Disaster prevention and control data collection and risk assessment of road system: a case study of Ningjin area

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Abstract. The impact of natural disasters on highway safety has always existed, and different disaster factors cause different consequences. It is necessary to find out which natural disaster factors have an impact on highway safety, and analyze the damage degree of different natural disaster factors to take corresponding protective measures. This paper investigates the impact of four natural disaster factors on expressways and county roads in Ningjin region, and makes a risk assessment on road safety. After obtaining the results of the road natural disaster assessment, on-site investigations were conducted to verify the results of the risk assessment. Preliminary research suggests that there are currently no natural disaster risk points in this area, and further risk analysis will be conducted in the future.

Keywords: expressways and county roads, natural disaster, risk assessment

1 Introduction

As an important infrastructure, highway is the main support of the national transportation system. The main components of the highway include subgrade, pavement, bridge and ancillary facilities along the line. In order to ensure the normal use of the highway, all facilities need high-quality maintenance after completion.

However, many destructive factors will cause the destruction of roads and facilities, among which natural disasters cannot be ignored. Natural disasters often damage roads, and their destructive power may be huge [1]. For example, geological disasters may cause highway pavement cracking and subgrade collapse, and floods may cause highway deformation and subgrade bearing capacity reduction [2]. Road damage caused by natural disasters can easily lead to traffic accidents and threaten the safety of drivers [3].

Therefore, people want to know which natural disasters may have an impact on road safety, or which regional roads are prone to collapse and deformation caused by natural

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disasters[4]. This is also the original intention of the country to carry out risk assessment of natural disasters to roads[5].

This paper evaluates the risk assessment of natural disasters of roads and bridges in Ningjin region of Shandong of China. We collected the highway information in the study area, especially the data of disaster prevention design, and checked whether the disaster prevention design of the completed highways met the requirements. On this basis, we carried out on-site investigation to find the possible damage points of these highways caused by natural disasters, and carried out risk assessment on these risk points.

2 Materials and methods

2.1 Area analysis

The survey area Ningjin County is under the jurisdiction of Dezhou City, and is located in the northwest of Shandong Province. With a total area of 833km2, it is located in the 39th zone with the central longitude of 117° E in 3-degree belts. Ningjin County has a permanent resident population of 480000, and has jurisdiction over 12 sub-districts, including Ningcheng Sub-district, Jincheng Sub-district, Chaihudian Town, Shiguan Town, Duji Town, Baodian Town, Daliu Town, Dacao Town, Xiangya Town, Shiji Town, zhangdazhuang Town and liuyingwu Town.

2.2 Data Preparation

Data collection includes attribute information of highway facilities and information of natural disaster risk points on the highway [6]. The data which is from the basic management and maintenance unit on the basis of the field investigation data, is collected by filling in the data sheet.

Table 1. Investigation record of highway natural disaster information

Highway Natural Disaster Information List			
General Information of the Highway/County Road		**Natural Disaster Risk Points**	
Road Name	Binzhougang-Yulin	Geological disasters:	
Route Number	G339		Landslide
Longitude	116.801104		Collapse
Mileage (km)	4.23		Subsidence
Hierarchy	Class II		Debris Flows
Number of Travel Lanes	2	Flood and Drought Disaster:	
Types of Surface Layer	Asphalt concrete		Washout
Design of Disaster Resistant:		**Site Photos:**	
Seismic fortification intensity:	☑6		Road photos
	□7		
	□8		
	□9		
Flood prevention standard:	□20_year		
	□30_year		
	☑ 50_year		
	□100_year		

2.1.1. The field data acquisition table. The field data acquisition table is shown in Table 1, including road information, natural disaster information and site photos. Road information, also known as general information of the highway/county Road, usually includes road name, road number, coordinates, mileage, road grade, number of travel lanes, and the description of the road surface. Natural disasters in the general sense mainly involve geological disasters, flood and drought disasters, earthquake disasters, meteorological disasters, marine disasters, forest disasters and grassland fires, among which geological disasters and flood and drought disasters will cause highway damage. Geological disasters are mainly landsliding, collapse, subsidence, debris flow, while flood and drought disasters are mainly washout damage, which will be reflected in the field data acquisition table.

2.1.2. Data filling method. The data collection is based on the highway section, using a combination of internal and external work, and is filled in the field data acquisition table. Conduct on-site investigation to verify the accuracy of the original road data [7]. After the on-site investigation is completed, data should be archived, including various original materials such as pictures, photos, images, transcripts, and recordings, as well as supplementary materials obtained from the on-site investigation.

2.1.3. Quality management of on-site investigations. Implement full process quality control for on-site investigations. Based on the on-site survey results and road characteristics, formulate technical methods and requirements for quality control of each road section, and conduct multiple spot checks to ensure the accuracy of recorded data. Quality control runs through the entire investigation process.

2.3 Indicator system of county roads risk assessment

The evaluation methods for systematic natural hazards in engineering are diverse and quantifiable [8]. Based on previous evaluation methods, the guide book of the first national roads comprehensive risk survey of natural disasters is used for the risk assessment in study area [9]. The risk assessment of natural disasters on highways and bridges within the study area was calculated using the County Road Risk Index (CRI).

The calculation of the Country Road Risk Index (CRI) depends on Five basic evaluation indicators, which are disaster frequency (A), historical disaster risk level (B), disaster treatment situation (C), disaster development level (D), and highway classification (E).

Five basic evaluation indicators assign different values according to the evaluation table in the technical measures for highway disaster assessment. Taking disaster frequency (a) as an example, the value can be assigned according to the number of disasters occurred in the country road within a decade. When the number of disasters is 0, the value is 25, the value is 50 for 1-2 disasters, 75 for 3-5 disasters, and 100 for more than 5 disasters. The maximum value of each basic evaluation indicator cannot exceed 100.

Five basic evaluation indicators have different weights in CRI calculation that Table 2 describes in detail.

Table 2. Weight of Five basic evaluation indicators in CRI[9]

Types	Weight	Disaster Frequency (A)	Historical Disaster Risk Level (B)	Disaster Treatment Situation (C)	Disaster Development Level (D)	Highway Classification (E)
Geological Disaster	Landslide	0.05	0.28	0.11	0.36	0.20
	Collapse	0.11	0.28	0.05	0.36	0.20
	Subsidence	0.05	0.28	0.11	0.36	0.20
	Debris Flows	0.11	0.36	0.05	0.28	0.20
Flood and Drought Disaster	Washout	0.05	0.36	0.11	0.28	0.20

CRI is calculated as follows:

$$CRI = A\times\gamma_1+B\times\gamma_2+C\times\gamma_3+D\times\gamma_4+E\times\gamma_5 \tag{1}$$

In the formula (1): A, B, C, D, E - the score of Five basic evaluation indicators; γ_1, γ_2, γ_3, γ_4, γ_5- weight to each evaluation indicators;

Calculate the CRI value of the risk points in roads and bridges in the study area to obtain the natural disaster level of the whole region. When the comprehensive index of CRI is below 48, it indicates that the risk value of the region is at a lower level. When it is above 83, it indicates that the region is a high-risk area.

3 Result

3.1 Field investigation

The basic information, seismic grade and flood control standard of all roads in Nanjing area were collected, the main structure type, pier type, pier and abutment anti-collision facilities type and seismic fortification grade of all bridges in the area were recorded, and the possible disaster risk points in roads and bridges were identified and checked.

The basic information of 382 expressways, county roads and 109 bridges in the study area was checked and updated, and all risk points were recorded in detail and taken photos is shown in table 3.

3.2 Risk assessment

The demonstrate the characteristics of the road in study area as follows:

- The original records are complete, and the road information and disaster prevention design information of the expressway and county road in the study area are clearly recorded.
- The original record and the road condition on site are basically consistent.
- Collect records of natural disasters that have occurred in the study area. The record of the past decade is relatively complete.
- The road and bridge conditions on site are good. The traffic in the region is operating normally, and there is no traffic jam caused by the impact of the disaster.
- There is no large-scale cracking, cracks, displacement, or deformation of the roadbed, bridge bearings, and piers in the region.
- There are local slight cracks and small-scale damages on the road pavement and bridge pavement in the area, and the vast majority of these damages have been repaired.
- The pavement conditions of expressways and high-speed bridges are significantly better than those of county roads and bridges. This may be due to the better maintenance of highways.
- According to the historical and geographical records collected, there has been no major natural disaster in the region in the past ten years.
- Evaluate the disaster situation of the highway in the study area according to the evaluation method of the National Natural Disaster Highway Risk Assessment Guidebook. Based on the existing external disaster manifestations of highways, analyze and identify disaster points that can be evaluated for road risk assessment of natural disaster.
- From the perspective of regional traffic flow, the vast majority of damaged roads are due to excessive traffic flow or traffic accidents. There are few cracks caused by natural disasters.
- The pavement of highways and county roads in the study area exhibits cracks and damages, however, the length and area of these defects are limited to less than three meters or one square meter, thereby refraining from classification as a disaster point.
- The pavement damage in the study area does not match the local natural disaster records, making it impossible to determine whether the damage is related to natural disasters.

Table 3. Interpretation mark of field investigation

Road Category		Site Photos	Characteristics
Highways and Bridges	Highways		Regular strips, dark colors, groups of building bays, attached vehicles with scattered color blocks, with green belts and other ancillary facilities. Check the differences between the original records and the site photos. For those damaged by natural disasters, additional photos of disaster characteristics shall be taken.

	Expressway Bridges		Viaduct. Regular strip with obvious centerline and supporting structure at the lower part. It is higher than the ground and has a shadow at the bottom. If the bridge deck or pier is damaged by natural disasters, additional disaster feature photos shall be taken.
County Road and Bridge	County Road	 	Regular strips, groups of buildings and dense vegetation nearby, there are many vehicle color patches, and there are green belts and other ancillary facilities. Compared with the original records, if the pavement is damaged by natural disasters, additional disaster feature photos shall be taken.
	Municipal Bridge	 	River-crossing bridge. Regular individual strips, regular abutment and pier shapes, connecting roads on both banks, and sporadic vehicle color patches. It forms an obvious color contrast with the water body under the bridge, and there is a shadow at the bottom. Take additional characteristic photos of bridge deck, abutment and pier damaged by natural disasters.

The on-site investigation on roads and bridges focuses on verifying the areas where natural disasters have occurred in the past 10 years and the natural disaster prone areas that may pose a threat to residential areas. According to the field survey results, no natural disaster risk points have been found in the expressways and county roads in the study area. After unifying the original records and the data obtained on site, the risk level of the risk point will not be calculated.

4 Conclusions

This paper collected and sorted out the basic information and disaster prevention design of expressways, county roads and bridges in the study area, carried out field survey of all roads and bridges, checked and updated the original disaster information, and evaluated the natural disaster risk of country roads in the area.

The geological disaster data and flood disaster data of the study area in recent ten years were collected. Combined with the results of this field survey, no natural disaster risk points of expressway were found in the study area. According to the risk assessment basis and evaluation principles in the national technical guide for comprehensive risk survey of natural disasters, the study found that no major damage caused by natural disasters has been found on the roads and bridges in the study area.

After the investigation of highway pavement conditions and the risk assessment of natural disasters to the highway in the study area were completed, it is worth noting that in August 2023, an earthquake of magnitude 5.5 occurred 60 kilometres southwest of the study area. The impact of the earthquake on the roads in the study area needs to be investigated again before it can be determined.

Due to the time limit of the study, this paper made a preliminary risk assessment of natural disaster for the roads and bridges in the study area. It can be seen that the field survey has obtained accurate on-site information of highway pavement, bridge pavement structure and piers, but it takes a long time. For areas with low probability of natural disasters, such risk assessment efficiency is not high. At present, the accuracy of remote sensing has basically reached the level of identifying the ground situation. If the remote sensing data can be used as a support to quickly identify the damage to roads in the study area by natural disasters, a more efficient natural disaster risk assessment will be obtained.

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