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土石流家戶災害損失模型之建立

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【摘 要】

本研究依據國家災害防救科技中心 2005 年之坡地災害調查問卷建立土石流家戶損失模型。問卷內容包括家戶人數題組、家戶損失題組、受災經驗題組、風險知覺題組等，調查樣本為依據社會司所提供之坡地災害受災名冊抽樣而得，調查完之有效樣本共 241 筆。經分析得知土石掩埋的面積、掩埋高度、受災經驗、家庭人口數、建築材料、社區備災行為及住宅類型(純住宅)等因子與家戶損失均呈高度的顯著相關，因此本研究用以建立家戶損失的評估模型。此模型除了應用於家戶損失計算外，亦可透過各因子分析的結果提供有用的防災方法，例如：家戶損失的量化可提高居民的風險知覺，進而強化其備災行為；災害評估模組的建立便於政府進行各類防災工程之成本效益分析；透過災前家庭人口數的減少(災前的疏散難)或平時的社區備災工作(社區預警系統、水土保持工程)都可有效降低坡地災害對家戶造成的損失。

關鍵詞：土石流、山崩地滑、損失評估、脆弱性分析

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A Household Loss Model for Debris Flow

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【Abstract】

This study proposed a debris flow loss model using the data from a survey conducted by the National Center for Disaster Reduction (NCDR) (2005). The sample focused on a debris flow victim list provided by the social welfare department in Taiwan. In total, 241 victims were recruited, all of whom were the main financial supporters of their household. A set of standardized questionnaires containing information with regards to demographic background, financial damage and disaster experiences as well as risk perception were filled in by the participants.

A set of vulnerability indices for debris flow loss was used in the proposed model. They were the total area covered by the debris flow, the height of debris flow coverage, the experience of the disaster, the type of residential building, the number of people per household, the community disaster preparedness, and the type of construction material. The results of the regression model showed that all the variables included were statistically significant. The coverage area, the height of debris flow coverage, the number of past disasters, the number of people per household and type of construction materials (RC) were positively associated with financial loss. Furthermore, this study provides many useful policies for slopeland disaster prevention, such as quantifying household loss to help the public engage in disaster mitigation, assessing loss to help the government create appropriate policies and choose the best prevention-mitigation plans, evacuating residents who live in hazard-prone areas, community preparedness, and so on.

Key Words：Debris flow, landslide, loss assessment, vulnerability analysis

1. Introduction

From the aspect of the past history of disasters, whenever Taiwan suffers from serious typhoons or downpours, serious slope land sediment disasters follow, with heavy casualties and financial losses. Especially when climate variation is hard to predict, the influence of typhoons or downpours will be higher than usual. Typhoon Toraji struck Taiwan in August 2001. The heavy rain it brought caused debris flows and landslides in several places, with a total of 129 casualties, 299 totally collapsed houses and 85 partially collapsed houses. Typhoon Aere struck Taiwan in 2004, bringing heavy downpours in the north, northeast, central, and south of Taiwan successively. The rain led to a serious sloping field disaster in Taoshan Village, Wufeng Township, Hsinchu County, with more than 20 casualties and more than 20 houses being buried by debris flows. Both Typhoon Kalmaegi and Typhoon Sinlaku struck Taiwan in 2008 with the heaviest downpours in over a hundred years, causing serious disasters in south Taiwan, with 200 collapsed and partially collapsed houses. Typhoon Morakot struck Taiwan in 2009 with the heaviest downpours in over two hundred years, causing over 600 deaths. The most serious disaster happened in Xiaolin Village, Kaohsiung County. The number of deaths in this village was over 400, with over 100 buildings collapsed. In order to solve these kinds of problems and to reduce the impact of slopeland sediment disasters in the future, risk management becomes very important.

Generally speaking, complete risk management is done in three phases. Phase one is to understand the hazard potential. Phase two is to understand the impact and influences disasters may bring. The third phase is to come up with corresponding solutions. Every phase is important and essential. However, there have been numerous studies and actual cases related to hazard potential. In comparison, the influences disasters may bring and their corresponding solutions need to be explored more. Currently, solutions are usually proposed according to a roughly estimated impact on the range of influences. Only a very few of them are proposed after assessing the actual loss within the range of influences.

Therefore, some strategies may be costly due to imprecise assessments resulting in inefficient execution. Thus, this study focused on the evaluation of loss, especially for households with more serious damage, in order to improve the precision of risk assessment.

2. Reference

There are many studies on debris flow risk assessment or hazard assessment, such as Hürlimann, Marcel and Copons, Ramon et al. (2006), who presented a multidisciplinary procedure including geomorphologic and geologic analysis, scenario simulations, hazard assessment, and hazard mitigation to evaluate the debris flow hazard at a local scale. Chen, Chien-chih and Tseng, Chih-Yuan et al. (2007) proposed the method of minimum entropy analysis (MEA) to assess debris flow hazard. They applied this method to a dataset of debris-flow occurrences in Taiwan and successfully identified three relevant variables, i.e. the hydrological form factor, landslide area, and number of landslides, to the occurrence of observed debris-flow events during Typhoon Herb in 1996. Others have used numerical methods to simulate the hazard area of debris flow, such as Laigle and Marchi (2000), Liu K.F. and Huang M.C. (2006), Gwo-Fong Lin etc. (2006), and so on.

Those studies discuss the range of affected areas and the degree of danger for those areas, but rarely focus on the loss assessment of exposure. Only a few studies such as Pasuto, Alessandro and Soldati, Mauro (2004) have made use of an integrated approach including historical, geomorphologic, geostructural, meteorological and forest-management aspects. That study took into account the increased frequency and magnitude of recent events and considered the location of roads and buildings in the accumulation area. The risk conditions were analyzed in order to identify a risk zonation and to propose mitigation measures. H.Staffler, E. Berger and A. Zischg (2006) used empirical and physical models to calculate the hazard area, and used the results to estimate the probable maximum loss of buildings, including the number of residential persons and the monetary value. Liu and Li et al. (2009) utilized economic concepts to propose a reasonable estimation of the hazard damage and the cost of proposed mitigation measures. The proposed method is composed of four steps, namely delineating the area of the disaster with different return periods, itemizing the land use within those areas, calculating the hazard loss using official values, and computing the expected probable maximum loss with a probability distribution.

Other than Liu and Li et al. (2009), most literature adopts an engineering point of view to deal with value-wise discussions. In the engineering research field, losses were usually classified into direct losses, indirect losses, tangible losses and intangible losses (White, 1945; Parker, Green and Thompson, 1987; UN, 2002). However, the definition of engineering classification for losses was indeterminate, and confused the opportunity cost with financial cost, and the capital stock with capital flow (Van der veen and Logtmeijer, 2005). For example, most research regards building loss as a direct loss, butif the building is damaged and uninhabitable, although the repair cost or the building value decrease is regarded as a direct loss, the moving costs and the expenses for temporary living elsewhere are usually regarded as indirect costs.

In order to avoid the above pitfalls and make the concepts of economic cost clearer and more appropriate for estimation, Shaw et al. (2005) and Shaw et al. (2007) redefined and reclassified natural disaster damage based on welfare economics. They used the multiple linear regression method to build a flood loss model for Taipei County. Their model considers many vulnerability factors, and provides a good explanation for loss estimation. However, this model can only be used in Taipei County, and is not applicable in other areas. This study used similar methodology, but as different disasters have different situations and vulnerability factors, this study also considered slopeland disaster related vulnerability factors and the survey data of slopeland disasters, to build a household loss model for slopeland disasters.

Table 3.1. Information from the 2005 slopeland sediment disasters survey

Item	Content
Survey Duration	2005/3/1~2005/4/15
Typhoon Event	Typhoon Mindulle (2004/7/1~2) Typhoon Aere (2004/8/25) 911 Flash Flood Event (2004/9/11)
Survey Range	(1) Jianshi Township, Hsinchu County: Yixing Village, Yufeng Village, Xiuluan Village, Jiale Village, Meihua Village, Jinping Village, and Xinle Village. (2) Wufeng Township, Hsinchu County: Taoshan Village (3) Heping Township, Taichung County: Lishan Village, Daguan Village, Ziyou Village, Tianlun Village, Nanshi Village, Zhongkeng Village, and Boai Village (4) Ren-ai Township, Nantou County: Datong Village, Nanfeng Village, Cuihua Village, and Qinai Village
Survey Method	Household interviews (261 valid questionnaires, 241 questionnaires with actual loss)

3. Building a household loss model for slopeland sediment disaster households

3.1 Data from the survey of slopeland sediment disasters

In 2004, Typhoon Mindulle and Typhoon Aere struck Taiwan one after the other, bringing heavy downpours in the north, northeast, middle, and south of Taiwan, causing serious slopeland sediment disasters and several landslides. The most serious damage was caused by debris flows and landslides in Taoshan Village, Wufeng Township, Hsinchu County and in the mountains of central Taiwan. According to the statistics from the typhoon database of the Central Weather Bureau, 48 people died in these two events. A total of 26 people went missing, and numerous houses collapsed. The loss of agriculture, forestry, fishing, and animal husbandry was over 10 billion dollars. Thus, in 2005, the subjects of the questionnaire survey conducted by the National Science and Technology Center for Disaster Reduction were the main disaster areas in north (Hsinchu County) Taiwan and central (Taichung County and Nantou County) Taiwan (Table 3.1). There were261 valid samples (241 samples of households with actual loss) with a 95% confidence interval, and the sampling error was approximately 5.7%. The estimation method for different types of household losses is listed in Table 3.1.

3.2 Methodology

In statistical analysis, the multiple linear regression method is most often applied for understanding the relation between loss and other variables. The definition of multiple linear regression is “the expected value of variable Y is the linear function of Independent variable X_i， i=1,2,…,k, andε_i is the independent random error variable”. Assume the linear function hask+1 variables, Y and X_1,X_2,……, X_k, and X_i is k independent variables, Y is a dependent variable. The function of the regression model is show as equation (1).

$$\begin{bmatrix} Y_1 = B_0 + B_1 X_{11} + B_2 X_{12} + \cdots\cdots\cdots + B_k X_{1k} + \varepsilon_1 \\ Y_2 = B_0 + B_1 X_{21} + B_2 X_{22} + \cdots\cdots\cdots + B_k X_{2k} + \varepsilon_1 \\ \vdots \quad \vdots \\ Y_n = B_0 + B_1 X_{n1} + B_2 X_{n2} + \cdots\cdots\cdots + B_k X_{nk} + \varepsilon_1 \end{bmatrix} \quad (1)$$

Equation (2) is shown as a matrix.

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix} = \begin{bmatrix} 1 & X_{11} & X_{12} \cdots X_{1k} \\ 1 & X_{21} & X_{22} \cdots X_{2k} \\ \vdots & \vdots & \vdots \quad \vdots \\ 1 & X_{n1} & X_{n2} \cdots X_{nk} \end{bmatrix} \cdot \begin{bmatrix} B_0 \\ B_1 \\ \vdots \\ B_n \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix} \quad (2)$$

Then extract the smallest error of random error$\varepsilon_i$with the least squares method. $Q(B_0,B_1,\ldots,B_k)=\sum\varepsilon_i^2$. Carry on the partial differentialto$B_0,B_1,\ldots,B_k$, leads to equation (3) and (4).

$$\frac{\partial Q}{\partial B} = -2\sum(Y_i - B_0 - B_1 \times X_1 - \cdots\cdots - B_k \times X_k)^2 \qquad (3)$$

$$\frac{\partial Q}{\partial B_j} = -2\sum(Y_i - B_0 - B_1 \times X_1 - \cdots\cdots - B_k \times X_k) \times (-X_j) \qquad (4)$$

Assume $Q(B_0,B_1,..,B_k)$ equals zero (minimum) and the parameters $b_1,b_2,..,b_k$ are the leastsquaresvalue. Then the normal matrix is shown as equation (5).

$$\begin{bmatrix} Nb_0 + b_1\sum X_1 + b_2\sum X_2 + \cdots\cdots + b_k\sum X_k = \sum Y \\ b_0\sum X_1 + b_1\sum X_1^2 + b_2\sum X_1.X_2 + \cdots\cdots b_p\sum X_1.X_p = \\ \vdots \quad \vdots \\ b_0\sum X_p + b_1\sum X_p.X_p + b_2\sum X_2.X_p + \cdots\cdots + b_p\sum X_p^2 = \sum X_p.Y \end{bmatrix} \qquad (5)$$

This result shows that the normal matrix is a symmetric matrix. A is the coefficient matrix, shown as equation (6); B is a constant matrix, shown as equation (7).

$$A = \begin{bmatrix} n & \sum X_1 & \sum X_2 & \cdots & \sum X_3 \\ \sum X_1 & \sum X_1^2 & \sum X_1 \cdot X_2 & \cdots & \sum X_1 \cdot X_k \\ \vdots & \vdots & \vdots & & \vdots \\ \vdots & \vdots & \vdots & & \vdots \\ \sum X_k & \sum X_1 \cdot X_k & \sum X_2 \cdot X_k & \cdots & \sum X_k^2 \end{bmatrix}$$
$$= \begin{bmatrix} 1 & 1 & \cdots & 1 \\ X_{11} & X_{21} & \cdots & X_{n1} \\ \vdots & \vdots & & \vdots \\ X_{1k} & X_{2k} & \cdots & X_{nk} \end{bmatrix} \cdot \begin{bmatrix} 1 & X_{11} & X_{12} & X_{1k} \\ 1 & X_{21} & X_{22} & X_{2k} \\ \vdots & \vdots & & \vdots \\ 1 & X_{n1} & \cdots & X_{nk} \end{bmatrix} = X' \cdot X \qquad (6)$$

$$\mathrm{B} = \begin{bmatrix} \sum \\ \sum X_1 \cdot Y \\ \vdots \\ \sum X_k \cdot Y \end{bmatrix} = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ X_{11} & X_{21} & \cdots & X_{n1} \\ \vdots & \vdots & & \vdots \\ X_{1k} & X_{2k} & \cdots & X_{nk} \end{bmatrix} \cdot \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix} = X' \cdot Y \qquad (7)$$

Therefore thenormalequation matrix can be represented as $(X'X)b= X'Y$ or Ab=B. Among the matrix, $b=(b_0,b_1,..b_k)$ are unknowns. Under the condition of the coefficient matrix being non-singular, an $(X'X)$inverse matrixexists; therefore coefficient b may be obtained by type (8).

$$b = (X'X)^{-1}X'Y \qquad (8)$$

According to equation (8) the multiple linear regression model can be extracted, shown as equation (9).This research namely used equation (9) to carry on the study of the household loss model.

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \cdots\cdots + b_KX_K \qquad (9)$$

3.3 Structure of Model Variables

The household loss model for debris flow disaster households was built according to a risk assessment framework. For the independent variables, there were three important factors of risk assessment framework, including hazard, exposure, and vulnerability (Hsin-Chi Li, et al, 2009). However, exposure could be combined with vulnerability and discussed together, as exposure refers to the possible damage and range of disasters, and vulnerability is the quality and capacity of the systems fighting disasters. The relationship between exposure and vulnerability is like that between quantity and quality. They are two sides of the same item (Figure 1). Therefore, from Figure 1, it can be seen that the category of factors which should be taken into account for the loss model include hazard, exposure and vulnerability.

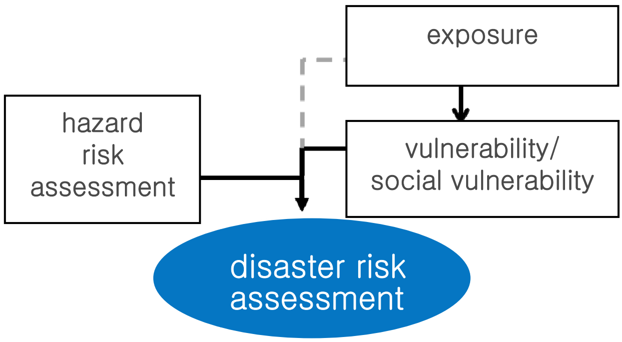

Figure 1. Risk assessment framework

For the dependent variables, this study used the variable of household loss. In the past, when estimating losses in the engineering research field, opportunity cost was usually not considered. The estimates were only from tangible losses. But according to the definition of loss in economics, complete loss shall be estimated with the concept of opportunity cost (H.C. Li, 2008, et al.). In Table 3.2, the estimation method of loss includes human capital and man-made capital. Besides real money loss, the loss of opportunity cost is also considered.

Table 3.2. Items of household losses from slopeland sediment disasters

Capital	Loss	Loss content		Estimation
Human capital	Human capital loss	Absent labor hours from employment		Opportunity cost
		Water Borne Disease or sickness caused by disaster	Medical expense	Restoration cost
			Salary decrease during sickness	Opportunity cost

Man-made capital	House loss	Repair expense for structural damage		Restoration cost
		Temporary living expense		Replacement cost
		Cleaning or repair cost for decoration, electricity and plumbing etc.	Salary loss causing by self cleaning or repair	Opportunity cost
			Cleaning or repair cost for hiring workers	Restoration cost
	Furniture loss	Repair or replacement cost for damaged furniture and electric appliances		Restoration or replacement cost
	Vehicle loss	Repair or replacementcost for damaged vehicles		Restoration or replacement cost
	Public loss	Shared cost of damaged public man-made capital		Restoration or replacement cost
Total Loss = Human capital loss + House loss + Furniture loss + Vehicle loss + Public service loss + others				

3.4 Model Building

Lastly, by referencing the data from the questionnaire and the estimation of loss, then discarding outliers, the household loss function for slopeland households can be built (shown as equation 10). The significance of the factors is listed in Table 3.3. The first field contains the independent variables of the model. The second field contains the original value distribution of every variable. The third field contains the coefficients of those variables. The fourth field contains the significance of the variables (p-values). When a p-value is less than 0.05 (with significance level of 95%), it means the corresponding variable can significantly explain the loss. The smaller a p-value gets, the higher the significance level would be, and the better the ability to explain the loss.

$$
\begin{aligned}
\text{LN(Total loss)} = {} & 9.36 + 0.603\ \text{LN(Height of debris flow coverage)} \\
& + 0.736\text{LN (Square measure covered by debris flow)} \\
& + 0.092\ \text{(Number of members per household)} \\
& + 0.210\text{(Disaster experience having been through)} \\
& - 1.015\text{(House type - residence)} \\
& - 0.231\text{(Community disaster preparedness)} \\
& + 0.451\text{(Construction type – RC material)}
\end{aligned}
\quad (10)
$$

In equation (10), “height of debris flow coverage (m)” and “square measure covered by debris flow (m^2)” are “hazard” factors. The higher the height of debris flow coverage and the larger the square measure being covered by debris flow, the more the loss will be. As these two variables are log values and their coefficients are significant, it means the marginal utility is diminishing. From the second field of Table 3.3, it is known the maximum height and covered area of the survey datawere18 meters and 991 m^2, which are the operative limits of this regression model.

Table 3.3. Analysis significances of factors

Independent Variables of the Model	Original Value Distribution (minimum to maximum)	Coefficient	Significance (p-value)
(Constant)		9.360	.000
Log height of debris flow coverage (m)	0.1m –18m	.603	.000
Log square measure covered by debris flow (m^2)	6.6 m^2– 991 m^2	.736	.000
Number of members per household	1 –15	.092	.009
Disaster experience having been through	1 – 9	.210	.001
House type- residence	90%residential	-1.015	.000
Community disaster preparedness	96%CP behavior (from 1 to 5 items)	-.231	.000
Construction type – RC material	24.7%RC material	.451	.010

The “Number of members per household” is an “exposure” factor. The more people in a household, the more the loss would be.

”Disaster experience having been through”, “house type - residence”, “community disaster preparedness” and “construction type (RC material)”are the “vulnerability” factors. The larger the number of disaster experiences having been through, the more the loss will be. If the chance of a recurrence of debris flow is high, and the stability of the slope toe or slope has been destroyed, a similar event might happen again. Therefore, areas with large “disaster experience having been through” numbers are disaster-prone areas. If residents of those areas do not move, the losses will climb as the number goes higher. The relationship between “house type - residential” and loss is negative, meaning if the house type is residential, then the loss would be less. In this study, households were categorized into “residential” and “non residential (including residential-commercial use and commercial use). The loss of stores is higher than that of household residences, due to the goods in stock. The relationship between "community disaster preparedness" and loss is negative. In a community, if the disaster preparedness work (preventative construction, conservation of water and soil, early warnings for the community, evacuation, etc.) is complete, the loss would be less. In the questionnaire, there were also questions about individual disaster preparedness. Although it is related to disaster preparedness, its influence on loss is not significant. The results showed that the focus of disaster preparedness work for debris flow disasters is on community disaster preparedness. The last factor is "construction type (RC material)", representing whether a house is made of RC material or not. The results showed that the cost of restoring RC houses is high, meaning the loss of those households is also high. The relationship between this variable and loss is positive. All the factors mentioned above have a significant influence on loss (with a significance level of 95%. For "height of debris flow coverage", "square measure covered by debris flow", "number of members per household", "house type - residential", and "community disaster preparedness", the significance level is99%).

The other factors in this questionnaire were not adopted due to their insignificance, except for "number of children under 12" being discarded, as it was highly related to "number of members per household", and "individual disaster preparedness" being discarded for being related to community disaster preparedness. In addition, many documents mention that "income per household" is an important factor for loss. However, this study did not have the same conclusion[1]. According to the results of the questionnaire, "income per household" is positively and significantly related to "construction type" (households with higher income can afford better materials).Therefore "income per household" was discarded.

Finally, the explanation power of this model was 55.0% (Adjusted R^2 =0.536). As a

[1] According to the experiences from previous surveys, households are usually conservative when they are asked about their household income. Analysis results would not be able to reflect the truth because of this reason.

social science survey model, this power was outstanding (Generally, Adjusted $R^2 > 0.3$ is acceptable).

4. Model Testing

There are many tests that can be applied to a regression model. They can be divided into three categories. The first type is used to test a regression model's significance. The second type is a test for collinearity. The third is residual analysis.

4.1. F test

The significance of a regression model's explanation power is generally tested with an F-test. The theory behind F-test is to use the ratio of variation between groups to variation within groups. This ratio is the so-called F value. The larger the F-value is, the more scattered the means of groups will be. If the F-value exceeds the cut-point, it can be concluded that the null hypothesis (H_0: Factors have no influence on the dependent variable) shall be rejected, and the alternative hypothesis (H_1: Factors have influence on the dependent variable) shall be accepted.

The F-value of the regression model from equation (10) was 39.979, which was higher than the cut-point of 99% significance level, as shown in Table 4.1. The results showed that the means of the groups were significantly different. Therefore the null hypothesis was rejected, meaning this model could significantly explain the variation of loss.

Table 4.1. Results of the F-test

Item	Sum of Squares	df	Mean Square	F	Sig.
Regression	336.181	7	48.026	39.979	.000(a)
Residual	275.095	229	1.201		
Total	611.276	236			

4.2 Collinearity test

If some variables are collinear in a model, regression coefficients would be influenced and the error would be larger. Therefore, it is necessary to check the collinearity before building a model. There are two types of collinearity tests: one is to test the collinearity of independent variables and other variables, and the other is to test the overall collinearity of the regression model.

4.2.1Testing the collinearity of independent variables and other variables

The theory behind the test of certain independent variable's collinearity with other variables is to evaluate the tolerance or variance inflation factor (VIF). The range of tolerance is from 0 to 1. Larger values represent smaller collinear problems. Generally, if the tolerance is smaller than 0.6, then there is a collinear problem. VIF is the inverse of tolerance. It is better if VIF is close to 1. If VIF is larger than 1.6, then there is a collinear problem.

Table 4.2. Diagnosis of collinearity between independent variables

Independent Variable of the Model	Tolerance	VIF
(Constant)		
Log height of debris flow coverage (m)	.813	1.230
Log square measure covered by debris flow (m^2)	.703	1.423
Disaster experience having been through	.963	1.038
House type- residential	.926	1.080
Number of members per household	.950	1.053
Community disaster preparedness	.919	1.088
Construction type – RC material	.844	1.185

The test results Table 4.2 showed that all the variables in equation (10)had tolerance values larger than 0.6, and most of them were larger than 0.9, and their VIF values were all smaller than 1.6. Thus, the collinearity problem for this model was small.

4.2.2 Testing the overall collinearity of the regression model

Diagnosing the overall collinearity of the regression model can be done using the eigenvalue (λ) and conditional index (CI). Generally, high eigenvalues represent minor collinearity, while high CI values show serious collinearity (Belsley, 1991). When the CI is lower than 30, collinearity is minor. When the CI is between 30 and 100, collinearity is from moderate to serious. When the CI is over 100, collinearity is very serious (Belsley, 1991; Belsley, Kuh & Welsch, 1980). The conditional number (CN) is the square root of the largest eigenvalue divided by the smallest one. The valuein the last row of CI(Table 4.3)is CN. CN reflects the degree of influence on a regression model.

The results in Table 4.3 showed that the CIs for all dimensions were less than 30, and the CN for this model was22.853, which is less than 30. Therefore the collinearity of this model was minor, and the predictions made with this model were not significantly influenced by collinearity.

Table 4.3. Diagnosis of overall collinearity of the regression model

Model Dimension	Eigenvalue (λ)	Conditional Index (CI)
1	5.798	1.000
2	1.031	2.372
3	.634	3.024
4	.194	5.467
5	.182	5.641
6	.094	7.856
7	.056	10.150
8	.011	22.853 (CN)

4.3 Residual analysis

The so-called residuals are the differences between “real values” and “estimates by models”. Generally speaking, the conditions that must be met in order for residual analysis to be used are: residuals must follow a normal distribution, and residuals must be independent of each other. If these conditions are not met, this method cannot be applied to the model.

4.3.1 Normality Test

The method used to test normality is very simple. It can be performed with a bar chart to decide whether it follows a normal distribution. If the chart shows a bell-like shape, the condition of normal distribution is satisfied on a preliminary basis.

Figure 4.2 is the bar chart of the residuals for this model. The bell-shaped line is a normal distribution. From the figure, it can be seen that the shape of the bars was bell-shaped, with a trend similar to the normal distribution line. Thus, judging from this figure, the regression model built in this study passed the normal test and the condition was met.

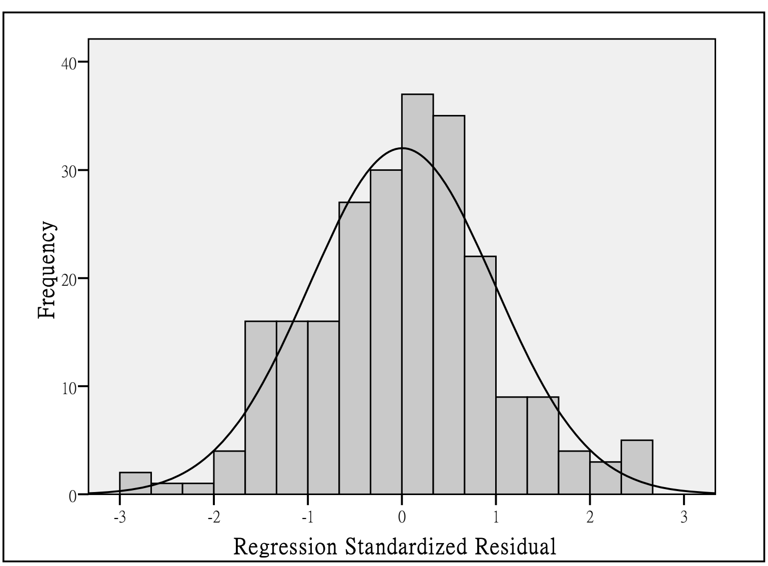

Figure 4.2 Standardized residual bar chart

4.3.2 Independence test

The Durbin-Watson test is an independence test generally adopted (Durbin, J., and Watson, G. S, 1950&1951) with the value DW. It is used to check the independency between residuals. If the residuals are not independent of each other, the situation is called autocorrelation of residuals, meaning previously observed values are related to later observed values, and one of the conditions is not met. The range of the DW value is from 0 to 4 and the cut-point is 2, meaning if the value is less than 2, the residual is positively autocorrelated , and if larger than 2 it is negatively autocorrelated. Therefore, if residuals are independent, the corresponding DW value should be close to 2.

After applying the Durbin-Watson test, the DW value derived was1.807, which was close to 2. Thus, the regression model built in this study passed the normal test and the condition was met.

5. Result application for slopeland disaster prevention

According to the analysis above, equation (10) can be used to assess household loss. Household loss is significantly affected by seven other variables. Based on the results, some appropriate policy recommendations are as follows:

(1) Quantifying household loss lets the public more easily understand the gravity of the disaster and helps them engage in disaster mitigation. According to past experiences, most of the public feel it is not necessary to engage in disaster mitigation, thereby quantifying the seriousness of the damage they might sustain in the event of actual slopeland disasters. With respect to this circumstance, when the government engages in risk communication, it must take into account whether to advise the public about mitigation measures already deployed by others, so as to increase the public's willingness to engage in their own disaster mitigation.

(2) The household loss model not only can help assess real losses after a disaster but also before a disaster strikes. If the numerical scheme can simulate a disaster situation

with mitigation measures, this method can be used to obtain the financial gain or loss of those measures. This can help the government to take precautionary measures before a disaster, or create appropriate recovery policies after a disaster.

(3) The establishment of a loss model is useful for the cost-benefit analysis of household prevention-mitigation plans. The benefit is the difference between the loss realized with the plan and that realized without the plan. Therefore, it is helpful for the government to choose the best plans through the application of a cost-benefit analysis method.

(4) From the study it is known the number of people in a household is a significant factor of loss; therefore, if the numbers can be reduced, the loss can be reduced. For example, residents who live in hazard-prone areas can be evacuated before a disaster happens. A possible method to reduce future losses is also to restrict the development of new housing lots in areas endangered by debris flow.

(5) The results of the analysis found that personal preparedness is not significant. Only community preparedness can effectively reduce losses. Although it is hard to change the house types in hazard-prone areas, it is possible to strengthen the work of community preparedness for reducing losses.

6. Conclusion

This study was based on a risk framework and used the data of an on-site survey to build a regression loss model of debris flow. In the proposed model, a set of hazard, exposure and vulnerability indices for debris flow loss were used. They were the total area covered by the debris flow, the height of debris flow coverage, the experience of the disaster, residential house type, the number of people per household, community disaster preparedness, and type of construction materials (RC). The results of the regression model showed that all the variables included were statistically significant.

Furthermore, an examination showed that this model has a good explanation of the loss, and a hypothesis consistent with the regression method. Therefore the results proved this model could calculate household loses from landslides.

Finally, this study provides many useful policies for slope-land disaster prevention. Quantifying household losses can help the public engage in disaster mitigation. Assessing losses can help the government create appropriate policies and choose the best prevention-mitigation plans. Evacuating residents who live in hazard-prone areas is useful for reducing losses, and community preparedness can effectively reduce losses.

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