A discussion of one of the large natural disasters to have occurred in northern Japan since 2000, and the efficacy of the disaster prevention and recovery measures taken

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ABSTRACT

In 2004, an extraordinary combination of a developing and stagnant low-pressure storm and a typhoon produced strong winds, heavy snows, and floods, including tidal floods, etc. In the same year, the Niigata Prefecture Chuetsu Earthquake caused extensive damage to life, property, crops, and the social infrastructure in northern Japan. Such events seem to be occurring more frequently, and the populace in Japan is becoming increasingly fearful. The disasters have severe economic impacts, and their effects on buildings and infrastructure often exceed the design values. Appropriate disaster prevention measures and prompt restoration measures, however, can limit the damage. In each case, an analysis of the conditions is necessary. Disasters can cause large-scale damage in densely populated areas. Major disasters can occur in large and growing cities such as Sapporo. Life-threatening situations can be expected during the winter months. It is necessary to review the steps to take when unprecedented disasters occur or when conditions exceed the design values. It is also necessary to review the disaster prevention measures and disaster recovery plans to ensure that they are adequate and appropriate. This study examines the characteristics of the natural disasters that recently occurred in northern Japan since 2000, as well as the effectiveness of the disaster prevention and recovery measures, etc.

1. Introduction

1.1 Background

In 2004, an extraordinary combination of a developing and stagnant low-pressure system and a typhoon produced strong winds, heavy snows, and floods, including tidal floods, etc. In the same year, the Niigata Prefecture Chuetsu earthquakes caused extensive damage to life, property, crops, and social infrastructure in northern Japan. Such events seem to be occurring more frequently, and the populace in Japan is becoming increasingly fearful. The disasters have severe economic impacts, and their effects on buildings and infrastructure often exceed the design values. Appropriate disaster prevention measures and prompt restoration measures, however, can effectively limit the damage. In each case, an analysis of the conditions is necessary. Disasters can cause large-scale damage in densely populated areas. Major disasters can occur in large and growing cities such as Sapporo. Life-threatening situations can be expected during the winter months. It is necessary to review the steps to take when unprecedented disasters occur or when conditions exceed the design values. It is also necessary to review the disaster prevention measures and disaster recovery plans to ensure that they are adequate and appropriate.

1.2 Purpose

This study examines the characteristics of the natural disasters that recently occurred in northern Japan, as well as the effectiveness of the disaster prevention and recovery measures, etc.

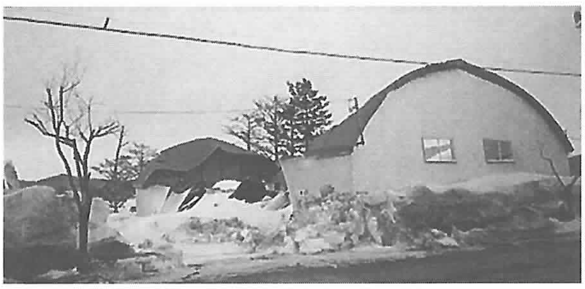
2. Study method

The recent disasters were analyzed using information from various organizations, field surveys of the areas affected by the disasters, etc. The disasters were compared to past disasters and standards were examined[1,2,3,4,5]. These investigations verified the effects of the disaster prevention and recovery measures. Problems with the measures were identified and used to predict possible problems in future disasters.

3. Results of analysis

3.1 Damage from record snowfall (January 2004)

On January 13, 2004, an extraordinary developing and stagnating low atmosphere pressure system eventually reached 964 hecto-Pascal, producing the record snow fall of 170 cm in the Okhotsk district. Such a snowfall occurs only once every 100 years on the Sea of Okhotsk coast and in the Kitami district. Several warehouses collapsed when the weight of the snow on their roofs exceeded the design values. These roofs had shapes that prevented the snow from sliding off (Photograph 1). The road system was cleared of snow only in a relatively few districts, which caused about one month of traffic confusion.



Photograph 1 An agricultural warehouse in the Kitami district that collapsed under a heavy load of snow in January, 2004. (Saroma-cho Sakae, along National Highway Route 333)

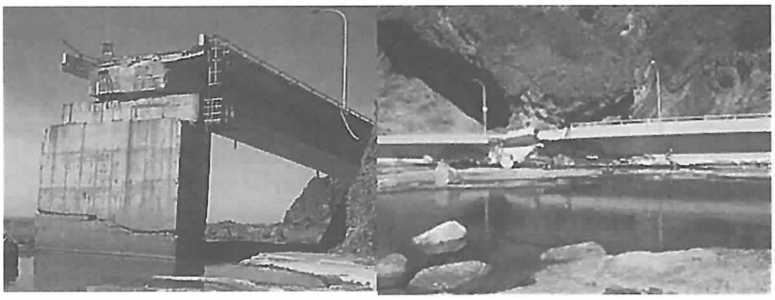
3.2 Damage from Typhoon 18 (September 2004)

Many typhoons hit Japan in 2004. During the first ten days in September, Typhoon 18 passed Soya Strait from the side of Sea of Japan and swept across the entire country. The typhoon had a central atmospheric pressure of 960 hPa, and reached its maximum wind speed on September 8th in Sapporo-shi and Omu-cho. The typhoon was larger than the Toyamaru typhoon, which struck on 26th

September in 1954, felling more trees, turning over more trucks, etc. In Kamoenai, tidal flooding destroyed the girder support beams between 4 spans of the Omori Bridge (Photographs 6, 7) and the girder fell, destroying the bridge. A pier suffered a large crack (Photographs 3, 4, 5). The steel reinforcing bars in the wall of the nearby shelter that faces the seashore were overwhelmed by the wind and waves (Photograph 2).

In Omu, wind and waves broke the concrete lighting poles along National road route 238.

Photograph 2 This concrete shelter wall on National road route 229 in Kamoenai (near Omori Bridge) was toppled by the strong wind and waves generated by Typhoon 18.



Photographs 4, 5 The PC girders of the fallen spans of the Omori Bridge on National Road Route 229. (Excessive compressive stress destroyed the girders when the support beams fell). A large crack destroyed this pier on the Omori Bridge.

Photograph 3 The broken girders and piers of Omori Bridge (completed October, 1985) on National Road Route 229. (The piers between 4 spans and the girders fell only on the Kamoenai side, to the southeast.)

Photographs 6, 7 The support beam attachment points and the destroyed support beams of the bridge.

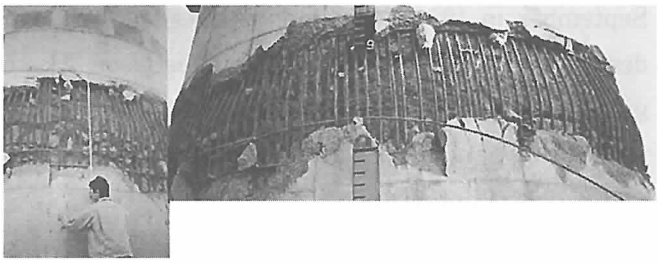
3.3 Damage from earthquakes

3.3.1 Niigata Prefecture Chuetsu Earthquake (October 23, 2004)

The Niigata Prefecture Chuetsu Earthquake struck at 5:56 p.m. on October 23, 2004. It was a strong local earthquake with a seismic intensity of 7 according to the Japan Meteorological Agency. The epicenter was in Kawaguchi town in the Chuetsu district of Niigata Prefecture. The earthquake occurred at a focal depth of 13 km, and had a magnitude of 6.8. A maximum acceleration of 1500 gal was recorded in Ojiya city.

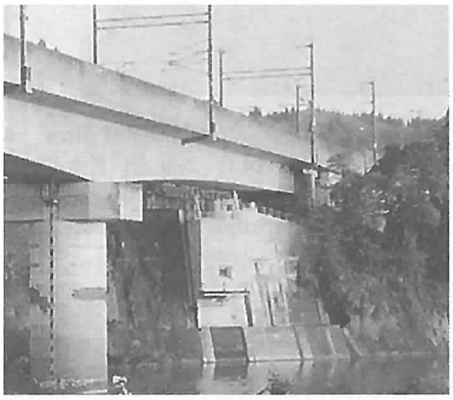
There was passage immediately ahead of Typhoon 23. Damage was slope failure and typical of earthquakes. Recovery and earthquake-proofing measures were promptly implemented.

Photographs 8, 9 An important traffic route along the Uono river at Wanazu in Kawaguchi town, near the epicenter of the main shock (about 3.5 km in the direction opposite that shown in the photograph). A northwestern view of National Road Route 17 from Wanazu Bridge. Bridges for the Kanetsu Expressway and Japan Railway (JR) Joetsu Line can be seen on the left. The beam on the Uonogawaha Bridge (JR Joetsu Shinkansen Line) can be seen in the background.

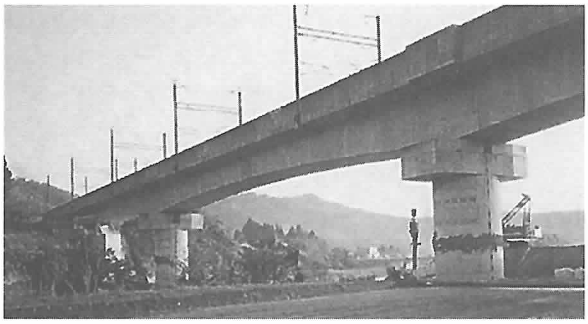


Photographs 12, 13 Wrapped parts of steel hoops came off at the same height level. The concrete cover on the steel reinforcing bars was damaged and suffered scaling at the termination points of the main steel reinforcing bars.

Photograph 10 The damage occurred at the termination points of the main steel reinforcing bars for the two circular piers on the Uonogawa Bridge beam (JR Joetsu Shinkansen Line). The photograph was taken from Wanazu Bridge on National Road Route 17 where it crosses the Uono river.



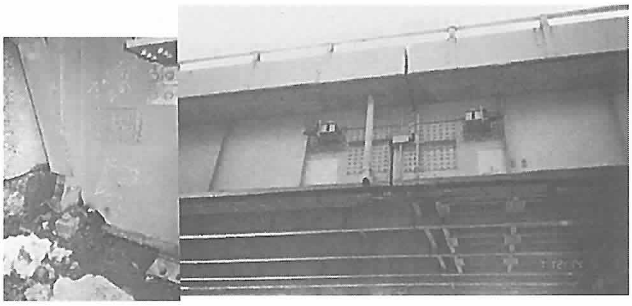
Photograph 14 Parts of the rigid-frame elevated structure suffered shear failure. They are shown here being repaired among the blue sheeting and trees.



Photograph 11 The damaged termination points of the main steel reinforcing bars in the piers of Uonogawa Bridge (JR Joetsu Shinkansen Line) (P1, P2).

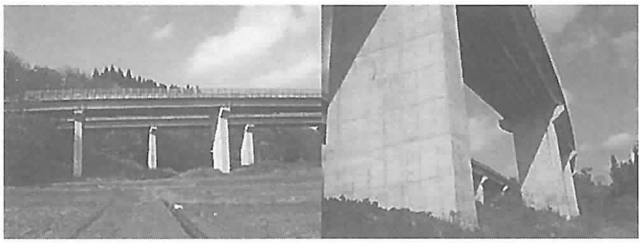
Photograph 15 This plate girder bridge on the JR Joetsu Line is in fairly good condition, but a bolt securing a railroad tie fell out.

Photograph 16 A crack appeared in the pier for Wanazu Bridge on National Road Route 17 (completed in 1954) and the edge of the main steel girder was damaged, but traffic flow was immediately restored.



Photographs 17, 18 Installed after Great Hanshin-Awaji Earthquake, this fallen girder arrestor proved effective during the Niigata Prefecture Chuetsu Earthquake. The damage to the edge of the main steel girder was possibly aggravated by corrosion and many years of use.

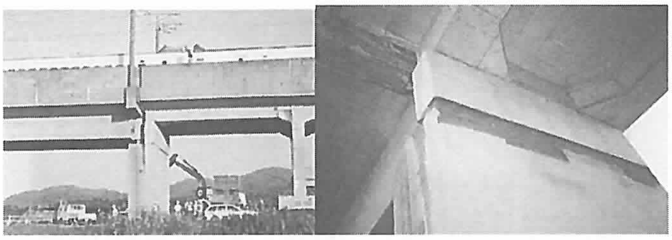
Photographs 19, 20 The timbering frame for the Wanazu Tunnel was repaired within 10 days. The reinforcement timbering repairs were given priority because the Wanazu Tunnel, on the route from the metropolitan area, was vital for disaster recovery efforts.



Photographs 21, 22 The piers of the Kanetsu Expressway are in fairly good condition.

Photograph 23 The concrete edges of these girders were only slightly damaged in the earthquake.

Photograph 24 The site of the Joetsu Shinkansen Line derailment in Nagaoka City. (Photo taken from the east side)



Photographs 25, 26 The concrete scaling at plumb down of the reverse side of the bridge abutment was scraped at the derailment site (Photograph at left). The center of the upper part of the RC pier on Higashi-oh-shin-e Bridge in the same site (photographed from the west side). It blows concrete into the shave part which drops scaling be in scrape (November 7 -8, 2004).

Photograph 27 The collapsed cliff where a boy was miraculously rescued from a car. Two others died.

Photograph 28 The radio controlled construction machine that was used the rescue work.

Photograph 29 The collapsed cliff beside National Road Route 17 and the JR Joetsu Line.

Photograph 30 This detour road was promptly repaired. (View to the north down the route and towards Nagaoka City).

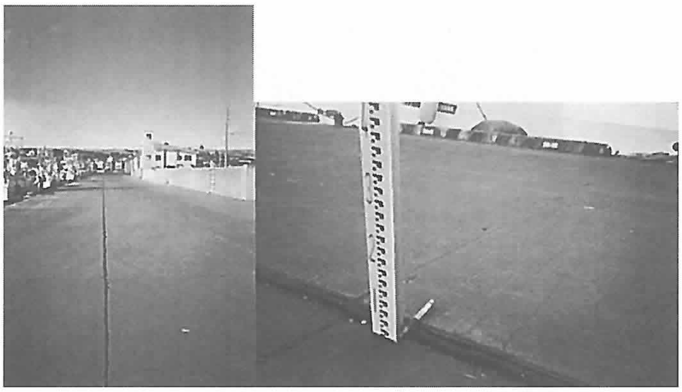
Photograph 31 Sections of the prefecture regional road route in Ojiya City collapsed and suffered extensive damage to the pavement, sub-base, course, and sub-grade.

Photograph 32 Quick repairs were needed because of the extensive damage to agricultural water irrigation systems, field access roads, drainage facilities, etc., in this major rice producing area. But next season's harvest may still be affected.

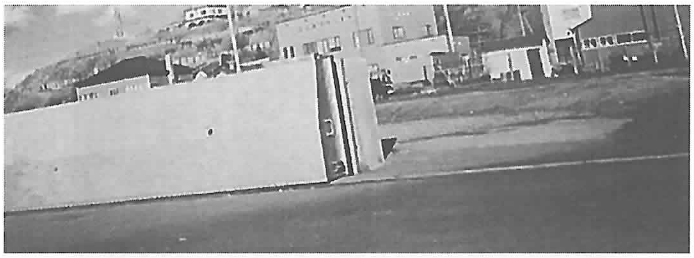
Photograph 33 After the earthquake, the Kashiwazaki nuclear power plants were able to quickly resume normal operations because the plants were designed using dynamic analysis and adequate measures had been taken to prevent liquefaction and other earthquake related problem.

3.3.2 Kushiro Oki Earthquake (November 29, 2004)

Earthquake-proof measures put into effect after the Kushiro Oki Earthquake in 1993 helped to lessen the damage caused by the Niigata Prefecture Chuetsu Earthquake [1,2,3,4]. The damage from the Kushiro Oki Earthquake was slight but useful for evaluating the costs and effectiveness of earthquake proofing measures.



Photographs 34, 35 Hanasaki port in Nemuro City (embankment at right). The wharf levels differ by only a few centimeters.



Photograph 37 The basic functions of the embankment gate of the anti tidal wave quay in Hanasaki port, Nemuro City were not damaged by the Kushiro Oki Earthquake (29th November in 2004), but were damaged by the Hokkaido Toho Oki Earthquake in 1994. An aftershock (December 7, 2004) of the Kushiro Oki Earthquake also did no damage to the gate but only because heavy snow protected it according to one report.

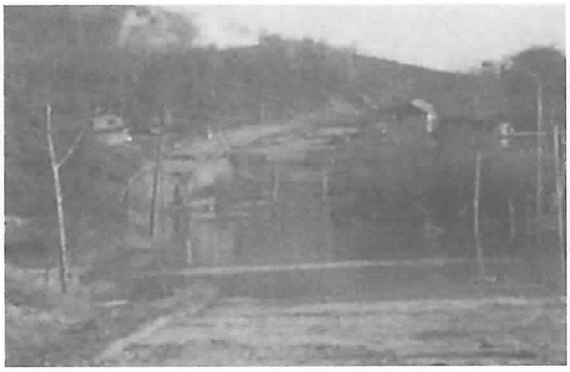
Photograph 36 Liquefaction at the wharf in Hanasaki port, Nemuro City. No real damage occurred because there were no buildings at the site.

Photograph 38 The Northern Territories communications system of the former Department of Communications is a cultural asset. Although it is 100 years old, the system suffered no damage, not even a crack or fallen mortar, because the structure incorporated a beam and an inner bulkhead.

3.4 Damage from Mt. Usu volcanic eruption (March 31, 2000)

Around March 28, 2000, Mt. Usu began showing signs of intense crustal deformation and impending eruption [5]. The volcano became active for first time in 23 years at 13:00 on March 31 of the same year, causing extensive damage to the lives and livelihoods of residents, as well as to the important sightseeing industry, communications and transportation infrastructures (including the main railroad line and the main road in Hokkaido), concrete structures, etc.

The damage to road pavements, building walls, etc., was caused by the impacts of volcanic stones ejected from nearby Nishiyama Crater, which lies to the south of the Lake Toya hot spring resort. Several crustal deformations were visible in the region between the south side of Lake Toya and the area near Uchiura Bay. Volcanic craters formed along National Highway Route 230 (Photograph 39). In the same area, the piers and foundations of bridges and other structures related to transportation and lifeline infrastructure (including the drain shown in Photograph 40) were elevated and damaged. Bridge piers, roadbed, and tunnels along the Doou (Hokkaido Central) National Expressway, the

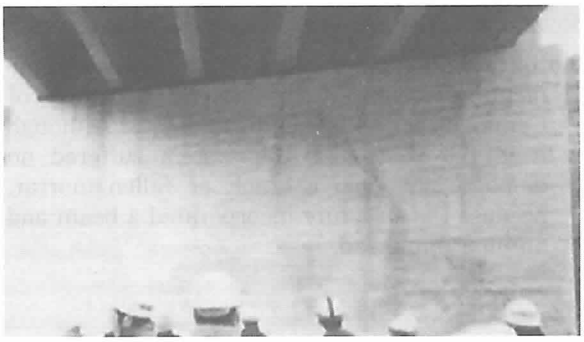


Photograph 39 Volcanic craters and depressions filled with water along National Highway Route 230.

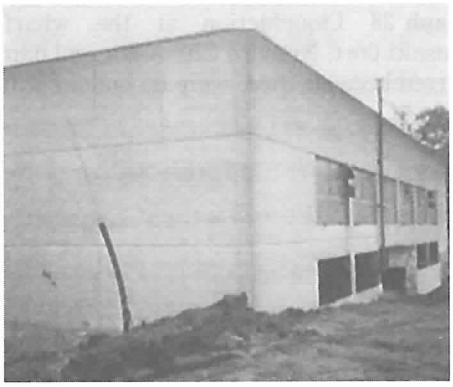
Photograph 42 Cracking and support failure by crustal deformation from volcanic activity along the Doou Expressway.

Photograph 40 Road drain damaged by crustal deformation from volcanic activity.

Photograph 43 RC-beam for road bridge on route 230, washed away by a mudflow.



Photograph 41 Bridge abutment damaged by crustal deformation from volcanic activity along the Doou Expressway.



Photograph 44 First floor classroom of elementary school damaged by a mudflow.

Muroran Main Line of JR Hokkaido Co. Ltd, and various Hokkaido prefecture and municipal roads, etc., were damaged by crustal deformation (Photograph 41). Examples of upward movement, cracking, and support failure are shown in Photograph 42. Structures along the shore of Lake Toya to the north of Konpira-yama Crater were washed away by volcanic ash mudflows. The damage was exceptionally intensive down slope of the nearby volcanic craters. Volcanic-ash mudflows caused particularly serious damage to National Highway Route 230 near the Nishiyama River in the Lake Toya hot spring resort. The RC beam of the Konomi Bridge on National Highway Route 230 was detached and pushed several tens of meters downstream toward Lake Toya by volcanic-ash mudflows from the Nishiyama River (Photograph 43). Mudflowed into the 1F classrooms of the Toyako-Onsen elementary school located near the river, destroying windowpanes and frames. The Mizuumi-Dokusyono-Ie, a wooden-frame mortar structure used as a community center by nearby residents and children, was completely destroyed (Photograph 4)

The following discussion is based on a study of the damage to concrete structures caused by the Mt. Usu volcanic eruption, and on strength tests performed on concrete made with the volcanic ash. Many structures related to the transportation infrastructure, river drainage and irrigation systems, lifeline infrastructure, etc., were damaged by the 2000 Mt. Usu volcanic eruption, as was much property. The damage was caused by ash, stone, gas, crustal deformation, mudflows, etc. Certain characteristic types of infrastructure damage were observed, such as damage to road bridges, drainage systems, etc. While the volcanic activity has stabilized, it continues even now, in the summer of 2001.

Experiments were performed using concrete mixed with volcanic ash from the 2000 Mt. Usu volcanic eruption. The experiments showed that the strength characteristics of the mixture were good. In order for the volcanic ash to be used as a construction material, it must be free of impurities, such as vegetable matter, garbage, etc. The information in guidelines and hazard maps for preventing damage to infrastructures and concrete structures from volcanic activity should be complete and up to date, since volcanic damage is assessed using standards for earthquake damage.

3.5 Reducing high risk of damage caused by disasters

An analysis of recent natural disasters shows that predictions of rainfall, snowfall, wind speed, tide level, wave height, and seismic coefficient should consider the potential for record-setting disasters to occur. Statistical methods and analyses should also consider the potential for major disasters to occur in cities with large populations, such as New York, Tokyo, and Sapporo. Transportation and lifeline functions can be lost in a large disaster, as occurred during the Nigata Prefecture Chuestu Earthquake in 2004 (from near the Uono River in Kawguchi town to the Shinano River in Ojiya city), during the Mt. Usu volcano eruption in 2000 (from Mt. Usu to the coast along Uchiura Bay [5]), and during the Great Hanshin-Awaji Earthquake in 1995 (from the east side of Kobe City to the west side of Osaka city [2]). Trunk line national roads, JR train trunk lines, super express train lines (Shinkansen), expressways, and various communications systems and public utilities, such as gas and water lines, etc., tend to be concentrated in specific areas. Dispersing them can help reduce the high risk of damage during disasters. If they cannot be dispersed, then they should be reinforced. Measures to prevent damage from earthquakes and disasters [4] should be evaluated after every such event to determine their effectiveness and need for improvement. The results should be applied to planning, budgeting, design, and construction. Specifically, to prevent earthquake damage, supports must be reinforced, fallen-girder arresters installed, and bridge piers reinforced. Such work will also help prevent damage from other types of disasters, including mudflows caused by volcanic activity, floods and high waves generated by storms, typhoons, and tsunami [1], etc.

4. Conclusion

The study produced the follow conclusions.

(1) An analysis of recent natural disasters shows that predictions of rainfall, snowfall, wind speed, tide level, wave height, and seismic coefficient, should consider the potential for record-setting disasters to

occur. Statistical methods and analyses should also consider the potential for major disasters to occur in cities with large populations.

(2) Earthquake and disaster prevention measures should be evaluated after every earthquake to determine their effectiveness and need for improvement. The results should be applied to planning, budgeting, design, and construction. Specifically, to prevent earthquake damage, supports must be reinforced, fallen-girder arresters installed, and bridge piers reinforced. Such work will also help prevent damage from other types of disasters, including mudflows caused by volcanic activity, floods and high waves generated by storms, typhoons, and tsunami [1], etc.

(3) When the scale of a disaster exceeds the design values, social infrastructure facilities should not collapse or otherwise endanger the lives and safety of the people using them. It is necessary to review the plan, the design, and the construction of the system keeping in mind the need to implement a "fail-safe" system that facilitates recovery and doesn't result in serious losses or damage.

(4) Public disaster data about the social infrastructure should be collected in the form closest to that of the crude data. This will promote research as well as allow citizens and researchers to understand the social infrastructure. Their trust and understanding will facilitate the implementation of disaster prevention measures both now and in the future.

(5) The high risk of damage from disasters can be avoided by dispersing the transportation trunk lines and other lifeline services. If they cannot be dispersed, they should be reinforced.

Acknowledgement

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