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Design of System of Earthquake Disaster Loss Assessment

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Abstract

It is of great significance to study how to assess the railway tunnel damage loss quickly after earthquake for the earthquake relief and post-disaster reconstruction work. Hierarchical weighted synthesis method is the theoretical foundation of the system of earthquake disaster loss assessment. The system is based on windows operation system and VB language is selected as integrated development environment. Access is as external database, the automotive conversion of the earthquake damage reduction value without manual entering and automotive computing of Loss Assessment will be achieved. The computing outcome will be saved in excel. The software can provide scientific evidence and improve the efficiency of the loss assessment.

Keywords: *Hierarchical weighted synthesis method, Reduction value, Earthquake Disaster Loss Assessment, Automotive conversion*

1. Introduction

Damage to railway tunnel seismic tends to be more serious, and once it is broken, it will be difficult to repair, especially for some tunnels in important line, economic losses caused by outage will far exceed its repair costs [1].

Constantly improving the earthquake disaster losses assessment has many practical significance in railway tunnel [2]. It can help to relate departments timely, accurately grasp the state of railway tunnel disaster, and take effective emergency measures. The establishment of railway tunnel earthquake disaster loss assessment system and earthquake disaster emergency system, make the content of the earthquake disaster loss assessment of the lifeline engineering more and more rich. Study of the loss of earthquake disaster assessment of railway tunnel play the positive role in promoting the development of the earthquake disaster research theory. And research on earthquake disaster loss assessment of railway tunnel, to a some extent, can reduce the secondary disasters, casualties and property losses, and provide scientific basis for the reconstruction of railway tunnel.

In order to realize the earthquake disaster loss assessment of railway tunnel, AHP weighted combination method [3] and weighted comprehensive evaluation method of hierarchical are adopted. This method fully reflects the advantages of qualitative and quantitative analysis of expression and complex fuzzy problem processing.

Method for determining the extent of the loss after the earthquake of bridge structure reference "urban bridge maintenance technology in CJJ99-2003", the tunnel disaster damage index (TDI-Tunnel Damage Index) to the extent of the damage of railway tunnel characterization after earthquake is the method of damage degree evaluation of structures commonly used [4]. Railway tunnel is mainly composed of a tunnel rail surface system, tunnel main buildings and ancillary buildings of three parts. The orbital plane system mainly includes the track structure and sidewalk assessment factors. The main building including tunnel support structure (such as lining or open cut tunnel portal) and other evaluation factors, and Ancillary buildings including guarantee railway

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tunnel the normal use of all kinds of auxiliary facilities required for assessment factors. There are several types of diseases of each assessment factors, on the basis of "destruction grade Lifeline Earthquake Engineering (Draft)", the tunnel earthquake damage is divided into five grades [5]: largely intact, slight damage, moderate damage, severe damage and destruction (see definition of different damage grades of document [6].

In recent years, in order to quickly and effectively complete the work of earthquake disaster loss assessment, it needs to develop earthquake disaster loss evaluation software. It can reduce labor intensity of disaster assessment effectively and save time [7]. This design is carried out under such a background.

2. The Overall Design of Software

2.1 Design and Running Environment of Software Architecture

Earthquake disaster loss evaluation system of railway tunnel mainly consists of database, function module and graphic user interface. Data storage and management in the system is used general database software Access, and each function module and graphical interface are used VB programming tools.

In view of using computer to complete data input the present earthquake site, calculation and output, and operating system are almost Windows XP. Based on the requirements of running environment and the stability of the software, the system selects the Windows XP operating system. Software development is completed, the operation of the soft, hardware environment without special requirements, operating system can be a Windows 2000/XP, application software only with Microsoft Office 2000 or above office software can be.

2.2 The Key Technology of Software Design

The key technology of the software design includes the following three aspects:

(1)External database and software integration technology

Using Access database, this technique is to solve the problem of data management and data call. The system display database data in the foreground, and we can add and modify data progressively.

(2) Automatic Input of Damage Survey and Automatic Calculation of Damage Index

Due to the damage grade of different disease are plentiful, the damage grade evaluation corresponding to the diseases type is very necessary in software. When running the system select the types of diseases, selection of damage level is based on field investigation. The first types of diseases damage grade will be displayed in a table in the database. The second assessment unit will be automatic input and stored sequentially, until finally evaluation unit save is complete. The page will display the complete earthquake damage survey and then the program can directly calculate the every kind of structure damage index.

(3) Data Output

To facilitate the writing of the earthquake disaster loss assessment. the basic data and various sampling survey data and the results stored in the databasewill be directly output to Excel document, it is need to solve the interface problem of database and Excel application software.

2.3 Software Function Design

According to the size of the design goal setting software, to determine the relationship of the various modules, railway tunnel earthquake disaster loss assessment system software design includes the following four parts:

(1) "Help" Module. it describe the hierarchical structure features of railway tunnel, earthquake damage forms and different damage level of description, hierarchical weighted comprehensive evaluation principles and steps.

(2)Questionnaire Input and Earthquake Damage Score Transformation Calculation Module. before the program design, the corresponding deduction criteria of different damage levels of each assessment elements of each structure is set, damage deduction score conversion and calculation will be realized.

(3) Loss Evaluation Calculation Module. According to the theoretical analysis of tunnel in the hierarchical structure of assessment factors and weight of the different failure forms, the automatic calculation of earthquake damage index will be realized, and then the level of earthquake damage and loss ratio of tunnel will be determined, earthquake disaster loss calculation of single tunnel and the railway tunnel of the whole region will be completed.

(4) Original Data and Access of Loss Assessment Calculation Results

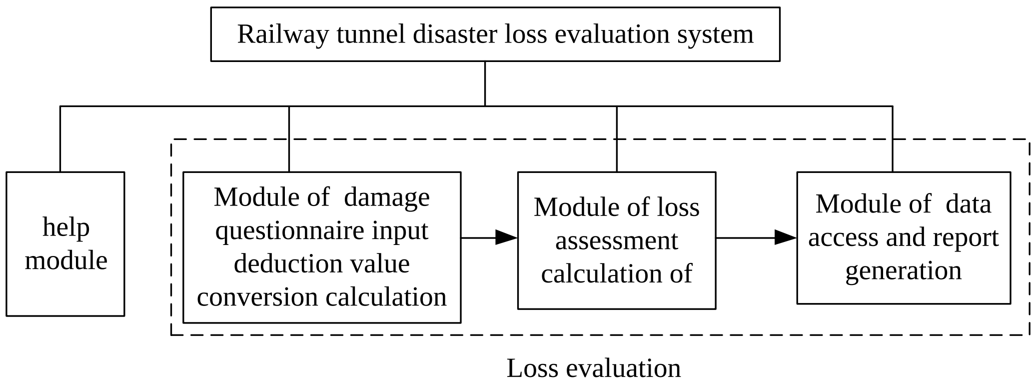


Figure 1. Function Module of S Earthquake Damage Loss Assessment System

3. Software Design and Implementation

Before the earthquake disaster loss calculation of railway tunnel, fill in the line name, the name of the tunnel, tunnel type and tunnel length, according to the tunnel length, automatically calculate the tunnel assessment unit number (per 100m for an evaluation unit, less than 50m is not a unit, the rounding method is adopted, such as the input of tunnel length of 650m, assessment unit number is 6). The basic data such as surrounding rock grade, the reset unit price, time, and the earthquake magnitude and tunnel seismic intensity region, is input to the software, checking and modifying the input data to ensure the accuracy of the calculation results.

According to the unit number to automated assess for each evaluation factor disease types , calculated the corresponding disease types of buckle scores of all the evaluation units, computing seismic damage index when take each damage conditions index of average, so it is concluded that the value is more rigorous. In the tunnel structure, part unit assessment is only hole body of the orbital surface lines and body building.

3.1 The Calculation Model of Software Development

(1) Orbital plane system evaluation and index calculation model of earthquake damage is shown in the following three equation:

$$TDI_t = 1/K\sum^{K} TDI_k \text{ ①}, \quad TDI_k = \sum^{2}(100 - GDP_{ki}) \cdot \omega_i \text{ ②},$$

$$GDP_{ki} = \sum^{m_i} DP_{kij} \cdot \omega_{ij} \text{ ③}。$$

i represents track plane assessment unit of assessment factors. For example, i=1 represents track structure, and there are five types of diseases, and i=2 represents the pavement track structure, it has one kind of disease type. j represents the types of damage in the assessment elements i (j = 1, 2,...,). DP_{kij} represents the first j damage deduction score of the first class i assessment elements in first k assessment unit of the track plane, which are obtained by field earthquake damage survey. TDI_t represents the average index of the first k assessment unit damage condition. TDI_k represents the damage condition index of the first k track plane evaluation unit. GDP_{ki} represents the total damage score of the first i assessment elements in the first k assessment unit of the track plane. ω_i represents the weights of the evaluation factors i in the first k assessment unit of the track plane and the ω_{ij} represents the first j damage item weights of the first i evaluation factors in the first k assessment unit of the track plane.

According to the basic data of the tunnel to determine the evaluation units' number, and the line data of the track surface damage survey rows to the numerical consistency. After the disease type be chosen, buckle score will be automatic generated according to the scene corresponding the damage level and various evaluation factors of all the disease types of damage grade will be saved after selecting. Data sheet will show all the disease score in the first evaluation unit of orbit plane, and then the second assessment unit buckle score will be automatically generated, until the last tip of all the evaluation units. Various diseases of the track surface in this tunnel department will be arranged in the earthquake damage survey.

The process of earthquake damage condition index calculation is as follows: first, using the formula (3) calculate the sum score of weighted of track structure and sidewalks various disease, Then using formula (2) to calculate the earthquake damage index of the whole the orbital plane. Finally using the formula (1) calculate the average evaluation index of damage conditions of all unit. The calculation process is shown in Figure 2.

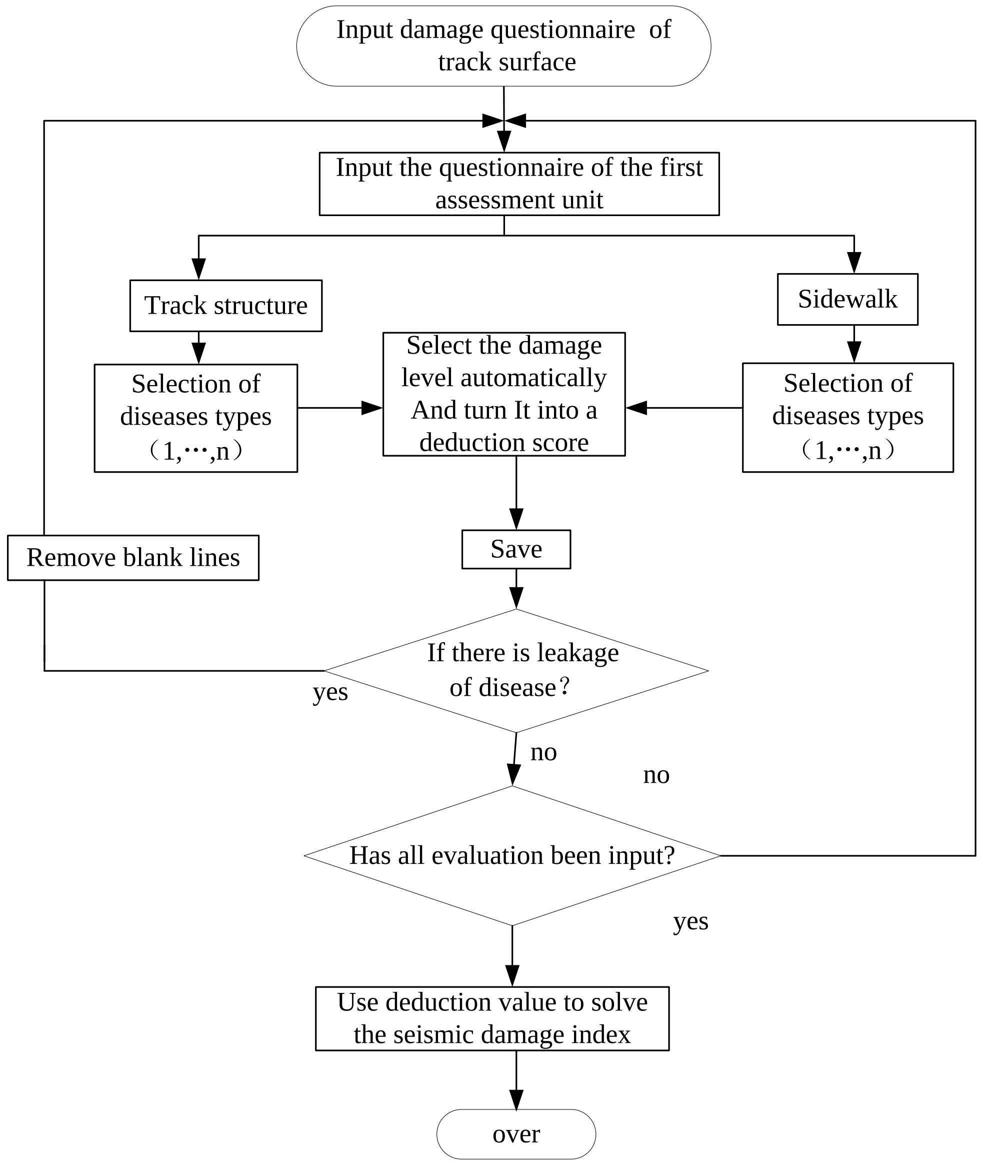


Figure 2. Automatic Calculation of Track Plane System Damage and the Damage Input Values Questionnaire Points

(2) Model for the calculation of the main building assessment and seismic damage index for the three formulas is as follows:

$$TDI_m = \sum^{2}(100 - CDP_i)\cdot \omega_i \text{ ①}, CDP_i = 1/K\sum^{K} CDP_{ik} \text{ ②}, CDP_{ik} = \sum^{m_i} DP_{ikj}\cdot \omega_{ikj}$$

③。

i represents the evaluation factors of the main building, i=1 it is the barrel and i=2 it is portal. The first j represent damage form in the first i assessment element (j=1,2,…, m_i). DP_{kij} represent the first j damage deduction score of the first class i assessment elements in first k assessment unit of the main body building.ω_i represents the weight of the first i evaluation factors of main building; ω_{ikj} represents the first j damage weights of the first i evaluation factors in the first k assessment unit of the main building; CDP_{ik} represents the total damage deduction score of the first i assessment elements in the first k assessment unit of the main building. CDP_i represents the averages of damage deduction score in the first i evaluation elements of main building.

The design of this model is that the open cut tunnel as part of a tunnel body and lining unified assessment unit will be divided along the length (each 100m as a unit). A unit in the hole will be considered as open cut tunnel when the length of a unit is more than1/2 unit length, otherwise will be considered as lining. The evaluation unit is lining or open cut tunnel will be confirmed by the people at the scene.

The open cut and the lining in the main part of the system will to be numbered in a unified and stored separately. When determining an evaluation unit is lining, select the display type of disease of lining and according to the field survey results, select the automatically transformed damage rating point's value, preserved in the lining of the survey. If it is determined to be the open cut tunnel, it will also display the data in the open survey as above.

The portal is divided into the entry and exit units to assess. The earthquake damage survey will be automatically generated by chosen the disease according to the data of investigation.

After obtain the data of the tunnel and portal points, we will first calculate various disease score of weighted sum in tunnel body and portal by formula 3 and calculate the added weight of the tunnel body and the portal respectively. And then calculating the average weighted sum of all the evaluation unit by formula 2, in the formula the value of K depends on the assessment unit for the tunnel body, and the value of K is 2 for the portal. The damage index of the main building obtained by weighted summation equation (1), and the calculation process is shown in Figure 3.

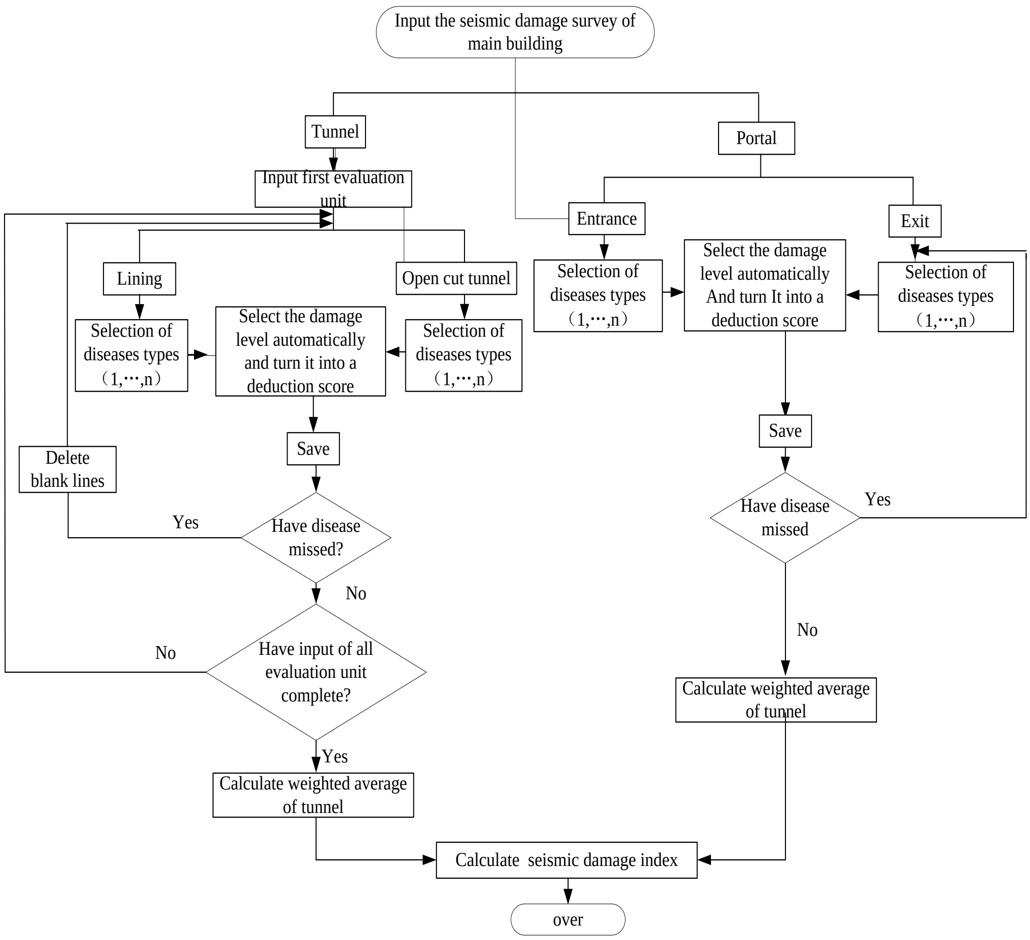


Figure 3. Automatic Calculation of the Main Building Earthquake Damage Survey Input and Damage Points Value

(3) The Assessment and Earthquake Damage Index Calculation of Ancillary Buildings

Damage index of tunnel ancillary buildings can be calculated as follows:

$$TDI_a = \sum_{i=1}^{4}(100 - FDP_i)\cdot \omega_i \text{ ①}, \quad FDP_i = \sum^{2} DP_{ij} \cdot \omega_{ij} \text{ ②}.$$

i represents the evaluation factors of ancillary buildings (i=1,2,... , 4); j represents the first j damage form in the first i evaluation elements of the ancillary buildings; DP_{ij} represents the first j damage deduction score of the first class i assessment elements of the ancillary buildings; ω_{ij} represents the first j damaged item weights of the first i evaluation factors of the ancillary buildings; FDP_i says the damaged total score of the first i assessment elements of the ancillary buildings; ω_i represents the weight of the first i evaluation elements in the ancillary buildings.

The design of this model is four basic facilities of the ancillary buildings(ventilation facilities, drainage facilities, power and communication facilities, safe avoidance device) does not divide, each facility is used equation ② to evaluate, then use the equation ① is used to w calculate the damage index by weighted summation, the computation process is shown in Figure 4.

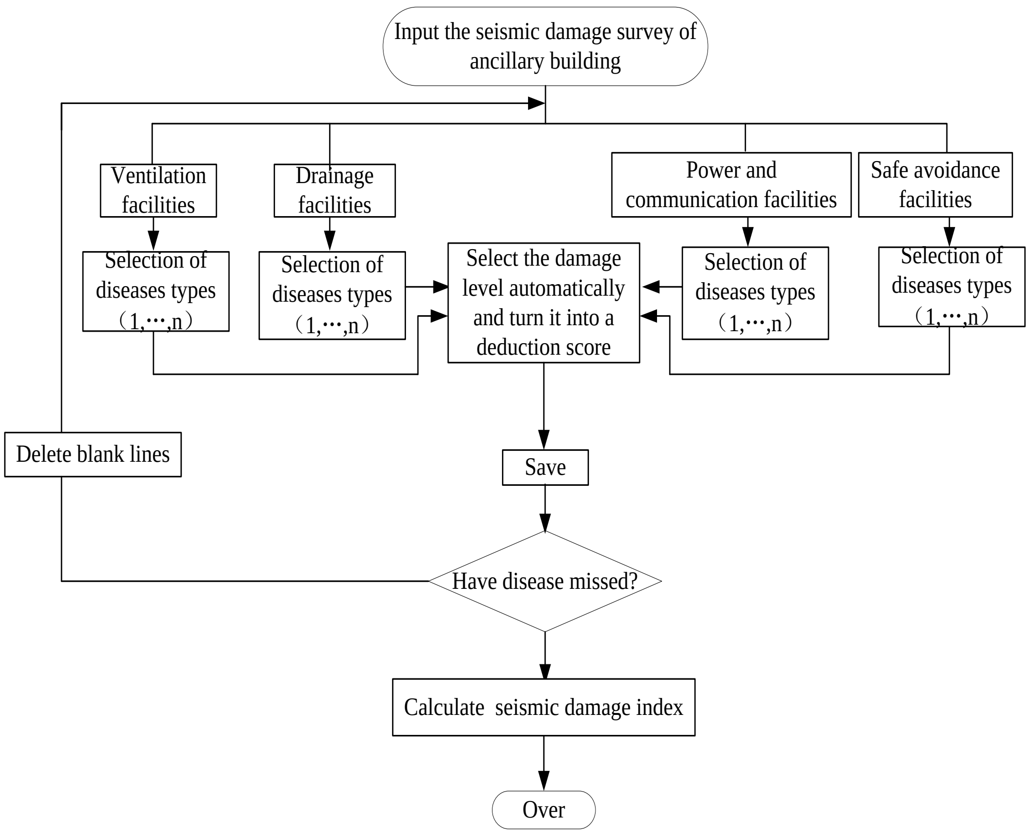


Figure 4. Automatic Calculation Process of Earthquake Damage of the Ancillary Buildings

(4) The Single Situation of Earthquake Damage Index Calculation of Railway Tunnel

Equation $TDI=TDI_t\cdot\omega_t+TDI_m\cdot\omega_m+TDI_a\cdot\omega_a$ is used to calculate the earthquake damage index of the single railway tunnel, that is the index weighted summation of the track surface, the main building and ancillary buildings. ω_t, ω_m and ω_a represent the weight of the track surface system, main buildings and ancillary buildings respectively. According to the values of the earthquake damage index, the the tunnel damage grade is determined, and eventually the specific value the loss ratio is determined. The standard of damage grade corresponding to *TDI* is shown in Table 1.

Table 1. Grade Standard Damage of Railway Tunnel

Damage level	Largely intact	Minor damage	Moderate damage	Serious damage	Destruction
Earthquake disaster index	$TDI \geq 85$	$85 > TDI \geq 75$	$75 > TDI \geq 50$	$50 > TDI \geq 35$	$TDI \leq 35$

(5) The Calculation of Single Tunnel Earthquake Disaster Economic Loss

In equation $Y_n = H_n X_n L_n$, Y_n represent the earthquake disaster economic loss of the first n railway tunnel; H_n represent replacement of the unit price of per unit length in the first n railway tunnel unit; X_n represent the damage levels of loss ratio (%) corresponding to the first n railway tunnel; L_n represent the length of the first *n* railway tunnel.

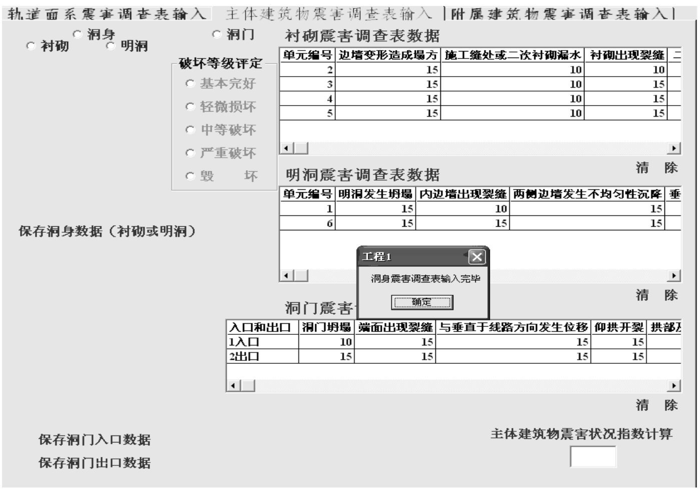
(6) The Calculation of Earthquake Disaster Economic Loss of all Railway Tunnel of the Whole Seismic Area

In equation $Y = \sum_{n=1}^{N} Y_n = \sum_{n=1}^{N} H_n X_n L_n$, Y represents the sum of seismic disaster economic loss of the whole area of all railway tunnels; N represents numbers of tunnel in the whole area..

3.2 Software Testing

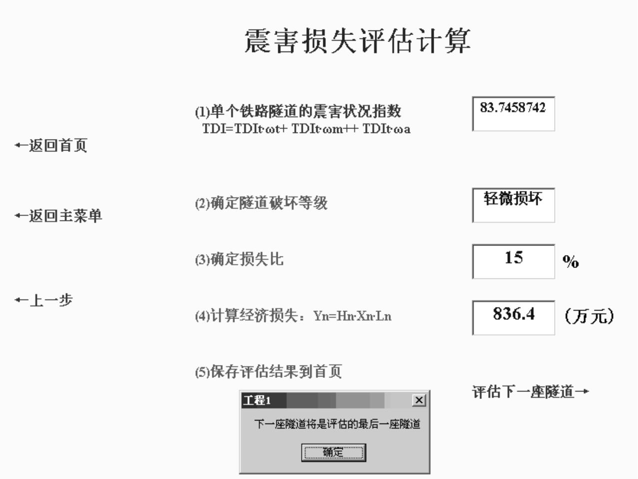
Figure 5 (a) shows the test of the whole railway tunnel seismic damage in the earthquake status, and Figure 5 (b) shows the test of the earthquake damage survey input in the main buildings. The whole process does not need input by keyboard.

Figure 5 (c) shows the assessment of earthquake loss calculation, and eventually the tunnel earthquake economic loss is calculated. Figure 5 (d) shows the deduction score data of each assessment unit and the test of the various data exported to Excel documents



5 (a)

5(b)



5 (c)

第1评估单元								
单元编号	线路弯曲变形	轨枕错动	ω扣件松动	钢轨断裂	道床隆起或塌陷	人行道损坏		
1	5	10	10	5	20	10		
2	5	10	55	20	10	10		
3	10	5	10	55	20	10		
单元编号	边墙变形造成塌方	施工缝处或二次衬砌漏水	衬砌出现裂缝	二次衬砌脱落	二次衬砌接缝处出现错位			
2	10	15	35	15	15			
3	10	10	35	35	15			
4	15	15	10	15	35			
5	10	15	35	35	15			
单元编号	明洞发生坍塌	内边墙出现裂纹	两侧边墙发生不均匀性沉降	垂直于线路方向发生错位	拱圈开裂			
1	10	35	35	15	15			
6	10	15	35	15	15			
	洞门坍塌	洞门端面出现裂缝	洞门与垂直于线路方向	仰拱开裂	拱部及附近部位出现剥落	侧墙出现剥落	泥石流次生灾害	
洞门入口	10	35	15	35	60	35	10	
洞门出口	10	15	15	35	15	35	10	
	通风设施通风不畅	通风设施坍塌	防排水设施排水受阻	防排水设施坍塌	电力及通信设施变形开裂	电力及通信设施坍塌	安全避让设备变形开裂	安全避让设备坍塌
	15	10	35	10	35	10	35	10
第2评估单元								
单元编号	线路弯曲变形	轨枕错动	ω扣件松动	钢轨断裂	道床隆起或塌陷	人行道损坏		
1	10	10	10	20	10	20		
2	10	20	55	10	10	10		
3	5	10	10	55	20	10		
4	10	10	10	20	10	10		
5	10	5	10	55	20	10		

5(d)

Figure 5. Software Test

4. Conclusion

Through calculation methods such as the hierarchical weighted method, the software system is constructed, realizing the automatic transformation of the earthquake damage score and the automatic calculation of the damage condition index. All data in the system can be saved and the system is convenient to input, modify and query, so the system can be used for assessment of earthquake disaster loss.

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