spatial autocorrelation model. This study compares multiple models, such as the spatial lag model (SLM) and the spatial error model (SEM). SLM and SEM are more suitable for analysis of disasters as dependent variables with spatial interdependence. Overall, the geological disaster risk assessment technology has been developed for rural areas.

Table 1. Disaster Evaluation Methods

Method	Content	Tool
Spatial autocorrelation analysis	Measure spatial dependence of geological disaster distribution	GIS
Correlation analysis	Measure correlation coefficient between factor and hazards	SPSS
Spatial regression model	Quantify the influence of disasters	GEODA
Logistic regression model	Measure occurrence probability of hazards	SPSS, GIS
Fuzzy comprehensive evaluation model	Measure the risk of hazards	GIS
Neural network model	Measure the risk of hazards	GIS

2.3 Database construction

Database construction is the basic work of the support system for disaster prevention and reduction. Databases can store and manage massive amounts of data and are therefore ideal for a planning support system of disaster prevention and reduction in villages that needs to store and manage high volumes of data.

In this study, the database should include not only the traditional spatial data, mainly remote sensing images, LiDAR point cloud data and the Digital Elevation Model, but also social and economic data with spatial attributes covering population distribution, administrative districts and the built-up area. Furthermore, it should include multi-resource data about stratigraphic lithology, landform partitions, and disaster prevention and reduction knowledge. Due to the diverse data sources, it is difficult to store uniform coded data and maintain updates. Meanwhile, data distribution and multi-user access also requires a new, consistent programmable solution to facilitate the various applications of the data.

This paper develops a multiple source database based on the ArcSDE for Oracle (*Figure 8*). As a major database engine for GIS, ArcSDE has the advantages of mass storage, multi-client concurrent access. Backed by Oracle's commercial Relational Database Management System (RDBMS), software performs better in terms of data integrity and consistency, as well as its advanced data management technology, such as asynchronous buffering, space index and multi-client concurrent access. The combination of ArcSDE and Oracle can not only solve the problems of storing, managing and quick access in RDBMS for spatial and non-spatial data, but also unify data encoding, data standard formatting and update mechanisms.

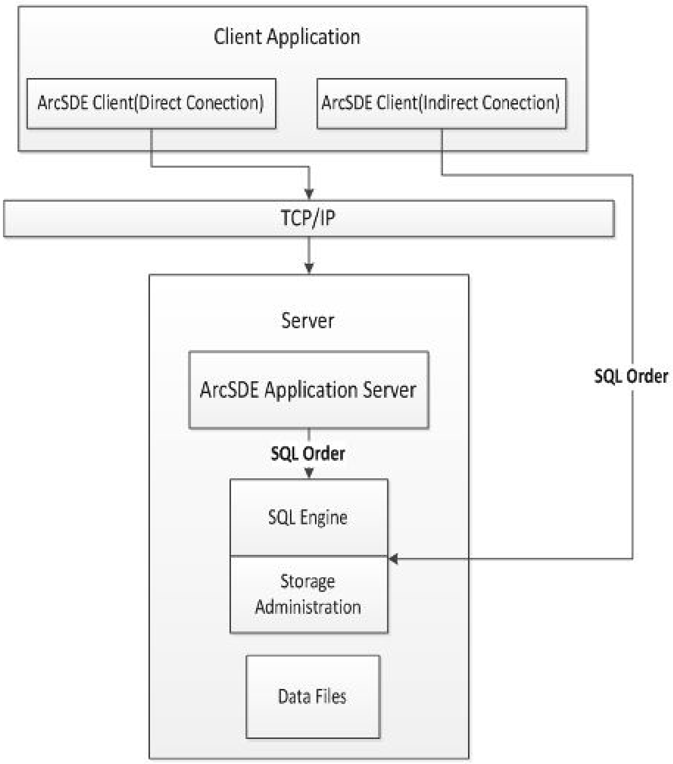

Figure 3. The Database Architecture Diagram

2.4 Planning support system for disaster prevention and reduction

By drawing experience and lessons from disaster prevention and reduction in cities and planning support system construction in urban areas and incorporating effective scientific methods, this paper establishes a framework for disaster prevention and reduction planning support systems in village-town areas. The main principle of the system is to maximally reduce the impact of disasters on people and property in those areas from the perspective of village-town planning.

For the system architecture, developers use an object-oriented approach to conduct system development. There is some background knowledge of planning and related disciplines incorporated into the system, and data interactions between the client and RDBMS server may be confidential. Developers therefore adopted the C/S system architecture (*Figure 9*) for this system development. Additionally, system developers use C# combined with ArcEngine to do integrated development.

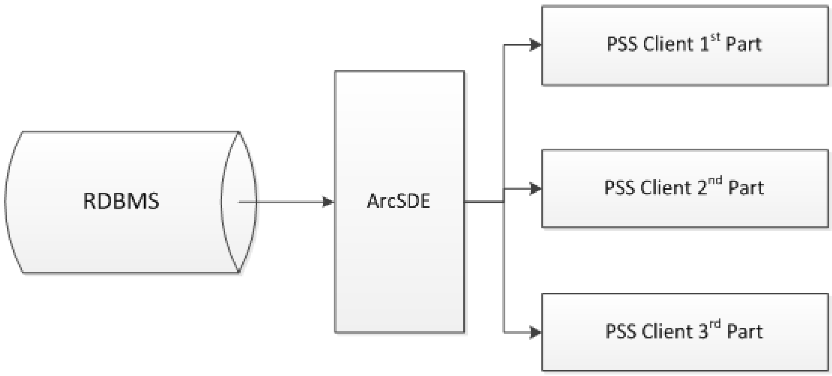

Figure 4. System Architecture Diagram

The planning support system includes the client presentation layer and business layer (*Figure 10*). The presentation layer's development is based on components provided by Windows, Net Framework 4.0 and ArcEngine (*Figure 11*). Developers strive to customise a set of interfaces for target users. In order to satisfy the demands of a particular user, the business layer uses the COM components provided by ArcEngine to conduct integrated development. The main functions of the business layer are as follows.

Database: the database includes the fundamental geographic database and case database.

Data input: this function can load many kinds of raster data and vector data, which can be recognized by ArcGIS.

Property edit: this function can add fields, remove fields and sort fields.

Graphics edit: this function can conduct graphics merging, graphics cutting, etc.

Map symbolisation: users can define the lines, font, colour, etc.

Spatial analysis: this function can conduct buffer analysis, superimposed analysis, path analysis and disaster risk prediction, and planning and decision-making.

Data output: this function can conduct format transmission such as raster, vector and CAD.

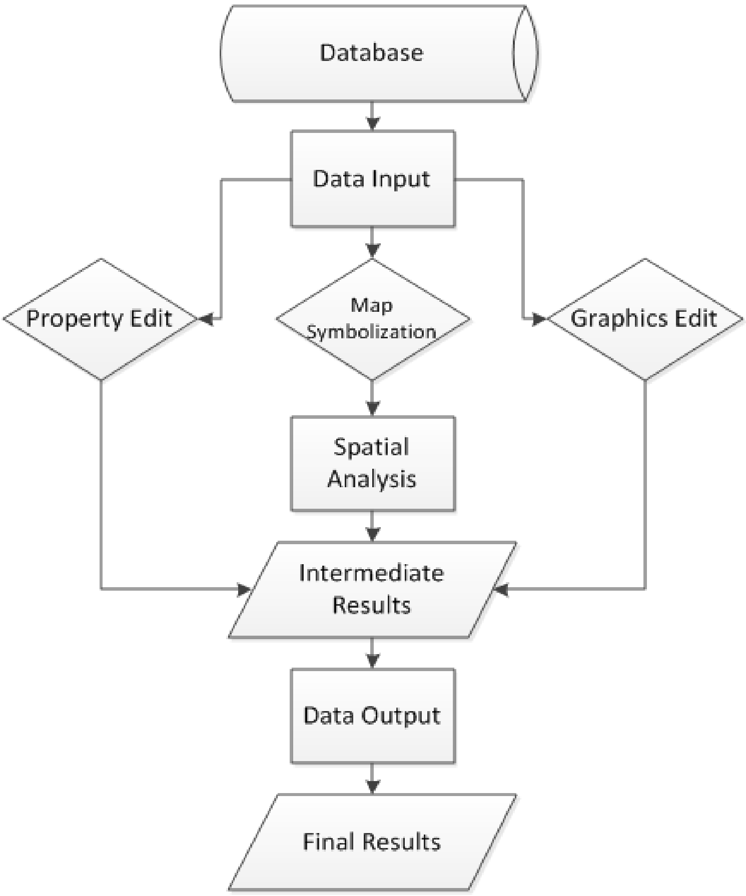

Figure 5. Working Process of The Business Layer

```
private void MainForm_Load(object sender, EventArgs e)
{
    //
    m_mapControl = (IMapControl3)axMapControl1.Object;
    m_tocControl = (ITOCControl2)axTOCControl1.Object;
    m_mapControl.Map.Name="图层";
    m_tocControl.Update();


    //

    if (item==esriTOCControlItem.esriTOCControlItemNone)
    {
        //当TOC中没有地图、图层时 属性查询显示为灰色
        this.Search_Menu.Enabled=false;
        this.SpatialAnalysisi_MenuItem.Enabled = false;
    }

    //disable the Save menu (since there is no document yet)

    menuSaveDoc.Enabled = false;
    //TOC右键菜单增加 添加数据功能
    m_TocMenu.AddItem(new ControlsAddDataCommandClass(), -1, 0, false, esriCommandStyles.esriCommandStyleIconAndText);
    //TOC右键菜单需要改变的是地图控件中的内容，所以地图控件相当于菜单的钩子
    m_TocMenu.SetHook(axMapControl1);
    //地图右键菜单增加 清除、复制、清除选择、属性表、识别功能
    m_MapMenu.AddItem(new ControlsEditingClearCommand(), 0, 0, false, esriCommandStyles.esriCommandStyleIconAndText);
    m_MapMenu.AddItem(new ControlsEditingCopyCommand(), 0, 1, false, esriCommandStyles.esriCommandStyleIconAndText);

    m_MapMenu.AddItem(new ControlsClearSelectionCommand(), 0, 2, false, esriCommandStyles.esriCommandStyleIconAndText);
    m_MapMenu.AddItem(new ControlsEditingAttributeCommand(), 0, 3, false, esriCommandStyles.esriCommandStyleIconAndText);
    m_MapMenu.AddItem(new ControlsMapIdentifyTool(), 0, 4, false, esriCommandStyles.esriCommandStyleIconAndText);
   // m_MapMenu.AddItem(new zoomtol, 0, 5, false, esriCommandStyles.esriCommandStyleIconAndText);

    m_MapMenu.SetHook(axMapControl1);//数据视图右键菜单需要改变的是地图控件中的内容，所以地图控件相当于菜单的钩子
}

Main Menu event handlers
```

Figure 6. Part of The Source Code of The Planning Support System

3. APPLICATION OF PLANNING SUPPORT SYSTEM FOR DISASTER PREVENTION AND REDUCTION IN CASE AREA

3.1 Case area introduction

China's geological environment is frail and it is subject to extreme climatic change. Compounding this, in the current period of rapid economic growth, construction projects increase continuously and blindly. This leads to increasingly frequent geological disasters in China. This is especially obvious in the case area, Shennongjia. Shennongjia is located in the western region of China's Hubei province (*Figure 12*), with a total area of 3,253 square kilometres and permanent resident population of about 76,700, as of 2014. Located in the eastern part of Ta-pa Mountains, Shennongjia is a typical mountainous area: limited by the terrain, the area is remote and poor, with villages and population distributed unevenly.

Figure 7. The Location and Geological Hazard Spot Distribution in The Shennongjia Area (Data Source: Shennongjia Land and Resources Bureau)

Based on the statistical analysis of past disasters, geological disaster is the most serious threat in Shennongjia. By 2014, there were 283 known geological hazard spots, mainly collapses, landslides and debris flows (*Figure 12*). The disaster scales are mostly micro and small, but the occurrences are frequent and wide ranging. Therefore, the study selects Shennongjia as the case area, which the planning support system for disaster prevention and reduction in villages is applied to.

3.2 Composition of planning support system for disaster prevention and reduction in the study area

The planning support system for disaster prevention and reduction in villages is the combination of planning and so called “3S” technologies (GIS, RS and GPS), which covers the plan scheme, socioeconomic indicators and the massive amount of spatial data. In the planning support system, a scientific and effective planning scheme for disaster prevention can be crafted intelligently. The system consists of a basic rural spatial information database, rural disaster base case, disaster risk assessment model-based case and rural planning support method-based case for disaster prevention and reduction, which is designed and implemented on a 3S technology integrated computer platform (*Figure 13*).

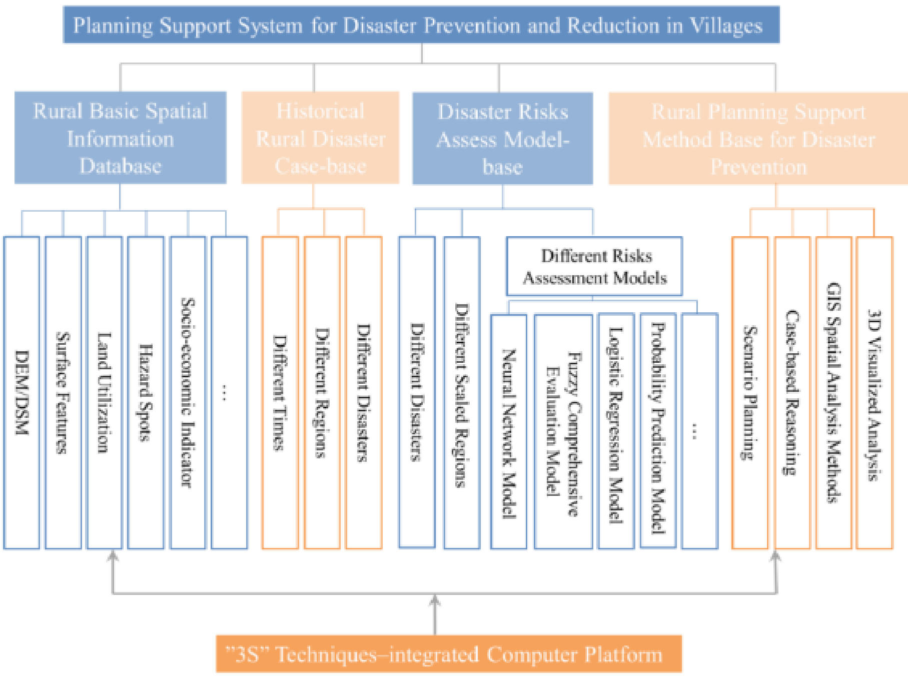

Figure 8. Structure Diagram of The Planning Support System for Disaster Prevention And Reduction in Villages

3.2.1 Basic rural spatial information database

With the aim of geological disaster prevention, the basic spatial information database of the case area was built in ArcGIS, and covers the distribution of geological disaster spots, topography-physiognomy information, geologic structural information, village construction map and detailed information of key areas (*Figure 14*, *Figure 15*, and *Figure 16*). The multiple-source data which was acquired by remote sensing image interpretation, field research, GIS spatial analysis and data mining, was efficiently stored and managed in the database.

	Data Set	Data Name	Data Content	Data Type
Shennongjia Area Basic Spatial Information Database	Raw Information	1. Topographic map of the whole region	Geographic, geomorphic and constructive information of Shennongjia area in 2014	vector
		2. Text notes of the whole region	Names of places, roads, rivers,lakes,vegetation,etc	vector
		3. Administrative division of the whole region	Boundary lines of villages and towns	vector
		4. Remote sensing images	Shennongjia area, Songbai town, Muyu town in 2014	raster
		5. 1:500 topographic map of Songbai township	Information of road, building, pipeline, etc of the township in 2014	vector
		6. 1:500 topographic map of Muyu township	Information of road, building, pipeline, etc of the township in 2014	vector
	Natural Element Information	1. River system	Information of river location and type	vector
		2.DEM, slope, aspect, curvature	The whole region: 10m precision The townships: 5m precision	raster
		3. Physiognomy	Geomorphology information	vector
		4. Denudation-planation surface	Denudation-planation surface information	vector
		5. Stratum lithology	Stratum lithology information	vector
		6. Geological fault lines	Information of geological fault lines	vector
		7.Engineering geological rock group	Character of engineering geological rock groups	vector
		8. Rainfall capacity	Month average rainfall in 2014	vector
		9. Vegetation coverage	Vegetation type and cover rate	
	Artificial Construction Information	1. Population distribution	Population of all villages in 2014	vector
		2. Road system	Information of road location and grade in 2014	vector
		3. Building	Distribution, structure, storeys and quality of buildings	vector
		4. Land use	Land use type and range in 2014	vector
		5. Socio-economic indicator	GDP, population, households, etc	vector
	Disaster Information	1. Geological hazard spots over the years	Location, type and scale of geological hazards(2005-2014)	vector

Figure 9. Basic Spatial Information Database of The Case Area (Shennongjia Area)

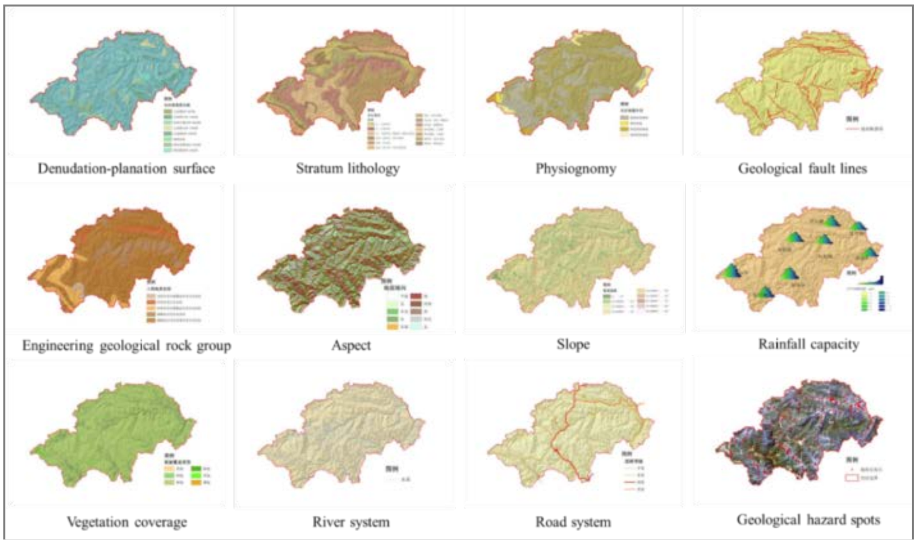

Figure 10. Content of Partial Data in Basic Rural Spatial Information Database

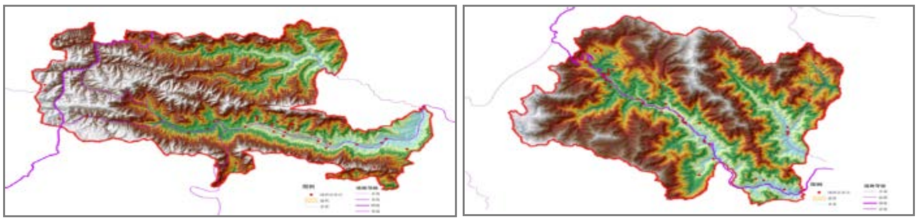

Figure 11. Basic Spatial Information of The Key Regions
(left: Songbai Town; right: Muyu Town)

3.2.2 Historical rural disaster base case

In accordance with the related research, the study selected landslide, collapse, debris flow, earthquakes and floods as objects of the base case and determined the different storage content for different disasters. Based on the principle of case selection, the research group has collected, classified and arranged 2,292 global disaster cases (1990-2016) from disaster bulletins, news reports and disaster databases (*Figure 17*), such as EM-DAT. The most direct function of the base case is to match the cases for references based on the retrieval demands of users, and knowledge extraction from the base case can contribute to the construction of the knowledge base. Based on the base case, general rules of disasters can be explored to develop strategies and and methods of disaster prevention and reduction.

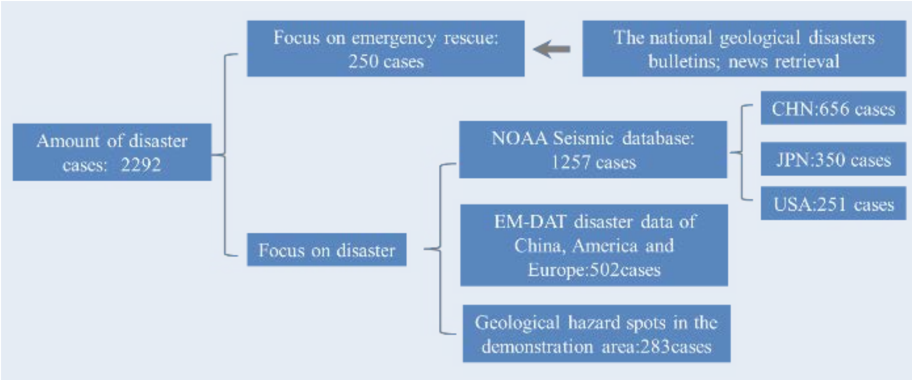

Figure 12. Composition of Historical Rural Disaster Base Case (Current)

3.2.3 Disaster risks assessment model-based case

The model-based case contains disaster risk assessment models for different disasters and different scaled regions, such as the fuzzy comprehensive evaluation model, neural network model and logistic regression model. The research contents of the disaster risk assessment include classified recognition of natural disasters, disaster probability prediction and vulnerability evaluation of hazard-affected bodies. With respect to the case area, Shenongjia, the study selects landslide, collapse, debris flow, earthquakes and floods to carry out the risk assessment (*Figure 18*).

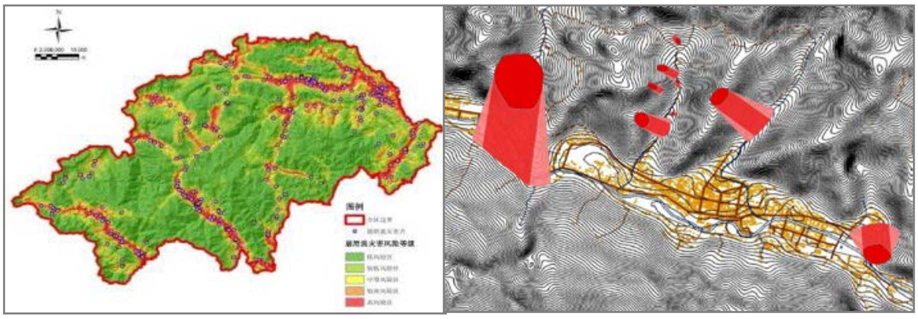

Figure 13. Results Based on Some Risk Assessment Models (Left: Binary Logistic Risk Assessment Model of Collapses, Landslides and Debris Flows in Shennongjia; Right: Prediction Research of Landslide Affected Area in The Key Region of Songbai Town)

3.2.4 Rural planning support method-based case for disaster prevention

The method-based case, which includes scenario planning, case-based reasoning, GIS spatial analysis methods and 3D visualized analysis, can support generation of a rural planning scheme for disaster prevention.

(1) scenario planning

In this study, the scenario refers to a certain situation, namely condition, background and circumstance, related to a disaster, such as the physical environment and socio-economic factors. Scenario planning requires analysis of the probability of disaster development. Since different inducing factors and different disaster intensities can lead to different disaster scenarios, which would differently impact villages, corresponding planning methods for different disaster scenarios must be supplied. In the method-based case, scenario planning steps aimed at rural disaster prevention include (a) scene factor extraction and knowledge representation, (b) initial scene building, (c) dynamic scene simulation.

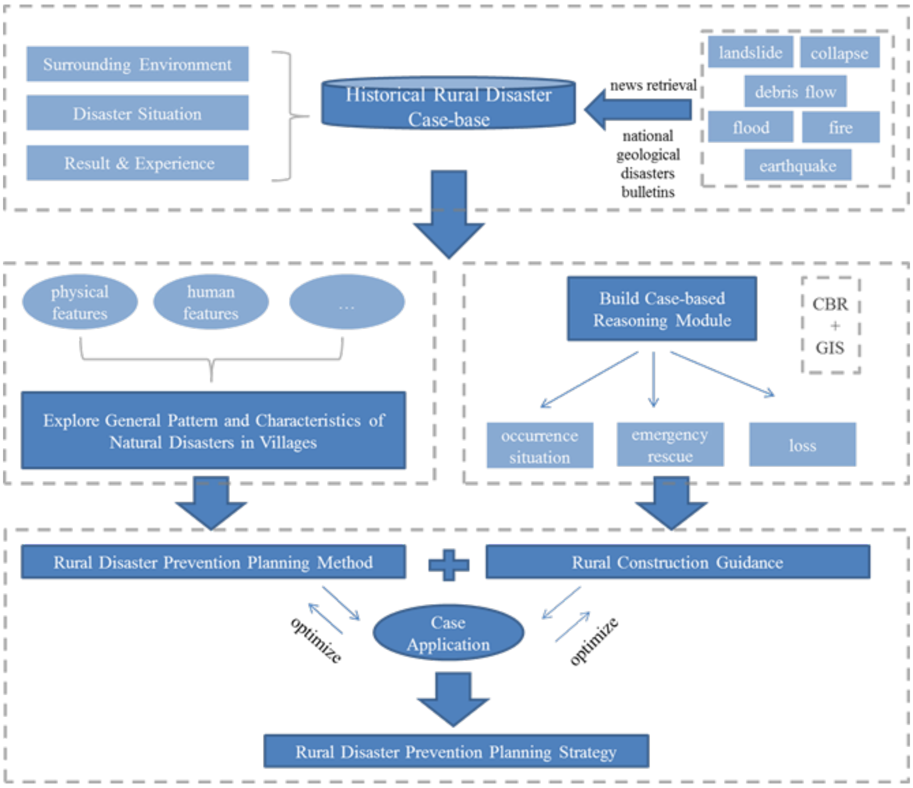

Figure 14. Research Strategy of Case-Based Reasoning

(2) case-based reasoning

As an important branch of Artificial Intelligence (AI), case-based reasoning, aimed at solving new problems by examination of existing experiences and cases, is a new learning mechanism and reasoning method. The historical rural disaster base case is an important foundation for the case-based reasoning. Once disaster occurs, based on similarity matching, solutions for the historical disaster case that is the most similar to the current disaster scenario would be selected as reference for emergency decision-making (*Figure 19*).

(3) GIS spatial analysis methods

On the one hand, GIS spatial analysis methods in the method-based case can be used to analyse the occurrence mechanism, development process and tendency of different disasters, to build a comprehensive disaster evaluation system and contribute to the prevention of disasters and reduction of disaster-related loss. On the other hand, the planning schemes for disaster prevention, such as emergency shelter layout and escape route organisation, can be generated by the GIS spatial analysis method using buffer analysis and shortest route analysis.

(4) 3D visualised analysis

3D visualisation is a significant technology used to dynamically display underground and ground features of topography and geology. In this study, 3D models and visual representation is based on LiDAR (Light Detection and Ranging) point cloud and remote sensing image data (*Figure 20*). The formation and development process of the disaster object is dynamically simulated. The plan and section of a landslide body, ground fissure, ground subsidence area and flood submergence area can be intuitively described by 3D visualisation, which would help related researchers and planners understand and analyse disasters better.

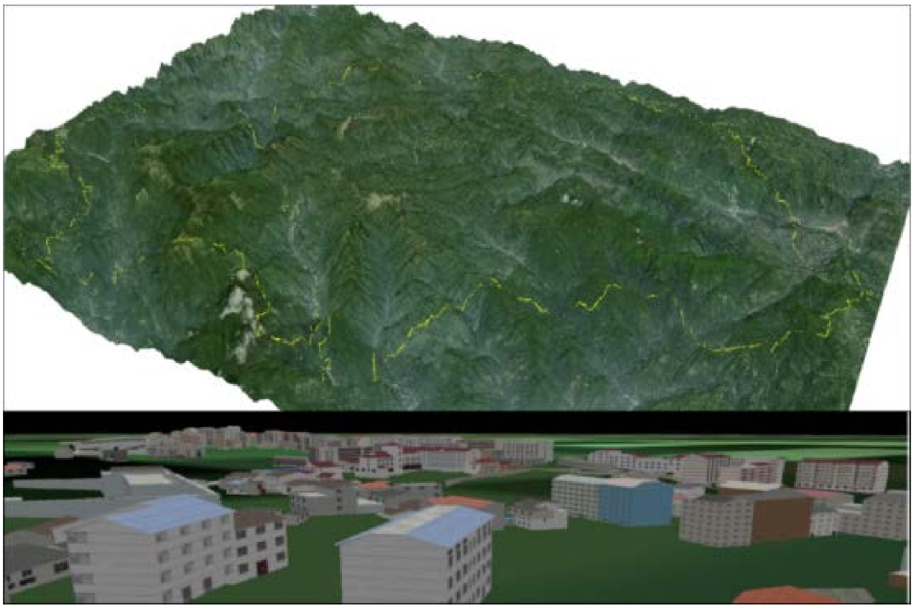

Figure 15. 3D Visualised Representation of Shennongjia

3.3 Planning support system for disaster prevention and reduction

The steps towards realising the system are as follows: (a) develop an automatic map drawing module using multi-source data, mainly from UAV measured data and LiDAR data, to build a basic rural spatial information database; (b) aimed at different disasters, develop a risk assessment module similar to the geographic information processing function in ArcGIS, to provide a risk assessment platform for basic data and automatic map drawing data; (c) construct a disaster base case and planning support method-based case, developing modules of scenario planning, case-based reasoning, GIS spatial analysis methods and 3D visualised analysis to assist decision-making and schemes of disaster prevention planning in villages (*Figure 21* and *Figure 22*). The main implementation methods contain C#+AE secondary development, automatic image registration, image segmentation and classification, multi-source image fusion, and generation of high accuracy DEM and DSM by LiDAR point cloud data.

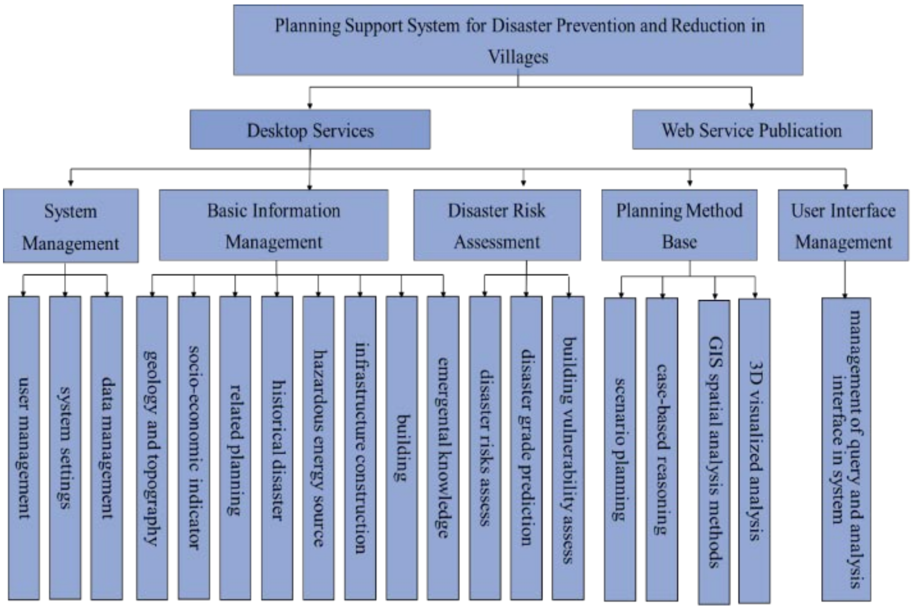

Figure 16. The Framework of a Planning Support System for Disaster Prevention and Reduction in Villages

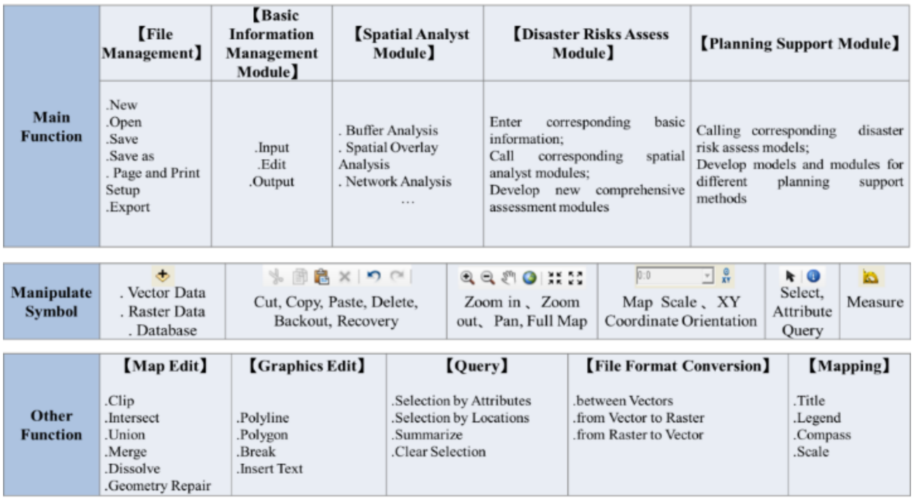

Figure 17. Main Functions of The System

4. DISCUSSION AND CONCLUSIONS

Because of the high frequency of the geological disasters in the villages of China, the work of disaster prevention and reduction is very meaningful in villages. In this paper, based on the case area of Shennongjia, which is a typical hilly and mountainous area prone to geological hazards, some conclusions could be drawn as follows.

1.Using UAV equipped with optical sensors and a laser scanner, rapid extraction methods and technologies for data-acquisition of the terrain, landform and construction, transportation and municipal facilities in rural areas have been developed. Those methods can either replace or improve solutions for acquiring data in villages.

2.In order to analyse the influence of geological disasters more scientifically, the risk assessment of geological disasters should incorporate multidisciplinary and interdisciplinary disaster research combined with the geological and engineering disaster database and case database. In this paper, evaluation models for geological disasters have been constructed that are more suitable for villages and towns in China based on a variety of mathematical models.

3. Disaster prevention planning theory and methods for the rural areas of China have been researched and developed in this study based on the actual situation of disaster prevention and reduction in villages. The disaster prevention planning is not only aimed at the special terrain and landform of villages, but also based on the disaster assessment model as above.

4. Distinguished from the general disaster warning system, this study constructs a support system for disaster prevention and mitigation based on the integration of 3S technology. The system can provide a full range of disaster relief programs which can quickly and effectively provide a scientific disaster relief program for rural areas.

5. Based on conclusions 1-4, the planning support system for disaster prevention and mitigation has been constructive for the case area, selected as a typically affected area. Through its application in the case area, the actual planning support system of disaster prevention and mitigation has been tested to verify the feasibility and effectiveness of the system.

Overall, this study clearly demonstrates the research on a planning support system of disaster prevention and mitigation with application in the Shennongjia area. Compared with previous studies, this study shows an obvious technical advantage for data acquisition using UAV in villages and towns. In addition, this paper has not only considered the influence of natural factors, but also the influence of human factors in the disaster risk evaluation, and based on the scientific disaster evaluation model, the method of disaster prevention planning is explored, usually lacking for villages and towns of China. Additionally, the application of the planning support system in disaster prevention and reduction has greatly improved the science and effectiveness of the disaster mitigation work.

However, any research has advantages and drawbacks, this study is no exception. On the one hand, the construction of the disaster prevention and mitigation planning support system is not deep enough: the number of historical rural disaster cases could be expanded and the interface of the planning support system further improved. On the other hand, Shennongjia presents only a limited number of case areas, so further studies should be done to select different types of villages to apply the planning support system of disaster prevention and mitigation.

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