ROAD GEOHAZARD RISK MANAGEMENT

APPENDIX C: JAPAN, SERBIA, AND BRAZIL CASE STUDIES

ACKNOWLEDGMENTS

Production of the report was led by Akiko Toya, program officer, Global Facility for Disaster Reduction and Recovery (GFDRR), with valuable guidance from Yuka Makino, senior natural resource management specialist of the Social, Urban, Rural, and Resilience Global Practice (GSURR), and Kazushige Endo, director of the United Nations Centre for Regional Development (UNCRD).

This report was prepared by Ian Greenwood, consultant to the World Bank's Transport and ICT Global Practice (T&I GP), based on substantive draft documents prepared by a consulting team led by Mikihiro Mori from Nippon Koei Co. The Nippon Koei Co. team was composed of Yutaka Inagaki, Kenichi Tanaka, Toshiaki Hosoda, Hiroaki Tauchi, Saúl Antonio Castelar, and adviser Shinjuro Komata. The report greatly benefited from insights and guidance from the Japanese experts, including the Ministry of Land, Infrastructure, Transport and Tourism, Government of Japan; the Japan International Cooperation Agency (JICA); Daisuke Higaki of the Japan Landslide Society; Hidetomi Oi of the International Sabo Network, Tokyo; and Masaki Hiruma of Sabo & Landslide Technical Center, Tokyo.

The team extends thanks to internal peer reviewers, namely Shomik Raj Mehndiratta, practice manager for South Asia, T&I GP; Fiona Collin, lead transport specialist, T&I GP; Ashok Kumar, senior highway engineer, T&I GP; and Masatsugu Takamatsu, disaster risk management (DRM) specialist, GSURR. The team is also grateful for support from Luis Tineo, lead operations officer, and Julie Dana, practice manager, of GFDRR.

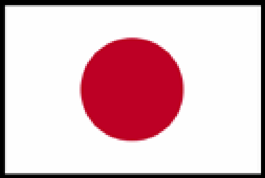
Special acknowledgments go to the following World Bank staff (and consultants): James Newman, DRM specialist, GFDRR, and DRM specialists Keiko Sakoda and Naho Shibuya of GSURR. In addition, we thank Satoshi Ogita, senior transport specialist, T&I GP; Grégoire Gauthier, senior transport specialist, T&I GP; Frederico Pedroso, DRM specialist, GSURR; Javier Escudero Marroquin, consultant, T&I GP; Deepak Malik, consultant, GSURR; Liljana Sekerinska, senior transport specialist, T&I GP; Senad Sacic, program assistant, T&I GP; Svetlana Vukanovic, senior transport specialist, T&I GP; Darko Milutin, DRM specialist, GSURR; consultants Biljana Abolmasov and Marinos Skempas, T&I GP, and consultants Yoganath Adhikari and Mohammad Dehghani, GSURR.

The report greatly benefited from professional editorial work by Mary A. Anderson and professional graphic design by Carlos Plaza Design Studio.


この先急カーブ
30

ROAD GEOHAZARD RISK MANAGEMENT

CASE STUDY OF JAPAN



CONTENTS

FIGURES

TABLES

ABBREVIATIONS

DRM	disaster risk management
JMA	Japan Meteorological Agency
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
TEC-FORCE	Technical Emergency Control Force (MLIT)
PWRI	Public Works Research Institute
VICS	Vehicle Information and Communication System

1 INTRODUCTION

A case study has been developed that captures Japan's experience in road geohazard risk management and offers a way forward for low- and middle-income countries. This case study report includes a discussion of

- Significant issues Japan overcame, such as the initially narrow scope of road management authorities and expansion of the mandate and planning for geohazard risk management in the road sector across various national and subnational governments;
- Turning points in geohazard risk management, such as serious road geohazard incidents;
- Development of critical institutional frameworks, such as passing key legislation and creating funding mechanisms;
- Steps the governments took to identify hazardous locations, conduct risk evaluations, and implement needed structural and nonstructural measures such as an early warning system; and
- Postdisaster response and recovery and preparedness for such reactive measures, including a contingency system.

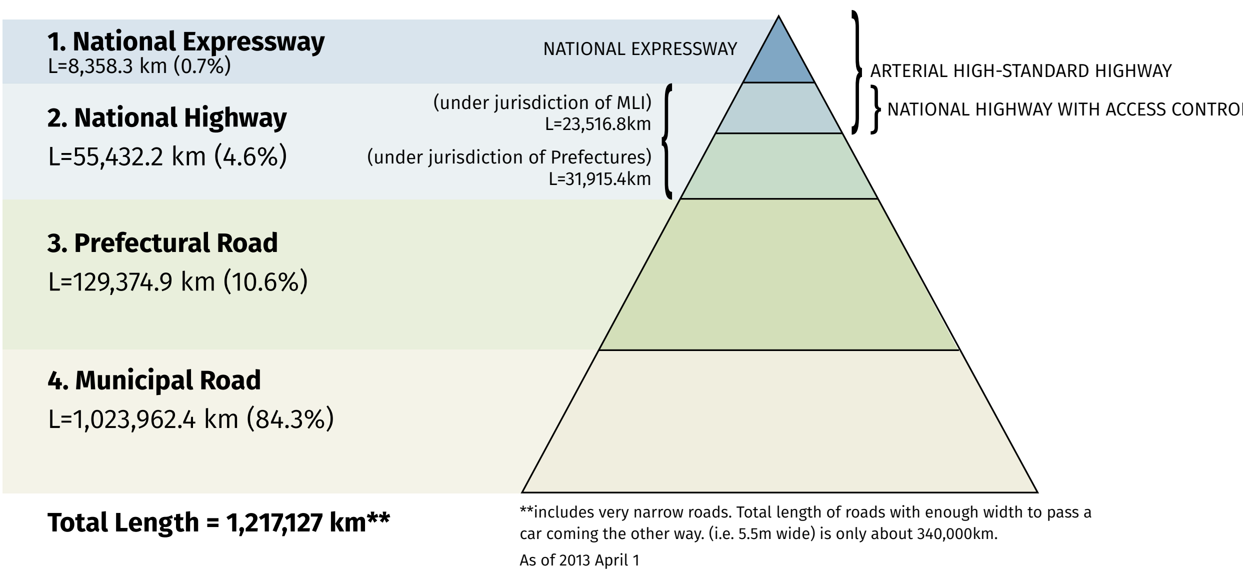
For background information on the overall topic of road geohazard risk management, readers are referred to the main handbook.

1.1 Road System in Japan, by Type

The Road Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has set its main geohazard targets for disaster prevention as earthquakes, heavy rainfall, and heavy snow (and cold). The program for road disaster prevention in Japan is thereby subdivided into programs addressing (a) earthquakes and tsunamis; (b) heavy rainfall; and (c) heavy snow and cold temperature (including prevention of surface freezing) (MLIT 2015a).

The MLIT is in charge of the statistical data on road geohazard damage events and road closures due to geohazards, including those affecting expressways, national highways, and rural roads covering a total of 1.2 million kilometers as of 2013 (Figure 1.1).

Figure 1.1 Roads in Japan, by Type and Length, as Defined by the Road Act, as of 2013



Source: MLIT 2015a.

Note: Figure includes roads classified under Article 3 of the Road Act of Japan (1952), which defines a road as a thoroughfare open to public use and classifies such roads as National Expressways, National Highways, Prefectural Roads, and Municipal Roads.

1.2 Background of Road Geohazard Risk Management

This section was summarized from the "White Paper on Disaster Management in Japan" (Cabinet Office 2015b); the "Disaster Management in Japan" pamphlet (Cabinet Office 2015a); the Government of Japan's MLIT website; and the website of the Japan Meteorological Agency (JMA).

1.2.1 General Situation of Natural Disasters in Japan

Japan is one of the most geohazard-prone countries in the world. Typhoons and heavy rainfall, especially during the rainy season every year, often cause geohazard events. Japan is also an earthquake- and tsunami-prone country where many volcanic eruptions also have occurred.

Japan is located in the circum-Pacific mobile belt, where seismic and volcanic activities occur constantly. Although the country covers only 0.25 percent of the earth's land area, it experiences a high number of earthquakes and active volcanoes: It had 302 earthquakes with a magnitude of 6.0 or more in 2004–13, accounting for almost 19 percent of all the earth's registered earthquakes of that magnitude (Cabinet Office 2015a). Meanwhile, it also has 110 active volcanoes, accounting for 7 percent of all active volcanoes on earth as of 2014 (Cabinet Office 2015a). Moreover, because of geographical, topographical, and meteorological conditions, the country is subject to frequent natural disasters such as typhoons, torrential rains, and heavy snowfalls, as well as earthquakes and tsunami.

Every year, natural disasters in Japan such as typhoons and earthquakes cause great loss of human life and property and extensive infrastructure damage. Until the second half of the 1950s, the thousands of annual casualties had been recorded. Since then, disaster damage has declined as the society increased its capabilities to respond to disasters and mitigate vulnerabilities to disasters by developing disaster risk management systems, promoting national land conservation, improving weather forecasting technologies, and upgrading disaster information communications systems.

In spite of such efforts, in 1995, more than 6,400 people died in the Great Hanshin-Awaji Earthquake (Cabinet Office 2015b). Also, in 2011, more than 18,000 people died or went missing in the Great East Japan Earthquake (Cabinet Office 2015b). A high probability of large-scale earthquakes persists, including impending possibilities of a Nankai Trough earthquake and a Tokyo Inland earthquake. As such, natural disasters remain a menacing threat to the country's safety and security.

1.2.2 Earthquake Disasters in Japan

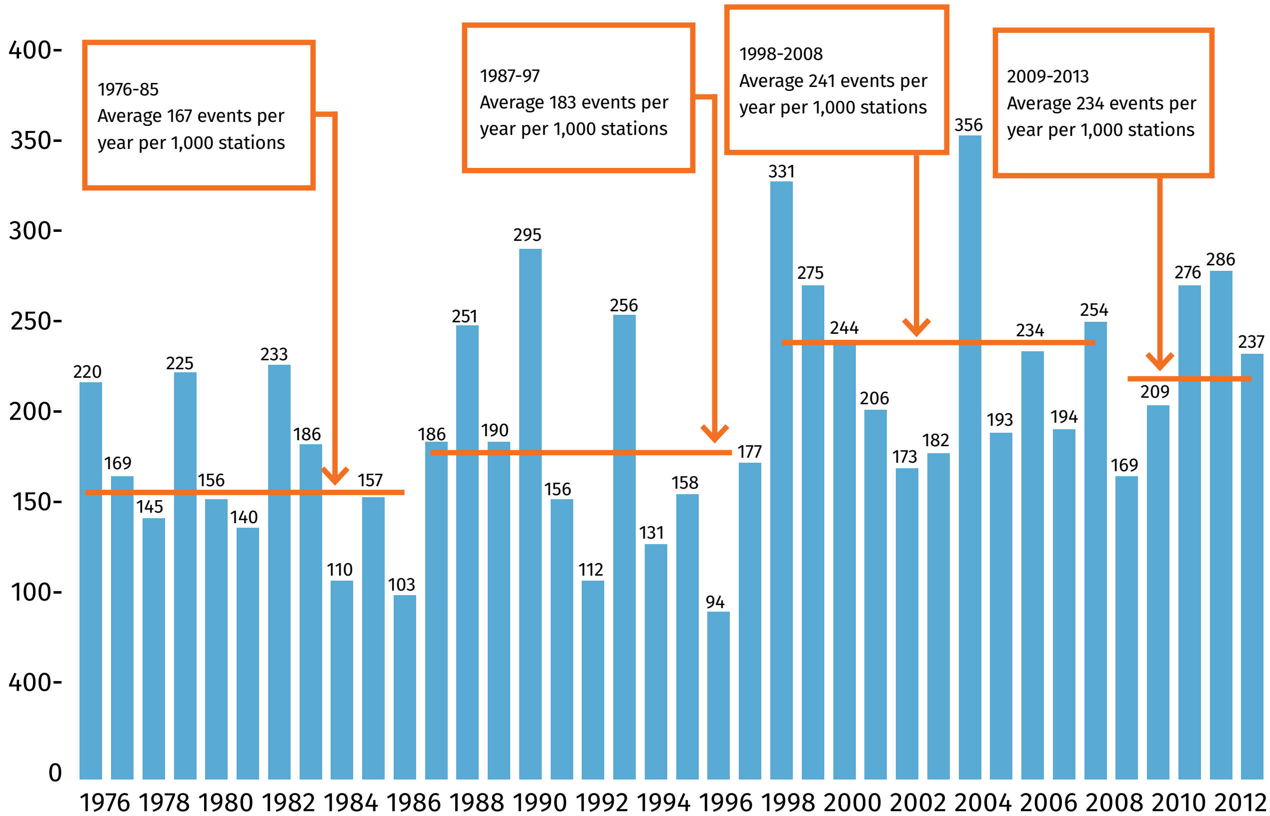
Japan is one of the most seismically active areas on earth, located where 4 of more than 10 tectonic plates covering the globe are crushed against each other, making it an archipelago susceptible to earthquake disasters. Nearly 20 percent of the world's earthquakes (of magnitude 6.0 or greater) have occurred in or around Japan (Cabinet Office 2015a). Japan has suffered great damages from the massive inter-plate earthquakes produced by plate subduction (such as the Great East Japan Earthquake and Tsunami of 2011) as well as from the inland crustal earthquakes caused by plate movements (such as the Great Hanshin-Awaji Earthquake of 1995).

1.2.3 Storm and Flood Disasters in Japan

Japan is prone to a variety of water- and wind-related disasters including flooding, landslides, tidal waves, and storm hazards because of meteorological conditions (such as typhoons) and geographical conditions such as precipitous terrains and steep rivers and settlement conditions in which many of the cities are built on river plains. Approximately one-half of the population (or 60 million people) are concentrated in possible inundation areas, which account for about 10 percent of the national land (Cabinet Office 2015a). Many years of soil conservation and flood control projects have greatly reduced the area inundated by floods, but the value of general assets damaged in flooded areas has increased in recent years.

A long-term trend of increasing downpours throughout the country has been observed. Based on data from the Japan Meteorological Association, rainfall stations recorded an upward trend in the average annual number of hourly rainfall events exceeding 50 millimeters per hour (Cabinet Office 2015a). This increased from 0.17 (events per year per station) during the 1976–86 period to 0.18 during the 1987–97 period, 0.24 during the 1998–2008 period, and 0.23 during the 2009–13 period (Figure 1.2).

Figure 1.2 Annual Torrential Rainfall Events per 1,000 Rainfall Stations in Japan, 1976–2013



Source: Cabinet Office 2015a.
Note: "Torrential rainfall" refers to rainfall of more than 50 millimeters per hour.

1.2.4 Volcano Disasters in Japan

Japan is a highly volcanic country. Poised on the circum-Pacific volcanic belt, or "Ring of Fire," the Japanese islands are home to 110 active volcanoes, which account for 7 percent of the earth's total (Cabinet Office 2015a). In the past, eruptions and other volcanic activities have caused heavy damage. Three recent examples—the eruptions of Mt. Usu and Miyakejima Island in 2000 and Mt. Kirishima (Shinmoedake) in 2011—caused thousands of residents to flee their homes.

1.2.5 Snow Disasters in Japan

Japan is a bow-shaped archipelago with steep mountain ranges. When cold winds blow from Siberia in the winter, the warm current up to the coast from the south brings heavy snowfall to the Sea of Japan side of the country. Thus, the northeastern part of Japan has frequent winter snows. Recently, snow had occurred not only in the northeastern part but also in other areas of Japan where it had seldom snowed before. Heavy snow in such areas often creates huge upheaval.

In the winter of 2006, the death toll reached 152. In the winter of 2012–13, many automobile drivers were killed in the snowstorm: some died in their cars from carbon monoxide poisoning because snow had clogged their cars' exhaust pipes, while others left their vehicles and froze to death (Cabinet Office 2015a).

From November 2013 to March 2014, the Kantō and Koshinetsu areas experienced record-breaking snow, damaging a vast area including areas that previously had never been snow-prone. Many stranded vehicles on the streets blocked traffic, forcing railway operations to stop. As many as 6,000 families in 130 settlements were isolated and stranded (Cabinet Office 2015a).

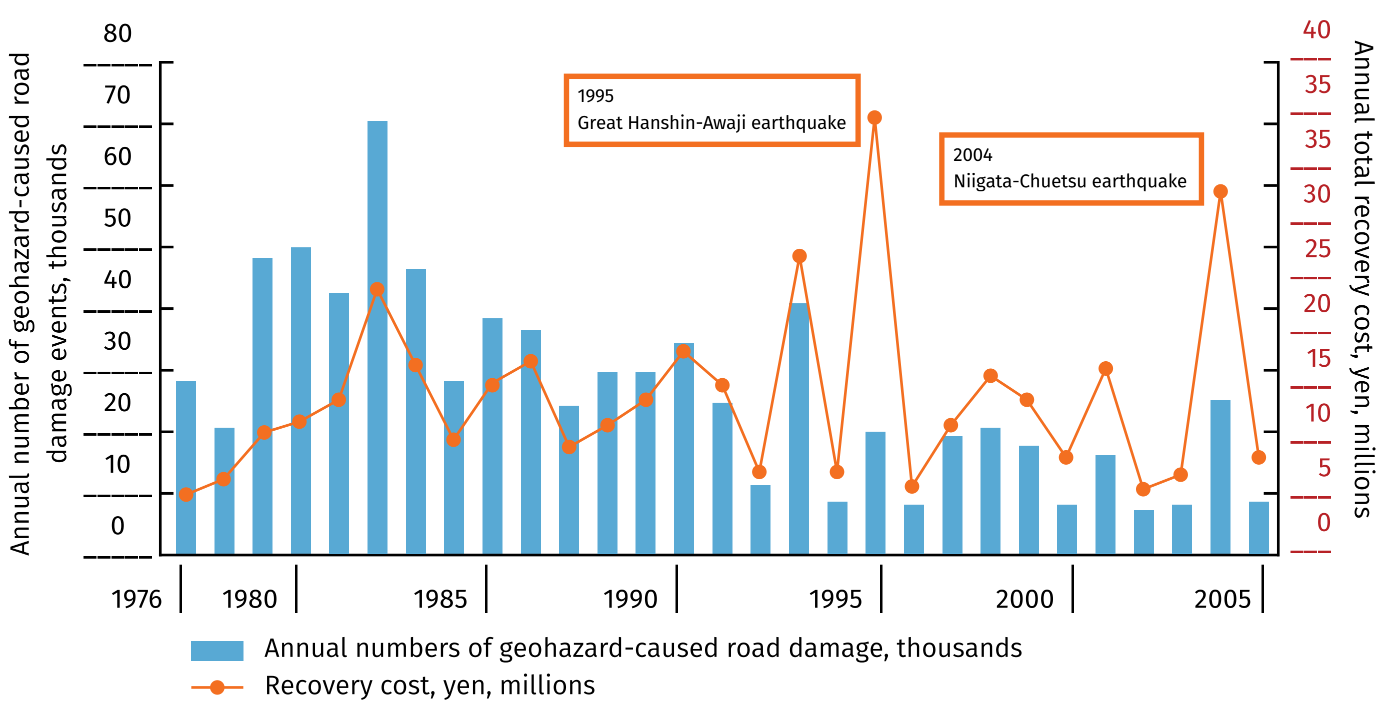
1.3 Current Condition of Road Geohazard Risk Management Issues

1.3.1 Road Geohazards in Japan

Over the long term, annual geohazard-caused road damage events have decreased in number (Figure 1.3). In 11 of the 17 years from 1977 through 1993 (65 percent of those years), more than 30,000 geohazard-caused road damage events were recorded. For the 13 years from 1994 through 2006, the annual number of such events remained fewer than 30,000. This downward trend seemed to be the effect of road geohazard risk reduction investments in proactive structural measures.

Whether the annual recovery cost also decreased is not clear because of the effect of price escalation through the years. The considerable recovery cost in 1995 and 2004 was due to catastrophic earthquake events in those years, which resulted in relatively higher average damage magnitudes and recovery costs for the road damage locations. Figure 1.3 shows the annual number of geohazard-caused road damage events and the recovery costs from 1977 to 2005.

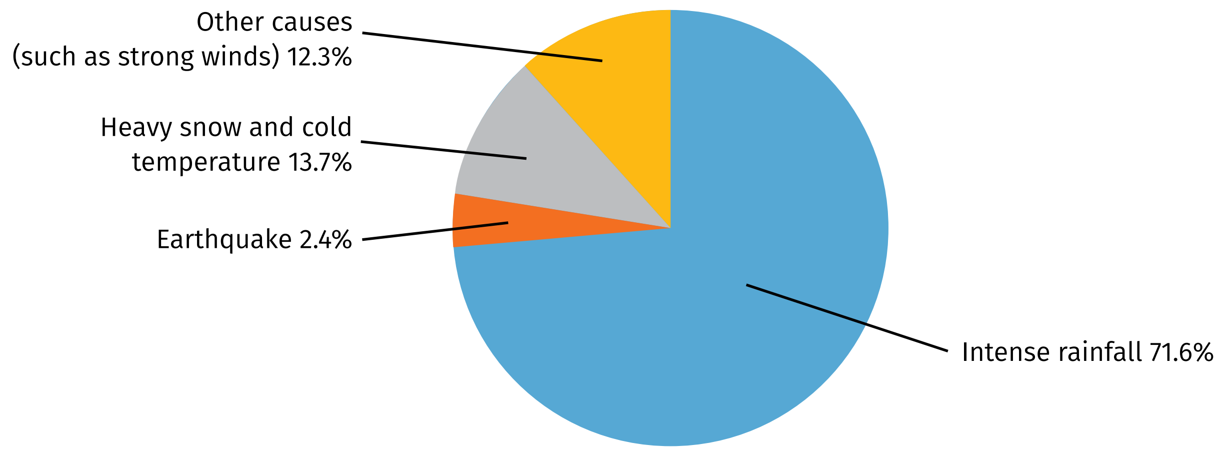
Figure 1.3 Annual Geohazard-Caused Road Damage Events and Recovery Cost in Japan, 1977–2005



Source: Road Bureau data, MLIT, http://www.mlit.go.jp/road/road_e/index_e.html.

Geohazards in Japan caused an average of 7,400 road closures per year during fiscal years 1995–2004. More specifically, the causes, by type of geohazard, are indicated in Figure 1.4, with precipitation-based events (intense rainfall and heavy snow) making up the vast majority of causes.

Figure 1.4 Causes of Road Closures due to Geohazards in Japan, by Type, 1995–2004



Source: Road Bureau data, MLIT, http://www.mlit.go.jp/road/bosai/dourokuukan/.

1.4 Opportunities for Enhancing Road Geohazard Risk Management

1.4.1 Lessons Learned from Historical Road Geohazard Events

Based on the lessons learned from dealing with frequent road geohazard events, the Japanese government has made systematic improvements to road geohazard risk management procedures. Table 1.1 summarizes the history of major road geohazard incidents and the government's actions to address them, including the formulation of laws and preparation of technical manuals. As shown, the legal system and countermeasure techniques have been improved and implemented after the lessons learned from historical road geohazard events.

Table 1.1 Events Related to Road Geohazard Risk Management in Japan, 1952–2014

Event	Geohazard details and government action
1952: Road Act revised (Act No. 180 of 1952)	The Road Act prescribes the authority and responsibility for road traffic by the road management authority to secure road traffic safety.
1954: "Road Earthwork: General Guidelines" published by the Japan Road Association	The guidelines include the countermeasures for road geohazards, describing surveys, plans, designs, construction, and maintenance. The latest edition of the guidelines was published in 2009 (Japan Road Association 2009b).
1959: Typhoon Vera (Isewan-Taifu in Japanese) severely floods and damages the Pacific coastal area of Ise Bay in Central Japan, killing 5,238 people.	The typhoon caused extensive flooding along with matching high tide. The government prepares the Disaster Countermeasures Basic Act to accelerate geohazard risk management.
1961: Disaster Comprehensive Countermeasures Basic Act (Act No. 223 of 1961) enacted	The Act prescribes the roles and responsibilities for each disaster phase (prevention, emergency response, rehabilitation, and reconstruction).

Event	Geohazard details and government action
1968: August 18 Hida River bus-fall incident on National Road No. 41 in Gifu Prefecture in Central Japan, killing 104 people	The road mountainside slope (100 meters high, 30 meters wide) collapsed, directly hitting and pushing three buses into the valley side. Two buses fell into the river during extremely intense, long rainfall. Most of the collapsed slope was outside the right-of-way (area of land managed by the road management authorities). At that time, six buses were isolated and stranded in the road location, blocked on both the front and rear of the road mountainside slope collapse. The Road Bureau of the former Ministry of Construction ordered the national road management authorities to conduct the road geohazard risk inspection (identification, inventory, and prioritization of hazard-prone road locations) and to establish a new risk avoidance system of precautionary road closure (to save lives) during situations highly susceptible to geohazard events affecting road locations.
1968: Japan's first nationwide road geohazard risk inspection conducted in September	After the Hida River bus-fall tragedy, the Road Bureau ordered the national road management authorities to conduct a nationwide road geohazard risk inspection and to prepare an inventory of hazard-prone road locations to be measured.
1969: Precautionary road closure operation established	Precautionary traffic closure is the traffic regulation intended to save road user lives. The director of the Road Bureau designated the road subsections for precautionary traffic closure nationwide. This type of nonstructural measure was established after the lessons learned from the Hida River bus-fall tragedy.
1970: Liability of the road management authority on road disasters determined by Supreme Court, August 20	The decision held that the road management authorities have the responsibility to determine hazard-prone road locations, to eliminate the danger, and to install proactive nonstructural measures such as precautionary road closure to save road user lives. The trial was held for road users because of the road slope collapse on National Road No. 56 in Shikoku Region in 1963. The Hida River bus-fall accident occurred during this dispute and may have affected the Supreme Court decision.
1970: Japan's second nationwide road geohazard risk inspection conducted in October	After the Supreme Court decision, the Road Bureau ordered the management authorities with responsibility for national, prefecture, and municipal roads to conduct road geohazard risk inspections and to update or prepare the inventory of hazard-prone road locations to be provided with proactive measures.
1989: Echizen Coast road rock shed collapse on National Road No. 305 near Tamagawa, Fukui Prefecture, killing 15 people	The rock shed collapsed because of rock collapse on the shed. This rock collapse was newly defined as a type of geohazard and was added to the "Draft Road Geohazard Risk Inspection Guidebook," which included the inspection sheet formats for rockfall, collapse, rock mass collapse, slides, snow avalanche, road embankments, drifting snow, rock sheds, and tunnels (Ministry of Construction 1990).
1990–95: Unzen Fugendake Volcano activities (62 debris flows and 9,472 pyroclastic flows), which hit Shimabara Peninsula (Nagasaki Prefecture, Kyushu Region), leaving 44 people dead or missing and isolating Shimabara City several times by road and railway closures	In 1993, the Ministry of Construction publicly offered the technology for the first remote-controlled, or unmanned, construction machinery for the hazard-prone location to meet the following requirements: • Braking boulders of 2–3 meters • Operation at 100 degrees centigrade, 100 percent humidity • Remote-control operation at 100-meter distance In 2004, the Ministry of Construction also adopted the first remote-controlled, or unmanned, construction machinery for earthworks operations (such as dump trucks, backhoes, and bulldozers) to remove debris from sand pockets or to fill earth dams for debris flow protection.

Event	Geohazard details and government action
1995: Great Hanshin-Awaji Earthquake (magnitude 6.9), with severe damage to Hyogo Prefecture in the southern region along the seashore, killing 6,402 people	The government recommends the strengthening of bridges and embankments against earthquakes. The preparation of the geohazard risk management plan by hazard type begins in addition to the designation of emergency roads. The designated emergency roads are arterial highways and connecting roads between disaster prevention facilities (evacuation points and facilities, storage facilities for emergency aid, rescue facilities, and information and communication facilities). The designated emergency roads are to be used exclusively for emergencies declared by the government. The designated emergency roads have high priority in investments for structural measures for road disaster prevention.
1996: Rock mass collapse at entry of Toyohama Tunnel, Hokkaido, in the northern region, killing 20 people	The rock mass collapse destroyed the entry of the tunnel and vehicles. Despite a sign of the impending collapse of the rock mass just before the incident, this was not relayed to the road management authority and road users. Regional partnerships for road disaster risk management were proposed based on the lessons from this tragedy. The "Road Geohazard Risk Inspection Guidebook" was updated after the accident (ROMAN-TEC 1996)[a].To share the concept and strengthen the quality of inspection, short training courses (four days on the whole, with one day at the site) for public and private engineers engaged in inspections were conducted. The "Road Geohazard Risk Inspection Guidebook" was revised for heavy rain, heavy snow, and earthquakes. Road geohazard risk inspections were conducted on national highways and subnational roads from 1996–97.
1997: Rock mass collapse at entry of the Second Shiraito Tunnel, Hokkaido, in the northeast region, no fatalities	Evaluations of rock mass collapse and advanced studies had commenced for road geohazard risk inspection techniques such as rock slope mass monitoring and numerical analysis of rock mass collapse mechanisms.
2001: Ministry of Land, Infrastructure, Transport and Tourism (MLIT) established by merging the Ministry of Construction, Ministry of Transportation, Hokkaido Regional Development Bureau, and National Land Agency	The Road Bureau in the former Ministry of Construction and the Japan Meteorological Agency (JMA) in the former Ministry of Transportation were transferred into the new MLIT. The Disaster Prevention Bureau of the old National Land Agency was transferred to the Disaster Management Cabinet Office in the Cabinet Office.
2005–06: Heavy snow, killing 152 persons and causing 115 avalanches to hit roads (most seriously, causing a five-day road closure on National Highway No. 405 at the border of Nagano-Niigata Prefectures, isolating 193 households, 501 residents)	The proactive structural measures and nonstructural measures for preparedness—including standby contracts with private construction companies for emergency snow removal—were enhanced. To avoid traffic suspension losses due to road closures on National Highway No. 17 (at the border of Niigata and Gunma Prefectures), the Road Bureau implemented a temporary toll-free opening of a section of National Expressway toll road. The National Expressway is a high-standard road structure and maintenance system that provides safe road driving conditions for non-high-speed driving even under severe weather.

Event	Geohazard details and government action
2006: "Road Geohazard Risk Inspection Guidebook" updated (ROMAN-TEC 2006), edited by a technical committee comprising public and private technical authorities 2009: New edition of "Road Geohazard Risk Inspection Guidebook" published (ROMAN-TEC 2009)[b] (as of 2016, the latest version) 2010: 2009 edition reprinted and published in 2010 (JGCA 2010)	Based on the road slope geohazard event records from 1996, some of the disasters occurred at road locations that had not been identified as hazard-prone locations in previous inspections conducted in 1996–97 after the 1996 publication of the "Road Geohazard Risk Inspection Guidebook" (ROMAN-TEC 1996). Thus, the criteria for identifying hazard-prone road locations were revised in the Guidebook, considering past disaster lessons (ROMAN-TEC 2006). The key aspect of the revision was to confirm the slopes up to the hilltop for possible geohazard by checking water flow possibility on mountainside water-collecting topography and the drainage capacity of developed land (for residents, business establishments, and agricultural land), which may cause water flow into the roadside slope. The 2009 edition included techniques on geohazard analysis using accurate maps formulated by laser (light amplification by stimulated emission of radiation) profiling (ROMAN-TEC 2009; JGCA 2010).
2008: Iwate-Miyagi Earthquake, Northeast Japan A slide-type geohazard blocked a river and formed a natural dam.	The Sediment Disaster Prevention Act was revised in 2011. It was intended to share information (such as susceptible geohazard situations and recommendable evacuation routes under the situation including accessibility of roads) on the emergency evacuation of residents for severe sediment disasters.[c] A natural dam formed by a geohazard is composed of loose soil materials and has a high possibility of an outbreak due to hydrofracturing or overflow of the dam.
2011: Great East Japan Earthquake, east-north region of Japan, killing 15,894 people with 2,563 people still missing; most fatalities killed by tsunami (other causes such as fall- or collapse-type geohazard making up less than 5 percent)	The Disaster Countermeasures Basic Act (1961) was amended in 2012 in response to lessons from disasters, mostly in the east-north region of Japan, such as the need to reopen roads for emergency response. Of note is the efficient reopening or eliminating of obstructions on damaged and closed roads to activate emergency transportation or evacuation roads. The national and regional road bureaus administer the operation through private construction companies. The priority targets were the arterial roads of the inland-coastal or east-west direction access to the seriously damaged coastal road in the north-south direction, starting from the undamaged arterial highway running through the inland (north-south direction). The operation was named "Comb's Teeth Strategy" because of the parallel shape of the inland-coastal connection roads. The cases confirmed that roads served as evacuation sites for local residents and were effective in preventing floods from spreading. In 2011, some of the expressway companies and subnational governments entered into an agreement to use the slope surface of expressway embankments in coastal areas as tsunami emergency evacuation sites. After the earthquake, MLIT started to promote the use of rivers as emergency transport routes—the dry riverbed for vehicles and the waterway for ships.
2013: Disaster Countermeasures Basic Act amended	The following aspects were added: • Intensification of the ability for emergency response on a large scale and forwide-area disasters • Preparation of smooth, secure evacuation routes • Improvement of shelters for victims • Strengthening of disaster risk reduction (proactive measures)
2014: Slope failure due to heavy rain, hitting residential area in Hiroshima, killing 74 people	The Sediment Disaster [= geohazard] Prevention Act was revised in 2014. Modifications made it compulsory to publish all potential hazards for citizens in a particular area.

Event	Geohazard details and government action
2013–14: Highest recorded snowfalls in the Kantō and Kōshin'etsu areas, stranding many vehicles on the street, blocking traffic, halting railway operations, and isolating as many as 6,000 households	Review and revisions are being made on issues such as (a) how the alert, warning, and weather advisories can be provided; (b) measures to clear stranded vehicles blocking traffic; and (c) timing of precautionary road closures, especially for the national expressways, which are relatively safer to use than other roads during heavy snow.
2016: Kumamoto Earthquake, killing 50 persons directly at the event; closing road subsections of National Expressway 23 (between adjacent intersections) and 54 locations on National Highway; and collapsing Aso-Ohashi bridge (205.96 meters long) on National Highway No. 25 because of abutment slope collapse of 500,000 cubic meters	The road closures due to bridge collapse or damage, and fallen utility poles (power and telephone) tied up emergency transportation and postdisaster response and recovery. The importance of the proactive seismic strengthening of roads for emergency transportation has once again been recognized. The many closed-circuit TV cameras for road traffic situation monitoring were useful to capture damage assessments for road infrastructure. But some of the camera and communication devices were damaged by the earthquake and had not functioned; thus, redundant or multiple camera installation systems are desirable.

Sources: Cabinet Office 2015a, 2015b; JGCA 2010; MLIT 2011, 2014a; ROMAN-TEC 1996, 2006, 2009; and information from websites of the Cabinet Office (http://www.cao.go.jp/index-e.html) and Ministry of Land, Infrastructure, Transport and Tourism (http://www.mlit.go.jp/en/index.html).

1.4.2 Lessons Learned from Hida River Bus-Fall Incident and Improvement of Road Geohazard Risk Management Procedures

A significant turning point in road geohazard risk management in Japan was the 1968 "Hida River Bus-Fall Incident," in which debris from a slope collapse hit two buses, pushing them from a mountainside into a river and killing 104 people. The debris flow occurred outside of the road management area (the road right-of-way) and was triggered by extremely heavy rains. The precipitation at that time had exceeded 100 millimeters per hour. The incident revealed the road geohazard risk management issues discussed below.

ISSUE 1: No Proactive Measures Existed for Roads outside the Road Management Authority's Area of Responsibility

ISSUE AND LESSONS LEARNED: The broad geohazard (slope collapse) occurred outside of the road management authority's area (right-of-way). Until this accident occurred, the road management authority in Japan had targeted only road structures (such as roads, bridges, and tunnels) and road earthwork structures (such as engineered slopes and embankments) and did not handle geohazard risks outside its area. Geohazards generated from long distances sometimes damaged the road. These were especially true in the case of steep mountainside rock or soil falls or collapses due to flow-type

[a] The Road Management Technology Center (ROMAN-TEC) was a foundation under the MLIT that conducted research and development and provided technical training on technology for the preservation of roads and road structures and for the operation of the road management system. ROMAN-TEC was established in 1990 and abolished in 2011.

[b] The 2009 edition was reprinted with same content by Japan Geotechnical Consultants Association (JGCA 2010) because the Road Management Technology Center (ROMAN-TEC) delegated the publication to JGCA when ROMAN-TEC was abolished in 2011. JGCA is a foundation under the MLIT's Road Bureau that provides technical training material for geotechnical inspection and investigation as well as training sessions and e-learning materials on road geohazard risk inspection.

[c] Sediment disaster has almost the same meaning as damage due to geohazards. Geohazards include floods, but sediment disasters do not in the exact sense. The relationship between flow-type geohazards of earth or debris flow (including sediment disaster) and flooding are categorized by the water contents, and a clear distinction cannot be made. Furthermore, a flow-type geohazard changes its water contents during an event—for example, starting from floodwaters and changing to earth or debris flow.

geohazards with high water content in the landscape ecosystem upstream of the hazard-prone road location. The hazard-prone location had no proactive structural measures.

Improvement of road geohazard risk management procedures. A month after the August 1968 tragedy, the Road Bureau of the Ministry of Construction ordered the national road management authorities to conduct the first nationwide road disaster prevention inspection simultaneously. Nationwide inspections have now been ordered 10 times (in 1968, 1970, 1971, 1973, 1976, 1980, 1986, 1990, 1996–97, and 2006). The purpose of the inspection was to formulate or update the inventory of hazard-prone road locations likely to suffer road damage from geohazards and to determine the locations where proactive measures could be installed. The evaluation procedure has been updated so as not to miss any hazard-prone road locations, including those that may be damaged by geohazards occurring far from the road. The proactive structural measures were installed in selected priority hazard-prone locations.

ISSUE 2: No Nonstructural Measures Existed for Emergency Information, Including Early Warning or Precautionary Road Closures

ISSUE AND LESSONS LEARNED: The Hida River bus-fall tragedy had occurred under extremely intense, lengthy rainfall, and the location was in a geohazard-prone road subsection. The bus drivers or conductors were not familiar with the geohazard danger to the road situation. The volunteer disaster emergency response team of the community along the road recommended that the bus drivers or conductors not proceed to the hazard-prone road subsection during the highly hazard-susceptible situation, but they had no authority and could not persuade the bus drivers or conductors to follow their advice. On the other hand, the railroad station master near the road location was familiar with the fragile local geology and the potential geohazard from historical heavy rainfall events, and he decided correctly to stop the train at the station to await recovery from the abnormal rainfall and highly susceptible geohazard situation, even though some passengers strongly complained. As a result, the train passengers' lives were saved.

Improvement of road geohazard risk management procedures. In 1969, the Road Bureau ordered the national and subnational road management authorities to identify geohazard-prone road subsections to be subject to precautionary road closure operations. The purpose of the precautionary road closure is to save road users' lives from a geohazard-induced disaster. A "precautionary road closure" is the decision ordering a road closure.

The precautionary road closure system enables each road management authority to apply the road closing criteria to the geohazard-prone road subsection. The Road Bureau director designates the precautionary road closure subsections with their road closure criteria identified, such as cumulative rainfall amount from the start of the rainfall. Geohazards are often triggered by heavy rainfall. Therefore, the rainfall index is normally used as a criterion for a precautionary road closure in Japan. The rainfall index is used to measure the continuous rainfall amount from the start of the rainfall. The road closure criteria using the rainfall index are determined by the value of the historical rainfall index of road geohazard events. The other criteria are dense fog, strong winds, high coastal waves covering the road, and other hazardous conditions.

The operation for precautionary road closure is undertaken not only for designated road subsections but also for any situations that are highly susceptible to geohazard. Road-hazard-prone situations or road closure situations are announced through the electronic road information boards along the roadsides (or above the roadways using the above road structures), in parking areas, through the mass media, and through the internet.

2 INSTITUTIONAL CAPACITY AND COORDINATION

2.1 Institutional Framework

2.1.1 Laws, Regulations, and Technical Standards

Japan has established laws that specify the guarantee of funds related to disaster relief, disaster management plans, and the fundamental matters related to systems during a state of emergency.

Technical standards and manuals have been prepared for (a) disaster risk management; (b) road disaster risk management; (c) risk evaluation for road geohazards; (d) benefit estimation of proactive measures for road geohazards; and (e) business continuity planning for road geohazards. However, regarding (c) risk evaluation for road geohazards, no practical manual on risk estimation of potential economic loss has been developed. Regarding (d) benefit estimation of proactive measures, no practical manual has been developed.

FUNDAMENTAL LAWS ON DISASTER RISK MANAGEMENT

Act on National Treasury Share of Expenses for Recovery Projects for Public Civil Engineering Facilities Damaged Due to Disasters (1951). Before this act was enacted, the cost for recovery was allocated through the budget of the prefectural government of affected areas in Japan. However, the budget allocation often exceeded the annual revenue of prefectural governments. Subsequently, the Japanese national government decided to subsidize a portion of the budget through this act. The amount of the subsidy is determined by the ratio of (a) the amount of the subsidy from the national government to the estimated recovery cost, to (b) the prefectural government's annual revenue (Table 2.1).

Table 2.1 Conditions for Subsidizing Prefectural Governments' Disaster Recovery Costs

Ratio of estimated recovery cost to prefectural government's annual revenue	Amount of subsidy from national government
Cost is less than half the prefectural government's annual revenue	Two-thirds of recovery cost
Cost is half to two times the prefectural government's annual revenue	Three-fourths of recovery cost
Cost is more than two times the prefectural government's annual revenue	All of the recovery cost

Source: Act on National Treasury Share of Expenses for Recovery Projects for Public Civil Engineering Facilities Damaged Due to Disasters (1951).

Disaster Countermeasures Basic Act (1961, the latest amendment as of 2016). The Disaster Countermeasures Basic Act comprises the following provisions:

- ***Definition of responsibility of each administrative body.*** The national government, prefectural administrations, and subnational public entities shall formulate disaster risk management (DRM) plans and implement the plans together with the cooperation of other organizations and shall have responsibility for the protection of human lives and properties through DRM.
- ***Formulation of comprehensive DRM.*** The national government, prefectures, and municipalities shall create a disaster management council to formulate disaster risk strategies and to administer preparedness for disaster. When a disaster is predicted or has occurred, the prefectures and municipalities shall mobilize the emergency response teams. When a serious disaster is

predicted or has occurred, the prefectures and municipalities establish emergency headquarters for disaster emergency measures and damage assessment. In the case of large-scale disaster emergencies covering many prefectures, the national government establishes a national emergency headquarters for major or urgent disaster management and carries out measures and coordinates with DRM organizations at different levels.

- ***Preparation of DRM plan for each administrative body.*** The national DRM council shall prepare a comprehensive national DRM plan based on the disaster risk plans of prefectural governments and municipalities.
- ***Development of DRM.*** The roles and responsibilities of each governmental body are determined for each DRM stage: disaster risk reduction, emergency, recovery, and restoration.
- ***Dispatch for national emergencies.*** If an extremely severe national disaster occurs, the prime minister can declare a state of emergency. The cabinet can prepare the special budget and formulate acts for the security and safety of the state.

Act on Special Financial Support to Deal with Extremely Severe Disasters (1962). The act defines the rules of special financial assistance for subnational public entities and victims in the occurrence of extremely severe disasters.

LAWS ON GEOHAZARD RISK MANAGEMENT

The laws on geohazard risk management are prepared for several geohazard types, software and hardware measures, and several sectors in addition to the road sector such as the river, agriculture, and forestry sectors (Table 2.2). Japan has been enforcing geohazard-related laws based on lessons learned from previous disasters.

Table 2.2 Geohazard Disaster-Related Laws in Japan

Basic DRM law	Purposes
Disaster Countermeasures Basic Act (1961, latest amendment as of 2016)	To maintain a systematic DRM administration system. The main contents are as follows: Clarification on DRM • DRM system • DRM plan • Disaster risk prevention • Disaster emergency measures • Financial measures • Disaster state of emergency
River Act (1964, latest amendment as of 2015)	Mainly to define the regulating authority responsible for river management to reduce damage due to flood
Erosion Control Act (1897, latest amendment as of 2013)	Mainly to prevent production and runoff of sediments from mountain streams and adjoining slopes affecting flood control Provides authorization for road construction near the boundary of a sediment-control designated area
Landslide Prevention Act (1958, latest amendment as of 2014)	To prevent or reduce landslides and the collapse of slag heaps.[a] To stipulate the authorization for road construction in the determined landslide prevention areas

Act on Prevention of Steep Slope Collapse Disaster (1969, latest amendment as of 2005)	To protect human lives and properties of citizens from the collapse of steep slope (more than 30 degrees inclination), it intends to • Restrict any activities; • Execute countermeasures; and • Develop alert and evacuation systems. Establishes guidelines for the authorization of road construction on the steep slope collapse prevention areas
Forest Act (1951, latest amendment as of 2016)	To implement preservation and conservation of the forests and increase forest production capacity Describes prevention measures for geohazard disasters such as the defense of the sediment runoff, soil collapse, and appointment of forest preservation to prevent geohazard Inside the forest preservation areas, certain activities are restricted or canceled if such activity causes the loss of some aspects of the forest function
Sediment Disaster Prevention Act (2000, latest amendment as of 2016)	To establish regulations for living in disaster-prone or dangerous zones and provide for the obligatory publication of all risks to inhabitants in particular areas starting in 2000

Note: DRM = disaster risk management.

a. Slag heaps are rock or soil disposal mounds from mining excavations. At the time the law was established, the Japan coal mine industry was active, and slag heap collapse had become a big problem. As of 2016, all the slag heaps have been measured, and no problem has occurred.

LAWS ON ROAD GEOHAZARD RISK MANAGEMENT

The Road Act (1952, the latest amendment as of 2016) is the basis for road geohazard risk management. Among its provisions,

- ***Article 42*** mandates that the road management authority maintains and repairs roads to keep them in good condition, also specifying the applicable technical standards (including for road inspection and maintenance); and
- ***Article 46*** gives the road management authority responsibility for traffic regulation during the following situations:
    - o The road is dangerous to use because of geohazards on the road.
    - o The road cannot be used because of construction or rehabilitation activities.

TECHNICAL STANDARDS AND MANUALS

Disaster risk management. The Cabinet Office is the agency responsible for DRM in Japan. Most government officials lack sufficient DRM knowledge because they lack experience in actual DRM activities. The Cabinet Office has developed the standard DRM guidelines for public officials. It is also currently developing the Guidelines on the Standardization of Disaster Management to standardize, make more practical, and share the procedures and practices of the disaster recovery system and business operations, based on the latest know-how and lessons acquired from actual DRM practice.

Road geohazard risk management. In Japan, in most cases, cost-benefit analysis has not been conducted for road geohazard risk reduction investment. The Public Works Research Institute (PWRI) developed the “Draft Manual on Risk Analysis and Risk Management Support for Road Slope Disasters” as a reference for conducting project economic feasibility analysis for risk reduction investments (PWRI 2006). The draft manual proposed the following procedures:

- Evaluation of road geohazard occurrence probability using multivariate statistical analysis of historical geohazards and the checklist or category of hazard-prone road locations
- Economic loss estimation of several magnitudes of road closure events due to geohazards
- Risk estimation of potential annual loss
- Risk management planning using the results of the risk estimation.

Risk evaluation for road geohazards. The MLIT's Road Bureau formulated a "Draft Road Geohazard Risk Inspection Guidebook" in 1990 (Ministry of Construction 1990), which was subsequently revised in 1996, 2006, and 2009 (ROMAN-TEC 1996, 2006, 2009) and in 2010 (JGCA 2010). The guide is used to identify hazard-prone road locations, categorized by three levels of road damage likelihood:

- ***High likelihood*** of disaster occurrence for hazard-prone road locations, requiring the application of structural measures
- ***Moderate likelihood*** of disaster occurrence for hazard-prone road locations, to be managed by routine visual inspections
- ***Low likelihood*** of disaster occurrence for hazard-prone road location, requiring no further action.

Benefit estimation of proactive measures for road geohazards. The 2006 PWRI manual (mentioned above in this section) also introduced the method to estimate the economic benefits of proactive measures based on the expected reduction in average annual economic loss. In addition, the MLIT Road Bureau and City Bureau are working jointly to develop manuals for cost-benefit analysis, road disaster function improvement, and measurements related to disaster prevention improvements for the road network and major cities.

Structural measures for road geohazards. The technical committees managed by the MLIT and the PWRI formulated manuals on structural measures for road geohazards and bridges or road crossing culverts, which were published by the Japan Road Association (2000, 2006, 2009a, 2009b). In addition, the Japan Institute of Construction Engineering compiled the *Exposition of Government Ordinance for Structural Standard for River Administration Facilities* to apply to road riverbanks and bridges (Japan River Association 2000). The Government Ordinance for Structural Standard for River Administration Facilities was enforced in 1976 and has been amended six times: in 1991, 1992, 1997, 2000, 2011, and the latest in 2013. Table 2.3 lists the guidelines and manuals that have been published on structural measures for road geohazards, which explain the planning, investigation, and design procedures.

Table 2.3 Manuals on Structural Measures for Road Geohazards in Japan

Title	Year of latest edition, publisher
Rockfall Countermeasure Handbook	2000: Japan Road Association
Exposition of Government Ordinance for Structural Standard for River Administration Facilities	2000: Japan River Association
Road Earthquake Disaster Countermeasure Manual (Proactive Measures)	2006: Japan Road Association
21 Year Edition Road Earthwork Guidelines	2009: Japan Road Association
Road Earthwork: Guidelines on Slope Cut and Slope Stabilization Works	2009: Japan Road Association

“Road Earthwork: General Guidelines” was introduced in 1954 as Japan’s first guidelines relating to road geohazard structural measures techniques (Japan Road Association 1954). The latest edition, published in 2009, reflects the revision of the guidelines (Japan Road Association 2009b). Related manuals on road earthwork that describe in detail the contents of the guidelines were also prepared (some of which are shown in Table 2.3). The guidelines and manuals cover geohazard risk management techniques for roadside slopes.

Road operation and maintenance for road geohazard risk management (nonstructural measures). Each road management authority (West, Central, and West Nippon Expressway companies; MLIT Regional Development Bureaus; and prefectures, major cities, and municipalities) has its own manuals on road operation and maintenance for road geohazard risk management (nonstructural measures). They usually include a typical reference book of

- Visual inspection procedures for road slopes, retaining walls, and road drainage;
- Actions under normal and abnormal weather conditions;
- Postdisaster response (emergency inspection, emergency traffic regulation, and public notice); and
- Emergency recovery from road geohazard damage (for example, debris removal from the road surface).

Business continuity planning for road geohazards. In 2005, the Japanese government, through a special committee of the Central Disaster Management Council, drew up a set of “Business Continuity Guidelines: Strategies and Responses for Surviving Critical Incidents,” which have since been revised twice (Cabinet Office 2013). Business continuity planning involves management strategies to continue business functions even after a significant disaster event. The national government’s own business continuity plan includes securing road functions. According to the Cabinet Office, only 13 percent of subnational governments (prefectures, major cities, and municipalities) have formulated their own business continuity plans as of August 2015.

2.1.2 National and Subnational Government Plans and Strategies

The National Disaster Management Plan was updated in 2015, including the country’s general and long-term DRM plan. The MLIT also prepared the Disaster Management Operations Plan, within which the road disaster management plan includes inspection and countermeasure planning, a monitoring and information sharing system, and rapid implementation of recovery measures. In addition, the MLIT formulated the “4th Infrastructure Improvement Priority Plan (2015–2020)” in 2015 (MLIT 2015b). The road sector plan describes the target rate of 50 percent for the implementation of structural measures for priority hazard-prone road slopes by 2020, after having already achieved 49 percent as of 2014. The road geohazard risk management programs and projects are formulated by each road management authority based on periodic or on-demand inspections as well as the Road Bureau’s road geohazard management program. The project is mainly classified as a countermeasure construction project, a monitoring project (including early warning system), or both.

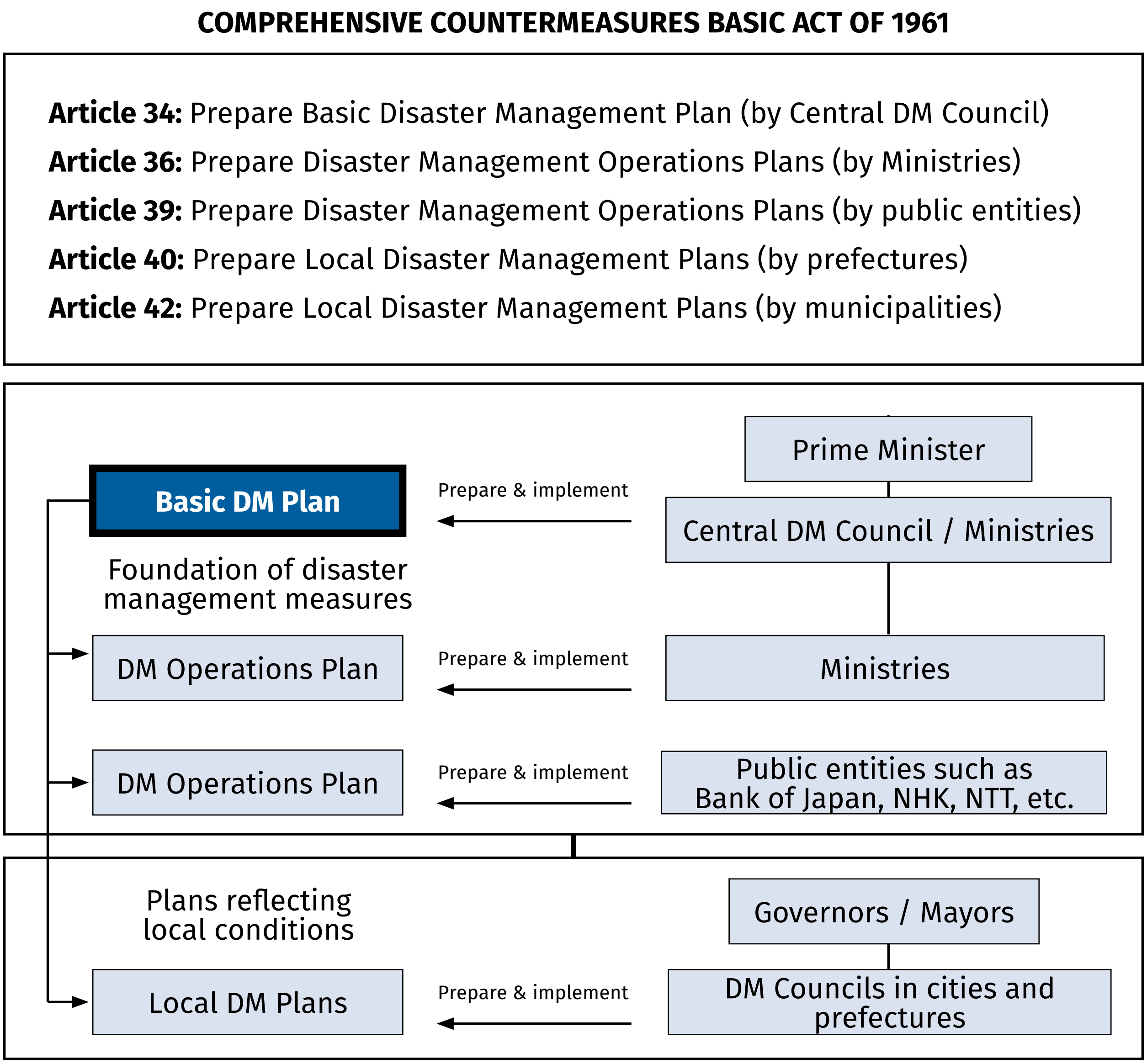
Basic DRM Plan

Based on the Disaster Countermeasures Basic Act (1961, the latest amendment as of 2016), the Central Disaster Management Council of the Cabinet Office updated the Basic Disaster Management Plan in 2015, including a general and long-term national DRM plan (Figure 2.1).

The MLIT also prepared and implemented the Disaster Management Operations Plan in 2012 as well as the seventh (and latest) amendment as of March 2015, which covers disaster risk reduction, emergency, and recovery and restoration from both natural disasters (earthquakes, tsunamis, water hazards, volcanoes, and snow hazards) and man-made disasters (maritime, aviation, railroad, road, nuclear, hazardous materials, large-scale fires, and forest fires). The plan also describes the following activities in the road disaster management field:

- Road inspection and countermeasure planning for disaster risk reduction
- Formulation of monitoring and information sharing system for emergencies
- Dispatch of staff and experts to regional offices and rapid implementation of measures for recovery from disasters.

Figure 2.1 Structure of Disaster Planning System in Japan



Source: "Disaster Management Plan," website of Cabinet Office, Government of Japan (accessed August 16, 2016), http://www.bousai.go.jp/taisaku/keikaku/english/disaster_management_plan.html.

Note: DM = disaster management. NHK = Nippon Hoso Kyokai (Japan Broadcasting Corp.). NTT = Nippon Telegram and Telephone Corp. (Japan Telegram and Telephone Corp.).

The 4th Infrastructure Improvement Priority Plan (2015–2020)

The MLIT formulated the "4th Infrastructure Improvement Priority Plan (2015–2020)" in 2015 to improve the efficiency and effectiveness of social capital in Japan. The plan addresses four challenges (MLIT 2015b):

(a) Strategic operation and maintenance of social capital

(b) Disaster risk reduction based on vulnerability and characteristics of geohazards

(c) Formulation of sustainable regional society against decline and aging of population

(d) Strengthening of the national economy by increasing private investments.

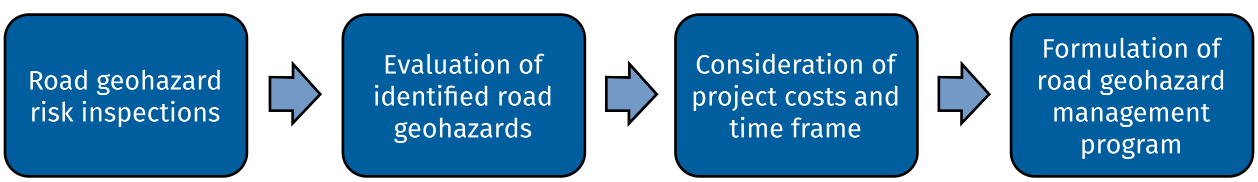
For challenge (b)—that is, disaster risk reduction corresponding to vulnerability and characteristics of geohazards (floods and slope disasters)—the criteria have been formulated to apply proactive measures for geohazards such as river improvements, flood control facilities, stormwater drainage, and debris-flow check dams. The software component highlights public awareness through dissemination of the study results in hazard-prone areas, the development of warning and evacuation systems, and the preservation of disaster prevention facilities.

For the road sector, the plan describes the implementation of geohazard measures to preserve the important transportation networks, to support socioeconomic and emergency lifesaving activities during large-scale disasters, and to promote measures on major hazardous locations such as road slopes and embankments. The target rate for the implementation of proactive measures on important road slopes and embankments is 54 percent by 2020 (having achieved 49 percent as of 2014).

Road Geohazard Risk Management Programs and Projects

The road geohazard risk management programs are formulated by each administrative body, such as the MLIT, subnational governments and authorities, expressway management corporations, and toll road management public corporations. The programs are formulated based on the results of periodic subnational and nationwide inspections of hazard-prone road locations (10 inspections since 1968), as shown in Figure 2.2.

Figure 2.2 Preparation of Road Geohazard Risk Management Programs in Japan



The MLIT's Road Bureau can request thematic subnational and nationwide inspections (such as tunnel portal slope inspections in 1996 and the inspections of large roadside rock-mass slopes in 1997) from the abovementioned road management authorities.

The purpose of the nationwide inspections is to identify the hazardous road locations where proactive measures can be applied, including preparation of the concepts and rough cost estimates of the required measures needed. The Road Bureau consolidates the inspection results and formulates the nationwide road geohazard risk management program using the list of hazard-prone road locations selected for proactive measures and the corresponding draft budget allocations.

Road geohazard risk management projects. Each road management authority formulates its road geohazard risk management projects based on the Road Bureau's road geohazard risk management program. The projects are prioritized for roads where geohazard events had occurred or are predicted to occur, and are identified mainly through the road geohazard risk inspections.

The project is mainly classified as a countermeasure construction project, a monitoring project (including early warning system), or both. Some of the project costs are subsidized by the MLIT, the rate being determined by the type of road (Table 2.4).

Table 2.4 Conditions for Subsidies for Road Geohazard Risk Management Projects

Road type	Manager	Cost burden ratio between national and subnational government	
		Maintenance	Repair
National expressway	Expressway company	Loan or toll revenue	Loan or toll revenue
National highway	MLIT	National: 100 percent	National: 100 percent
	Prefecture or major city	Prefecture or major city: 100 percent	National: 50 percent Prefecture or city: 50 percent
Prefectural road	Prefecture or major city	Prefecture or major city: 100 percent	National: 50 percent Prefecture or city: 50 percent
Municipal road	Municipality	Municipality: 100 percent	National: 50 percent Municipality: 50 percent

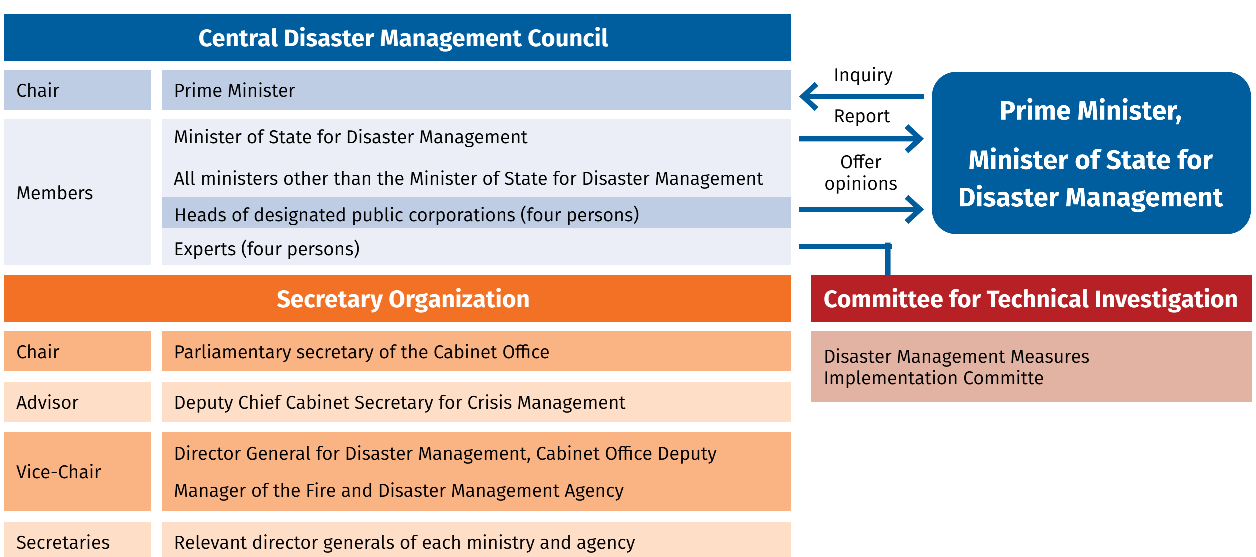
Source: MLIT website (accessed August 16, 2016), http://www.mlit.go.jp/en/index.html.
Note: MLIT = Ministry of Land, Infrastructure, Transport and Tourism.

2.1.3 Mechanisms for Implementation

Cabinet Office

As mentioned earlier, the Cabinet Office is the nerve center of the Japanese government for DRM, including road geohazards. It organizes the Central Disaster Management Council, which is the lead agency responsible for formulating national DRM policies (Figure 2.3). All ministers are members of the Central Disaster Management Council.

Figure 2.3 Organization of Central Disaster Management Council



Source: Cabinet Office website, (accessed September 20, 2016), http://www.cao.go.jp/en/pmf/pmf_5.pdf.

In case of "major" or "extreme" disasters—depending on the disaster's magnitudes of impact—the Cabinet Office establishes either a Major Disaster Management Headquarters (headed by the minister of state for disaster management) or an Extreme Disaster Management Headquarters (headed by the prime minister) upon consultation with relevant cabinet members, according to the Disaster Countermeasure Basic Act (1961, latest amendment as of 2016) (Table 2.5).

Table 2.5 Cabinet Office Roles in Major Disaster or Extreme Disaster Management Headquarters

Disaster management type	Information collection and emergency operation coordination	Major Disaster Management Headquarters	Extreme Disaster Management Headquarters
Consultation by related cabinet members	n.a.	Applicable	Applicable
Declaration of disaster emergency and headquarters set up by Extraordinary Cabinet Meeting decision	n.a.	n.a.	Applicable
Chief of headquarters	n.a.	Minister of State for Disaster Management	Prime Minister
Location of headquarters	n.a.	Cabinet Office	Prime Minister's Office
Secretariat	n.a.	Cabinet Office	Prime Minister's Office and Cabinet Office
Interministerial meeting	Applicable	n.a.	n.a.
Management activities	• Coordination of emergency operations by each ministry • Dispatch of government investigation team • Administration of on-site disaster headquarters and so on		

Source: Based on Cabinet Office 2015a.
Note: n.a. = not applicable.

As of August 2016, during the 55 years since the Disaster Countermeasure Basic Act has been enforced, 24 disaster events (an average of 0.4 per year) have been managed by the Major Disaster or Extreme Disaster Management Headquarters. Major Disaster Management Headquarters were established for 23 major disasters (eight earthquakes, seven storms, six volcano eruptions, one snowstorm, and one crude oil spill). The only case of an Extreme Disaster Management Headquarters was the one established for the Great East Japan Earthquake and Tsunami of 2011.

MLIT and Other Road Management Institutions and Authorities

Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The MLIT is the lead agency for DRM specifically related to land and infrastructure, including proactive and recovery and emergency activities. All MLIT bureaus are concerned with disaster management, particularly the Road Bureau (in charge of road DRM), the City Bureau (in charge of urban DRM), and the Water and Disaster Management Bureau (responsible for geohazard risk management). On January 27, 2014, MLIT also established the Water Disaster Prevention and Mitigation Headquarters for urgent and comprehensive measures to manage severe hydrological hazard events such as typhoons. It is chaired by the MLIT minister (MLIT 2014b).

Whenever a Major Disaster Management Headquarters or an Extreme Disaster Management Headquarters is established in the Cabinet Office or the Prime Minister's Office, respectively, the MLIT establishes its own Major Disaster Management Headquarters or Extreme Disaster Management Headquarters for recovery (Photo 2.1).

Photo 2.1 Meeting at MLIT Extreme Disaster Management Headquarters

Personnel convene for the 32nd meeting at the MLIT Extreme Disaster Management Headquarters for the Great East Japan Earthquake. The Disaster Management Center—in this case, at MLIT's Central Office in Tokyo—equipped real-time monitoring of the disaster site situations.

Source: ©Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

TEC-FORCE. To respond to the occurrence or likelihood of large-scale natural disasters, the MLIT established the Technical Emergency Control Force (TEC-FORCE) in April 2008.

TEC-FORCE members are deployed to smoothly and rapidly implement technical support of subnational governments in affected areas to carry out various emergency disaster measures such as rapidly assessing the extent of the disaster, preventing damages, and assisting affected areas in rapid recovery (MLIT 2014b). Their main activities during emergencies are damage inspection; dissemination of digital images of damaged areas; and emergency recovery work on drainage, earthworks, temporary bridge construction, and so on. As of 2015, TEC-FORCE members comprised 7,296 personnel (mainly staff of the Regional Development Bureaus). Box 2.1 describes the machinery and equipment that TEC-FORCE uses for emergency activities.

Box 2.1 Emergency Machinery and Equipment Used by MLIT TEC-FORCE

When a large-scale disaster occurs, the MLIT's TEC-FORCE calls up machinery and equipment from all over the country to the disaster areas (Table B2.1.1), some of which is shown in Photos B2.1.1, B2.1.2, and B2.1.3.

Photo B2.1.1 Disaster Headquarters Car

Members of a TEC-FORCE team meet at a Disaster Headquarters to report on local activities, procure materials and equipment, and coordinate emergency activities.

Source: ©Water and Disaster Management Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

Table B2.1.1 Machinery and Equipment for Geohazard Recovery

Machinery or equipment type	Number *(as of April 1, 2015)*
Pump truck	347
Mobile lighting vehicle	262
Headquarters car or standby support vehicle	113
Remote-controlled backhoe	16
Satellite communication vehicle	49
Small satellite image transmission equipment (Ku-SAT)	166
Helicopter for disaster risk management	8
Sandbag manufacturing equipment	22
Emergency assembly bridge	30
Sprinkler truck	Undisclosed
Bridge inspection vehicle	Undisclosed
Side ditch cleaning vehicle	Undisclosed
Road sweeper	Undisclosed

Photo B2.1.2 Satellite Communication Vehicle

Even if communication lines are disrupted because of a disaster, disaster communication vehicles ensure the continuation of telephone communication, video distribution, and other transmissions in the field using communications satellites. This vehicle was stationed in in Hakuba-mura, Nagano Prefecture, after the North Nagano Prefecture Earthquake in November 2014.

Source: ©Water and Disaster Management Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

Photo B2.1.3 Small Satellite Image Transmission Equipment (Ku-SAT)

Ku-SAT enables outdoor phone or fax communication as well as video transmission (over a 64 kbps line), as used in Otaki-mura, Nagano Prefecture, after the Ontake-san volcano eruption in September 2014.

Source: ©Water and Disaster Management Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

Road Bureau. The national authority for road geohazard risk management is the MLIT's Road Bureau, which is the government's lead agency for institutional coordination between the national and subnational governments. It is in charge of all road management organizations covering the national expressways, national highways, prefectural roads, and municipal roads (table 2.6). It is also in charge of road geohazard risk management policies and provision of technical and financial support.

As such, the Road Bureau issues orders to the road management authorities, national expressway companies, MLIT Regional Development Bureaus, subnational governments, and other entities—including orders to conduct road geohazard risk inspections to comprehend the requirements for proactive structural measures. After the results of the inspection are collected, the Road Bureau prepares the implementation plan and time frame for the geohazard risk reduction program as well as the budgetary allocations for the national and subnational road management authorities.

Water and Disaster Management Bureau. In addition, the MLIT's Water and Disaster Management Bureau is responsible for river and landscape ecosystem management and thus supports road geohazard risk management (Table 2.6). Because road geohazard risk management includes flow-type geohazard risk management (earth or debris flow, flooding, and road or bridge foundation erosion), coordination is required on river and landscape ecosystem management.

Table 2.6 Organizational Structure for Road Geohazard Risk Management Institutions

Cabinet office	Road management authority		Road length (L), by type (total: 1,214,917 kilometers)[a]
	Road manager	Road management office	
Ministry of Land, Infrastructure, Transport and Tourism (MLIT) *Road Bureau:* supervises national and subnational road management authorities *Water and Disaster Management Bureau:* supports road geohazard risk management *Japan Meteorological Agency:* disseminates meteorological information and issues warnings or advisories for geohazard events and risky conditions	Minister of Land, Infrastructure, Transport and Tourism	Six expressway companies: East Nippon, Central Nippon, West Nippon, Metropolitan, Hanshin, and Honshu-Shikoku Bridge	National expressways L = 8,358 kilometers (0.7 percent)
		10 MLIT Regional Development Bureaus	National highways (MLIT jurisdiction) L = 23,517 kilometers (1.9 percent)
	Governor of prefecture or mayor of major city	47 prefectures, 20 major cities	National highways (jurisdiction of prefectures and major cities) L = 31,915 kilometers (2.6 percent)
		47 prefectures, 20 major cities	Prefecture roads L = 129,375 kilometers (10.6 percent)
	Mayor of municipality	1,741 municipalities	Municipal roads L =1,023,962 kilometers (84.3 percent)

Sources: Websites of the Cabinet Office (http://www.cao.go.jp/index-e.html) and MLIT (http://www.mlit.go.jp/en/index.html).
a. Road lengths as of April 1, 2013.

Road Types and Lengths as of April 1, 2013

As Table 2.6 indicates, “roads” are classified into four types: national expressways, national highways, prefecture roads, and municipal roads. The road management authorities comprise (a) 6 expressway companies; (b) 10 MLIT Regional Development Bureaus; (c) 47 prefectures and 20 major cities; and (d) 1,741 municipalities. The national and subnational organizations also have branch offices, which include the road management sections.

As of 2013, the various road management authorities managed a total of about 1.217 million kilometers of roads, as follows:

- ***Six expressway companies*** manage about 8,000 kilometers of national expressway; they also have branch offices including the road management sections. The expressway companies are East Nippon, Central Nippon, West Nippon, Metropolitan, Hanshin, and Honsyu-Shikoku Bridge. The MLIT’s Road Bureau formulates the management policies on national expressways and controls the expressway companies.
- ***Ten MLIT Regional Development Bureaus*** have the Road Bureau’s satellite function in the regions and manage about 24,000 kilometers of the national highway. They have 89 subnational offices and 272 branch offices (Figure 2.4). The branch offices manage road maintenance and activities for geohazard events including highly hazard-susceptible situations such as storms.
- ***Prefectures and major cities*** (47 prefectures and 20 major cities and their subnational offices) have jurisdiction over about 32,000 kilometers of national highway and 130,000 kilometers of prefectural or major city roads. In some cases, the subnational offices have branch offices in remote areas or geohazard-prone areas. These subnational offices manage road maintenance and have task teams responsible for activities in response to abnormal conditions and geohazard events (including preparedness). The governors of the prefectures and mayors of the major cities are representatively responsible for road administration including road geohazard risk management.
- ***Municipalities*** (totaling 1,742) manage about 1.02 million kilometers of prefectural roads, averaging about 590 kilometers per municipality. The road management sections of the municipal government offices manage road maintenance and activities for geohazard events including highly hazard-susceptible situations such as storms. The mayors of municipalities are representatively responsible for road administration including road geohazard risk management.

Figure 2.4 Responsibilities of Road Geohazard Risk Management Authorities for National Highways under MLIT Jurisdiction

MLIT Road Bureau
- National road management planning, including for roads under subnational government management
- Budget planning and allocation
- Administration of postdisaster activities and recovery for roads after widespread geohazard events

Regional Development Bureaus (10)
- Include regional branches of the Road Bureau that exercise the Road Bureau’s function in the regions

Subnational Offices (89)
- Average road jurisdiction extends to around 260 kilometers
- Road management and budget planning
- Road information management
- Risk evaluation and management planning for road geohazards
- Design, cost estimation, and construction management for structural measures for road geohazards
- Operation of nonstructural measures for road geohazards
- Establishment of headquarters for disaster control administration during abnormal conditions and road geohazard events (including preparedness)

Branch Offices (272)
- Average road jurisdiction extends to tens of kilometers
- Management and deployment of patrol and maintenance staff
- Establishment of the task teams with jurisdiction over road geohazard risk management for abnormal conditions and geohazard events (including preparedness)

Sources: MLIT 2015a and MLIT website (http://www.mlit.go.jp/en/index.html). Note: The numbers of bureaus and offices are as of 2012.

Meteorological and Hydrological Organizations

Japan Meteorological Agency (JMA). The JMA disseminates meteorological information and warnings or advisories on geohazard events, including dangerous conditions. It also issues notifications to the public on abnormal weather or likely geohazards, including real-time landslide risk maps.

National and subnational road management authorities take precautions based on the JMA warnings. The agency analyzed the relationship between historical geohazard events and rainfall and developed a rainfall index: the soil water index. The index shows numerically simulated shallow groundwater contents for rainfall-induced landslides. The 5-kilometer grid data—indicating precipitation data for two hours of forecasting and the five risk-level warnings for slope- or stream-type geohazards—are provided in detail. These data are useful for specifying the local risk levels and appropriate evacuation decisions.

JMA researchers also advise the road management authorities on the warning criteria for the rainfall index regarding precautionary road closure measures. When the risk of geohazard events increases because of heavy rainfall, a geohazard alert is jointly issued by the prefectures and the JMA in each municipality. Road management authorities can refer to the geohazard alerts to make decisions on preparedness for emergency activities, including evacuation orders announced by municipalities or calls for the voluntary evacuation of residents. Road users can also use this alert information to make appropriate driving decisions.

Japan Weather Association (JWA). Established in 1950 as Japan's first private weather forecasting company, the JWA provides rainfall forecasts for the operation of specific precautionary road closure sections. The JWA has brought timely weather information to all areas of Japan and provides rainfall forecasts to enable road management authorities to calculate rainfall volumes for the management of designated precautionary road closure sections. Because precautionary road closure is a trade-off between saving human lives and preventing losses from traffic suspension, proper precautionary operation (road closure based on accurately forecast danger circumstances) is essential. Therefore, the JWA's provision of forecast rainfall data is significant.

Technical Road Institutions

The government technical institutions supporting road management in engineering and/or administrative fields—all under the MLIT—are the key organizations developing manuals, research, and development of efficient new technologies for road geohazard risk management:

- ***The National Institute for Land and Infrastructure Management (NILIM)*** conducts technology and policy research in a variety of areas, including road geohazard risk management.
- ***The Public Works Research Institute (PWRI)*** provides research and development services related to civil engineering, including geohazard-resilient road infrastructures.

Expressway companies, universities, and private construction companies or construction consultants also have their own technical institutions.

In addition, MLIT started an online (Internet and intranet) New Technology Information System (NETIS) in 1998 to promote new technology development by private and public institutions to solve public-works issues, including road geohazard risk management (particularly issues that are costly, dangerous, time-consuming, or have a negative impact on the environment).

Road Users and Other Stakeholders

The direct participation of road users is important in informing the road management authorities about any abnormality detected on a road location, such as rockfall, collapse, cracks, road deformation, or inundations. The information they provide is beneficial and valuable in preventing road damages because it enables the road management authorities to take road maintenance emergency measures before road damage develops. Even when road damage has already developed, early abnormality information can also shorten road traffic recovery times because of the early action of road maintenance staff.

Road users, residents, and the private sector can participate in road geohazard risk management by dialing the free emergency information number (#9910) to reach the corresponding road management authorities—the same number used throughout Japan (Photo 2.2). Signboards including this information are placed particularly in roadside parking pits in geohazard-prone road subsections (Photo 2.3).

Photo 2.2 Signboard at Roadside Parking Pit Shows How to Report Emergency Road Conditions to Road Management Authorities

The signboard on a roadside parking space in Odate City enables the public to call and report emergency road abnormalities (report number #9910) to the road management authority, or to make requests, complaints, or suggestions to the road management authorities using the road consultation number (0185-58-5446).

Source: ©World Bank. Permission required for reuse.

Photo 2.3 Roadside Parking Pit in a Geohazard-Prone Road Subsection

Roadside parking pits in geohazard-prone road subsections (such as this one in Odate City) provide emergency safety parking as well as signboards that display phone numbers enabling road users to report road abnormalities to the road management authorities.

Source: ©World Bank. Permission required for reuse.

In addition, the volunteer support program for roads is the main channel for civic participation in road maintenance and cleaning activities—especially road drainage cleaning, which helps reduce road geohazard risk. Road drainage cleaning is particularly effective in reducing the risk of road inundations and road embankment collapse due to the overflow of water from roadside drainage. Volunteers also assist with road beautification and cleaning (weeding, planting, growing flowers, and snow removal) as well as the provision of information.

After civic groups apply for the volunteer support program, the road management authorities evaluate the applications, prepare the contracts, and provide required tools and garbage bags to support the volunteer activities. As of March 2013, a total of 2,393 people were involved in the volunteer support program, of whom 105 (4 percent of the total) undertake snow clearance.

Funding Mechanisms

The funding processes for new road and existing road projects are detailed below for four types of cost: road geohazard risk evaluation; road geohazard risk management planning; proactive measures; and postdisaster activities and recovery.

Funding for road geohazard risk evaluation. The funding sources for road geohazard risk evaluation differ for new roads and existing roads. For new road projects, geohazard risk evaluation is often included in the engineering survey budget of the MLIT or the subnational governments at the preconceptual, conceptual, or design stage. For existing roads, the budget is generally included in the operation and maintenance cost of existing roads by each road management authority. In special cases, nationwide road geohazard risk inspections of existing roads (identification and risk evaluation surveys of hazard-prone road locations) are ordered by the MLIT's Road Bureau. The MLIT allocates the additional national subsidy to all road management authorities.

Funding for road geohazard risk management planning. The annual MLIT or subnational government budget allocations include funding for road geohazard risk management planning for new road and road rehabilitation projects. For existing roads, funding is included in the road management authorities' annual expenses for road operation and maintenance.

Funding for proactive measures. Based on the results of the nationwide road geohazard risk inspections—including the results from the subnational governments (subnational road management authorities) and expressway companies—the MLIT's Road Bureau formulates a nationwide, medium-term budget plan for proactive measures for national and rural roads. The budget is allocated by the national government to the national road management authorities and the subnational governments (subnational road management authorities).

Funding for postdisaster activities and recovery. For road disaster events (damages due to geohazards), the costs of postdisaster activities (emergency inspection, emergency traffic regulation, and public notification) are included in the ordinary road operations and maintenance costs. The recovery (recovery or recovery with improvement) for geohazard-damaged public facilities (including roads) are undertaken under the direct control of the national or the subnational governments by using each road management authority's budget and the national contingency fund. The subsidy from the contingency fund is provided by the Ministry of Finance's Treasury Division. The amount of the subsidy from the contingency fund is determined by taking into account both the estimated annual cost of the recovery and the subnational government's annual revenue.

The process is as follows (Table 2.7): The contingency fund requirements are prepared by the road management authorities, evaluated by the MLIT's Road Bureau using the estimated cost for postdisaster activities and recovery, and allocated to the road management office. Finally, after the activities or measures are completed, the MLIT recalculates the actual costs of the activities or measures through site inspections, and the road management authorities return the remaining amount to MLIT as necessary.

Table 2.7 Process of Contingency Fund Allocation for Disasters in Japan

Stage	MLIT	Management authorities
Contingency fund preparation	• Review the cost required for recovery • Allocate the contingency funds needed	Estimate costs of recovery
Implementation	None	Implement recovery
Completion	• Recalculate actual amount of recovery costs through inspection • Request refund of remaining contingency-fund allocation from the management authorities as necessary	Inform MLIT of completion of recovery Refund remaining amount received from the contingency fund to MLIT

Source: Based on MLIT data.
Note: MLIT = Ministry of Land, Infrastructure, Transport and Tourism.

2.2 Institutional Capacity Review

This capacity review for Japan was conducted based on Handbook appendix A, "Terms of Reference 1 (ToR1): Institutional Capacity Review and Target Setting." A sample of the assessment tables is contained in annex C1 (at the end of this case study) to illustrate the form of responses. Of note is that even for a country such as Japan—where there is a long history of geohazard management—for many of the factors under assessment, Japan is only at the starting point of developing appropriate capability and capacity.

The results of the review were shared with concerned people in the public sector, private sector, and academia, including the MLIT, the Japan International Cooperation Agency (JICA), the Japan Landslide Society, the International Sabo Network, and the Sabo & Landslide Technical Center. The review was also discussed with, and comments collected from, participants in the 12th Disaster Risk Management Seminar—"Road to Resilience: Managing Geohazards for Less Risky Roads in Developing Countries"—organized by the World Bank's Tokyo Office and Tokyo Disaster Risk Management Hub (Tokyo DRM Hub) and held in Tokyo on July 21, 2016.

3 SYSTEMS PLANNING

3.1 Risk Evaluation

The national road management authority of the Ministry of Land, Infrastructure, Travel and Tourism (MLIT) in addition to subnational road management authorities are responsible for evaluating related risks related to their respective road systems. The road bureaus are the lead agencies for (a) developing technical manuals or guidelines for risk evaluation, and (b) setting rules and time frames for conducting on-demand or periodic risk evaluation inspections on existing roads. The risk evaluation inspections are normally conducted by the staff, experts, or engineers contracted by the national or subnational road management authorities.

3.1.1 Geohazard Risk Evaluation for New Roads

Detailed hazard mapping is a common practice in Japan for new road planning. Detailed hazard maps are used for selecting a safer route or to avoid causing man-made geohazards to the surrounding areas such as cutting or banking.

Detailed hazard mapping is conducted by experts in geology and hydrology of engineering consulting firms contracted by the road management authorities. Mapping of geohazards should indicate falling, collapsing, or sliding slope areas and historically damaged areas of flow-type geohazards (earth or debris flow, flooding, river erosion). The consultants prepare the detailed hazard maps by interpretation of maps, aerial photographs, or satellite images together with field reconnaissance and interviews regarding historical geohazard events.

In Japan, slide-type geohazard distribution maps that cover all of Japan (which are good examples of detailed hazard maps) are prepared by the National Research Institute for Earth Science and Disaster Prevention (NIED) as reference material for infrastructure or regional development projects.

Engineering consultants contracted by road management authorities usually conduct the outline investigations for new road planning. They prepare detailed hazard maps through simple evaluation of the potential hazard levels such as slope instability. Each geohazard is assigned to one of either two (high and low) or three (high, medium, and low) potential hazard levels. The hazard levels are determined by using available geographical information such as maps, aerial photographs, and satellite images.

It is a general practice that the engineering consultants contracted by the road management authorities prepare the alternative road alignments including the risk evaluation results. The risk evaluation results include detailed hazard maps showing the new road alignment, an inventory table of hazard-prone locations with simple hazard level evaluation, and a risk summary of alternative road alignments (number of hazard-prone locations, their potential hazard levels, and geohazard characteristics).

The alternative new road alignment is planned to avoid hazard-prone locations as much as possible. This geohazard avoidance saves construction costs, including the costs of structural measures for geohazard and subsequent maintenance costs.

It is a general practice that the engineering evaluation includes a social and environmental assessment process. To this end, the National Institute for Land and Infrastructure Management (NILIM) developed a technical procedure for the evaluation of ground deformation and geohazards (NILIM 2013).

3.1.2 Geohazard Risk Evaluation for Existing Roads

Identification of Hazardous Locations

In Japan, hazardous locations are identified according to the following three method levels: basic, intermediate, and advanced.

Basic method: Identification of hazard-prone road locations by road maintenance staff using maintenance experience, on-site visual inspections, and information from road users. The basic methods are conducted during routine maintenance activities by the road maintenance staff. In 1962, the Road Bureau disseminated an "Order for Road Maintenance and Management" to national and subnational road management authorities. This order instructed the road management authorities to conduct routine patrols of roads with annual average traffic volume exceeding 300 vehicles per day. It further stipulated that the patrols be conducted during typhoons or heavy rains. The purposes of the patrols were to preserve the roads, ensure smooth traffic, and properly maintain the roads—enabling the authorities to immediately address defective road locations with the appropriate measures as soon as possible. As still practiced according to the 1962 order, the patrols were undertaken once a day throughout the week.

Information provided by road users is also used: users can call the road management authority by dialing #9910.

Intermediate method: Identification survey of hazard-prone road locations by engineering geology experts. The Road Bureau of the MLIT ordered all road management authorities to conduct a total of 10 nationwide road geohazard risk inspections from 1968 to 2006. These inspections were to identify hazard-prone road locations through visual inspection by engineering geology and civil engineering experts in private engineering firms contracted by road management authorities. The identification categories of hazard-prone road locations were stipulated by the Road Bureau for each order given for the nationwide road geohazard risk inspection.

The 1st nationwide road geohazard risk inspection was ordered in September 1969, triggered by the August 18 Hida River bus-fall accident—a road geohazard incident that killed 104 people when two buses fell into a flooded river because extreme storms had caused a slope collapse.

The 2nd nationwide road geohazard risk inspection was ordered in October 1970 after the Supreme Court judgment on August 20 that the road management authority was liable for a 1963 road mountainside collapse incident on National Highway No. 56 in Shikoku Region. The court pointed out the liability of the road management authority to identify and eliminate the geohazard dangers along roads and to order precautionary road closure because of the high possibility of geohazard occurrence.

The 3rd nationwide road geohazard risk inspection was ordered in 1971 after a rock mass fall on National Highway No. 150 in Shizuoka Prefecture in Central Japan.

The 4th–8th nationwide road geohazard inspections were ordered in 1973, 1976, 1980, 1986, and 1990. The identification procedures for hazard-prone road locations were improved every time. The first "Draft Road Geohazard Risk Inspection Guidebook" was prepared by the Road Bureau for the 8th nationwide geohazard inspection in 1990 (Ministry of Construction 1990).

The 9th nationwide road geohazard risk inspection, conducted over two years in 1996–97, was called a "comprehensive nationwide road geohazard risk inspection," for which a full-fledged "Road Geohazard Risk Inspection Guidebook" was prepared by a technical committee of public, academic, and private experts appointed by the Road Bureau (ROMAN-TEC 1996). The 1996 inspection guidebook refined the criteria for identifying hazard-prone road locations in consideration of the many unidentified road locations that had been seriously damaged in past geohazards despite the prior eight geohazard risk inspections. It specified nine types of geohazards: rockfall or collapse, rock mass collapse, slide, snow avalanche, debris flow, embankment collapse, retaining wall collapse, scouring of bridge foundation, and drifting snow.

For example, a location would be identified for a "rockfall or collapse" type of geohazard if any one of these conditions corresponds to the road mountainside slope:

- Slope height is more than 15 meters or with a natural slope of 45 degrees.
- There are loose rocks susceptible to falling from rock cliffs or boulders on the slope.
- There is collapsible soil or rock property, and cracks or a geological discontinuity plane (bedding, joint, shearing or fractured plane, fault, or other) structure is collapsible.
- Existing structural measures are damaged or old.

Engineers in both public and private sectors received training on the use of the guidebook. The 9th nationwide road geohazard risk inspection identified 356,000 hazard-prone road locations.

The 10th nationwide road geohazard risk Inspection was ordered in 2006 (10 years after the 9th inspection) because the 9th road geohazard risk inspection had not identified all of the hazard-prone locations and had not accurately evaluated the hazard level (likelihood of road disaster occurrence). The 10th inspection focused on the identification of hazard-prone road locations missed during the 9th inspection as well as the missed geohazard sources (such as rockfall, slope collapse, and debris flow) and locations (mostly outside the right-of-way under the jurisdiction of road management authorities). The latest edition of the "Road Geohazard Risk Inspection Guidebook" (for heavy rain and snow) was prepared by a committee of public, academic, and private expert members delegated by the Road Bureau (JGCA 2010).

In the case of very serious road geohazard incidents, the Road Bureau ordered that the inspections identify similar types of hazard-prone locations nationwide and evaluate the necessity of countermeasures. Thus, two specific thematic geohazard risk inspections were ordered:

- A tunnel entrance slope inspection was conducted in 1996 after the rock mass collapse at the entrance of the Toyohama Tunnel, Hokkaido, in the northern region, which killed 20 people.
- A large rock slope inspection (inspection of roadside rock slope of more than 30 meters in height) was conducted in 1997 after the rock mass collapse at the portal of the Second Shiraito Tunnel, Hokkaido, in the northern region.

Advanced method: detailed hazard mapping of geohazard-prone road subsections and landscape ecosystem areas. Detailed hazard mapping was mostly prepared for geohazard-prone road subsections on national highways using private engineering consulting firms.

The road geohazard risk inspection guidebooks (ROMAN-TEC 2006, 2009; JGCA 2010) stipulated a geohazard identification procedure consisting of desk-checking and field visual inspection. Desk-checking is the review of geohazard information on historical disaster events and designated geohazard areas and interpretation of maps and aerial photographs. Geographical interpretation identifies microtopography and evaluates assumed geohazard movement types, magnitudes, and effects on roads.

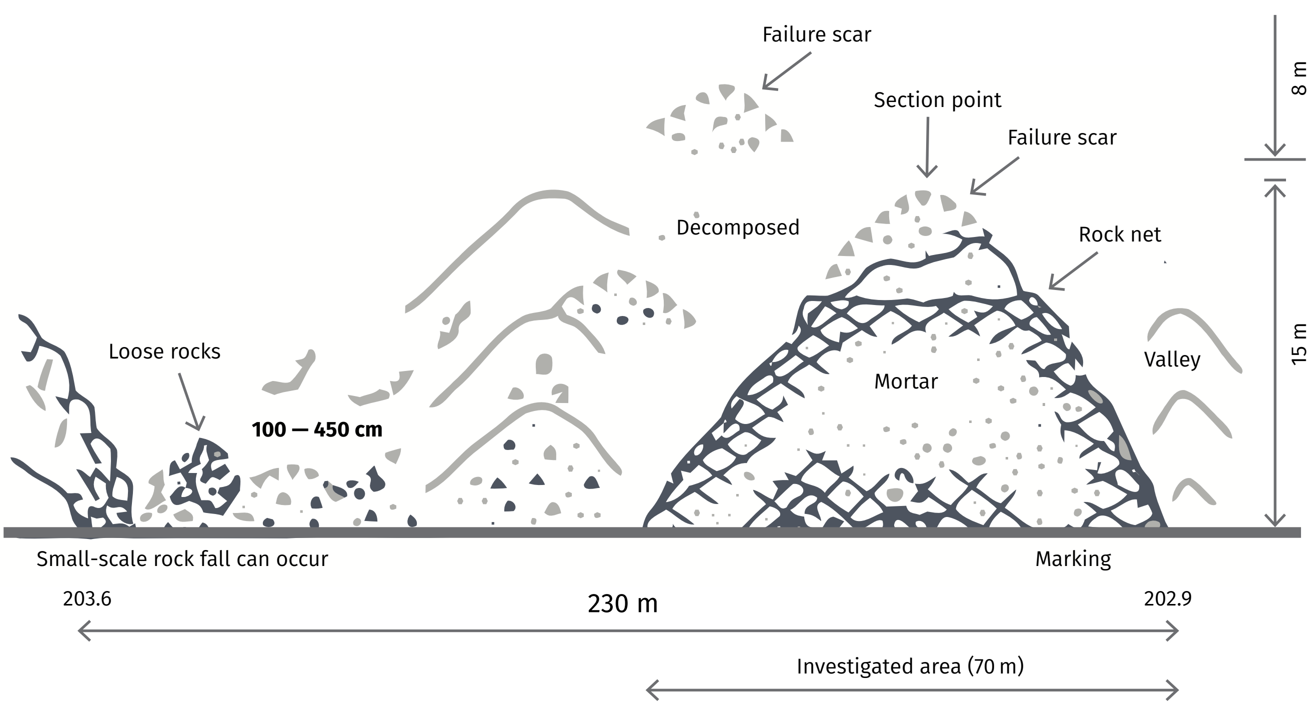
The inspection area of the road geohazard risk inspection in 1996–97 was mostly in the right-of-way or the management area of the road management authority. The road geohazard risk inspection guidebook (ROMAN-TEC 2006) stipulated that the slope facing the road should be interpreted from the mountain ridge (or hilltop) to the valley bottom and, if a geohazard-contributing factor is identified, it should be confirmed by visual field inspection. Nowadays, accurate maps using laser profiling and geographical information systems (GIS) are used to conduct detailed hazard mapping.

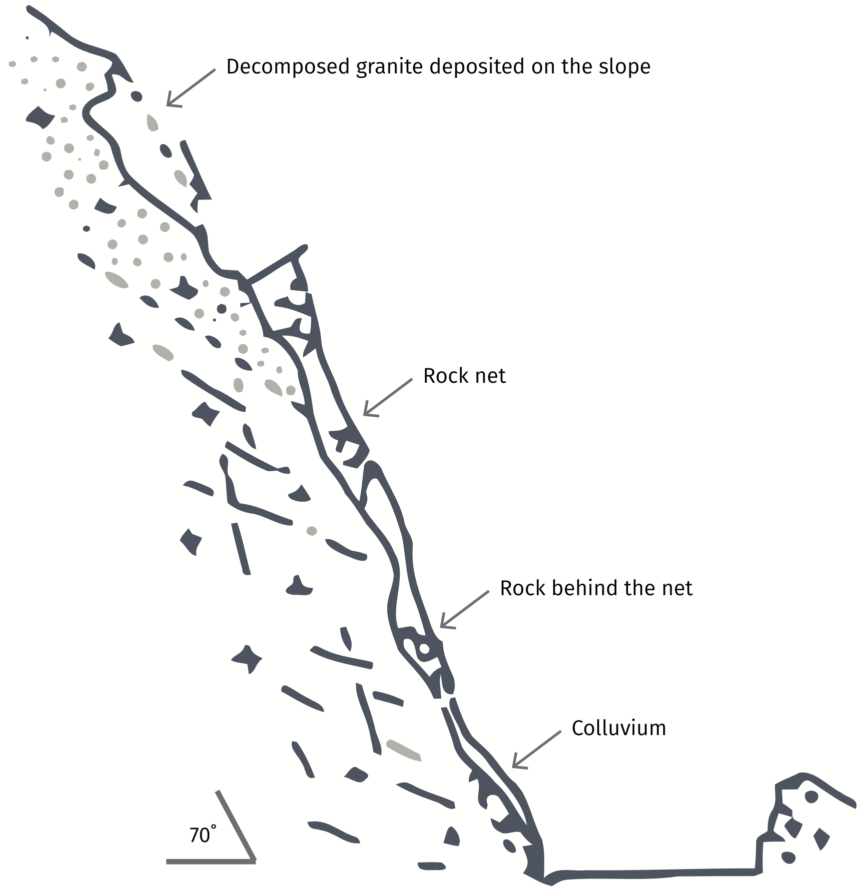
Risk Evaluation of Endangered Road Locations

In Japan, the risk evaluation of hazardous locations is also undertaken according to three method levels: basic, intermediate, and advanced, as described below.

Basic method: simple risk evaluation of a hazard-prone road location using multiple criteria. The Road Bureau recognized that past inspections had been conducted without a clear inspection procedure, and the result of the inspections had not accurately evaluated the hazard-prone road locations. The 1996 "Road Geohazard Risk Inspection Guidebook" contained the vulnerability (or stability) inspection check sheet (ROMAN-TEC 1996). This check sheet evaluates the likelihood of road geohazard damage events using a rating score from 0 to 100 (a score of 0 indicating stability and a higher score indicating more vulnerability). The vulnerability inspection check sheets are prepared for nine types of geohazards: rockfall or collapse, rock mass collapse, slide, snow avalanche, debris flow, embankment collapse, retaining wall collapse, scouring of bridge foundation, and drifting snow. The inspection format includes sketches of the plan and cross-section and photographs (Figure 3.1).

Figure 3.1 Sample Sketches in Road Geohazard Risk Inspection for Rockfall or Collapse





Source: ©Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

If a location has risks for several types of geohazard, all of the geohazard types will be checked. An example of the rating system for rockfall or collapse is as follows (Figure 3.3):

- ***A: Contributing factors of road geohazard damage occurrence.*** The score is the sum of evaluation points assigned to the selected category for 13 check items. For example, in the check item for "the road slope talus cone," 3 points are given for "applicable to talus cone," while a score of 0 (zero) is given to "not applicable to talus cone." The maximum score for all the check items is 100 points (Figure 3.2).
- ***B: Effectiveness of existing structural measures.*** The evaluation score for "A: Contributing factors of road geohazard damage occurrence" is modified by the score for "B: Effectiveness of existing structural measures" as follows (Figure 3.2):
  - — For prevention of a rockfall or collapse or for sufficient protection in case a rockfall or collapse occurs: multiply zero by the score for "A: Contributing factors of road geohazard damage occurrence."
  - — For prevention of a rockfall or collapse but for less than 100 percent of sufficient protection: subtract 20 points from the score for "A: Contributing factors of road geohazard damage occurrence."

— For only partial prevention of a rockfall or collapse, or for only partial protection: subtract 10 points from the score for “A: Contributing factors of road geohazard damage occurrence.”

— If a countermeasure is not installed, or if an existing countermeasure is expected to have almost no function: add or subtract 0 points from “A: Contributing factors of road geohazard damage.”

- ***C: Historical road damage events due to geohazards and their damage levels.*** The assigned individual points (not added to the combined scores of A and B) are as follows (Figure 3.2):

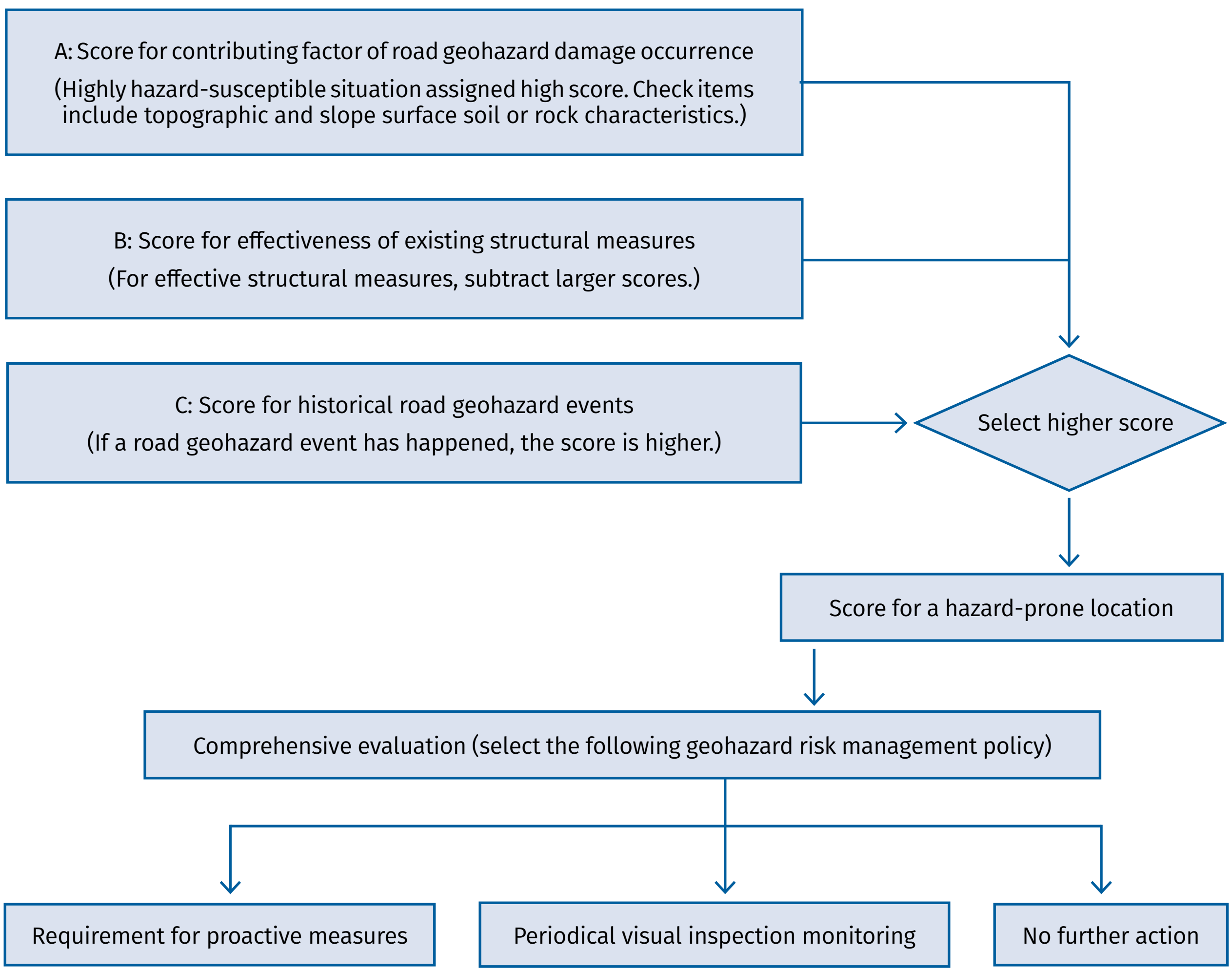
— If there were historical disturbances of traffic, 100 points are given.

— If there was no historical disturbance of traffic, but some rockfall or collapse occurred, 70 points are given.

— If some rockfall or collapse occurred but did not reach the road carriageway, 40 points are given.

The final rating is the higher of either (a) “A: Contributing factors for road geohazard damage occurrence” plus “B: Effectiveness of existing structural measures”; or (b) “C: Historical road damage events due to geohazard and their damaged level.”

Figure 3.2 Evaluation Structure Using Vulnerability Evaluation Check Sheet for a Hazard-Prone Road Location



Source: Ando et al. 2015.

Figure 3.3 Score for Contributing Factors of Road Geohazard Damage Occurrence for Rockfall Collapse

A: Score for contributing factors of road geohazard damage occurrence

Factor		Cause	Excavation Slope: Evaluation	Score Allotment	Evaluation Score	Natural Slope: Evaluation	Score Allotment	Evaluation Score
Topography	Topography with collapsing factors	G1: Telus slope	If G1	3		More than one conditon from G2	③	
		G2: Slope of old failure Clear knick line				If G2	2	
			If not G1	⓪		If not G2	0	
		G3: Foot of plateau, Toe erosion, Overhanging, Catchment slope, Debris flow deposits	More than one condition from G2, 3	③		More than one condition from G1, 3	③	
			If G2 or G3	2		If G1 or 3	2	
			If not G2, G3	0	3	If not G1, 3	0	6
		G4: Convex slope	If G4	○	(6)	If G4	○	(6)
Soil, Geology, Structure	Collapsing soil	The soil is week against erosion. The soil lowers its strength in a wet condition.	Conspicuous	8		Conspicuous	②	
			Less conspicuous	④	4	Less conspicuous	1	2
			None	0	(8)	None	0	(2)
	Collapsing rocks	Density of cracks and soft layers is high. The rock is weak against erosion and weathers fast	Conspicuous	⑫		Conspicuous	⑧	
			Less conspicuous	6	12	Less conspicuous	4	8
			None	0	(12)	None	0	(8)
	Collapsing structures	Dip slope structure (Bedding plane)	Conspicuous	⑧		Conspicuous	②	
			None	0		None	0	
		Soil covering impervious bedrock The rocks are hard at the upper part and weak at the foot part	Conspicuous	6		Conspicuous	4	
			Less conspicuous	④	12	Less conspicuous	③	5
			None	0	(14)	None	0	(6)
Conditions of surface		Conditions of soil, loose rocks and boulders	Unstable	⑫		Unstable	24	
			Slightly unstable	6		Slightly unstable	⑫	
			Stable	0	12	Stable	0	12
		Loose rocks, boulders are unstable～slightly unstable	Condition met		(12)	Condition met		(24)
		Conditions of spring water	Unstable	8		Unstable	4	
			Slightly unstable	4	0	Slightly unstable	2	0
			Stable	⓪	(8)	Stable	⓪	(4)
		Conditions of surface	Unstable	5		Unstable	16	
			Slightly unstable	3	1	Slightly unstable	⑩	10
			Stable	①	(5)	Stable	0	(16)
Form		Gradient (i), Height (H)	Soil: H＞30 m	18		Height: H≧50 m	⑩	
			Soil: H≦30, i ＞ Standard	15		Height: 30≦H<50 m	8	
			Soil: i ≦Standard, 15≦H<30	10		Height: 15≦H<30 m	6	10
			Soil: i ≦Standard, 15<H	5		Height: H<15	4	(10)
			Rock: H≧50 m	18		Gradient: i ≧70°	10	
			Rock: 30≦H<50 m	16		Gradient: 45≦ i <70°	⑩	10
			Rock: 15≦H<30 m	⑫	12	Gradient: i <45°	5	(10)
			Rock: H<15	10	(18)			
Disturbance		Present disturbance (Slumps, small rock falls, gully erosion, scouring, piping hole, depression, bulge, fallen trees, cracks, crevices and others)	More than one clear evidence	⑫		More than one clear evidences	⑩	
			Obscure evidence	8	12	Obscure evidence	5	10
			No evidence	0	(12)	No evidence	0	(10)
		Disturbances of the adjacent slopes (rock falls, collapses, cracks, bulge and others)	More than one clear evidences	⑤		More than one clear evidences	④	
			Obscure evidence	3	5	Obscure evidence	2	4
			No evidence	0	(5)	No evidence	0	(4)
Total Score			Excavation Slope : 73 (A1)			Natural Slope : 77 (A2)		

B: Score for effectivness of existing structural measures

(Bi) = (Ai) + α or $\times$ 0

Effect of the existing countermeasure works	Score (α)	Evaluation	
		Excavation	natural
Well-effective against the possible rock falls and slope failures.	×0		
Effective against the possible rock falls and slope failures but not perfect.	−20		
Not perfectly protected from the possible rock falls and slope failures.	−10	○	
No countermeasure work is constructed.	±0		○

Total	(B1:Excavation slope) 63	(B2:Natural slope) 77

C: Score for historical road geohazard

[Disaster Record] (C)

Frequency and degree of disaster	Score	Evaluation
The disaster has caused a traffic disturbance after the recent implementation of the countermeasure work.	100	
No traffic disturbance has occurred, but there is a record of comparatively serious rock falls and slope failures that reached to the road.	70	
There are records of rock falls and slope failures on a small scale that did not reach to the road.	50	○
	(C) 40	

(D) = MAX (B, C)

Total score of main cause	(B)=MAX(B1, B2) 77
Total score of disaster record	(C) 44
Bigger score in (B) and (C)	(D)=MAX(B, C) 77

Source: Based on data from the Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

Intermediate method: risk level rating of a hazard-prone road location. In Japan, a "risk level rating" is not conducted; only the "hazard level rating" (likelihood level of road geohazard damage event occurrence) is conducted, as described in the preceding description ("Basic method: simple risk evaluation of a hazard-prone road location using multiple criteria"). A "risk level rating" procedure has not been established.

Advanced method: risk estimate calculated as potential annual economic loss. The Japanese practice of the advanced method of risk evaluation (risk estimate calculated as the potential annual economic loss) is further summarized in subsection 3.1.3.

Evaluation Results of the 9th and 10th Nationwide Road Geohazard Risk Inspections

The 9th nationwide road geohazard risk inspection was a comprehensive nationwide road geohazard risk inspection. As of 2017, progress management of structural measures was being conducted based on this nationwide geohazard inspection. The 10th nationwide road geohazard risk Inspection, ordered in 2006, was just a review of the 9th inspection.

The 9th nationwide road geohazard risk inspection (in 1996–97) was carried out by engineers of contracted private consulting firms with experience in geohazard evaluation and geohazard structural measure engineering. The inspections were conducted by selecting the appropriate season when geohazard factors can be well observed (for example, in the rainy season to detect spring water or in the winter when vegetation is sparse). The multiple-criteria evaluation was conducted by inspectors in three categories of the risk management policy: "requirement for structural measures," "periodical visual inspection monitoring," and "no requirement for structural measures" (Table 3.1).

Table 3.1 Multiple-Criteria Evaluation Results of Nationwide Road Geohazard Risk Inspection in Japan, 1996–97

Risk management policy category	Number of hazard-prone road locations nationwide
Requirement for structural measures	83,000
Periodical visual inspection monitoring	118,000
No requirement for structural measures	155,000
Total	356,000

Source: Ando et al. 2015.

Photos 3.1 and 3.2 depict views of road geohazard risk situations found during the 9th nationwide road geohazard risk inspection. The inspections were conducted by an engineering geologist or geotechnical engineer. The Road Management Technology Center (ROMAN-TEC) held training sessions both in the training venue and on-site in 1996 and 2009 for the consultant engineers who had applied to participate. After the ROMAN-TEC dissolved in 2011, the Japan Geotechnical Consultants Association (JGCA) took over annual training sessions for such engineers. The JGCA also provides e-learning materials for road geohazard risk inspection, which are prepared under the supervision of the MLIT's Road Bureau and the Public Works Research Institute (PWRI).

Photo 3.1 Road Geohazard Risk Inspection from Distant View

Distant-view observation is needed for proper understanding of the entire slope.

Source: ©Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Reproduced, with permission, from Road Bureau, MLIT; further permission required for reuse.

Photo 3.2 Road Geohazard Risk Inspection with Proximity Observation

A proximity observation confirms a boulder's characteristics.

Source: ©Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Reproduced, with permission, from Road Bureau, MLIT; further permission required for reuse.

Because the evaluation rating results of the vulnerability check sheets have some vague descriptions, there was variability in the evaluation results even among well-experienced inspectors.

Periodical visual inspection monitoring aims to (a) record slight abnormalities and their progress, and (b) detect serious geohazard damage events at an early stage. The inspection is performed periodically (once a month) and after extreme rainfall events by the road maintenance staff with the aid of simple methods (taking photos and measuring crack openings using rulers). The inspection format includes sketches for plane and cross-section and photographs. If the progress of abnormality is apparent in the deformation of the geohazard area, the hazard-prone road location will be subjected to engineering inspection for structural measures.

The 10th nationwide road geohazard risk inspections, in 2006, were the latest nationwide road geohazards inspections as of 2016. The Road Bureau ordered reinspection of the geohazard-prone road subsections (limited section, not nationwide) in 2009 and in 2010 using the 2009 edition of the "Road Geohazard Risk Inspection Guidebook" (ROMAN-TEC 2009) or its reprint (JGCA 2010).

3.1.3 Calculation of Risk Estimation as a Potential Annual Economic Loss

The PWRI developed a "Draft Manual on Risk Analysis and Risk Management Support of Road Slope Disasters" in 2006 (PWRI 2006). This draft manual provides the calculation procedure to estimate the potential annual economic loss. (Potential annual loss can be estimated using integral computation of sets of probability and economic loss due to road geohazard damage for a road location.) Some road locations or road subsections are evaluated for the potential annual economic loss. The study is resource-intensive, so it has no practical use yet.

Some of the Japan International Cooperation Agency (JICA) projects or surveys simplified this procedure and used it in the Philippines in 2006–07 (JICA 2007); in Nepal in 2007–08 (JICA 2009); in Santa Catarina State, Brazil, in 2010–11 (JICA 2011); in El Salvador in 2012–15 (JICA 2015a, 2015b); and in Honduras and Nicaragua in 2015 (JICA 2015a).

3.2 Risk Management Planning

3.2.1 Geohazard Risk Management Planning for New Roads

In Japan, the following is undertaken to manage geohazard risks during planning for new roads:

- Survey(s) to identify the geohazard locations or areas
- Avoidance (to the extent possible) of road routes into potentially hazard-prone locations to reduce construction costs for geohazard countermeasures and to reduce potential economic losses during the service period caused by road damage or closure due to geohazard(s)
- Planning of proactive structural measures for hazard-prone locations on selected new alignments—including consideration of minor alignment shifting and using bridge structures and tunnels as alternative solutions for securing road users' lives and reducing economic losses due to road closing and recovery.

Types of New-Road Planning for Geohazard Risk Reduction

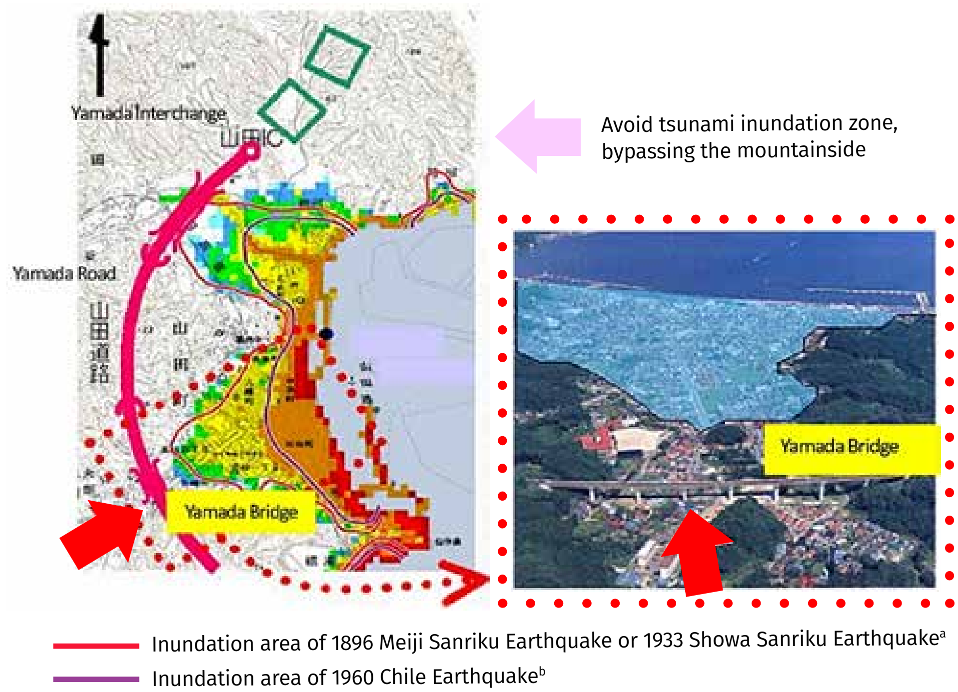
Tunnels and bridges can shorten the road distance, which generates benefits in terms of travel time-saving. At the same time, tunnels and bridges can avoid hazard-prone locations and make roads robust against geohazards. Such roads can be emergency transportation and evacuation routes during wide-area disasters such as earthquakes, tsunamis, storms, and so on (Figure 3.4).

The geohazard risk management policy takes into account the road priority type—with lower-priority roads having a lower design safety factor and also permitting temporary road traffic suspensions. This is especially relevant for flooding conditions because it permits the use of low-cost structures such as river ford crossings.

Historically, roads were built with a low initial investment and road geohazards managed mostly through recovery measures. Now, road geohazard management focuses on proactive measures. Currently, there are road plans, which restrained road function or investment, such as 1.5-lane roads out of 2 lanes, for partial operation. In this case, proactive measures for road geohazard are essential.

If the new road planned is an expressway or a national highway under MLIT jurisdiction that has major geohazard issues such as flooding, two MLIT bureaus—the Road Bureau and the Water and Disaster Management Bureau—coordinate their geohazard risk management efforts.

Figure 3.4 Use of a Bridge to Avoid Potential Geohazards on a High-Standard Highway



Source: ©Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT).
Note: "High-standard highway" refers to a national expressway or highway planned as part of a strategic high-speed surface-traffic network.
a. The 1896 Meiji Sanriku Earthquake and 1933 Showa Sanriku Earthquake hit approximately the same location on the Sanriku coast of the Tōhoku region of Honshu, Japan, and were of almost identical magnitude (8.5 and 8.4, respectively).
b. The 1960 Chile Earthquake (or Valdivia Earthquake), the most powerful earthquake ever recorded (9.4–9.6 in magnitude), had its epicenter in southern Chile but sent a tsunami affecting Hawaii, Japan, the Philippines, eastern New Zealand, southeast Australia, and the Aleutian Islands.

The following are Japanese examples of new-road planning practices that take into account regional geohazard risk reduction:

- Retarding facilities (temporary water storage facilities to cut peak water flow runoff) are installed if the new road construction would increase the runoff to the downstream areas.
- Redundancy planning within the subnational road network ensures that robust roads are available to secure an alternative detour option for emergency situations such as earthquakes and tsunamis.
- Residential accessibility to road networks is planned so that no residential areas would be isolated during a serious disaster event.
- Emergency road designations are made of some roads that are connected to emergency protection centers (Photo 3.3).
- Adoption of embankment structures serve a river dike or tide barrier function on new roads; these can function as flood control structures along the roads.

Photo 3.3 Example of Emergency Road Designation

The road information board (on Sotobori Avenue in Kagurazaka-shita, Shinjuku Ward, Tokyo) informs the public that, in the event of a major earthquake, it is an emergency road that will be open only to emergency vehicles. It is announced by the Government of Metropolitan Tokyo and Metropolitan Tokyo Police Department.

Source: ©World Bank. Permission required for reuse.

Roadside Stations (Michi-no-Eki)

Roadside stations, or rest areas (Michi-no-Eki in Japanese), have been built since 1993 on national highways to provide users with three amenities: “a place for resting” including parking and restrooms for road users, “a place to provide information” for both road users and locals, and “a place to facilitate communications” between communities and visitors (MLIT 2015a).

Roadside stations are also important as a facility for road disaster risk management (DRM). The MLIT is promoting the enhancement of the roadside stations for DRM functions. The municipalities manage their roadside stations as disaster evacuation centers in their DRM plans. Roadside stations have the following DRM functions (MLIT 2015a):

- Disaster evacuation or support centers for early warning and postdisaster situations. Some roadside stations have in-house power generators in preparation for disasters, and they have played important roles in life-saving activities and distribution of relief goods and food.
- Information delivery centers for damage information, including road closures.

About 1,093 roadside stations have been constructed in all parts of Japan as of May 2016. Information provision at the rest areas is being enhanced to improve and increase services provided for road users. Roadside stations are also expected to revitalize local economies by serving as a spot for tourists visiting nearby natural, historical, and cultural sites (Figure 3.5 and Photo 3.4).

Figure 3.5 General Layout of Roadside Station (Michi-no-Eki) in Japan

Source: MLIT 2005. ©Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Reproduced, with permission from MLIT; further permission required for reuse.

Photo 3.4 Road and Regional Climate Information Board at a Roadside Station

This electronic bulletin board keeps visitors updated on weather and road conditions at a roadside station in Kuragi, Saga Prefecture, Kyushu Region.

Source: ©World Bank. Permission required for reuse.

3.2.2 Geohazard Risk Management Planning for Existing Roads

Precautionary Road Closure of Hazard-Prone Subsections

Critical geohazard-prone road subsections are identified through operation and maintenance activities. After the Hida River bus-fall incident in August 1968, the MLIT designated geohazard-prone road subsections as "Precautionary Road Closure Subsections" and defined the road closure criteria based on rainfall indexes. The designated road subsections and road closing criteria are updated based on the results of routine periodic inspections.

The use of the rainfall index for a precautionary road closure in Japan has been implemented using the cumulative rainfall amount from the start of the rainfall (generally called the continuous rainfall amount). However, for evaluating highly susceptible rainfall-induced geohazards, the rainfall index has some weak points. A new rainfall index that accurately predicts geohazard events using rainfall intensity has been studied. Since July 2015, on national highways under MLIT jurisdiction, some road subsections were designated for the trial use of new precautionary road-closing criteria based on hourly rainfall amounts (rainfall intensity). This is to save road users from suffering in case of a road geohazard event caused by intense rainfall. In the adaptation of hourly rainfall volume (rainfall intensity), conventional criteria using the cumulative rainfall amount are also utilized.

Geohazard Risk Management for Each Hazard-Prone Location

The road geohazard risk management authorities conduct the initial decision making by reviewing the recommendations of the engineering consulting firms on the results of the road geohazard risk inspections. The risk management policy for each hazard-prone location is based on the following three criteria, by risk level: "requirement for structural measures" (for high risk), "periodical visual inspection monitoring" (for medium risk), and "no requirement for structural measures" (for low risk).

Planning of Combination of Nonstructural Measures, Structural Measures, and Preparedness for Postdisaster Actions and Recovery

The road management authorities are in charge of the planning activities. Proactive measures are planned by combining structural and nonstructural measures against the likelihood of geohazard events and the concept of life-cycle cost including the maintenance and repair of the countermeasures.

As a tool of the nonstructural measures for road geohazards, various monitoring devices for hazard activity detection are used, and precautionary road closure measures are put in place to protect road users. These proactive measures are planned in consultation with relevant government organizations such as DRM authorities, river management, police, and subnational government. As mentioned earlier (in chapter 2), the MLIT's online New Technology Information System (NETIS) promotes the use of new technology by private and public institutes to solve public works issues. The new technology would reduce both the costs and the potential environmental problems of these measures.

Each national and subnational government (in coordination with the government's road management authorities) takes local DRM plans into consideration as part of geohazard risk management on existing roads. Sometimes, the coordination extends to other government and road management authorities at the national, prefecture, major city, and municipality levels.

If the existing risk management plan for an expressway or national highway addresses major geohazard issues including flood management (thus under MLIT jurisdiction), two MLIT units—the Road Bureau and the Water and Disaster Management Bureau—must coordinate their efforts. For example, flow-type geohazard risk management (earth or debris flow, flooding, or roadside river erosion) aims not only to preserve the road but also to protect human lives and properties in the surrounding landscape ecosystems.

3.2.3 Cost-Benefit Analysis of Investment for Road Geohazard Risk Reduction

The estimation of benefits and cost-benefit analysis for road geohazard risk reduction is not conducted in most cases in Japan because it involves costly investigations and studies. Instead, the focus is on identifying the lowest life-cycle-cost option, on the presumption that the need for the road to be open was justified when the road was first constructed and that benefits would generally be similar between options.

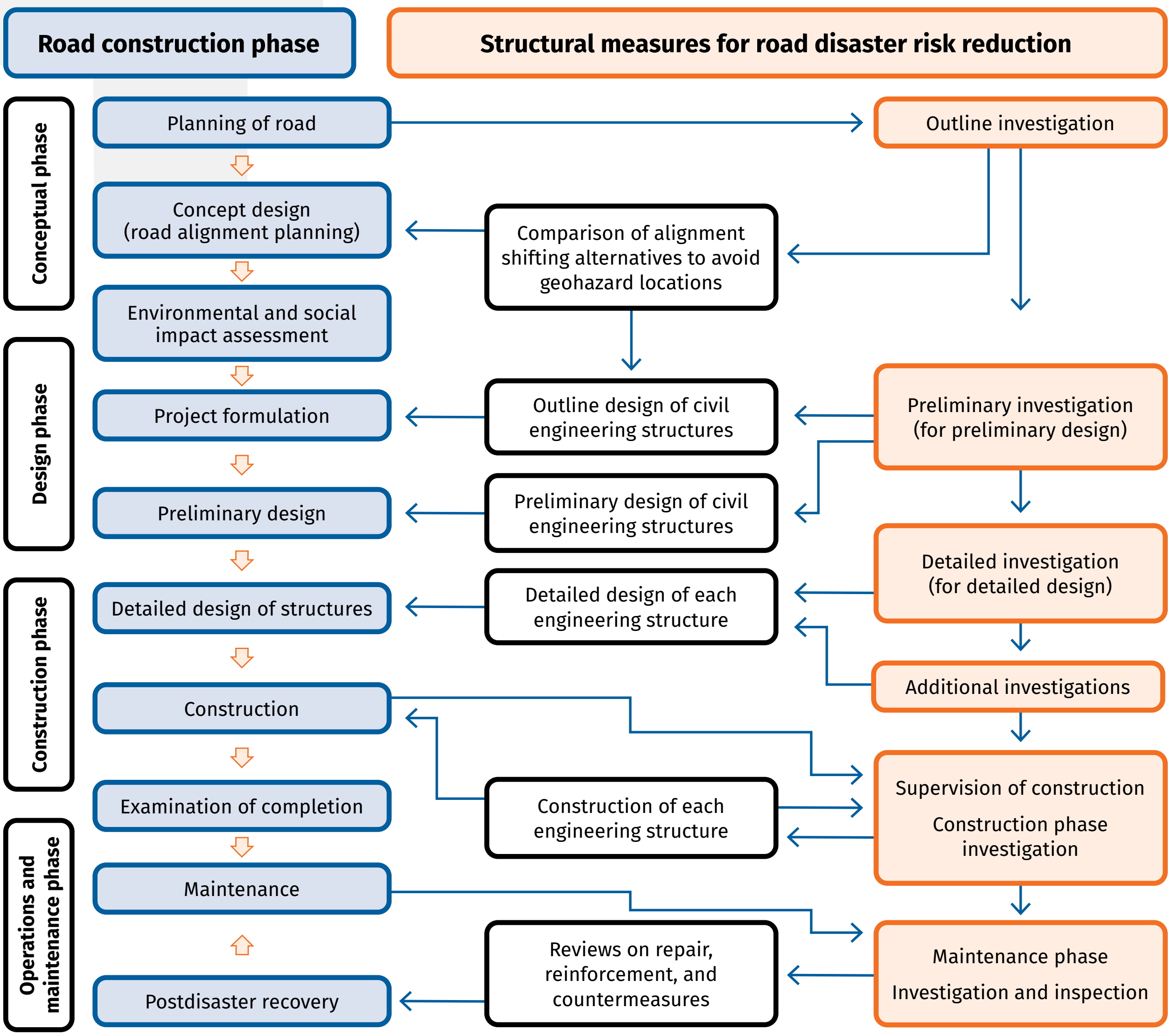
4 ENGINEERING AND DESIGN

4.1 Process of Implementing Structural Measures

In Japan, the term "construction of countermeasure" is used to define structural measures. In the case of small works conducted without design (such as removal of soil deposits, repair of cracks on retaining walls, and so on), the countermeasures are called "maintenance works." The maintenance works are undertaken by the road maintenance staff of the road management authorities.

Structural measures are usually implemented based on the priority of the hazardous locations where countermeasures are required (Figure 4.1). Structural measures for geohazard risk reduction can also be implemented as postdisaster reactive (recovery) measures. An environmental and social impact assessment (ESIA) is conducted during the concept design phase of the new road construction or during the planning of proactive structural measures for existing roads.

Figure 4.1 General Flow of Road Construction and Structural Measures



Source: Japan Road Association 2009b. ©Japan Road Association. Reproduced, with permission, from the Japan Road Association; further permission required for reuse.

4.2 Types of Structural Measures and Design Considerations

A number of measures are implemented to protect road users from road geohazards: roadside slope stabilization or protection works, construction of roads that bypass geohazard-prone areas, and structural measures in road crossings or along rivers or streams (Photos 4.1 through 4.6). Other types of structural measures are described in "Landslides in Japan," which provides engineering knowledge on structural measures in Japan in English (JLS 2012).

The road management authority usually determines the type of structural measures after consultation between the road management authority and the engineering consultant. If there is a significant impact on the surrounding social environment, a technical review committee (including authorized specialists, universities, and technical and/or administrative institutes) is organized to support the decision-making process.

Photo 4.1 Slope Stabilization Measures for Mountainside Road Slope

Slope stabilization measures here use a retaining wall, a slope framework (grid beam) with anchoring, shotcrete, and vegetation (bioengineering).

Source: ©Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Reproduced, with permission, from MLIT; further permission required for reuse.

Photo 4.2 Slope Stabilization Measures for Road Mountainside Rock Collapse

Unstable rock mass is stabilized here using steel wire rope with anchoring to prevent collapse.

Source: ©Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Reproduced, with permission, from MLIT; further permission required for reuse.

Photo 4.3 Shelter for Road Mountainside Fall or Collapse

Shelters against rock, debris, and snow are often built over roadways adjacent to steep slopes. There is no substantial difference between shelters that protect against rock or soil fall and those built for snow avalanches. They usually serve both rock or soil fall and snow avalanches in a snowy region. The material of the shelter is three types: reinforced concrete, prestressed concrete, and steel.

Source: MLIT 2015a. ©Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Reproduced, with permission, from MLIT; further permission required for reuse.

Photo 4.4 Barrier (Catch Fence with Wall Foundation)

Concrete retaining walls are often used as the foundation of fences to prevent falling rocks. Energy absorption capacity of 45–650 kilojoules (kJ) was the norm; however, recently, a rockfall prevention fence capable of high energy absorption up to 1,000 kJ has been developed, and in the MLIT's New Technology Information System (NETIS).

Source: MLIT 2015a. ©Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Reproduced, with permission, from MLIT; further permission required for reuse.

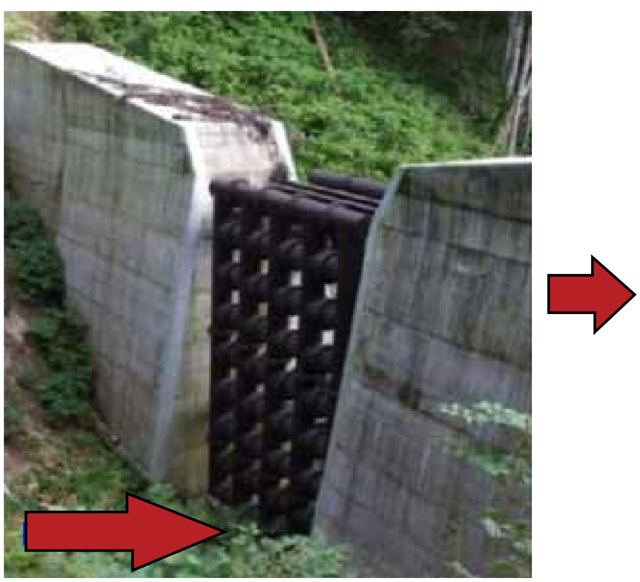
Photo 4.5 Wire Netting (Rockfall Net)

Wire netting (rockfall net) is subdivided into covering type and pocket type (shown in the photo, left). The covering type tightens loose rock mass and stops these from falling through the tensile force of the wire net. The pocket type is a barrier to protect roads against rockfalls from reaching the road, while the flexible net does not break and buffers the falling rock energy and retains the rockfalls on the mountainside of the road.

Source: MLIT 2015a. ©Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Reproduced, with permission, from MLIT; further permission required for reuse.

Photo 4.6 Debris Flow Protection Check Dam (Permeable Type)

a. Before debris flow event on September 11, 2015



b. Just after the debris flow event on September 11, 2015

This example shows a check dam in Nikko City, Tochigi Prefecture, before and after the September 2015 Kanto-Tōhoku Storm.

Source: ©Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Reproduced, with permission, from MLIT; further permission required for reuse.

5 OPERATIONS AND MAINTENANCE

5.1 Maintenance of Structural Measures

The engineering staff (contracted by the road management authority) is in charge of maintaining structural measures as part of road maintenance in most cases. Private contractors usually provide the heavy equipment required for maintenance such as removal of debris deposits in dam reservoirs or the repair of damaged slope reinforcement works.

Substantial infrastructures have been built during the rapid growth period of Japan's economy in the 1960s and 1970s, but they are nearing the end of their useful life within the 2010–2030 period. The Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) made the "Action Plans for Life Extension of Infrastructure" in May 2014, which includes the following activities to be conducted by the MLIT and subnational governments (MLIT 2014a):

- Inspection, diagnosis, maintenance, and renewal
- Preparation of engineering standards
- Preparation of information database
- Preparation of maintenance plan for structural measures at each facility
- Research and development of new technology
- Budget allocation
- Formulation of maintenance procedure and organization
- Formulation of laws and regulations.

5.2 Early Anomaly Detection and Emergency Information Collection

Visual inspections of the road (just watching for abnormalities from patrol cars) are conducted by road management authorities as part of their routine patrols. A daily patrol is conducted by road patrol cars for national expressways, national highways, prefecture roads, and arterial municipality roads.

The Road Bureau of the MLIT ordered nationwide road geohazard risk inspections and on-demand specific thematic risk inspections (as described earlier in section 3.1.2, "Geohazard Risk Evaluation for Existing Roads"). These visual inspections are conducted on foot by the engineer of the contracted consulting firms. For highly vulnerable geohazard sites, the geohazard monitoring is conducted with the aid of devices such as closed-circuit television (CCTV) and detection devices for land movement or debris flow.

An efficient communication system for road networks was developed in Japan in 2005. Any person can report a road disaster or road abnormality to the corresponding road management authority by calling the road emergency information number #9910. This system has also been a tool for emergency information collection. After notification from road users or other personnel, patrol cars and vehicles equipped with satellite communication systems rush to the site and collect information.

Recently, besides the conventional field surveys, more efficient methods are being used to identify traffic congestion due to road closings, such as the use of probe cars equipped with Global Positioning Systems (GPS), the use of Vehicle Information and Communication System (VICS) data, and other intelligent transportation system (ITS) technologies in cooperation with police departments.

5.3 Road Condition Emergency Information System Including Early Warning or Precautionary Road Closure

On arterial roads, electrical road information boards are installed by road management authorities along the road and at driver amenity areas. The driver amenity areas, sometimes called roadside stations (or Michi-no-Eki), were developed by the national government to provide road users with amenities such as parking, restrooms, road and local information displays, and community centers for residents (Photos 5.1 through 5.6). These provide information on the occurrence of road geohazard damage events; road closures due to geohazards (with recommended detour routes); early warning for geohazard occurrence; or driving conditions during dangerous situations (such as heavy rain, strong winds, and dense fog). Such emergency information is also provided via mass media (radio and television), the internet, and VICS.

Photo 5.1 Road Information Board above a Carriageway

This electronic information board—placed above a carriageway using a bridge structure—announces traffic regulations or conditions. During normal conditions, the electric information board delivers messages that remind vehicle drivers to drive carefully.

Source: © World Bank. Permission required for reuse.

Photo 5.2 Road Information Board in a Parking and Rest Area

This electronic information board announces the traffic regulation for one-way alternating traffic on a road subsection.

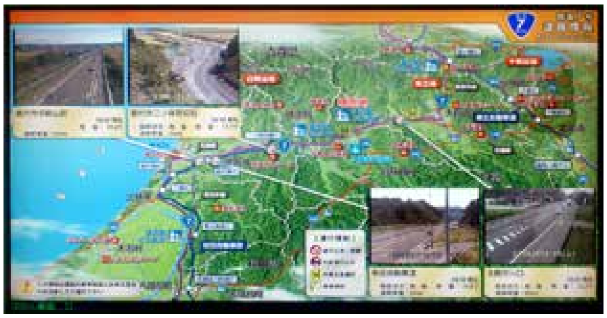
Source: © World Bank. Permission required for reuse.

Photo 5.3 Roadside Information Center

This building, which provides road information, is managed by a Regional Development Bureau of the MLIT at the Takanosu Roadside Station on National Highway No. 7, Akita Prefecture, Tōhoku Region.

Source: © World Bank. Permission required for reuse.

Photo 5.4 Video Display of Road Information, Driving Conditions, and Traffic, Including Geohazard Information



This real-time video display provides updated road, driving, traffic, and geohazard information to visitors at the Takanosu Roadside Station on National Highway No. 7 in Tōhoku Region.

Source: © World Bank. Permission required for reuse.

Photo 5.5 Detail of Road and Weather Information from a CCTV Camera

The information board displays closed-circuit television (CCTV) monitoring images of hazard-prone road locations with weather conditions such as temperature and cumulative rainfall amount from the start of the rainfall.

Source: © World Bank. Permission required for reuse.

Photo 5.6 Detail of Legend in Video Display to Indicate Traffic Regulation and Road Closures

The legend at the bottom of the screen helps viewers to identify road traffic situations: whole-width closures, partial-width closures, closures for large vehicles only, or road subsections with alternating one-way traffic.

Source: © World Bank. Permission required for reuse.

The precautionary road closure is an established system, and the MLIT's Road Bureau has designated the hazard-prone road sections based on criteria such as a threshold rainfall amount. These traffic regulation criteria—for historically known or apparent dangerous situations for geohazard disasters such as slope or progressing road deformation—are used to ensure the safety of road users from disasters by

- Prohibiting vehicle traffic on dangerous subsections identified beforehand when an abnormal weather condition, mostly rainfall, exceeds the regulation criteria;
- Enabling the road management authority to protect road users from running or stopping their vehicles in dangerous road subsections; and
- Avoiding the risk of subjecting road users to a possible disaster—despite the consequences of traffic closures in terms of road users' loss of time waiting for traffic to reopen, increases in vehicle operating costs, loss of time from possible longer detours, and opportunity losses due to the cancellation of trips.

Road management authorities suspend the road closure when geohazard-induced situations are normalized and danger no longer detected through emergency visual observation patrols. The weather association provides the forecast data for rainfall intensity to calculate the rainfall index and to apply the criteria for precautionary road closures.

The road management authorities have equipment, machinery, staff, and operating rules to respond to emergencies caused by abnormal weather conditions, other highly geohazard-susceptible conditions, and reported disasters or other abnormalities along the roads. The road management authorities can also have yearly contracts with private companies to provide additional staff and machinery.

5.4 Local and Institutional Partnerships for Geohazard Risk Management

As described in chapter 1 (Table 1.1), a massive rock-mass failure killed 15 road users on a national highway in 1989. The lesson learned after this tragedy was that lives could have been saved if road users or residents had previously reported the abnormalities (small intermittent rockfall) to the road management authority and had precautionary road closures been implemented.

In 2012, the Local Disaster Prevention Research Committee for Rock Collapse—formed in 1997 under the MLIT's purview and comprising five academic researchers in DRM and disaster information management—proposed the concept of "local disaster prevention partnerships" to create strong local alliances against disasters among residents and road users, subnational DRM agencies, and road management authorities.

These local partnerships contribute to disaster risk reduction activities such as road patrols and proactive structural measures against geohazards. Specifically, residents and road users allied under the proposed partnerships can ideally undertake the following:

- Help to obtain geohazard information such as disaster history and abnormalities
- Strengthen the region's overall disaster prevention capabilities.

After the MLIT put the partnership concept into practice, a nationwide road emergency number (#9910) was established, and some roadside emergency phones and parking spaces were provided in the hazardous road subsections of the arterial roads.

5.5 Control of Road Disasters Caused by Human Activities

Human activities that trigger road geohazard events are regulated by several laws (Table 5.1).

Table 5.1 Countermeasures to Mitigate Road Geohazards Caused by Human Activities

Human activity	Road geohazard-inducing mechanism	Countermeasures
Garbage disposal in roads	Garbage in roadside drainage makes the drainage less effective and could activate road geohazards.	Garbage disposal on public infrastructure such as roads is prohibited under the Waste Management and Public Cleaning Act of 1970 (last amended in 2015). Police control the illegal garbage disposal. Signboards to stop the activities are placed by the road management authority in cases of frequent garbage disposal.
Sand extraction from rivers or streams that cross or run along roads	The sand extraction may increase roadside river erosion or erosion of the foundations of road-crossing rivers and streams.	The sand extraction activities require approval under the Gravel Gathering Act of 1968 (last amended in 2015).
Deforestation of landscape ecosystems along roads	Deforestation may increase the peak flow rates of rivers or streams along roads, thus increasing the erosion of roads along rivers and also increasing flow-type geohazard risks (such as flood or earth or debris flow).	The minister of the Ministry of Agriculture, Forestry and Fisheries (MAFF) or the governors of prefectures designate the conservation forest and restrict deforestation under the Forest Act of 1951 (last amended in 2016).

Human activity	Road geohazard-inducing mechanism	Countermeasures
Watering or earthwork near roads	Watering such as irrigation, banking of the potential sliding slope head, or cutting the slope foot may cause geohazards.	The Landslide Prevention Act of 1958 (last amended in 2014) restricts landslide-inducing activities such as watering or earthworks in designated landslide prevention areas, which are areas of high probability for inducing landslides, as designated by the MLIT, MAFF, and the Forestry Agency (under MAFF). Project approval for new watering systems or earthworks in landslide prevention areas is the responsibility of the governor of the prefecture where the project is located. New watering systems or earthworks plans require an environmental impact assessment (EIA) under the Environmental Impact Assessment Law of 1997 (last amended in 2014). (For more information, see a translated version at http://www.env.go.jp/policy/assess/2-2law/1.html, or see Ministry of the Environment [2012].)

5.6 Traffic Signs

In Japan, road signage delivers messages such as traffic regulation, warning, and dangers. As for road geohazard risk management, danger warning signs for rockfall and crosswinds are used (Figure 65.1).

Figure 5.1 Danger Warning Signs for Geohazards

a. Sign code 209-2: Rockfall caution

b. Sign code 214: Crosswind caution

Source: ©Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

At designated geohazard-prone road subsections, the road management authorities provide information boards notifying road users that the road subsections are designated for precautionary road closures, displaying road closure criteria. When roads are closed during highly dangerous situations or because of geohazard, the road management authority places the temporary danger warning on the information board, and the affected road is closed using barricades or crossing bars (Photos 5.7 and 5.8). Reactive road closure (road closure as a reactive measure) may be implemented for any roads as needed. The road information board announces the permanent or temporary dangerous road condition and/or the road closure situation.

Photo 5.7 Road Information Board for Precautionary Road Closure

The information board displays closed-circuit television (CCTV) monitoring images of hazard-prone road locations with weather conditions such as temperature and cumulative rainfall amount from the start of the rainfall.

A roadside information board on traffic regulation in between Kouchiumi District, in Miyazaki-shi City, and Kazeda District in Nichinan City reads as follows:

> Traffic is closed for this subsection in case of
> (1) Continuous rainfall amount from the start of the rainfall is 170mm or more; or (2) Highly rockfall-dangerous situation. Thank you for your cooperation.
>
> Ministry of Land, Infrastructure, Transport and Tourism, Director of the Miyazaki River and National Highway Administration Office

Source: ©Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Reproduced, with permission, from MLIT; further permission required for reuse.

Photo 5.8 Roadside Electrical Information Board with Alarm Light

A sample notice on this roadside electrical information board, if the alarm light were on, would note in red light, "Caution! Flooded due to rain. Water depth 30 cm."

Source: ©Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Reproduced, with permission, from MLIT; further permission required for reuse.

5.7 Awareness Raising and Training for Road Stakeholder Engagement

Raising road disaster awareness involves educational activities to improve and disseminate knowledge on road disaster prevention to residents and road users. Since 1992, Road Disaster Prevention Week has been held during the period of August 25–31 and preceding Disaster Prevention Day (September 1). (August is Road Preservation Month.) During Road Disaster Prevention Week, road management authorities provide exhibitions, lectures, and workshops on road DRM to residents and road users (Photos 5.9 and 5.10).

Photo 5.9 Disaster Prevention Exhibit by Road Management Authority

Local residents and road users visit a public exhibit displayed during Road Disaster Prevention Week, August 23–28, 2015, in a local shopping mall of Tokushima Prefecture in Shikoku Region.

Source: ©Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Reproduced, with permission, from MLIT; further permission required for reuse.

Photo 5.10 Poster for Road Disaster Prevention Week

A poster advertising Road Disaster Prevention Week (August 25–31, 2001) promotes exhibitions, lectures, workshops, and other activities to educate road users about road DRM. The poster states, in part, "It is not just other people's concern, but road disaster threatens our very lives."

Source: ©Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Reproduced, with permission, from MLIT; further permission required for reuse.

In addition, with cooperation from the media, experienced scholars, and others involved in education, the MLIT's Kantō Regional Development Bureau has released a textbook—"Prepare for a Major Earthquake (Consider Life's Path)"—for elementary school students. It covers "road disaster prevention and mitigation" and "the importance of self-help, cooperation, and rescue and assistance during a rapid evacuation and relief in case of a disaster." To make the textbook easy to use in an educational setting, the "Disaster Prevention Training Start Guide" was also published. The textbook was distributed to public elementary schools in five prefectures (Tokyo, Ibaraki, Saitama, Chiba, and Kanagawa) at the beginning of September 2016 so that they can use it in the educational field. The textbook and "Disaster Prevention Training Start Guide" are expected to have many applications.

6 CONTINGENCY PROGRAMMING

Within Japan, the three main focus points of contingency programming in relation to postdisaster response and recovery are

- Emergency inspection and postdisaster needs assessment;
- Emergency traffic regulations and public notice arrangements pertaining to the closure of roads; and
- Emergency recovery activities.

These are each expanded upon further in the sections below.

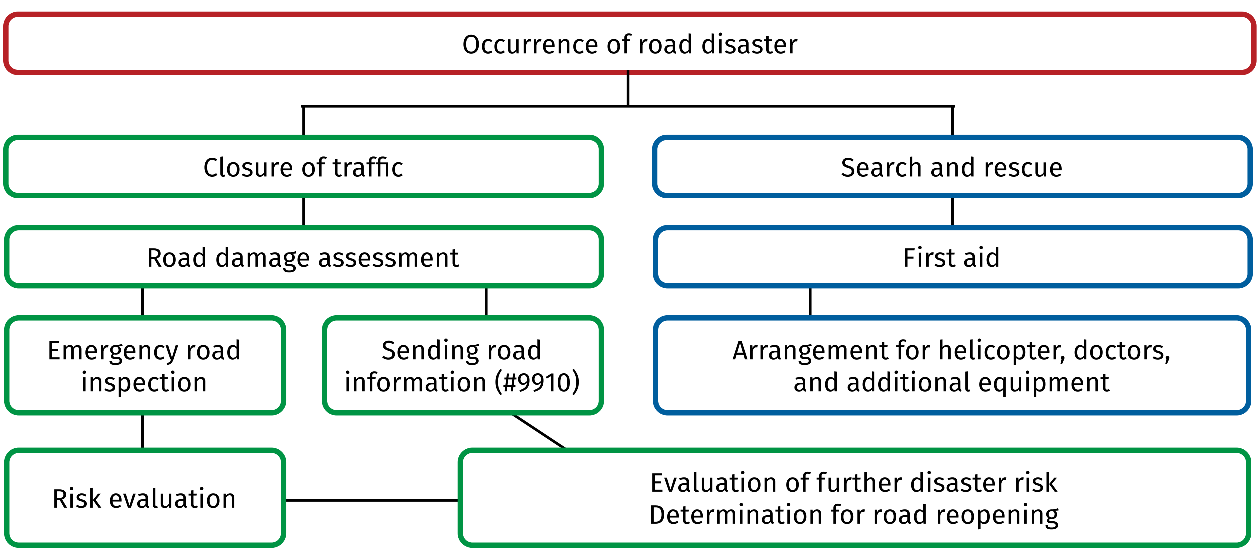
6.1 Emergency Inspection and Postdisaster Needs Assessment

Postdisaster damage information is collected by the same staff responsible for routine road maintenance. If road users are injured or killed or if vehicles are damaged, the police also conduct inspections. Along with the required emergency inspections, any necessary urgent measures are taken to protect road users and road structures from secondary damage.

The procedures for emergency inspections and postdisaster needs assessment are shown in Figure 6.1. Postdisaster needs assessments are carried out by personnel including rescue teams dispatched by the major cities or municipalities in response to the emergency calls by victims, road users, or residents. A rescue team evaluates the first aid needs of injured road users and carries out the proper emergency treatment. The rescue team or road operation staff may request additional rescue teams, ambulance cars, rescue helicopters, or medical helicopters equipped with medical instruments.

The road management authority assesses the condition and availability of the road network by collecting local road damage information. The free road emergency number (#9910) is used to obtain information from users concerning the routes. Information exchange with other road organizations such as the police is also conducted. Assessment results on the road network availability are used to coordinate the required operation for reopening the roads (elimination of road obstacles).

Figure 6.1 Procedure for Emergency Inspection and Postdisaster Needs Assessment



Note: Boxes outlined in green designate tasks conducted by road management authorities. Boxes outlined in blue designate tasks conducted by police or subnational government rescue teams.

6.2 Emergency Traffic Regulation and Public Notice

When road traffic is unpassable or highly dangerous based on the results of the emergency inspection, the road management authority sets a temporary barricade and closes the roads in consultation with the traffic police until the road obstructions and highly susceptible hazard source(s) are eliminated.

In addition, emergency information is published for road users and residents through information boards on the highways. The information system can be linked to various media such as television, radio, car navigation sets, and the internet. The Vehicle Information and Communication System (VICS), the world's first real-time road traffic information system, began in April 1996. The information is transmitted to onboard equipment such as car navigation systems.

6.3 Emergency Recovery

Emergency recovery for minor works such as road debris removal is managed by the road maintenance offices of the road management authorities, including the branch offices of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

As part of emergency preparedness for disasters, some road management authorities make agreements with private construction companies to undertake emergency activities concerning severe geohazards. These private companies remove road obstructions and restore hazardous situations upon request from the road management authorities. The MLIT also developed a "Doctors for Road Disaster" system to dispatch experts and professionals in academic societies and engineering associations when road disasters occur, to provide technical recommendations to the road management authorities.

In addition, the MLIT's Technical Emergency Control Force (TEC-FORCE) mobilize special emergency recovery staffs as well as special equipment in the MLIT Regional Development Bureaus, including pump trucks, mobile lighting vehicles, headquarters cars or standby support vehicles, remote-controlled backhoes, disaster management helicopters, sandbag manufacturing equipment, emergency assembly bridges, sprinkler trucks, side ditch cleaning vehicles, and road sweepers.

In the case of large-scale geohazard events, the TEC-FORCE and teams with equipment are dispatched, depending on requirements, not only to roads under MLIT jurisdiction but also to roads under the jurisdiction of subnational governments for emergency recovery work needed in the wake of disasters. Private construction companies also conduct emergency recovery work by order of the MLIT or subnational governments, in collaboration with TEC-FORCE. For emergency cases, the MLIT can make standby contracts with private construction companies for emergency recovery works.

Photo 6.1 shows an emergency recovery operation using an emergency assembly bridge and mobile lighting vehicle in 2004.

Photo 6.1 Example of Emergency Recovery Operations

August 2, 2004: Immediate aftermath of road geohazard event

August 4, 2004: Installation of emergency assembly bridge

August 5, 2004: Traffic secured on one-way alternating road

General vehicle traffic was restored about three days after geohazard damage occurred on National Highway No. 32, Otoyo Town, Kōchi Prefecture, Shikoku Region.

Source: ©Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Reproduced, with permission, from MLIT; further permission required for reuse.

Box 6.1 discusses emergency recovery after the magnitude 9.0 Great East Japan (or Tōhoku) Earthquake and Tsunami in 2011. This emergency recovery strategy was implemented efficiently for several reasons:

- The MLIT staffs (assigned to the branch offices or for road management) had prepared emergency action plans for the maintenance of roads.
- TEC-FORCE employees at the MLIT's Regional Development Bureau routinely had carried out training with equipment arranged for emergency recovery.
- MLIT had made standby contracts for emergency recovery operations with private construction companies.

To facilitate and expedite payment to the companies involved in the emergency recovery and restoration works, an increased advance payment rate and the reduction of the confirmation documents of finished work quality and quantities were taken into consideration under the exceptional circumstances.

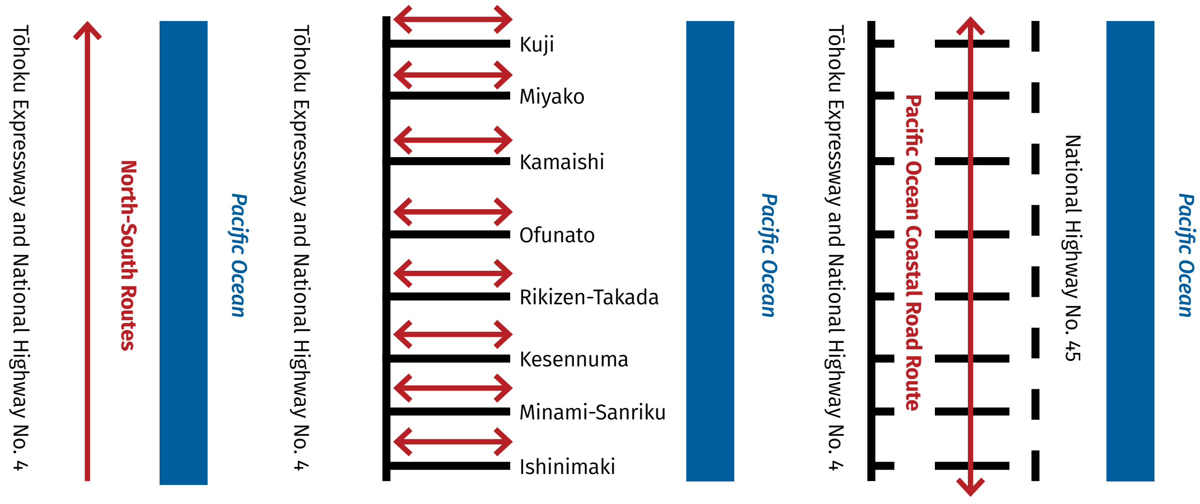
Box 6.1 Efficient Operation to Reopen Roads (Eliminate Road Obstructions) after Massive Earthquake and Tsunami of 2011

The magnitude 9.0 Great East Japan (or Tōhoku) Earthquake caused a series of tsunamis and damaged the main roads along the Pacific coast. However, the high-standard roads transecting northeast Japan inland with the longitudinal highways of North–South Routes (Tōhoku Expressway and National Highway No.4) were not damaged so much.

A key for efficient recovery was the reopening of the main eight East–West Routes in parallel, connecting inland longitudinal highways to seriously damaged coastal roads.

The road reopening operation was later called "Operation Toothcomb" because the shape of the transportation network of East–West Routes in parallel resembled a comb's teeth (figure B6.1.1).

Figure B6.1.1 Steps to Eliminate Road Obstructions after Great East Japan Earthquake, 2011



Step 1:
Secured Tōhoku Expressway and National Highway No. 4, "North–South Routes."

Step 2:
Opened East-West routes toward the damaged areas along the Pacific Ocean until March 15, 2011.

Step 3:
Reopened 97 percent of National Highway No. 45 until March 18, 2011.

Source: @Ministry of Land, Infrastructure and Transport and Tourism (MLIT).

7 CONCLUSIONS AND KEY FINDINGS

Based on this case study, the following are the key findings and conclusions across each phase of the geohazard risk management process.

1. Institutional capacity and coordination. Japan has established laws that specify the guarantee of funds related to disaster relief, disaster management plans, and the fundamental matters related to systems during a state of emergency.

Technical standards and manuals have been prepared for (a) disaster risk management; (b) road disaster risk management; (c) risk evaluation for road geohazards; (d) benefit estimation of proactive measures for road geohazards; and (e) business continuity planning for road geohazards. However, regarding (c) risk evaluation for road geohazards, no practical manual on risk estimation of potential economic loss has been developed. Regarding (d) benefit estimation of proactive measures, no practical manual has been developed.

The capacity review for Japan concluded that even for a country such as Japan—where there is a long history of geohazard management—for many of the factors under assessment, Japan is only at the starting point of developing appropriate capability and capacity. For those just commencing implementation of geohazard risk management practices, a long-term commitment is required.

2. Systems planning. Japan makes extensive use of geohazard mapping as part of the planning and management of risks on both proposed and existing roads. Using a mix of basic, intermediate, and advanced methodologies allows the Japanese to make efficient use of their resources—focusing the advanced methodologies where they are most needed to address complex situations.

The estimation of benefits and cost-benefit analysis for road geohazard risk reduction is not conducted in most cases in Japan because it involves costly investigations and studies. Instead, the focus is on identifying the lowest life-cycle-cost option, on the presumption that the need for the road to be open was justified when the road was first constructed and that benefits would generally be similar between options.

3. Engineering and design. Structural measures are usually implemented based on the priority of the hazardous locations where countermeasures are required. Structural measures for geohazard risk reduction can also be implemented as postdisaster reactive (recovery) measures. An environmental and social impact assessment (ESIA) is conducted during the concept design phase of the new road construction or during the planning of proactive structural measures for existing roads.

To protect road users from road geohazards, a number of measures are implemented, including roadside slope stabilization or protection works, construction of roads that bypass geohazard-prone areas, and structural measures in road crossings or along rivers or streams. There are other types of structural measures, such as those described in "Landslides in Japan" (JLS 2012), which provides engineering knowledge on structural measures in Japan in English.

The road management authority usually determines the type of structural measures after consultation between the road management authority and the engineering consultant. If there is a significant impact on the surrounding social environment, a technical review committee (including authorized specialists, universities, and technical and/or administrative institutes) is organized to support the decision-making process.

4. Operations and maintenance. The O&M tasks within Japan consist of

- Routine maintenance of the structural measures;
- Early anomaly detection and emergency information;
- Road condition emergency information systems;
- Establishment of partnerships with other road authorities and institutions;
- Management of human impact on the causation of geohazards;
- Appropriate traffic signs for managing geohazards; and
- Awareness raising and training for road stakeholders.

5. Contingency programming. Within Japan, the three main focus points of contingency programming in relation to postdisaster response and recovery are

- Emergency inspection and postdisaster needs assessment;
- Emergency traffic regulations and public notice arrangements pertaining to the closure of roads; and
- Emergency recovery activities.

The overarching finding of the Japanese approach to road geohazard risk management is that of taking a systematic approach—covering all aspects of geohazard risk management from governance and laws; through to the design, construction, and maintenance of countermeasures; and on to the engagement with a wide range of stakeholders before, during, and after a geohazard event occurs.

ANNEX C1 CHECKLISTS FOR INSTITUTIONAL CAPACITY REVIEW

Tables C1.1, C1.2, and C1.3 contain a sample of the road geohazard risk management checklists as completed for Japan. They are provided to illustrate the nature of completing the checklists and the variation in resulting score between categories.

Table C1.1 Checklist A: Institutional Framework for Road Geohazard Management (Sample of Checklist Only)

Question	Item number	Check items	Status (options 0–4)	Score	Effectiveness or appropriateness 0: No 1: Low 2: Moderate 3: High
Have laws and/or regulations been formulated?	I-1	Laws of disaster risk management	0. Not yet started 1. Formulating 2. Formulated 3. Enforcing partially 4. Enforcing fully	4	2
	I-2	Laws of general geohazard risk manage-ment	0. Not yet started 1. Formulating 2. Formulated 3. Enforcing partially 4. Enforcing fully	4	2
	I-3	Laws of road geohazard risk management	0. Not yet started 1. Formulating 2. Formulated 3. Enforcing partially 4. Enforcing fully	4	2
Have technical standards, guidelines, or manuals been prepared?	I-4	Disaster risk management	0. Not yet started 1. Preparing 2. Prepared 3. Utilizing partially 4. Utilizing fully	1	0
	I-5	Road geohazard risk management	0. Not yet started 1. Preparing 2. Prepared 3. Utilizing partially 4. Utilizing fully	4	2
	I-6	Risk evaluation for road geohazard	0. Not yet started 1. Preparing 2. Prepared 3. Utilizing partially 4. Utilizing fully	4	2
	I-7	Benefit estimation of proactive measures for road geohazard	0. Not yet started 1. Preparing 2. Prepared 3. Utilizing partially 4. Utilizing fully	1	0

	Description of current status **Summarize current status, effectiveness, problems, and so on.** **Add remarks and/or comments if necessary.**	**Reference materials** **or name of respondent, position, and agency** **Author (year): Title of reference** **or** **Name, position, agency**
	The Disaster Countermeasures Basic Act (1961) defines the (a) responsibility of each administrative body; (b) creation of disaster management councils; and (c) strategies by the national/local government. The rules on the contingency are defined by related laws.	Japan (1951): Act on National Treasury Share of Expenses for Recovery Projects for Public Civil Engineering Facilities Damaged Due to Disasters Japan (1961): Disaster Countermeasures Basic Act Japan (1962): Act on Special Financial Support to Deal with Extremely Severe Disasters
	The laws on general geohazard risk management were prepared for several types of geohazard, for structural and nonstructural measures. Japan has been enforcing geohazard-related laws based on lessons learned from previous geohazard events.	Japan (1961): Disaster Countermeasures Basic Act Japan (1964): River Act Japan (1897): Erosion Control Act Japan (1958): Landslide Prevention Act Japan (1969): Act on Prevention of Steep Slope Collapse Japan (1951): Forest Act Japan (2000): Sediment Disaster Prevention Act
	The Road Act (1952) is the basis for road geohazard risk management. Article 42 mandates that the road management authority maintains and repairs roads to keep these in good condition. Article 46 gives the road management authority responsibility over traffic regulation and control when the road is dangerous to use due to geohazards.	Japan (1952): Road Act
	The Cabinet Office is currently developing the Guidelines on the Standardization of Disaster Management.	Cabinet Office: web page in Japanese
	The Public Works Research Institute (PWRI) developed the “Draft Manual on Risk Analysis and Risk Management Support for Road Slope Disasters” in 2006, which includes risk estimates of potential economic annual losses.	Public Works Research Institute (PWRI 2006): “Draft Manual on Risk Analysis and Risk Management Support for Road Slope Disasters”
	The Road Bureau formulated the “Draft Road Geohazard Risk Inspection Guidebook” (Ministry of Construction 1990), which was subsequently revised. For the latest version, see JGCA (2010).	Japan Geotechnical Consultants Association (JGCA 2010): “Road Geohazard Risk Inspection Guidebook”
	The Public Works Research institute (PWRI), which developed the “Draft Manual on Risk Analysis and Risk Management Support for Road Slope Disasters” in 2006, introduced the methodology to estimate the economic benefits of proactive measures based on the expected reduction in average annual economic loss.	Public Works Research Institute (PWRI 2006): “Draft Manual on Risk Analysis and Risk Management Support for Road Slope Disasters”

Table C1.2 Checklist B: Geohazard Risk Management Activities for New Roads (Sample of Checklist Only)

Check items	Status (options 0–4)	Score	Effectiveness or appropriateness 0: No 1: Low 2: Moderate 3: High
Detailed hazard mapping of new road planning for landscape ecosystem areas	0. Never done 1. Planning 2. Planned 3. Conducting partially 4. Conducted fully	4	3
Simple evaluation of hazard levels at each hazard-prone location	0. Never done 1. Planning 2. Planned 3. Conducting partially 4. Conducted fully	4	3
Risk evaluation for new alternative road alignment plan	0. Never done 1. Planning 2. Planned 3. Conducting partially 4. Conducted fully	4	3
Evaluation of potential damage to local social environment	0. Never done 1. Planning 2. Planned 3. Conducting partially 4. Conducted fully	4	2
Geohazard management planning for new roads	0. Never done 1. Planning 2. Planned 3. Considering partially 4. Considering fully	4	2

Description of current status Summarize current status, effectiveness, problems, and so on. Add remarks and/or comments if necessary.	Reference materials or name of respondent. position, and agency Author (year): Title of reference or Name, position, agency
Detailed hazard mapping is a common practice in Japan for new road planning. Detailed hazard maps are used for selecting a safer route or to avoid causing man-made geohazards to the surrounding areas such as cutting or banking. Detailed hazard mapping is conducted by experts in geology and hydrology of engineering consulting firms contracted by the road management authorities. Mapped geohazards are falling, collapsing, or sliding slope areas and historically damaged areas of flow-type geohazards (earth or debris flow, flooding, river erosion). The consultants prepare the detailed hazard maps by interpretation of maps, aerial photographs, or satellite images together with field reconnaissance and interviews regarding historical geohazard events.	Ministry of Land, Infrastructure, Transport and Tourism (MLIT) National Research Institute for Earth Science and Disaster Prevention (NIED): http://www.bosai.go.jp/e/
Engineering consultants contracted by road management authorities usually conduct the outline investigations for new road planning. They prepare detailed hazard maps through simple evaluation of the potential hazard levels such as slope instability. Each geohazard is assigned to one of either two (high and low) or three (high, medium, and low) potential hazard levels. The hazard levels are determined by using available geographical information such as maps, aerial photographs, and satellite images.	MLIT
It is a general practice that the engineering consultants contracted by the road management authorities prepare the alternative road alignments including the risk evaluation results. The risk evaluation results include detailed hazard maps showing the new road alignment, an inventory table of hazard-prone locations with simple hazard level evaluation, and a risk summary of alternative road alignments (number of hazard-prone locations, their potential hazard levels, and geohazard characteristics). The alternative new road alignment is planned to avoid hazard-prone locations as much as possible. This geohazard avoidance saves construction costs, including the costs of structural measures for geohazard and subsequent maintenance costs. Figure 3.3 of the main Handbook shows the sample of a detailed hazard map showing the alternative new road alignments.	MLIT
It is a general practice that the engineering evaluation (as contracted by the road management authorities) include a social and environmental assessment process. To this end, the National Institute for Land and Infrastructure Management (NILIM) developed a technical procedure for the evaluation of ground deformation and geohazards (NILIM 2013).	MLIT National Institute for Land and Infrastructure Management (NILIM 2013): "Environmental Impact Assessment Technique for Road Project (Edition of FY 2012)."
The following is undertaken to manage geohazard risks during planning for new roads: • Survey(s) to identify the geohazard locations or areas, including flow-type geohazard sources in landscape ecosystem areas through which a new road is planned • Avoidance (to the extent possible) of road routes into potential hazard-prone locations to reduce construction costs for geohazard countermeasures and to reduce potential economic losses during the service period caused by road damage or closure due to geohazard(s) • Planning of proactive structural measures for hazard-prone locations on selected new alignments—including consideration of minor alignment shifting and using bridge structure and tunnels as alternative solutions for securing road users' lives and reducing economic losses due to road closing and recovery. Tunnels and bridges can shorten the road distance, which generates benefits in terms of travel time-saving. At the same time, tunnels and bridges can avoid hazard-prone locations and make roads robust against geohazards. The roads can be emergency transportation and evacuation routes at the time of wide-area disasters such as earthquakes, tsunamis, storms, and so on.	MLIT

Table C1.3 Checklist C: Geohazard Risk Management Activities for Existing Roads (Sample of Checklist Only)

Question	Item number	Check items	Status (options 0–4)	Score	Effectiveness or appropriateness 0: No 1: Low 2: Moderate 3: High
Has risk evaluation for existing roads been conducted?	ER-1 Basic method	Identification of road hazard-prone location Basic method: On-site visual inspections and information from road users	0. Never done 1. Planning 2. Planned 3. Conducting partially 4. Conducting fully	4	3
	ER-1 Intermediate method	Identification of geohazard-prone road locations Intermediate method: Identification survey	0. Never done 1. Planning 2. Planned 3. Conducting partially 4. Conducting fully	4	2
	ER-1 Advanced method	Identification of geohazard-prone road locations Advanced method: Detailed hazard mapping	0. Never done 1. Planning 2. Planned 3. Conducting partially 4. Conducting fully	3	2

	Description of current status Summarize current status, effectiveness, problems, and so on. Add remarks and/or comments if necessary.	Reference materials or name of respondent, position, and agency Author (year): Title of reference or Name, position, agency
	The basic methods are conducted during routine maintenance activities by the road maintenance staff. In 1962, the Road Bureau disseminated an "Order for Road Maintenance and Management" to national and subnational road management authorities. This order instructed the road management authorities to conduct routine patrols of roads with annual average traffic volume exceeding 300 vehicles per day. It further stipulated that the patrols be conducted during typhoons or heavy rains. The purposes of the patrols were to preserve the road, ensure smooth traffic, and properly maintain the roads—enabling the authorities to immediately address defective road locations with the appropriate measures as soon as possible. As practiced according to the 1962 order, the patrols are undertaken once a day throughout the week. Information provided by road users is also used: users can call the road management authority by dialing #9910.	Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
	The Road Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) ordered all road management authorities to conduct a total of 10 nationwide road geohazard risk inspections from 1968 to 2006. These inspections were to identify hazard-prone road locations through visual inspection by engineering geology and civil engineering experts in private engineering firms contracted by road management authorities. The identification categories of hazard-prone road locations were stipulated by the Road Bureau for each order given for the nationwide road geohazard risk inspection.	MLIT Japan Geotechnical Consultants Association (JGCA 2010): "Road Geohazard Risk Inspection Manual" Ando et al. (2015): "Risk Inspection Procedure for Road Slope Geohazard Prevention"
	Detailed hazard mapping was mostly prepared for geohazard-prone road subsections on national highways using private engineering consulting firms. The "Road Geohazard Risk Inspection Guidebook" (JGCA 2010) stipulated a geohazard identification procedure consisting of desk-checking and field visual inspection. Desk-checking is the review of geohazard information on historical disaster events and designated geohazard areas and interpretation of maps and aerial photographs. Geographical interpretation identifies microtopography and evaluates assumed geohazard movement types, magnitudes, and effects on roads. The "Road Geohazard Risk Inspection Guidebook" (JGCA 2010) stipulated that the slope facing the road should be interpreted from the mountain ridge (or hilltop) to the valley bottom and, if a geohazard-contributing factor is identified, it should be confirmed by visual field inspection. Nowadays, accurate maps using laser profiling and geographical information systems (GIS) are used to conduct detailed hazard mapping.	National Highway and Risk Management Division, Road Bureau, MLIT Japan Geotechnical Consultants Association (JGCA 2010): "Road Geohazard Risk Inspection Guidebook"

Question	Item number	Check items	Status (options 0–4)	Score	Effectiveness or appropriateness 0: No 1: Low 2: Moderate 3: High
Has risk evaluation for existing roads been conducted?	ER-2 Basic method	Risk evaluation of a geohazard-prone road locations Basic method: Simple risk evaluation using multiple criteria	0. Never done 1. Planning 2. Planned 3. Conducting partially 4. Conducting fully	4	2
	ER-2 Intermediate method	Risk evaluation of a geohazard-prone road location Intermediate method: Risk level rating	0. Never done 1. Planning 2. Planned 3. Conducting partially 4. Conducting fully	1	0

	Description of current status Summarize current status, effectiveness, problems, and so on. Add remarks and/or comments if necessary.	Reference materials or name of respondent, position, and agency Author (year): Title of reference or Name, position, agency
	Risk evaluation includes evaluation of likelihood and damage impact (or consequence) of a road location. The Japanese practice first evaluates the likelihood of occurrence of a road geohazard event, after which the damaging impact or consequence is evaluated by priority road section, including identification of the designated emergency roads and existence of detour roads. The risk evaluation procedure is as follows: 1) Evaluate the likelihood of a geohazard occurrence for a road location using three categories: (a) requirement for proactive measures; (b) periodical visual inspection monitoring; and (c) no further action. 2) The road location of the "required for proactive measures" is categorized by the road section priority (arterial or not arterial, designation as emergency road, and/or existence of detour road).	National Highway and Risk Management Division, Road Bureau, MLIT Japan Geotechnical Consultants Association (JGCA 2010): "Road Geohazard Risk Inspection Guidebook"
	In Japan, a "risk level rating" is not conducted; just the "hazard level rating" (likelihood level of road geohazard damage event occurrence) is conducted, as described in subsection 3.1.2 ("Basic method: Simple Risk Evaluation of a Hazard-Prone Road Location Using Multiple Criteria"). A "risk level rating" procedure has not been established.	MLIT

REFERENCES

Ando, Shin, Masashi Ueno, Shinjuro Komata, Akihiro Nakasuji, Kenzo Fukui, Yasuhiro Sasaki, and Kenichi Asai. 2015. "Risk Inspection Procedure for Road Slope Geohazard Prevention." Civil Engineering Journal (Public Works Research Center) 57 (6): 52–53 (in Japanese).

Cabinet Office, Government of Japan. 2013. "Business Continuity Guidelines: Strategies and Responses for Surviving Critical Incidents. 3rd ed." Management guidelines document, Cabinet Office, Government of Japan, Tokyo. http://www.bousai.go.jp/kyoiku/kigyou/pdf/guideline03_en.pdf.

———. 2015a. "Disaster Management in Japan." Pamphlet, Cabinet Office, Government of Japan, Tokyo. http://www.bousai.go.jp/1info/pdf/saigaipamphlet_je.pdf.

———. 2015b. "White Paper: Disaster Management in Japan 2015." Annual report to the Diet of Japan, Cabinet Office, Government of Japan, Tokyo. http://www.bousai.go.jp/kaigirep/hakusho/pdf/WP2015_DM_Full_Version.pdf.

Japan River Association. 2000. *Exposition of Government Ordinance for Structural Standard for River Administration Facilities.* Tokyo: Japan River Association.

Japan Road Association. 1954. "Road Earthwork: General Guidelines." Manual, Japan Road Association, Tokyo.

———. 2000. *Rockfall Countermeasure Handbook.* Tokyo: Japan Road Association.

———. 2006. *Road Earthquake Disaster Countermeasures Manual (Proactive Measures).* Tokyo: Japan Road Association.

———. 2009a. *Road Earthwork: Guidelines on Slope Cut and Slope Stabilization Works.* Tokyo: Japan Road Association.

———. 2009b. *21 Year Edition Road Earthwork Guidelines.* Tokyo: Japan Road Association.

JGCA (Japan Geotechnical Consultants Association). 2010. "Road Geohazard Risk Inspection Guidebook." Reference guide, JGCA, Tokyo.

JICA (Japan International Cooperation Agency). 2007. "The Study on Risk Management for Sediment-Related Disaster on Selected National Highways in the Republic of the Philippines." Final Report, JICA, Tokyo.

———. 2009. "The Study on Disaster Risk Management for Narayangharh-Mugling Highway in Nepal." Final Report, JICA, Tokyo.

———. 2011. "Preparatory Survey for the Project on Disaster Prevention and Mitigation Measures for the Itajaí River Basin in Brazil. Vol. II: Main Report." Final Report, JICA, Tokyo.

———. 2015a. "Information Collection Survey and Verification on Resilient Infrastructure Facilities against Natural Disasters in Central America." Final Report, JICA, Tokyo (in Japanese or Spanish).

———. 2015b. "The Project for Capacity Development of the Department of Climate Change Adaptation and Strategic Risk Management for Strengthening of Public Infrastructure in El Salvador." Final Report, JICA, Tokyo (in Japanese or Spanish).

JLS (Japan Landslide Society). 2012. “Landslides in Japan (The Seventh Revision).” Report, JLS, Tokyo.

JMA (Japan Meteorological Association). 2013. “National Catalogue of the Active Volcanoes in Japan.” 4th ed., English-language website, JMA, Tokyo.
http://www.data.jma.go.jp/svd/vois/data/tokyo/STOCK/souran_eng/menu.htm.

Ministry of Construction. 1990. ”Draft Road Geohazard Risk Inspection Guidebook.” Reference guide, Ministry of Construction, Government of Japan, Tokyo.

Ministry of the Environment. 2012. “Environmental Impact Assessment in Japan.” Pamphlet, Environmental Impact Assessment Division, Environmental Policy Bureau, Ministry of the Environment, Government of Japan, Tokyo. https://www.env.go.jp/policy/assess/1-3outline/img/pamph_e.pdf.

MLIT (Ministry of Land, Infrastructure, Transport and Tourism). 2005. “Roads in Japan 2005.” Brochure, Road Bureau, MLIT, Tokyo. http://www.mlit.go.jp/about/file000077.html.

———. 2011. “White Paper on Land, Infrastructure, Transport and Tourism in Japan, 2011.” Annual report to the Diet of Japan, MLIT, Government of Japan, Tokyo.
http://www.mlit.go.jp/english/white-paper/2011.pdf.

———. 2014a. “Action Plans for Life Extension of Infrastructure, May 2014.” Planning document, MLIT, Tokyo.

———. 2014b. “White Paper on Land, Infrastructure, Transport and Tourism in Japan, 2014.” Annual report to the Diet of Japan, MLIT, Government of Japan, Tokyo.
http://www.mlit.go.jp/en/statistics/white-paper-mlit-2014.html.

———. 2015a. “Roads in Japan 2015.” Brochure, Road Bureau, MLIT, Tokyo.

———. 2015b. “The 4th Infrastructure Improvement Priority Plan (2015–2020).” Planning document, MLIT, Tokyo.

NILIM (National Institute for Land and Infrastructure Management). 2013. “Environmental Impact Assessment Technique for Road Project (Edition of FY 2012).” NILIM Technical Note No. 71 and Public Works Research Institute No. 4254, Ministry of Land, Infrastructure, Transport and Tourism, Government of Japan, Tsukuba City (in Japanese).

PWRI (Public Works Research Institute). 2006. “Draft Manual on Risk Analysis and Risk Management Support for Road Slope Disasters.” Manual, PWRI, Tokyo.

ROMAN-TEC (Road Management Technology Center). 1996. “Road Geohazard Risk Inspection Guidebook.” Reference guide, ROMAN-TEC, Tokyo.

———. 2006. “Road Geohazard Risk Inspection Guidebook.” Reference guide, ROMAN-TEC, Tokyo.

———. 2009. “Road Geohazard Risk Inspection Guidebook.” Reference guide, ROMAN-TEC, Tokyo.

ROAD GEOHAZARD RISK MANAGEMENT

CASE STUDY OF SERBIA

CONTENTS

FIGURES

TABLES

MAPS

ABBREVIATIONS

DRM	disaster risk management
EU	European Union
GDP	gross domestic product
MCTI	Ministry of Construction, Transport and Infrastructure
PERS	Public Enterprise Roads of Serbia
SES	Sector for Emergency Situations (Ministry of Interior)

PART I

CASE STUDY SCOPE, BACKGROUND, AND GEOHAZARD RISK MANAGEMENT FRAMEWORK

1 CASE STUDY SCOPE

1.1 Scope of the Case Study

This Serbia road geohazard risk management case study is designed to capture the present status of road geohazard risk management in Serbia and to offer a way forward for future development.

The case study reports institutional mechanisms and a framework for geohazard risk management of the road sector across national key institutions and bodies, with reference to turning points in road geohazard risk management, such as serious road geohazard incidents (for example, 2014 floods and landslides in Serbia). The case study highlights the following:

- Development of critical institutional frameworks for passing key legislation and creating funding mechanisms
- Government efforts toward geohazard risk management, including identification of hazardous locations, risk evaluations, and development of strategies for structural and nonstructural disaster risk countermeasures
- Disaster preparedness measures, including disaster education among citizens, disaster risk planning activities, and early warning systems.

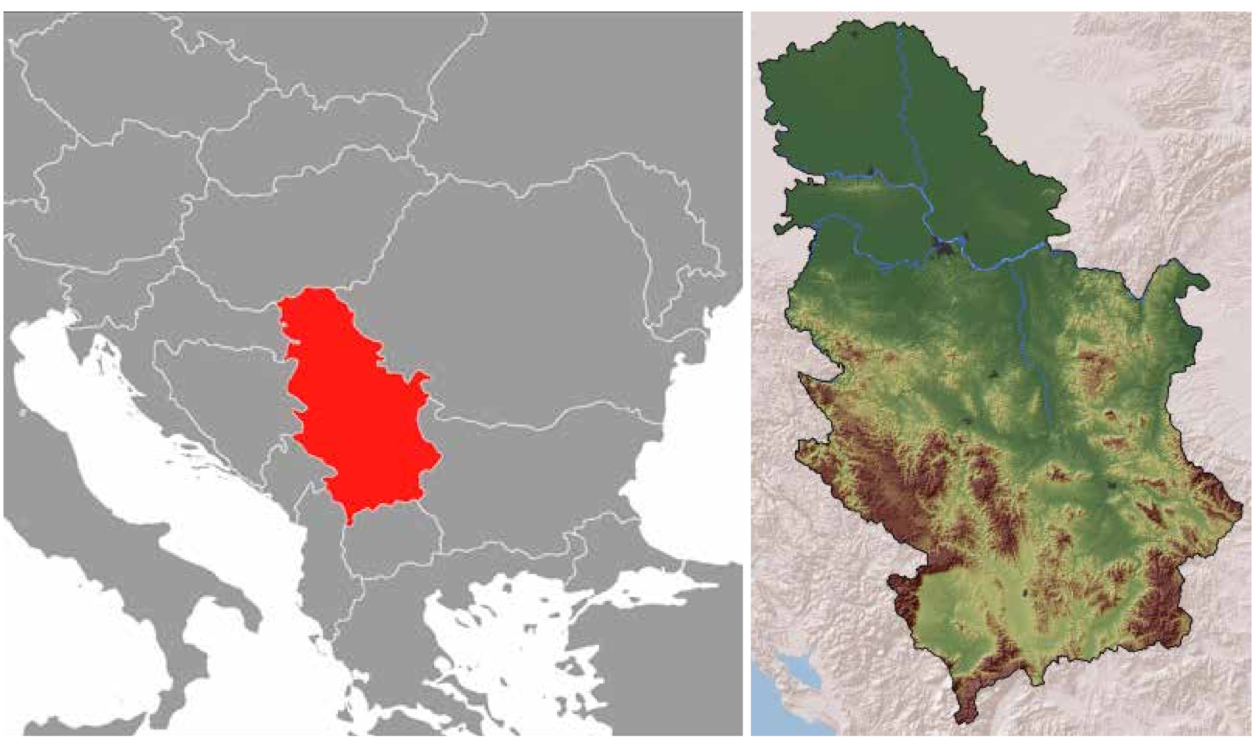
1.2 Geography and Climate of Serbia

Serbia is located on the Balkan Peninsula in southeast Europe (map 1.1), covering an area of 88,361 square kilometers and with a population of 7,186,862. In 2016, the total nominal gross domestic product (GDP) was US$37.755 billion, and GDP was US$5.293 billion.

Map 1.1 Geographical Position of the Republic of Serbia

a. Location within Europe

b. Digital elevation model



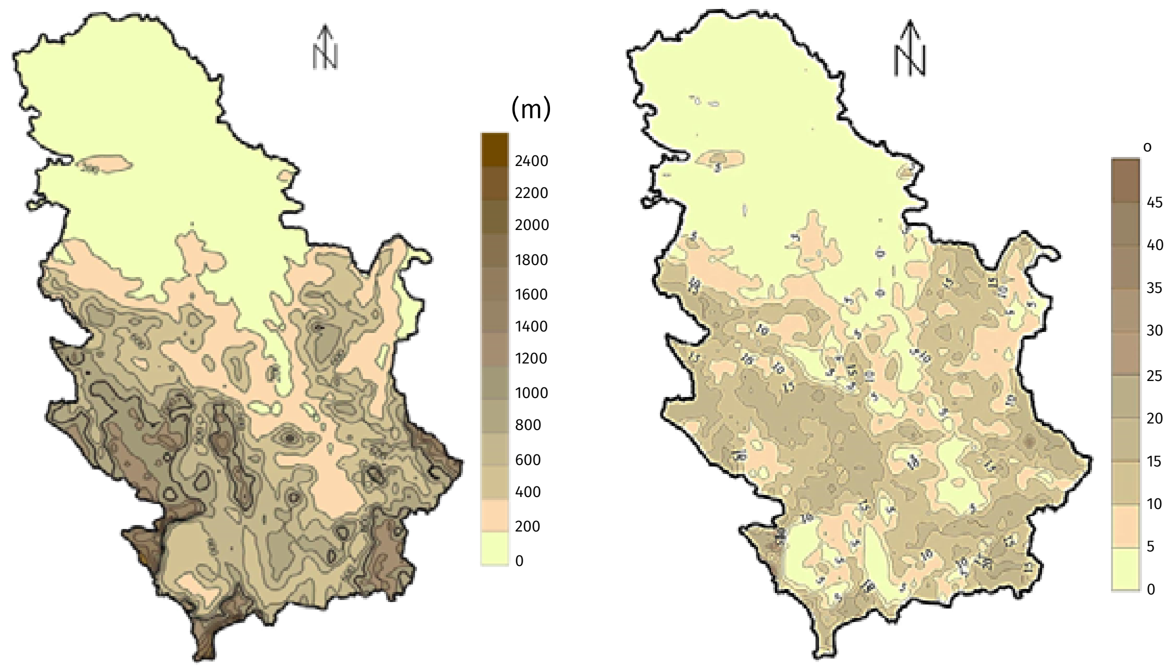
Source: Adobe Stock.

Serbia is a hilly to low mountainous country with many lowlands. The altitude is 0–400 meters over 52.6 percent of the whole territory, 400–800 meters over 37.5 percent, and higher than 800 meters over 19.9 percent (map 1.2, panel a) (Dragićević et al. 2011). Analysis of general slope angle shows that 44.5 percent of the territory is plain or with very gentle slopes (0–5 degrees), 36.9 percent is a gentle slope (5–15 degrees), and the rest is rugged mountains with slopes greater than 15 degrees (map 1.2, panel b).

Map 1.2 General Morphology of Serbian Territory

a. Altitude

b. Slope angle



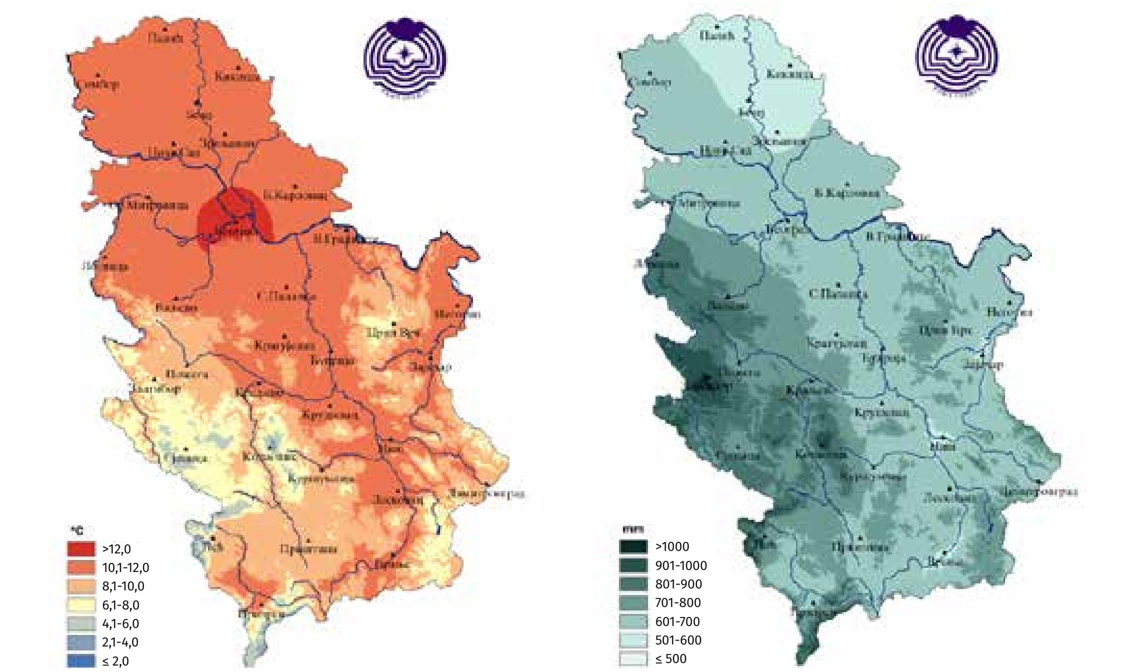
Source: Dragićević et al. 2011.

Serbia's climate varies between a continental climate in the north (cold winters and hot, humid summers with well-distributed rainfall patterns) to a more Adriatic climate in the south (hot, dry summers and autumns and relatively cold winters with heavy snowfall). Differences in elevation and large river basins, as well as exposure to the winds, account for climate differences. Data from the Republic Hydrometeorological Service of Serbia (RHMZ) provide the spatial distribution of annual temperature averages and precipitation totals across the territory of Serbia for the reference period 1981–2010 (Smailagić et al. 2013). Annual temperature averages vary, and most of the territory has an average temperature of 10.1–12.0 degrees Celsius (50.2–53.6 degrees Fahrenheit) (map 1.3, panel a). Mean annual precipitation ranges from 557 millimeters (21.9 inches) in Kikinda (north of Serbia) to 1,018 millimeters (40 inches) in Zlatibor (southwest Serbia) for the same reference period. Mean annual precipitation varies from 500–600 millimeters (19.6–23.6 inches) in central Serbia to 700–1,000 millimeters (27.6–39.4 inches) in the western part of Serbia (map 1.3, panel b).

Almost all of Serbia's rivers drain to the Black Sea by way of the Danube River. The Danube, Europe's second largest river, passes through Serbia for 588 kilometers (21 percent of its overall length). The Velika Morava River also passes through Serbia for 493 kilometers and is one of the biggest tributaries of the Danube in Serbia. The Sava and Tisa Rivers also join the Danube in Serbia. One notable exception is that the Pčinja River flows into the Aegean Sea.

Map 1.3 Climate Characteristics of Serbia, 1981–2010

a. Mean annual air temperature, degrees Celsius — b. Average annual total precipitation, millimeters



Source: Smailagić et al. 2013. ©Republic Hydrometeorological Service of Serbia (RHMZ). Reproduced, with permission, of RHMZ; further permission required for reuse.

1.3 Background of Natural Disasters in Serbia

Serbia has rugged terrain, rainy areas, and a huge river network, which makes the country vulnerable to natural hazards—particularly landslides, floods, and flash floods that destroy transportation, communication networks, and other infrastructure facilities. Other natural hazards, such as droughts and forest fires, destroy agriculture land, forests, and other properties (table 1.1, map 1.4).

Table 1.1 Types of Natural Hazards and Their Spatial Distribution in Serbia

Natural hazards	Total area (square kilometers)	Share of total area (percent)
Earthquakes VIII–IX MCS	16, 388.59	18.55
Earthquakes IX–X MCS	1,109.71	1.26
Excessive erosion	3,320.80	3.76
Landslides	13, 327.60	15.08
Drought	18, 306.93	20.72
Floods	15, 198.07	17.20
Forest fire	3,154.95	3.57
Total	50, 659.87	57.33

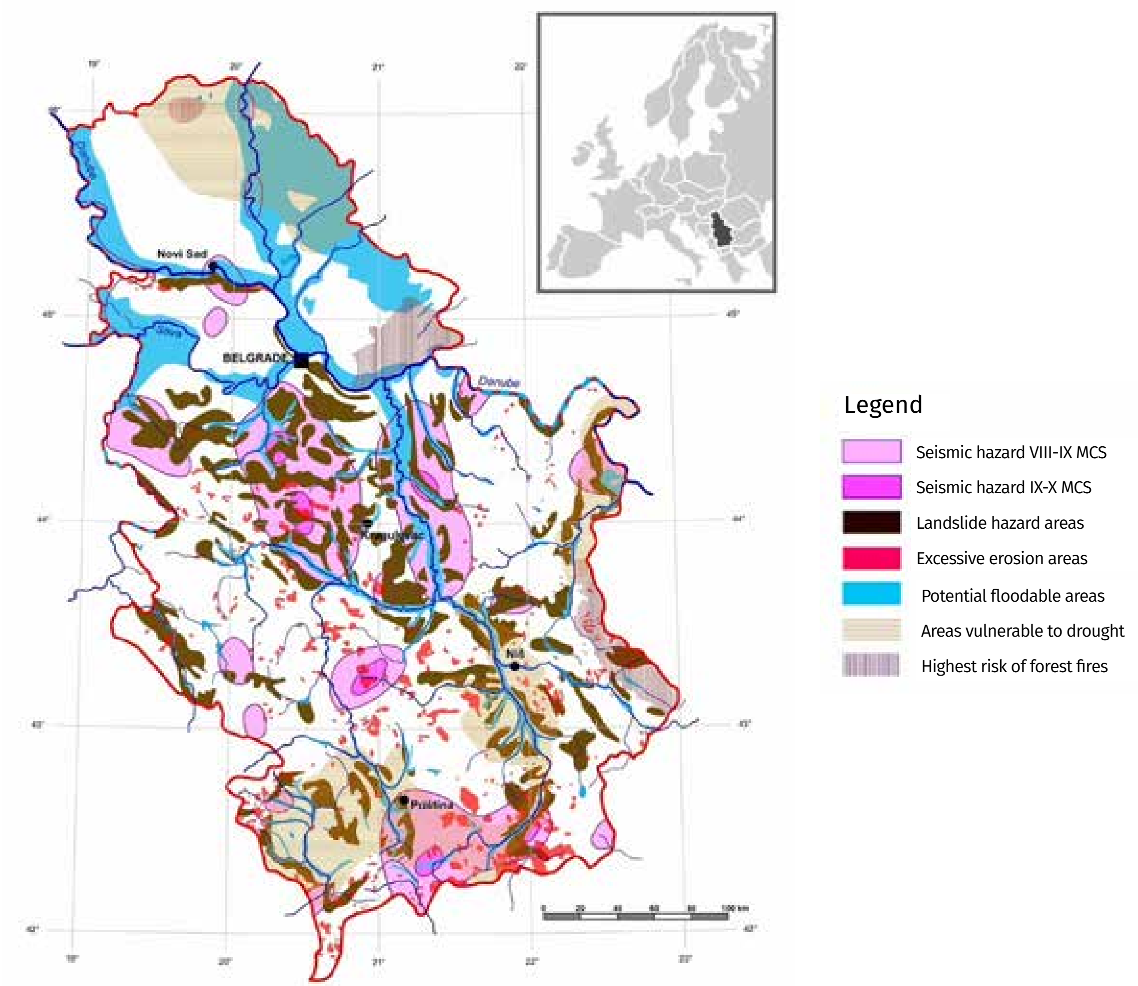
Source: Dragićević et al. 2011.
Note: MCS refers to the Mercalli–Cancani–Sieberg seismic intensity scale, ranging here from VIII (“severe”) to X (“extreme”).

Almost 17 percent of Serbian territory is prone to riverine floods (Dragićević et al. 2011). The most vulnerable regions are the areas around the largest river systems, such as the Sava, Drina, Tisza, Kolubara, and Zapadna (West) and Južna (South) Morava. The smaller river catchments are prone to flash floods, and there are no systematically collected data about their hazardous effects (Ristić et al. 2012). Though the river systems are vulnerable to hydrological disasters, they are also located in highly populated areas that are not only tourism centers but also contain many infrastructure facilities such as pipelines, roads, railways, agriculture holdings, private sector activities, and industrial facilities, including the most important energy production facilities (open pit coal mines).

The main geological hazards in Serbia are landslides. Depending on the type of movement, the common ones are slides, flows, and falls (Cruden and Varnes 1996), and the types of material involved are rocks, debris, and earth-soil. Historically occurring landslides or areas identified as prone to landslides cover more than 15 percent of the Serbian territory (table 1.1, map 1.4).

Earthquakes with a magnitude of more than 5.0 in Serbian territory are relatively rare, with only seven such events in the past 120 years. Landslides and rockfalls induced by earthquakes destroyed a road at Kraljevo-Raška after the Kraljevo earthquake (magnitude 5.4) in November 2010.

Map 1.4 Spatial Distribution of Natural Hazards in Serbia



Source: Dragićević et al. 2011.
Note: MCS refers to the Mercalli–Cancani–Sieberg seismic intensity scale, ranging here from VIII ("severe") to X ("extreme").

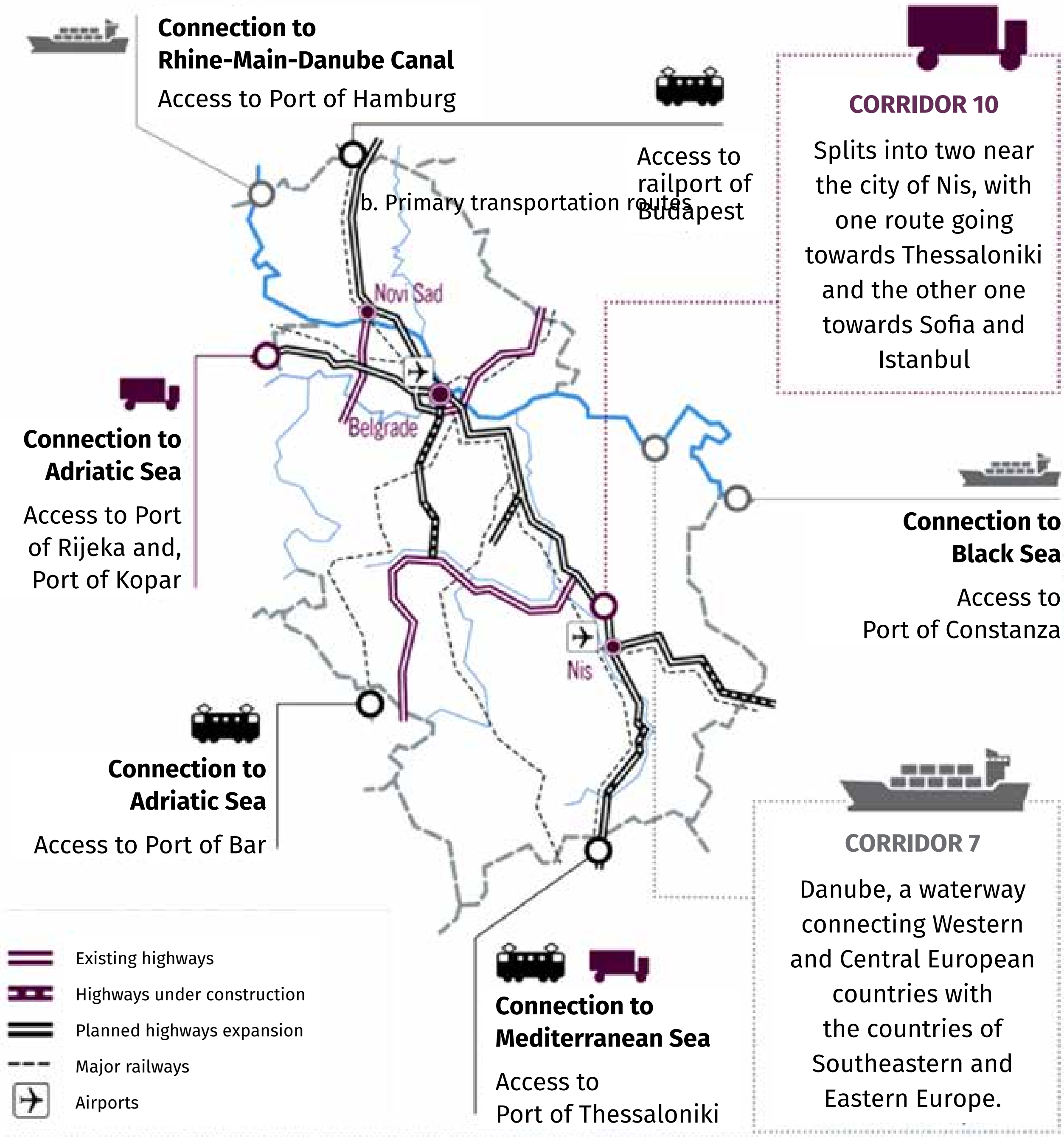
1.4 The Serbian Road Network

Serbia is a landlocked country and is surrounded by eight neighbors (map 1.5, panel a). The primary road network is concurrent with the trans-European Corridor 10 connecting central and eastern Europe (comprising routes E-70, E-75, and E-80) (Map 1.5, panel b). Those routes have long connected Serbia with the main Adriatic and Mediterranean ports (Rijeka, Croatia; Kopar, Slovenia; and Thessaloniki, Greece). It is evident that road network construction and management are priorities for the country.

Map 1.5 Serbia's Location amid Neighboring Countries and Main Transportation Routes

a. Serbia and neighboring countries

Source: Vidiani.com "Maps of the World," http://www.vidiani.com



Serbia's primary road network of 16,162 kilometers (table 1.2 and map 1.6, panel a) is valued at about US$13 billion (World Bank 2012). Its connectivity and conditions are indispensable for local, regional, and European transport, communication, and supply systems for Serbia's economic growth because of its central geographical position in the Balkan Peninsula. Despite the importance of the road network, the Serbian roads remain unfavorably placed in *The Global Competitiveness Report 2015–2016*, ranking 114th out of 140 countries in road quality (Schwab 2015).

Note: The country labeled at bottom right (left map) as the "Former Yugoslav Rep. of Macedonia" was renamed the Republic of North Macedonia, effective February 2019.

Table 1.2 Length of State Road in Serbia, by Category, 2016

Road category (I or II) and subcategory (A or B)	Length (kilometers)
I A state roads (motorways)	741.46
I B state roads	4,486.10
II A state roads	7,765.00
II B state roads	3,170.15
Total category I	5,227.56
Total category II	10,935.15
Total categories I + II	16,162.71

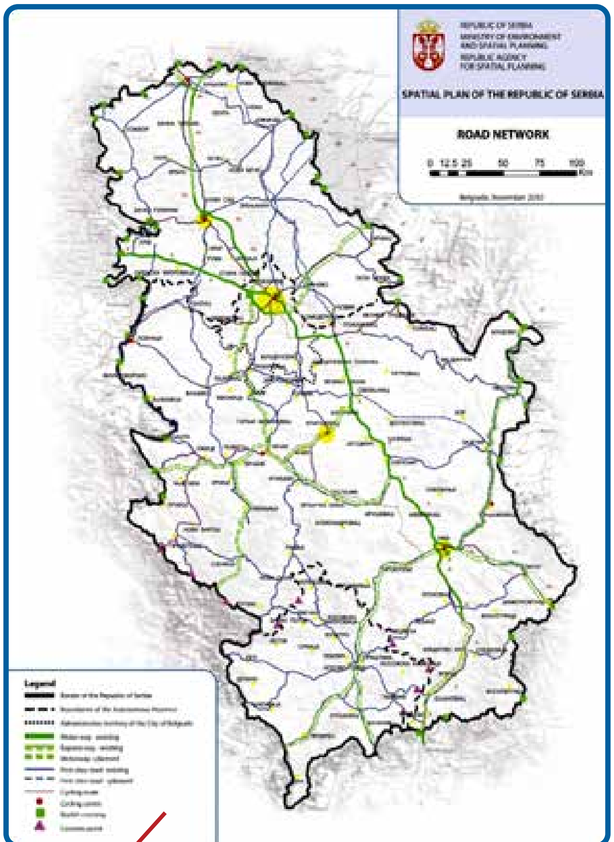
Source: Public Enterprise Roads of Serbia (PERS) 2016 (in Serbian).

There are frameworks delineating the legal processes for the construction and maintenance of roads in Serbia, including the trans-European motorways (such as Corridor 10). The legal frameworks—such as the Law on Ministries (put in place in 2014 and amended in 2015, 2016, and 2017) and the Law on Public Roads (2013)—guide the relevant ministries, agencies, sectors, and departments in planning, constructing, and maintaining the road and communication networks.

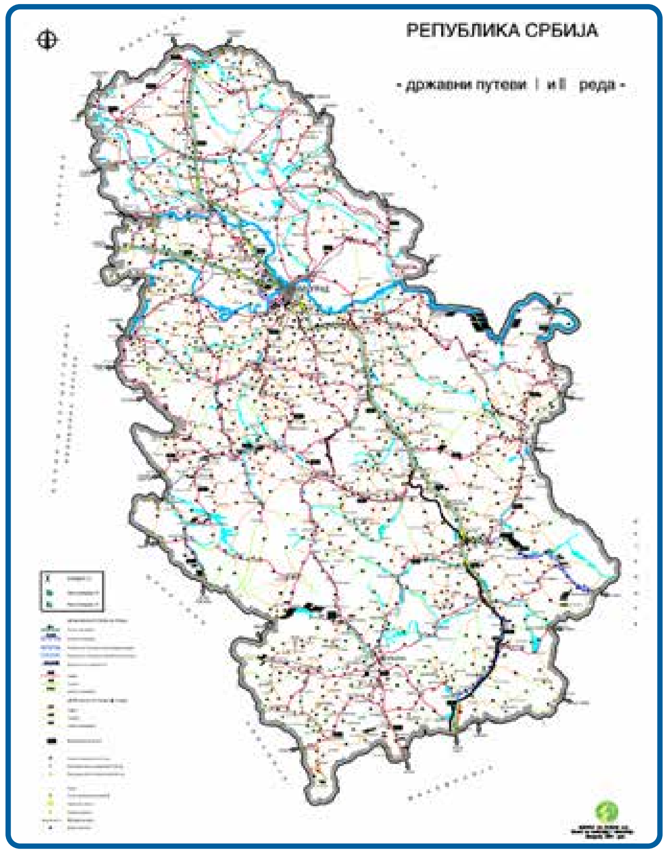
The "Spatial Plan of the Republic of Serbia: 2010–2014–2020," which the government adopted in 2010, is the main national planning document for the entire territory of Serbia (Republic of Serbia 2010). It defines the main strategic priorities for territorial development and contributes to horizontal cooperation at the national level as well as vertical coordination between different levels of planning. Such a plan for the road networks from a public domain clearly delineates the existing and planned motorways and highways in a systematic manner (map 1.6, panel b).

Map 1.6 Current Road Network and Spatial Road Plan for Serbia

a. Current state roads, categories I and II



b. Spatial plan for road networks



Legend

- Border of the Republic of Servia
- Boundries of the Antonomous Province
- Administrative territory of the City of Belgrade
- Motor way - existing
- Express way - existing
- Motor way - planned
- First class road - existing
- First class road - planned
- Cycling route
- Cycling center
- Border crossing
- Customs points

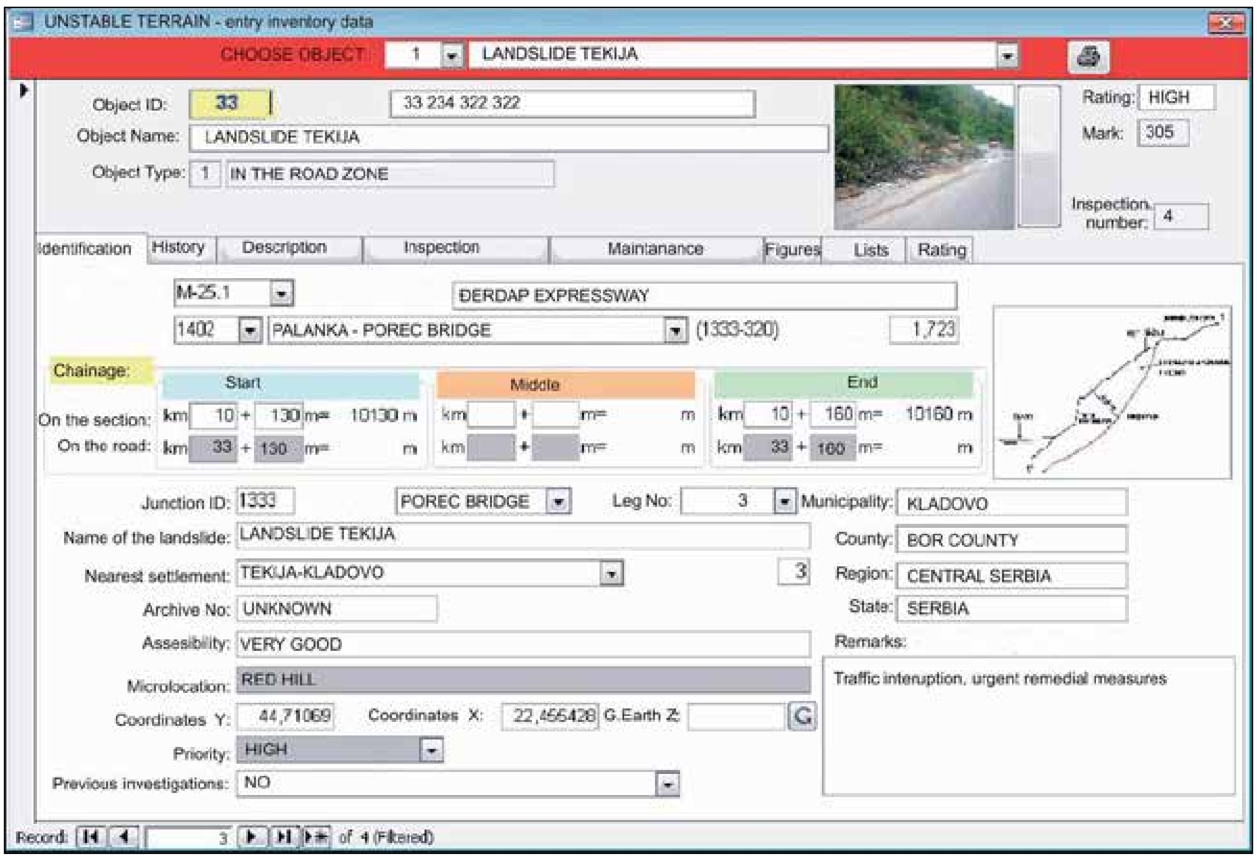
Source: Public Enterprise Roads of Serbia (PERS) 2016 (in Serbian).

1.5 Geohazards on Roads in Serbia

Geological hazards are events caused by geological conditions or processes that represent serious threats to human life, property, or the natural environment (UNISDR 2004). As stated earlier, the most disastrous road geohazards (geological) in Serbia are landslides, followed by earthquakes. Serbian territory is also prone to hydrological and climate-related hazards such as floods (inundation) and flash floods (torrential floods). Landslides, flash floods, and floods are the primary natural hazards affecting roads in Serbia, according to the adopted definition and classification. They have varying impacts on road construction, depending on the type, mechanism, magnitude, and frequency of events—that is, landslides primarily cut off road slopes, while flash floods destroy culverts, bridges, and road foundations.

As stated in section 1.3, the main types of landslides in Serbia are earth slides, debris slides, and rockslides; rockfalls; and earth flows and debris flows, which mainly cut off roads and often destroy their foundations. The Public Enterprise Roads of Serbia (PERS) landslide database has been in use since the late 1990s, and populating it is an ongoing task. The database has completed entries for 80 landslides, while another 220 exist in spreadsheets and 300 more in the original inventory analog form (PERS, December 2016). The database concentrates on occurrence data for specific dates and uploads (figure 1.1).

Figure 1.1 Screen for Landslide Database Entry



Source: Milenković et al. 2014. ©Highway Institute, Belgrade (http://www.highway.rs/en/). Reproduced, with permission, from the Highway Institute; further permission required for reuse.

The qualitative and quantitative assessments of relative hazards and risks are highlighted in a data sheet. The scoring and rating systems are extracted from the Landslide Hazard Assessment Manual (Milenković et al. 2014), which explains the hazard categories, types, and descriptions, and ranks them according to the intensity or the magnitude (table 1.3). The suggestions of the World Road Association (PIARC) are incorporated into the database as well. The database validates landslide parameters and establishes the objective level of danger in relation to defined conditions of the road network. Some questions remain regarding the objectivity of this procedure for proper quantification of some entry data and assessments of the landslide hazards (Milenković et al. 2014).

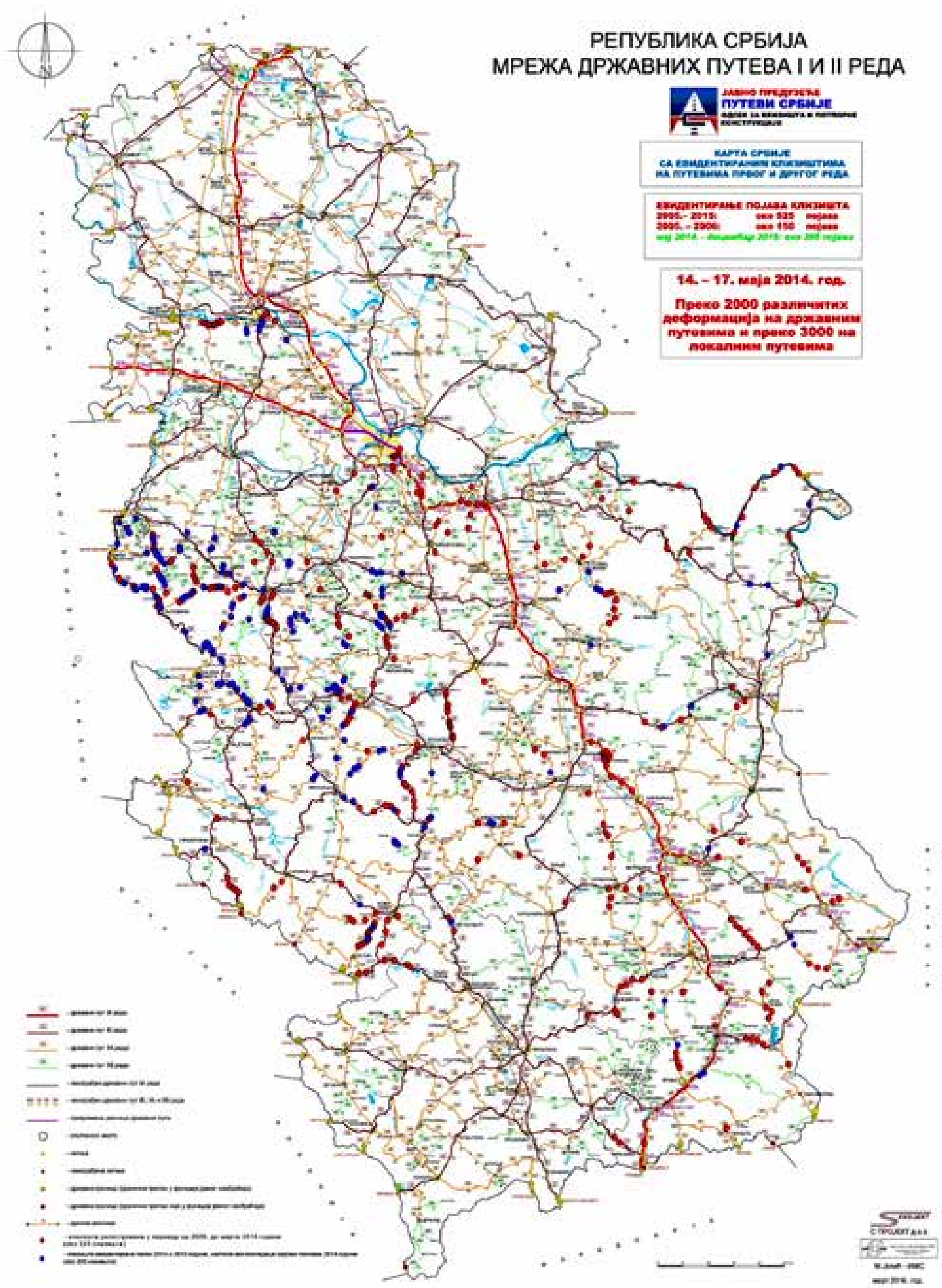
Table 1.3 Landslide Hazard Assessment for Roads in Serbia

Hazard category	Hazard type	Points		Hazard category description
		Without measures	With measures	
I	No Hazard	0—25	0—50	Landslides not foreseen under any expected circumstances.
II	Low Hazard	26—50	51—100	Landslides may occur under extremely unfavorable conditions, which have a low probability of appearance (millennium precipitations, high-magnitude earthquakes in the area of low seismic features and so on), or under conditions with a high probability of occurrence, yet with small masses set in motion.
III	Medium Hazard	51—75	101—150	Landslides may occur under the circumstance that one might expect in the period under study, with a slow motion of large volumes of rock masses.
IV	High Hazard	76—100	151—200	Landslides will presumably appear in the near future under circumstances that occur regularly under existing patterns. Landslides are expected to take up large or very large volumes of rock masses. This hazard level encompasses the cases when, for the motion of masses, several unfavorable factors coincide so that the probability of occurrence is lower, yet potential volumes and areas taken up by slides are very large and are moving at very high speed.

Source: Milenković et al. 2014.

Map 1.7 shows the importance of the database, using the data to highlight the distribution of landslides on the road network, which helps the road authorities deal with the events on different road sections. Further improvement of the data within the database from systematic collection procedures is desired. The red dots in map 1.7 show the landslide locations from 2005 to 2014, and the blue dots delineate the landslides after 2014. Efforts have been made to collect as much geohazard data as possible, realizing their importance.

Map 1.7 Landslides on Roads in Serbia since 2005



Source: PERS 2016 (in Serbian). ©Public Enterprise Roads of Serbia (PERS). Reproduced, with permission, from PERS; further permission required for reuse.
Note: Red dots indicate landslides that occurred 2005–14. Blue dots indicate landslides that occurred after 2014.

1.6 Overview of May 2014 Extreme Rainfall Event

In May 2014, unprecedented rainfall resulted in massive flooding, flash floods, and landslides, leading to the declaration of a nationwide state of emergency. A postdisaster needs assessment found that floods, flash floods, and landslides caused a total of €1,525.3 million in losses and damages (table 1.4)—amounting to 5 percent of GDP—in the 24 affected municipalities (UN Serbia, EU, and World Bank 2014).

Table 1.4 Summary of Estimated Damages and Losses from the May 2014 Rainfall Disaster in Serbia

Sector and subsector	Disaster effects, €, millions		
	Damage	Losses	Total[a]
Social	234.6	7.1	241.7
Housing	227.3	3.7	231.0
Education	3.4	0.1	3.5
Health	3.0	2.7	5.7
Culture	1.0	0.6	1.6
Productive	516.1	547.6	1,063.7
Agriculture	107.9	120.1	228.0
Manufacturing	56.1	64.9	121.0
Trade	169.6	55.2	224.8
Tourism	0.6	1.6	2.2
Mining and energy	181.9	305.8	487.7
Infrastructure	117.3	74.8	192.1
Transport	*96.0*	*70.4*	*166.5*
Communication	8.9	1.1	10.0
Water and sanitation	12.4	3.2	15.6
Cross-cutting	17.2	10.6	27.9
Environment	10.6	10.1	20.7
Governance	6.7	0.6	7.3
TOTAL	885.2	640.1	1,525.3

Source: UN Serbia, EU, and World Bank 2014.
a. Because of rounding, some totals do not add up exactly.

The massive landslides in the western and central part of Serbia occurred following the flash floods in local river-stream catchments, while the main river systems (Sava, Drina, and Morava) responded with massive flooding. This event destroyed bridges, embankments, and roads—cutting off and disrupting main and local road systems (photo 1.1). It was reported that more than 2,000 landslides were activated along the category I and II state roads in addition to more than 3,000 landslides along local roads during and after the May 2014 rainfall event (Jotić et al. 2015). The country declared a state of emergency, with the rainfall event estimated as a 100-year-probability disaster that exceeded existing structural countermeasures, especially in the western part of Serbia. As such, it is considered a turning point in Serbia's disaster risk history.

The transport sector incurred damages and losses of €166.5 million (table 1.4). The repair budget for the 2014 floods and landslides consequences on the road network was around €15 million from 2014 to 2016, whereas the annual expense for road disaster risk in an average year is approximately €2 million to €3 million.

Photo 1.1 Road and Bridge Damage in Serbia after 2014 May Rainfall Disaster

Source: www.alo.rs.

Source: B92.net website (www.b92.rs).

After the event, Serbia received funds and technical support from donor countries and international agencies. For example, a project called BEyond Landslides AWAREness (BEWARE)—funded by the people of Japan and coordinated by the United Nations Development Programme (UNDP) Office in Serbia—covered approximately 14,510 square kilometers in 27 municipalities in western, central, and eastern Serbia in 2015–16. The deliverable information of the project was an open-access landslide database of more than 2,000 landslides for the most-affected municipalities.

PART II

ROAD GEOHAZARD RISK MANAGEMENT

2 INSTITUTIONAL CAPACITY AND COORDINATION

2.1 National Disaster Risk Management Program for Serbia

After the 2014 floods caused damage estimated at 5 percent of the Serbian gross domestic product (GDP), the National Disaster Risk Management Program for Serbia was officially launched on March 4, 2015, by Prime Minister Aleksandar Vučić at Palata Srbije (UNDP 2015). The program builds on the momentum and partnership created between the European Union (EU), the United Nations, the World Bank, and the government of Serbia during the response to the devastating May 2014 floods and "intends to implement more proactive resilience strategies to protect Serbia's development paths by reducing the existing risk, avoiding the creation of new risk, and responding more efficiently to disasters" (World Bank 2015).

The program creates a common platform for managing risks associated with various types of disasters by identifying potential hazard risks and reducing them in the long term. It emphasizes a dual view of risk management on transport, not only as an exposed infrastructure but also as a key part of preparedness, response, rescue, and reconstruction. The program also provides an open platform to enable various sectoral actors and donors to coordinate and avoid replication of similar activities (World Bank 2015).

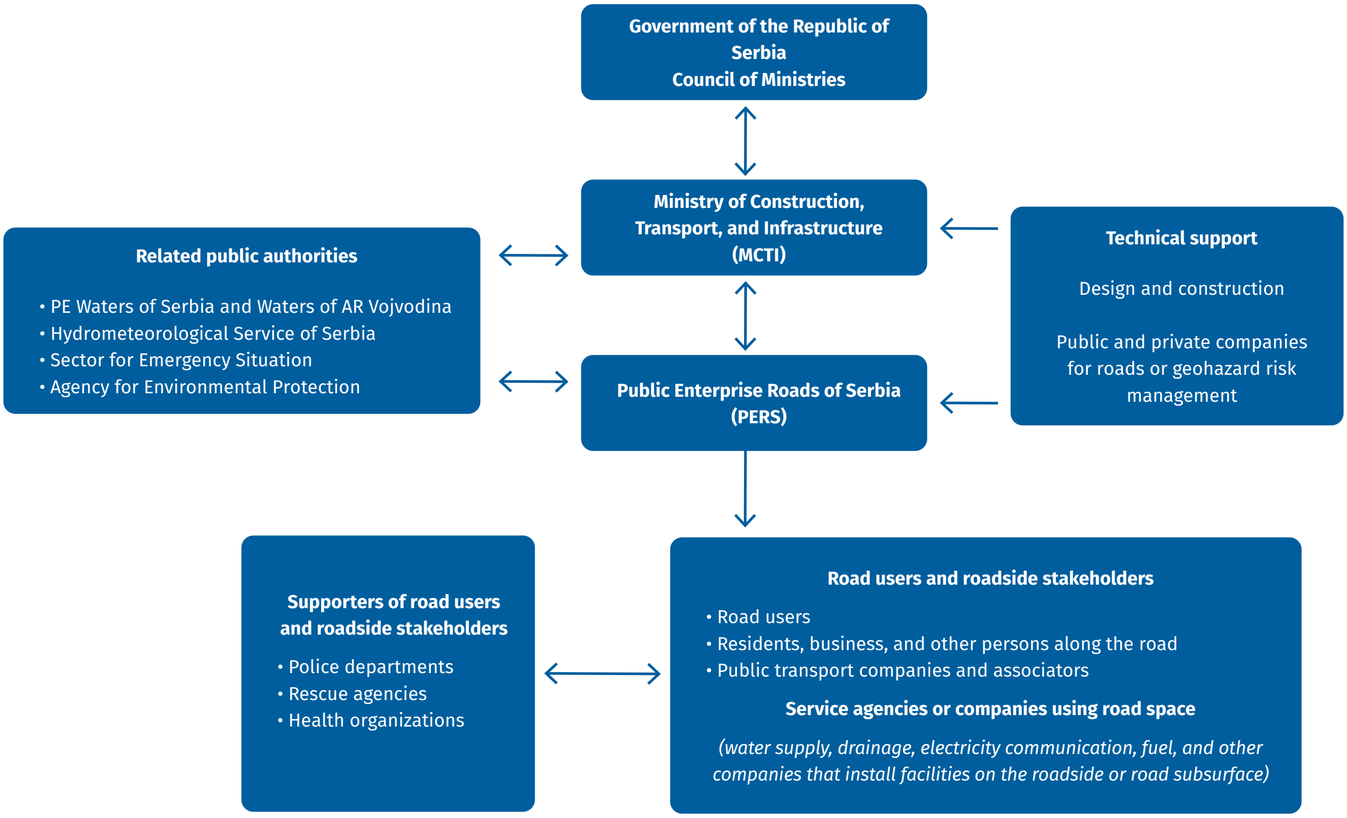
2.2 Road Geohazard Risk Management Framework in Serbia

Most of the mechanisms for the implementation of road management have been formulated based on the legal frameworks described later in this chapter. As for Serbia's overall road management institutional framework, road geohazard management activities revolve around the Ministry of Construction, Transport and Infrastructure (MCTI), the umbrella institution for granting construction permissions, budget allocation, and planning. Public Enterprise Roads of Serbia (PERS) is a state-owned construction company that maintains and takes care of road geohazard management of the category I and II public roads (figure 2.1 and table 2.1).

In Serbia, public enterprises like PERS are under a ministry (in this case, the MCTI) and provide services to all the ministries as required. The local roads, other than state road categories I and II, are managed and maintained by local authorities. Figure 2.1 also shows the detailed functions of each authority, such as the MCTI, that plans, allocates, budgets, and administers the postdisaster activities. PERS holistically takes care of the state road categories I and II in the field, and local authorities take care of local roads. The structure also includes road authorities, institutions, and stakeholders, as well as coordination mechanisms for road management, such as the related public authorities and sources of technical support: design and construction companies, fire and police departments, and roadside stakeholders.

Road disaster management in Serbia is a coordinated task involving different sectors—such as water, hydrometeorology, environment, and emergency operations—to get information and consultation during emergencies. The police department, rescue agency, and health department provide the first responders to the emergency site to save lives and property. The road users and local communities inform PERS in case of an emergency, thus participating and helping at the time of the emergency, and the technical institutions provide the knowledge for disaster risk reduction and management.

Figure 2.1 Road Management Institutional Framework in Serbia



Note: AR = autonomous region. PE = public enterprise.

Table 2.1 Institutional Roles and Responsibilities for Road Management

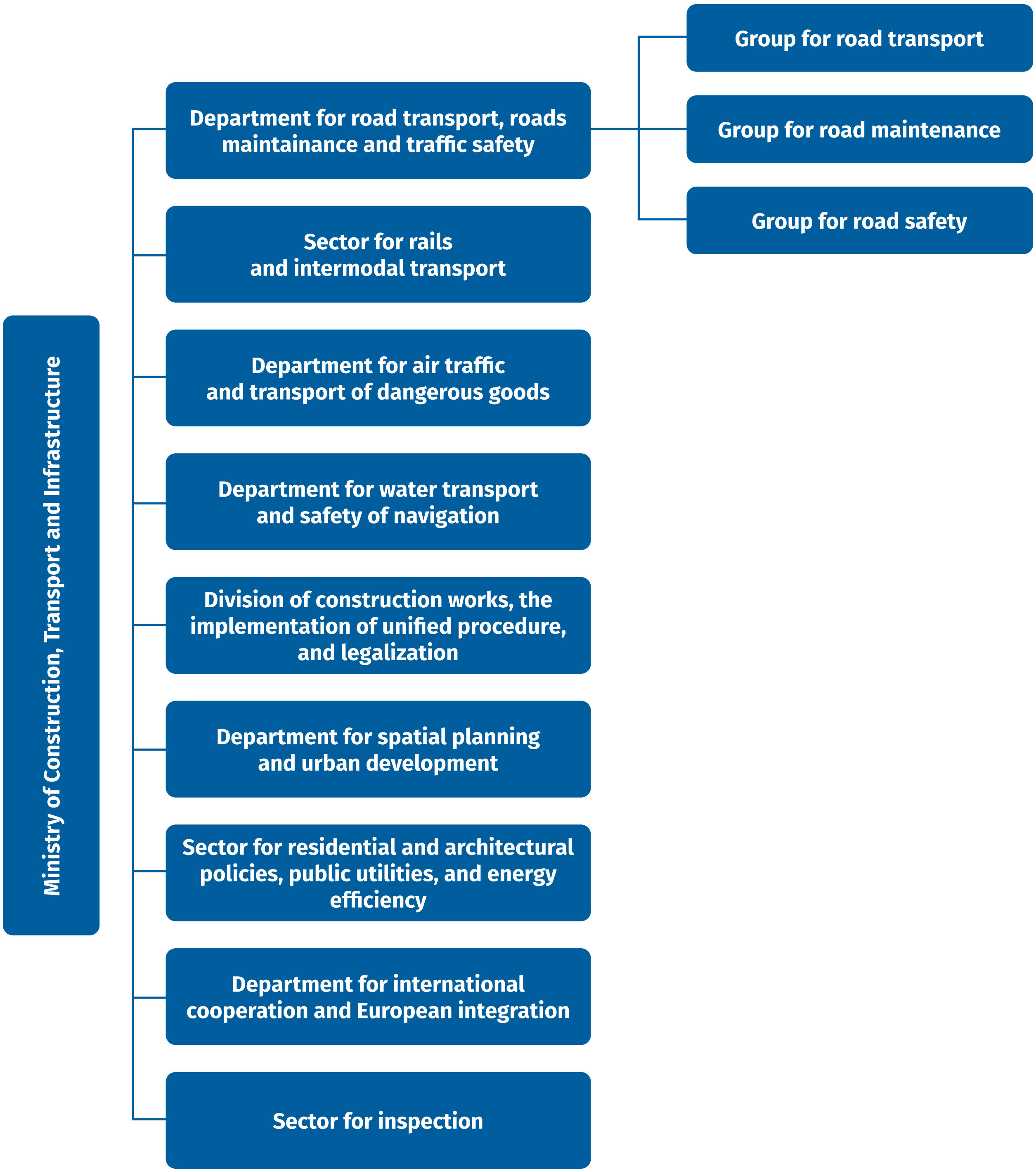
Ministry for Construction, Transport and Infrastructure (MCTI)	Public Enterprise Roads of Serbia (PERS)	Road management local authorities
National road management and new road planning Budget planning and allocation Overall coordination with other governmental bodies Administration of postdisaster activities	Jurisdiction over state roads, categories I and II Road management and budget planning for roads in coordination with MCTI Road information management for state roads Design, cost estimation, and construction management for new roads Operation and maintenance management for existing roads Postdisaster management Coordination with other public enterprises Coordination with technical support companies (design and construction of engineering structure or countermeasure)	Jurisdiction over urban roads—streets and local state roads aside from categories I and II

2.3 Institutional Framework for Road Geohazard Risk Management

2.3.1 Ministry of Construction, Transport and Infrastructure

As mentioned in section 2.2, the MCTI is the overall institution in charge of the roads in the country (figure 2.2).

Figure 2.2 Organization of the Ministry of Construction, Transport and Infrastructure, Republic of Serbia



Source: Ministry of Construction, Transport and Infrastructure website: https://www.mgsi.gov.rs/en.

Under the Law of Ministries and the MCTI's internal departmental organization, the Department of Road Transport, Roads Maintenance and Traffic Safety's three groups—the Group for Road Transport, Group for Road Maintenance, and Group for Road Safety—carry out activities related to the following:

- Preparation and implementation of proposed measures to improve the hazardous situation and intergovernmental relations in domestic and international road transport, roads, and traffic safety
- Preparation of strategies, plans, laws, and other legal documents, as well as establishment of cooperation with scientific research institutions within the scope of sectors
- Preparation of an expert basis for drafting laws and other regulations in the labor sector
- Preparation of the proposal as a basis for negotiations to conclude multilateral and bilateral agreements in the field of road transport, roads, and traffic safety
- Performance of administrative procedures
- Preparation of draft answers to parliamentary questions
- Application of laws and regulations of the respective areas
- Maintenance of registers and records from the scope of the sector
- Monitoring of the execution of the annual work program on the maintenance, protection, and development of roads, road equipment, and other facilities of road infrastructure and proposing measures for the implementation of plans
- Coordination of the work of operators in road safety
- Promotion of road safety measures
- Technical regulation of traffic on public roads
- Participation in the preparation of plans for financing road safety measures
- Performance of administrative and other measures
- Filing of requests for initiating misdemeanor and criminal proceedings for commercial offenses
- Preparation of opinions on acts prepared by other agencies and organizations in the relevant areas
- Other activities within the purview of the department.

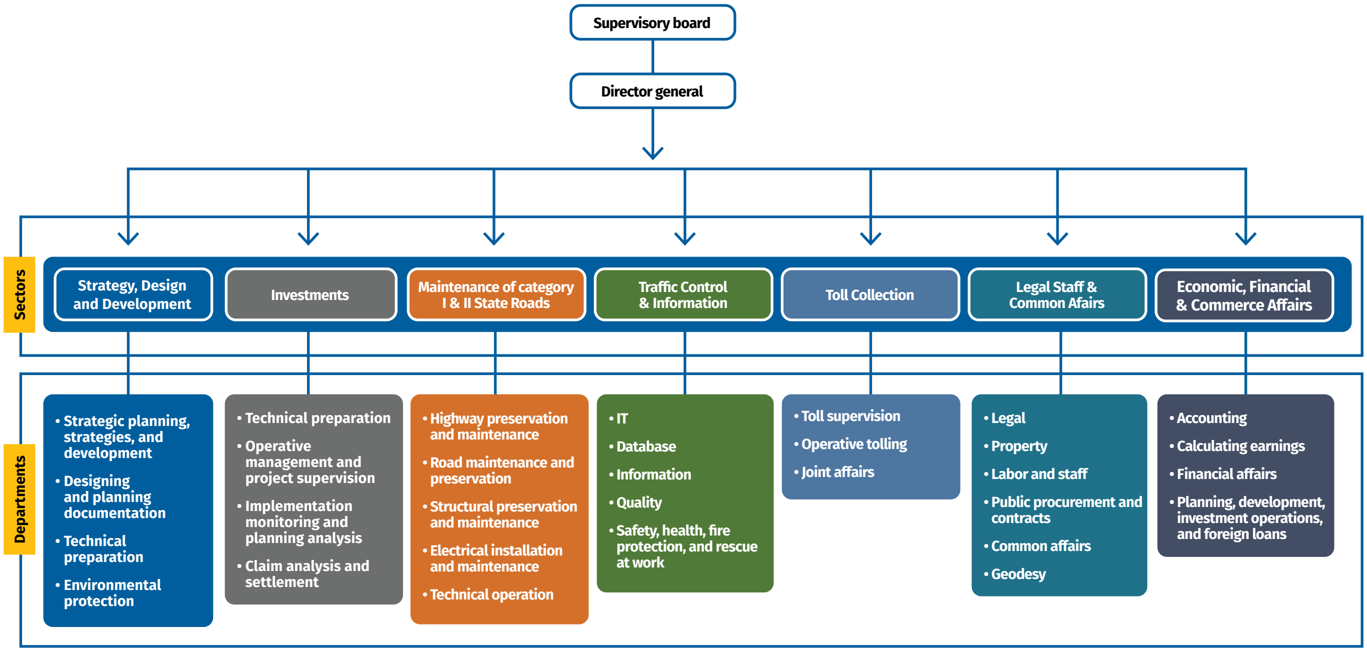
2.3.2 Public Enterprise Roads of Serbia

Under the MCTI, the Public Enterprise Roads of Serbia (PERS) was established pursuant to the Law on Public Roads. PERS provides all the required public road services to the related ministries and government agencies and the public.

The main objectives of PERS are to (a) prevent road deterioration; (b) preserve the road network's value and improvement; (c) invest in construction, rehabilitation, and reconstruction; and (d) prepare studies and designs. Each task is carried out by the specialized department under each sector (figure 2.3). PERS also announces tenders for engineering investigations and structural measures designed to outsource the road construction projects.

Additionally, PERS takes care of traffic safety through the elimination of dangerous locations and protects the environment through the elimination or mitigation of the harmful effects of roads and traffic on the environment. PERS engages design, construction, and other services from external companies as necessary to deliver its outcomes.

Figure 2.3 Organization of Public Enterprise Roads of Serbia



Note: IT = information technology.

PERS has seven sectors (figure 2.3):

- Strategy, Design and Development
- Investments
- Maintenance of Category I and II State Roads
- Traffic Control and Information
- Toll Collection
- Legal, Staff and Common Affairs
- Economic, Financial and Commerce Affairs.

Each of these sectors has several departments for specific purposes, which are overseen by the director general. PERS performs professional activities relating to permanent, continuous, and good-quality maintenance and preservation; construction, reconstruction, organization, and control of toll collection; and development and management of state road categories I and II. It has five regional road management offices to cover the country efficiently and effectively.

Financing of construction and reconstruction, maintenance, and rehabilitation and preservation of public roads is provided from a combination of the fees for using state roads (tolls), financial loans, the budget of the Republic of Serbia, and other sources, such as grants and loans.

2.3.3 Corridors of Serbia

The government of Serbia established a state-owned company called Corridors of Serbia (CoS) in 2009 to manage and oversee the construction activities associated with Corridor X in the southeast of the country connecting Bulgaria and Greece as a part of the strategic European route. In 2017, CoS took a leading role in the construction of Corridor X and Highway E-763.

2.3.4 Sector for Emergency Situations

The Sector for Emergency Situations (SES) is a disaster coordinating body under the Ministry of Interior. As the name indicates, the SES is operative only during a state of emergency, and it coordinates, operates, and responds to all types of natural and man-made disaster-related events. SES has an extensive network consisting of 27 units and 3,800 people around Serbia, which includes fire brigades, police, ambulance (health), and central and local authorities.

PERS sends a representative to SES, and the representative becomes a member of the headquarters team during the emergency situation. For instance, in the May 2014 rainfall event, the SES coordinated the emergency situation together with other related agencies such as fire departments, police departments, and PERS. Because the SES's role is limited to emergency situations, it cannot play a strong role in road geohazard risk management. Under Serbian laws, it is not authorized to propose any kind of proactive or reactive, or nonstructural or structural, countermeasures. Operational road geohazard risk management activities are provided by public or private companies (design or construction firms) that are licensed (by law and the Serbian Chamber of Engineers) to propose and design structural and nonstructural measures, for existing and new roads, as well as for all stages of road geohazard risk management.

2.4 Laws, Regulations, and Technical Standards

There are numerous national and institutional binding documents—such as laws and bylaws on planning and construction, mining and geological exploration, emergency situations, and public roads—as well as policies covering all stages of road planning, design, construction, and the management and use of state roads. All of these documents define the criteria for institutional functioning so that there is no misunderstanding between ministries, agencies, and users. These documents also define the criteria of workflow. The main legislative documents that cover various aspects of road management activities are listed below.

Law of Planning and Construction. This is the main legislative document that defines and provides for all stages of planning and construction in the Republic of Serbia, including roads. In the frame of the law, acts, and bylaws documents, the planning (both spatial and urban) and construction stages for all types of construction are defined. The MCTI is responsible for the implementation of the law.

Law of Public Roads. This is the main legislative document that, with its bylaw divisions, provides for all issues related to road construction (certifications), use of public roads, and maintenance. The law contains no specific act that defines geohazard management for the state public roads. The MCTI is responsible for the implementation of the law.

Bylaws–Division of Urgent Maintenance of Public Roads. These bylaws define the responsibilities, urgent measures, and procedures during an emergency or natural disaster situations (Disaster Countermeasures Act). The MCTI is responsible for the implementation of the bylaws.

Law of Mining and Geological Explorations. This covers activities related to the mining industry and geological investigation of natural resources, engineering geological and geotechnical investigations, and hydrogeological investigations, as well as the position of the Geological Survey of Serbia. In the frame of the law, terms such as geological hazards and risk are defined. The National Landslide Database should be prepared and maintained by the Geological Survey of Serbia. The Ministry for Mining and Energy is responsible for implementation of the law.

Law on Emergency Situations. This law covers the local, regional, and national levels of responsibilities of each administrative body. According to the law, natural disasters are categorized into geological (such as earthquakes and landslides) and hydrological (such as floods and flash floods) as well as other climatological (such as storms, snow, and high or low temperatures) and technological disasters. Under the law, the role of the SES is defined as a key national coordinator and operator responding to the urgency of disaster events. The Ministry of Interior is responsible for the implementation of law.

"Road geohazard risk management" is new terminology for which there is not yet a specific law or clause in Serbia. Nevertheless, as mentioned above, the Division of Urgent Maintenance of Public Roads defines the responsibilities, urgent measures, and procedures during emergency or natural disaster situations according to the Disaster Countermeasures Act, and all the road-related sectors, departments, and private enterprises must follow the Division's definition. In addition, the Law on Emergency Situations—the binding document for disaster risk management (DRM)—covers all types of natural disasters, including the framework for institutional setup, emergency coordination, and its application during the state of emergency. These are positive steps toward natural disaster risk management and reduction, and in the future the process may cover road geohazard risk management, hence streamlining the process into country development planning.

2.5 National and Local Government Plans and Strategies

2.5.1 Preparation of DRM Plan for Each Administrative Body

Serbia's Ministry of Interior has drafted the Law for Disaster Risk Reduction and Emergency Situation Management, which is in the process of update on enactment. The ministry's SES is making efforts to reduce the gap by developing a robust methodology to evaluate disaster risk and conduct vulnerability assessments for all administrative levels in Serbia. Under the Law on Emergency Situations, local authorities and municipalities are obliged to prepare an "Assessment of Disaster Vulnerability Act of the Municipality," which covers vulnerability and risk assessment for all types of natural and man-made disasters corresponding to their situations. Several municipalities have already prepared those documents, although the methodology for the preparation of vulnerability and risk assessment is ongoing. The SES is responsible for the National Disaster Vulnerability Assessment, another ongoing activity that was finalized in December 2017.

2.5.2 Basic DRM Plan for Roads in Serbia

Basic disaster management plans for roads in Serbia (both new and existing roads) are prepared under the umbrella of the MCTI (as further discussed in chapter 4). Basic DRM plans for new roads are part of predesign and design activities, while the DRM plans for existing roads are part of road maintenance activities—that is, reconstruction and rehabilitation (section 6).

Under PERS, the Sector for Maintenance of Category I and II State Roads prepares a short-term road disaster management operations plan or program based on regular, periodic, or on-demand road inspections. The road geohazard risk management planning starts with a risk estimation by PERS maintenance staff based on visual inspections and geohazard risk assessment data from the field (sections 4.2 and 6.2). Countermeasure planning and strategies for road disaster risk reduction oriented to structural and nonstructural countermeasures covering all maintenance activities are prepared annually within Serbia's regular road maintenance budget. PERS focuses mainly on emergency response and repair activities after a geohazard event.

2.6 Mechanisms for Implementation of DRM

PERS oversees and manages all state roads (categories I and II—covering the national motorways and national and regional highways). It issues orders to its regional road management offices (in five regions with four departments each), which are responsible for road risk inspections (including geohazards) to monitor roads, collect data, and analyze the data to comprehend the requirements for proactive or reactive nonstructural and structural countermeasures. Based on the field inspection results and collected data and information, PERS prepares the implementation plan and period for the geohazard risk reduction program and seeks budgetary allocations from the MCTI. The local roads (mainly urban roads—that is, streets and roads outside of state categories I and II) are maintained by local authorities such as cities and municipalities.

2.6.1 Technical Standards, Guidelines, and Manuals

PERS follows EU standards and procedures in coordination with the MCTI. Quality management systems follow two important international standards: ISO 9001:2015 (“Quality Management Systems—Requirements”) and OHSAS 18001:2008 (“Occupational Health and Safety Management System”).

During the late 1990s, the Highway Institute (a public road design company), in collaboration with the University of Belgrade’s Faculty for Civil Engineering and Faculty of Mining and Geology, prepared two technical guideline manuals: “Technical Guidelines for Road Design” and “Technical Guidelines for Road Geotechnical Investigation.”

Both manuals are in use today. There are no separate technical standards, guidelines, and operational manuals for road geohazard management in Serbia because the country’s geotechnical investigation and road design standards already incorporate geohazard risk issues. Most of the activities are based on good engineering practices and lessons learned on the subject during university education (the University of Belgrade’s Faculty of Civil Engineering, Faculty of Transportation, and Faculty of Mining and Geology). Continuing education for engineers is obligatory and is provided by the Serbian Chamber of Engineers.

2.6.2 Institutional and Technical Coordination Mechanisms

PERS gets guidance and a budget from the MCTI and receives technical consultancy and assistance from geoengineering academia, design and construction public or private companies, the Republic Hydrometeorological Service of Serbia (RHMZ), the state Agency of Environmental Protection, and others. For instance, the abovementioned Highway Institute manuals are in use, and the data gathered by the RHMZ are available online or on demand when needed. In addition, the University of Belgrade’s Faculty of Civil Engineering, Faculty of Mining and Geology, and Faculty of Transportation as well as other universities provide consulting and advisory services as needed on road geohazard management.

2.6.3 Road Users and Other Stakeholders

The direct participation of road users in Serbia is important for collecting information about any abnormality detected at a road location, such as rockfalls, landslides, flash floods, and road cracks or deformation, among others. Road users, local residents, and the private sector can inform road management authorities such as PERS through a toll-free emergency information phone number, 0800-111-004. The information from stakeholders helps expedite road maintenance and emergency countermeasures, and the information is beneficial for future use and is free as well.

2.6.4 Funding Mechanisms

Public roads are state property and are therefore constructed, managed, and maintained with the budget from government revenue. The funds for these tasks are pulled from toll fees, financial loans, and the budget of the Republic of Serbia. During extremely severe disasters, such as floods and flash floods in 2014, financial support from international donors is organized and managed by the national government’s Public Investment Management Office.


1620

3 SYSTEMS PLANNING

3.1 Geohazard Risk Evaluation for New Roads

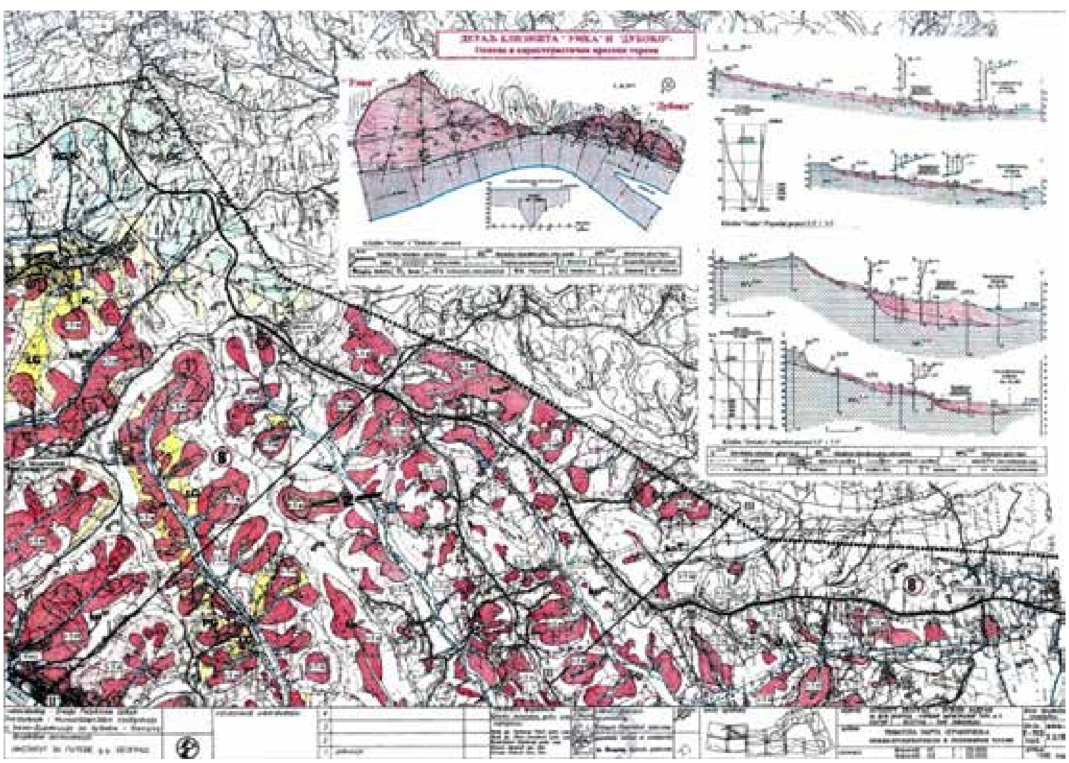
3.1.1 Detailed Hazard Mapping of Planned New-Road Landscape Ecosystem Areas

Engineering geological investigations and mappings are mandatory for new-road planning, design, and construction. Depending on the stage of planning and design and the road category, engineering geological maps are prepared in scales from 1:25,000 to 1: 5,000 or larger. Apart from other spatial or ground characteristics, the maps present spatial distribution of geodynamic phenomena such as slope movements, erosion and deposition, the formation of karstic conditions, suffusion, subsidence, volume changes in soil, and data on seismic phenomena, including active faults and current regional tectonic movements.

Engineering geological maps should include interpretative cross-sections and an explanatory text and legend—commonly used when preparing comprehensive engineering geological maps. There are two kinds of these maps in practice in Serbia: (a) maps of engineering geological conditions, depicting all the principal components of the engineering geological environment; and (b) maps of engineering geological zoning, which evaluate and classify individual territorial units based on the uniformity of their engineering geological or stability conditions. These two types of maps combine in different scales and provide reliable data for design, as well as for disaster risk management (DRM).

An example of an engineering geological map for a new road in Serbia (map 3.1) delineates the 1998 feasibility study for the construction of Highway E-763, section Belgrade-Obrenovac, in a scale of 1:25,000. Reddish polygons are locations of landslides or marginally stable slopes.

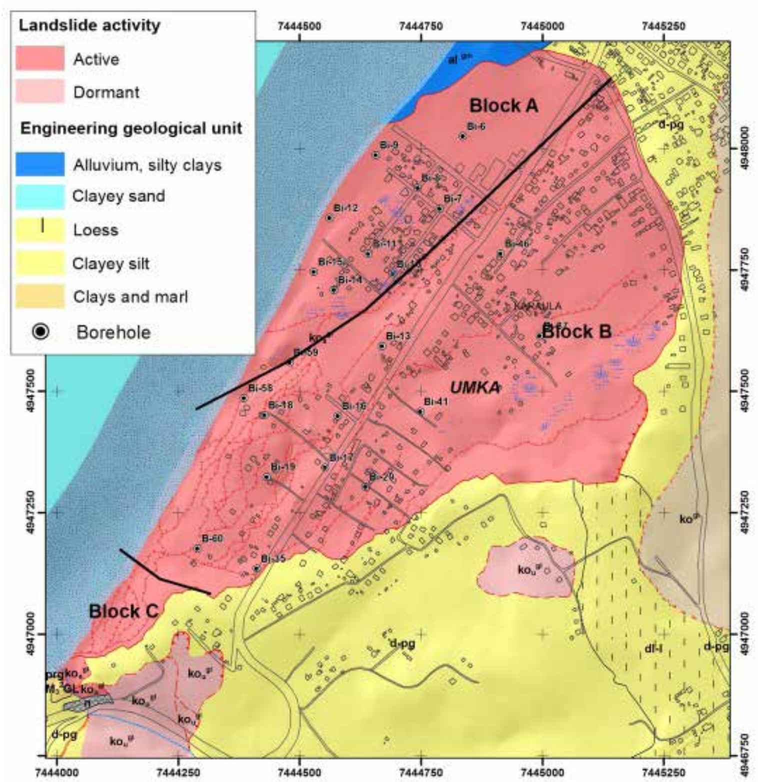
Map 3.1 Scan of Engineering Geological Map for a New Road in Serbia Feasibility Study for the Construction of New Highway E-763, Section Belgrade-Obrenovac



Source: ©Highway Institute, Belgrade. Reproduced, with permission, from Highway Institute; further permission required for reuse.
Note: Map scale is 1:25,000. Reddish polygons indicate the locations of landslides or marginally stable slopes.

A large-scale engineering geological map of the Umka landslide (near Belgrade), prepared for the preliminary design stage for the Highway E-763 new road, shows section Belgrade-Obrenovac, 2006 (map 3.2). Together, the geological maps (map 3.1 and map 3.2) present the geological properties and landslide activities at different scales and different stages of new-road planning and design activities for E-763.

Map 3.2 Large-Scale Engineering Geological Map of Umka Landslide on New Highway E-763 Near Belgrade-Obrenovac, at Preliminary Design Stage, 2006



Source: Abolmasov et al. 2015.
Note: Map scale is 1:5,000.

3.1.2 Evaluation of Hazard Levels at Each Hazard Location

Engineering geological maps include the spatial distribution of all types of geodynamic processes and phenomena and the state of their activity—for example, whether slope movements are active, inactive, or marginally stable. Engineering geological consultants assess the state of landslide activity as active, suspended, dormant, relict, or marginally stable slopes during field engineering geological mapping according to the guidelines of the International Association for Engineering Geology and Environment (IAEG). Engineering geological maps or special-purpose engineering geological comprehensive maps are part of the technical documentation for new-road planning and design and one of the layers for new-road alignment planning, design, and construction covering the basis of natural disaster risk.

3.1.3 Risk Evaluation for Alternative New-Road Alignment Plans

In Serbia, the road planners are the licensed engineers or consultants who prepare the risk evaluation overlapping the new-road alignment with engineering geological maps or with special-purpose engineering geological comprehensive maps—layers obtained from engineering geological field mapping (see section 3.1.1)—with the guidance of the Ministry of Construction, Transport and Infrastructure (MCTI) and the direct supervision of Public Enterprise Roads of Serbia (PERS).

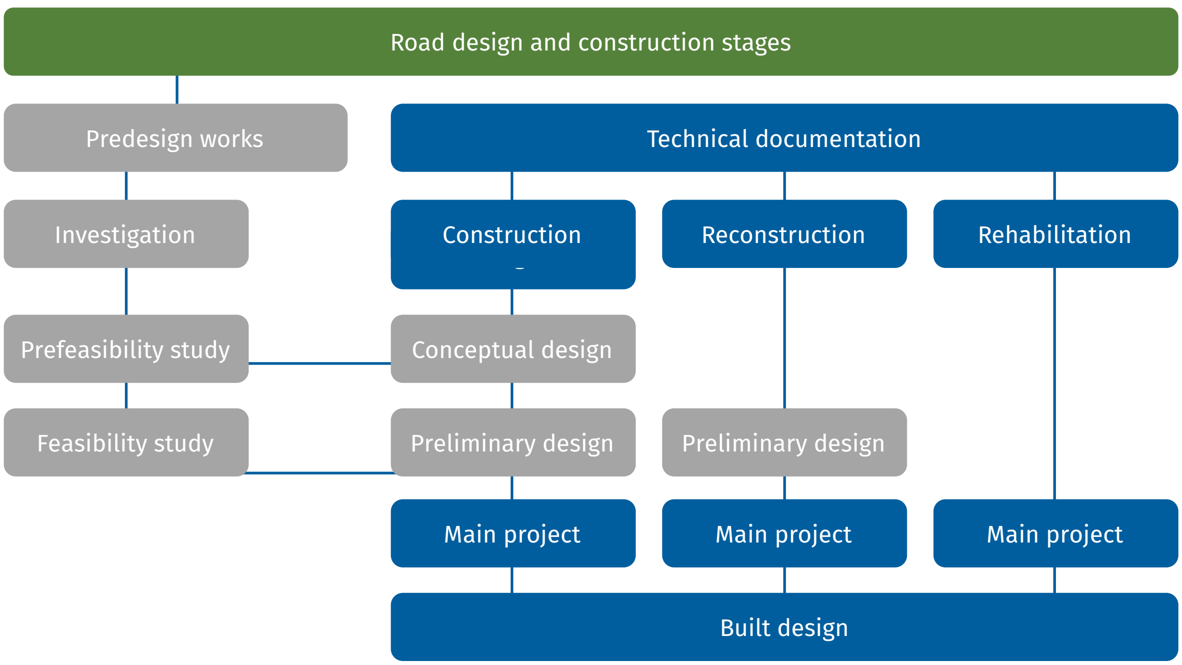
In the early planning and design stages, any alternative new-road alignment is planned to avoid locations of active geodynamic processes and phenomena as much as possible to save construction costs, including the costs of required proactive structural countermeasures and subsequent maintenance costs. Third-party licensed experts or state revision commission consultation and supervision is mandatory for state roads (categories I and II).

3.1.4 Evaluation of Potential Damage to Local Social Environment

The social and environmental assessment of the local environment is performed during the early stages of new-road planning activities—that is, the prefeasibility and feasibility study stages (figure 3.1). As mentioned earlier, the contractors or a responsible design company under the supervision of PERS conducts these studies and, finally, the MCTI approves the study before approving the project and incorporating it into the early design.

As figure 3.1 shows, before the construction work begins, the predesign and design studies are mandatory. The grey boxes in the figure show stages when engineering geological mapping is used for geohazard risk evaluation. Blue boxes show design stages when simple geohazard risk evaluation is assessed within engineering geological mapping.

Figure 3.1 Road Design and Construction Stages Practiced in Serbia



Note: Grey boxes indicate stages that use engineering geological mapping for geohazard risk evaluation. Blue boxes indicate design stages that assess simple geohazard risk evaluation within engineering geological mapping.

3.2 Geohazard Risk Evaluation for Existing Roads

The main purpose of the geohazard risk evaluation for existing roads is to identify and prioritize endangered road locations to plan the corresponding road geohazard risk management procedure for each location and geohazard-prone road section or location. In Serbia, a geohazard risk evaluation for existing roads follows these steps:

1) Identification of endangered road sections or locations
2) Risk evaluation of those sections or locations
3) Risk management planning activities.

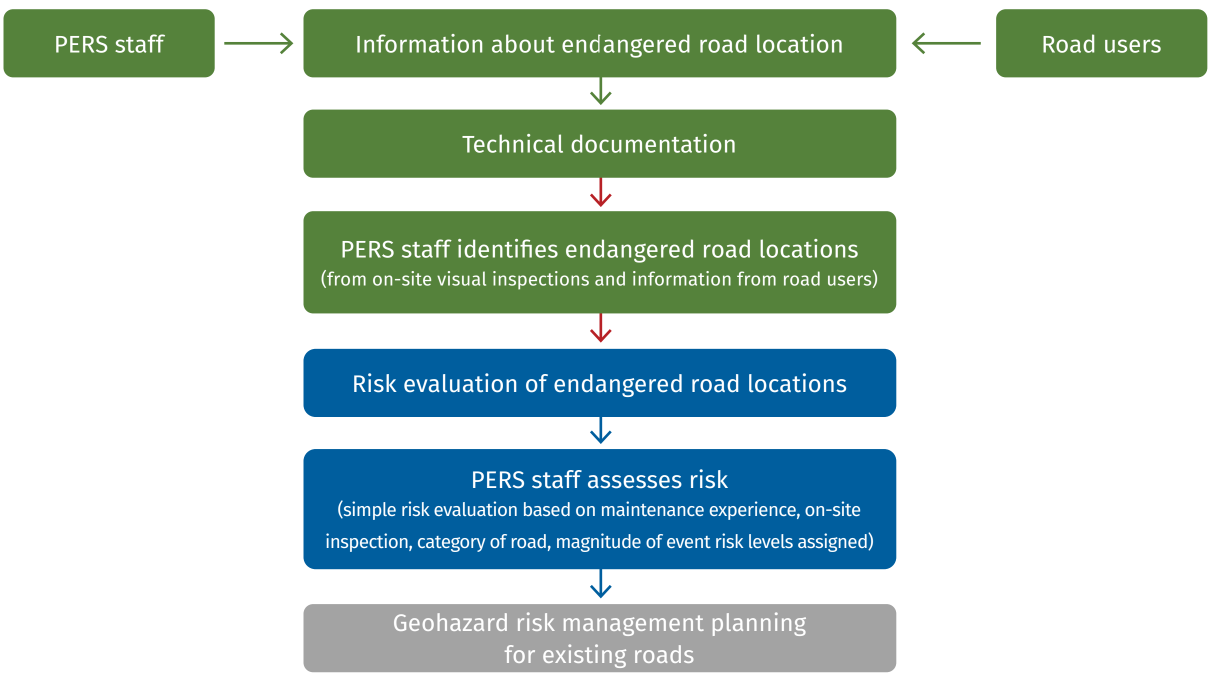
3.2.1 Identification of Endangered Road Locations

Identification of endangered road locations is provided daily by PERS staff from the Sector for Maintenance of Category I and II State Roads or information from road users and other stakeholders. The PERS staff is responsible for daily visual inspection of roads by road patrols, or they do it on demand after receiving urgent information from road users or other stakeholders. The daily road patrols' reports and results are sent to their supervisors for review and identification of potential geohazards (among other things). This leads PERS to send geotechnical or civil engineers and other experts for an identification survey of the geohazard-endangered road section or location.

3.2.2 Risk Evaluation of Endangered Road Locations

Risk evaluation and prioritization is ad hoc in Serbia, depending on the affected road category and level of damage. Risk evaluation of endangered road locations is provided by experienced PERS maintenance staff (geotechnical or civil engineers) by visual inspection (figure 3.2). Even if a procedure for standard hazard and risk evaluation is proposed through a landslide database, the risk evaluation and prioritization are ad hoc depending on the road category and level of damage.

Figure 3.2 General Workflow of Geohazard Risk Evaluation for Existing Roads



Note: PERS = Public Enterprise Roads of Serbia.

3.2.3 Risk Management Planning Activities

The results of risk evaluations from endangered locations managed by PERS are used for initial decision-making processes, which could include consideration of

- Nonstructural countermeasures, such as monitoring, data collection, afforestation, road closures, and so on, that can be conducted without design;
- Structural countermeasures, such as the construction of walls, levies, gabions, and so on, with geotechnical investigation and design;
- Routine visual inspections; or
- No further actions.

4 ROAD GEOHAZARD RISK MANAGEMENT PLANNING

4.1 Geohazard Risk Management Planning for New Roads

In Serbia, geohazard risk management planning for new roads is performed to minimize the total life-cycle cost of the new infrastructure and to ensure the public safety and reliability of roads against geohazard risk. Geohazard risk reduction is considered for each and every new state road construction in the country, and some new roads are targeted for possible use for emergency transport and evacuation operations during state emergencies.

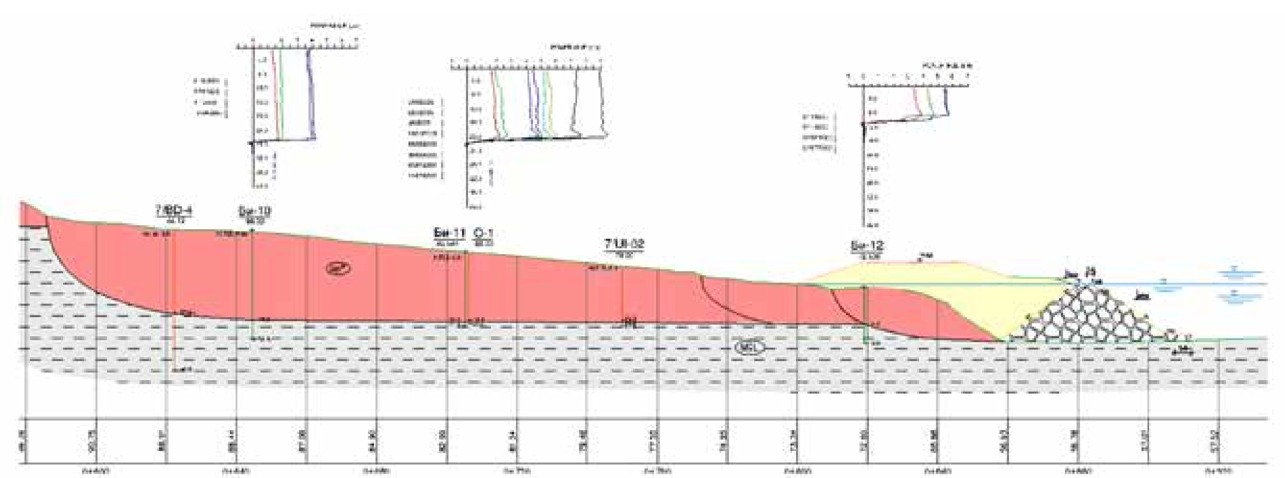
4.1.1 New-Road Predesign and Design to Reduce Geohazard Risks

The concept of geohazard risk management planning for new roads is followed during the predesign stages, when a thorough feasibility study is conducted for the alignment or the new road. The basic obligatory investigations are engineering geological mapping and geotechnical investigation. The main differences between the predesign and design stages involve the scale of engineering geological mapping, along with the type and number of geotechnical investigations undertaken.

Minimizing the geohazard risk is the main goal for any proper new-road alignment (as illustrated in figure 4.1 and figure 4.2). As a part of road design, all activities are performed by responsible licensed design companies, while supervision is provided by third parties or by the revision commission under the Ministry of Construction, Transport and Infrastructure (MCTI).

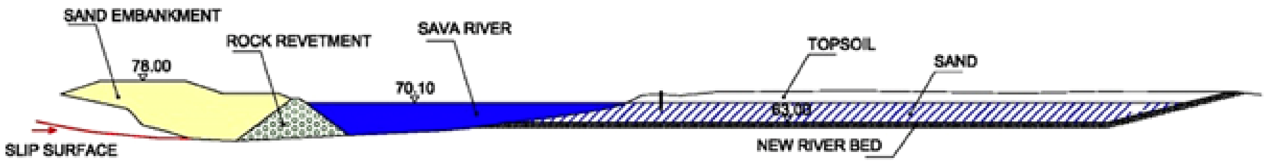
Planning of proactive structural countermeasures for geohazard-endangered locations on selected new alignments—including consideration of minor alignment shifting or using other construction as an alternative solution—is included in the road design stages. Examples of such concepts are presented in figure 4.1 and figure 4.2, illustrating where countermeasures were proposed (using results of geotechnical field investigation and monitoring and proposed countermeasures) to mitigate risk from the active Umka landslide near Belgrade during a preliminary design stage for an E-763 new motorway section.

Figure 4.1 Preliminary Design of E-763 New Motorway, Section Belgrade-Obrenovac, 2006: Engineering Geological Cross-Section with Inclinometer Measurements and Proposed Countermeasures for Umka Landslide



Source: ©Highway Institute, Belgrade. Reproduced, with permission, from Highway Institute; further permission required for reuse.

Figure 4.2 Preliminary Design of E-763 New Motorway, Section Belgrade-Obrenovac, 2006: Proposed Countermeasures Concept Design for Umka Landslide



Source: ©Highway Institute, Belgrade. Reproduced, with permission, from Highway Institute; further permission required for reuse.

4.1.2 New-Road Spatial Planning for Local Geohazard Risk Reduction

The MCTI is responsible for road planning and construction activities in Serbia and considers disaster risk reduction in coordination with Public Enterprise Roads of Serbia (PERS) and other government bodies (ministries, agencies, and enterprises). The new-road planning follows the National Spatial Plan of Serbia for national roads, the Regional Spatial Plan for regional roads, and the Municipality Spatial Plan for municipal roads. The City Road Plan is regulated by different levels of urban planning.

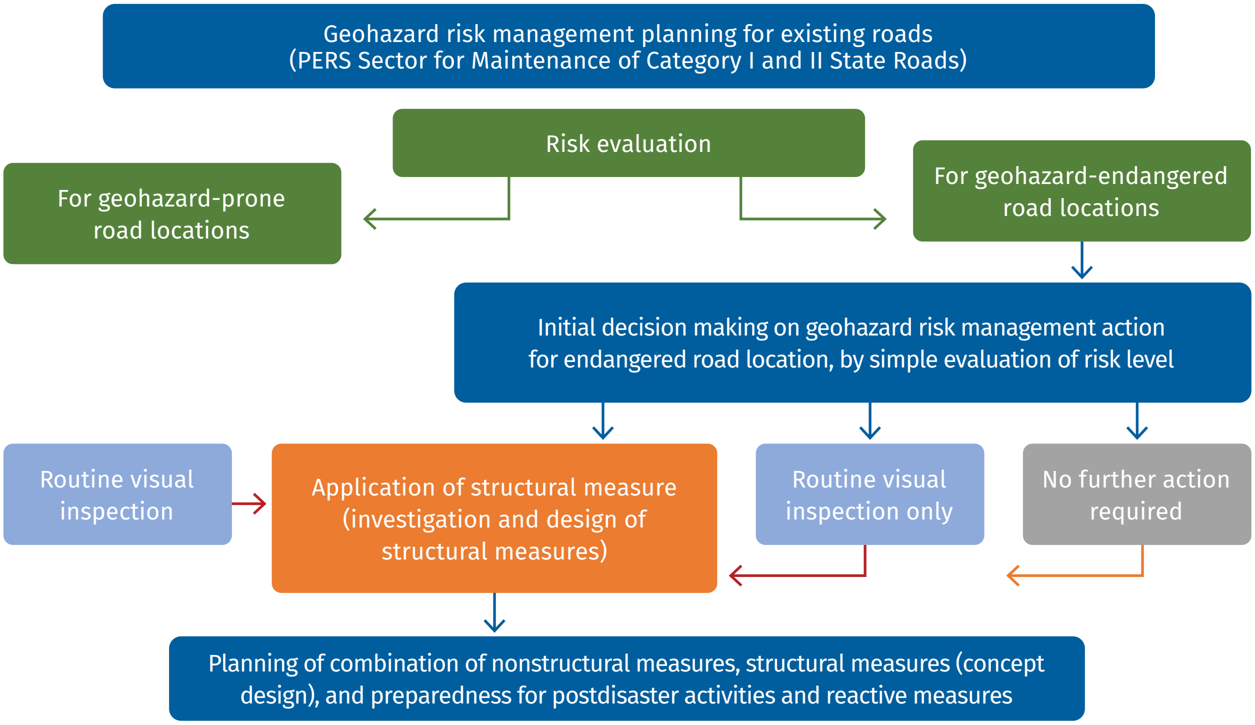
From 2014 onward, the MCTI Sector for Spatial Planning, Urbanism and Housing has been in charge of spatial planning, with the goals and objectives of use and protection of natural resources through the management of population, settlements and regionalization, transport, tourism, the environment, natural and cultural heritage, and sustainable land use.

4.2 Geohazard Risk Management Planning for Existing Roads

4.2.1 Identification and Data Collection for Geohazard-Prone Road Subsections

The PERS Sector for Maintenance of Category I and II State Roads collects information about hazardous road sections or subsections primarily from five regional offices and departments—in Belgrade, Niš, Užice, Kosovska Mitrovica, and Novi Sad—as well as from regional private companies and road users. The staff of this PERS sector performs field inspections, on request from regional offices and departments, for geohazard risk management planning (figure 4.3). The regional staff of PERS collects information from the field, and local people help by calling and informing the PERS staff in case of road disasters. Field identification and data collection are not usually on a real-time basis because of limited human and other resources.

Figure 4.3 Geohazard Risk Management Planning Workflow for Existing Roads



Note: PERS = Public Enterprise Roads of Serbia. Red arrows indicate cases and stages where it is possible to change the risk status if a hazard event occurs.

4.2.2 Initial Decision Making on Geohazard Risk Management Policy for Each Geohazard-Endangered Location

The initial risk management decisions are made after field inspection by PERS engineers; the action and budget priority depend on the road category and geohazard event magnitude. The PERS staff prioritizes and focuses on response after a geohazard event instead of on identification and data collection for geohazard risk-prone areas because of the limited number of professionals and funds.

4.2.3 Planning for Existing Roads Considering Regional Disaster Risk Reduction

The government of Serbia, through the MCTI and PERS, is preparing geohazard risk reduction plans for existing state roads within operational maintenance programs as well as yearly budget plans for all category I and II roads. Sometimes, the coordination on risk reduction extends to local authorities or to neighboring governments' road authorities for international or cross-border road management.

4.3 Cost-Benefit Analysis of Investment for Road Geohazard Risk Reduction

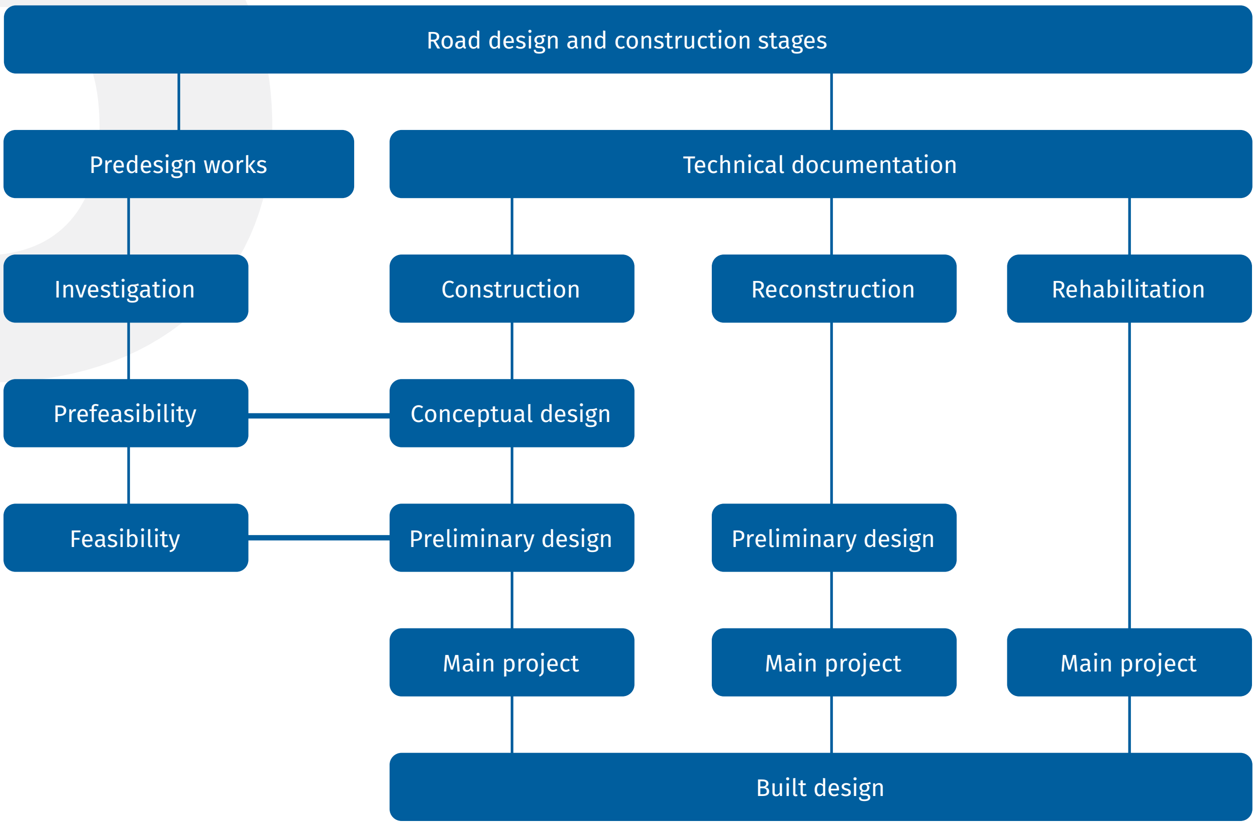
No data are available on cost-benefit analysis for road geohazard risk reduction in Serbia because the responsible authority repairs the damaged section of the road whatever the cost may be, considering the length and the importance of the road. In other words, the assumption is that all roads must be maintained, and the only decision concerns which repair solution offers the lowest life-cycle-cost solution and what priority each repair is given. At the same time, PERS estimates the cost of repairs yearly and includes these in its investment plans for submitted to the MCTI. PERS focuses primarily on reactive measures after a geohazard event, so a cost-benefit analysis of investment is sometimes out of context.

5 ENGINEERING AND DESIGN

5.1 General Flow of Road Construction and Structural Measures

The road planning, design, and construction stages, as well as structural disaster countermeasure implementation, are defined by the Law of Planning and Construction (discussed in section 2.4). A general flowchart of road design and construction stages covers the activities from predesign and technical documentation through the completion of the construction project (figure 5.1).

Figure 5.1 Flowchart of Road Design and Construction Stages and Structural Countermeasures Implementation



5.2 Engineering Investigation of Endangered Locations for Structural Countermeasures Implementation

Engineering investigations of endangered locations for structural countermeasures implementation are defined by the Law of Planning and Construction, the Law of Mining and Geological Explorations, and the Bylaws–Divisions of Urgent Maintenance of Public Roads, as discussed earlier (section 2.4). Public Enterprise Roads of Serbia (PERS) announces tenders for engineering investigations and structural countermeasure designs on category I and II state roads—that is, topographic surveys, engineering geological mapping, drillings, laboratory tests, sample collection, numerical slope stability analysis, and reporting. The structural countermeasure design and construction are outsourced to third parties such as local companies licensed by the Ministry of Construction, Transport and Infrastructure (MCTI).

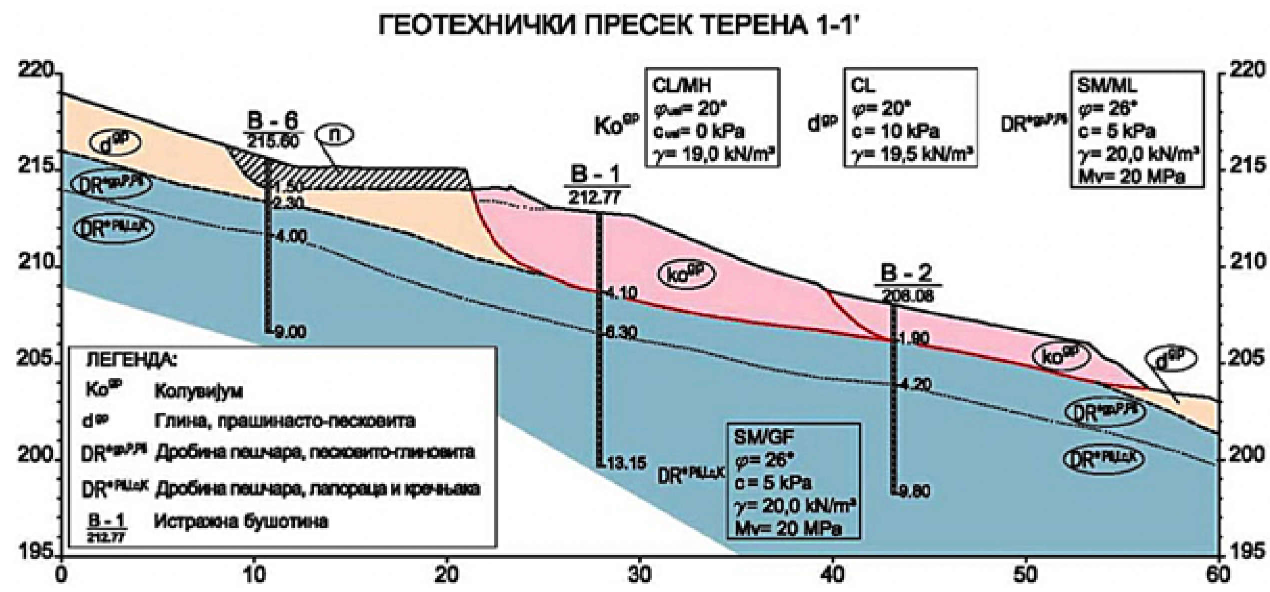
The design of appropriate structural countermeasures depends on the type and magnitude of the hazardous event, which is determined from field investigations. Common contents of important engineering investigations to support the design of structural countermeasures include geodetic survey; engineering geological mapping; drilling to find out water table and soil strength, bedrock, and so on; hydrological analysis; geotechnical monitoring; and more (table 5.1).

Table 5.1 Contents of Engineering Investigation to Support Design of Structural Countermeasures

Method	Purpose	Outputs
Geodetic survey	Measure the terrain surface for survey plan, further analysis, and design of structural measures	Topographic map (scale 1:1,000–1:500) Cross-section (scale 1:500–1:100)
Engineering geological mapping	Map the spatial distribution of engineering geological units and other relevant engineering geological properties	Engineering geological map (scale 1:1,000–1:500) Engineering cross-sections (scale 1:1,000–1:500)
Drilling	Confirm the geology, soil strength, and existence of groundwater	Drilling log Engineering geological cross-section
Laboratory tests	Test the strength of rock and soil sampled at the implementation site	Physical and mechanical data of rock and soil at the site
Hydrological analysis	Analyze catchment area, rainfall, and discharge	Hydrological report related to geohazard occurrence
Geotechnical monitoring	Analyze displacement along slip surface Monitor groundwater level Monitor precipitation Geodetic benchmarks	Inclinometers log Piezometers log Precipitation diagrams Surface displacement diagram
Numerical analysis	Analyze slope stability	Stability analysis sheet Geotechnical report
Geotechnical data summarizing and reporting	Summarize and report data for reference or to adopt the result of investigations and design concept for structural countermeasures	Compiled data geotechnical report with concept design for structural countermeasures

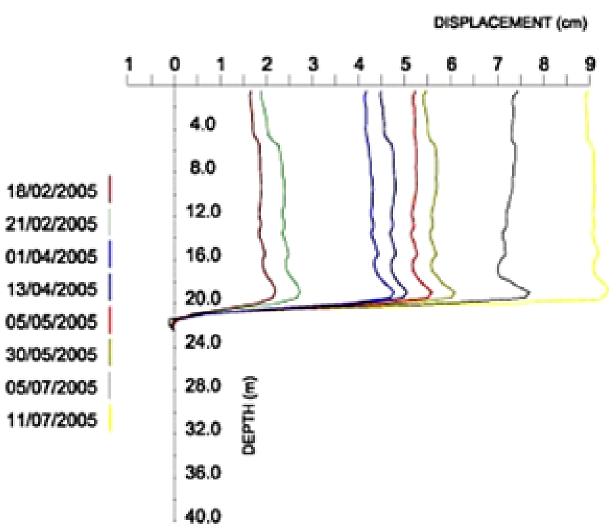
Several figures present typical results of engineering investigations for landslide: field investigations, monitoring, and laboratory testing to support geohazard countermeasure design. An example of an engineering geological cross-section of a landslide is presented in figure 5.2; an inclinometer log for landslide displacement rate measurement in figure 5.3; and a plasticity chart (soil parameter) from a laboratory test in figure 5.4.

Figure 5.2 Sample Engineering Geological Cross-Section of a Landslide



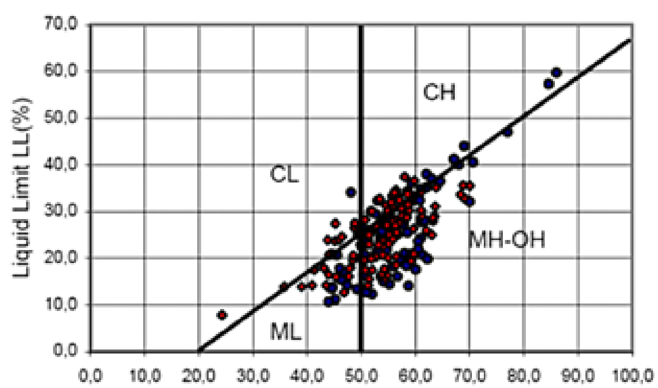
Source: ©Highway Institute, Belgrade. Reproduced, with permission, from Highway Institute; further permission required for reuse.

Figure 5.3 Inclinometer Log of Displacement Rate from Umka Landslide



Source: ©Highway Institute, Belgrade. Reproduced, with permission, from Highway Institute; further permission required for reuse.

Figure 5.4 Plasticity Chart for Soil Samples from Umka Landslide



Source: ©Highway Institute, Belgrade. Reproduced, with permission, from Highway Institute; further permission required for reuse.

5.3 Types of Structural Countermeasures and Design Considerations

The types of structural countermeasures depend on different parameters such as the location, the type of hazardous event and its magnitude, the type of road section or construction threatened, and the geology and hydrology of the site. Structural countermeasure design considerations in Serbia are based on the results of engineering investigations and appropriate numerical analyses of geohazards. The proposed design solution is subject to review by another licensed company or by the revision commission of the MCTI. Upon finalization of the design, the countermeasure construction is outsourced by PERS. Photos 5.1 through 5.5 present examples of various geohazard countermeasures such as shotcrete, anchors, retaining wall, wire nets, geotextiles, and their combinations.

Photo 5.1 Structural Countermeasures on the Entrance of Tunnel Manajle, E-75

a. Shotcrete

b. Anchors

Source: B. Abolmasov / Abolmasov et al. 2015.

Photo 5.2 Local Road Stabilization Countermeasures

a. Before countermeasures

b. After construction of retaining wall

Source: ©Highway Institute, Belgrade. Reproduced, with permission, from Highway Institute; further permission required for reuse.

Photo 5.3 Local Road Stabilization Countermeasures

a. Before countermeasures

b. After construction of retaining wall

Source: ©Highway Institute, Belgrade. Reproduced, with permission, from Highway Institute; further permission required for reuse.

Photo 5.4 Use of Anchors and Shotcrete as Structural Countermeasures on Road Čačak-Užice, Exit of Tunnel Mečkovo brdo

a. Before countermeasures

Source: B. Abolmasov / Abolmasov et al. 2015.

Photo 5.5 Use of Anchors, Wire Nets, and Geotextile as Reactive Measures on Cuts, Corridor X, E-80 (LOT1-Prosek-Tunnel Bancarevo)

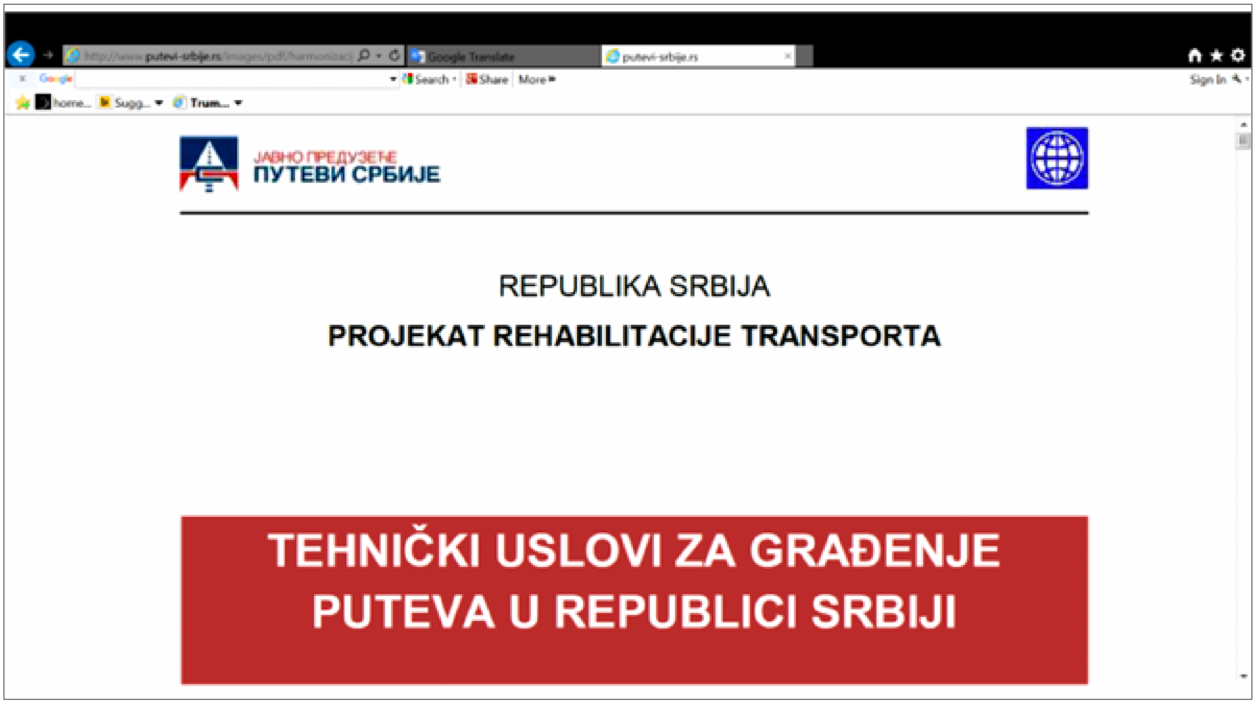
b. After construction of retaining wall

Source: B. Abolmasov / Abolmasov et al. 2015.

5.4 Construction Management (Standard Specifications and Quality Assurance)

The MCTI strictly checks the quality of structures based on design survey results before granting permission for any construction, including state roads, and this process is fully supported by PERS. They establish standard construction specifications and complete design norms and criteria. Standard specifications and quality assurance documents (in Serbian) related to road design and construction management (SRCS 1-0, SRCS 2-1 to 2-9) are publicly available online. A screenshot of one of the standards is presented in figure 5.5.

Figure 5.5 Sample PERS Website for a Technical Standard for Road Construction in Serbia



Source: ©Public Enterprise Roads of Serbia (PERS). Reproduced, with permission, from PERS; further permission required for reuse.

6 OPERATIONS AND MAINTENANCE

6.1 Maintenance of Engineering Structures

Public Enterprise Roads of Serbia (PERS) maintains road engineering structures on category I and II state roads. Public or private design and construction companies sign the contract and execute all maintenance tasks, including removal of debris deposits, repair of damaged roads (cuts or slopes), and reinforcement works for the national roads. The local authorities maintain local roads in a similar way.

A road asset database is under construction at PERS, and some information about engineering structures (tunnels, bridges, and others) is available on this database for state roads in Serbia. There are 2,960 bridges with a total surface area of more than 1 million square meters, and 377 of these bridges are on motorways. Bridges vary in age, shape, and construction type; are made of timber, stone, concrete, steel; and have various static systems, spans, and lengths (from 5 meters to 2,212 meters). Serbia has eight bridges across the Danube River and six bridges across the Sava River. Photo 6.1 shows rehabilitation activities on a bridge across the Sava River.

Eighty-five tunnels totaling 14 kilometers in length have been constructed on state roads in Serbia. There are six tunnels on the motorways; two were not open for traffic as of 2017. The tunnels are of various ages and involve various construction technologies in different geological surroundings. The longest tunnel is Šargan in the direction from Kremna toward Višegrad and is 775 meters long. Thirty-nine of the road tunnels in Serbia are more than 100 meters long. All of these structures are maintained by PERS.

Photo 6.1 Rehabilitation Works on Ostrznica Bridge, Sava River

Source: B. Abolmasov / Abolmasov et al. 2015

6.2 Nonstructural Countermeasures

6.2.1 Visual Inspections and Hazard Monitoring for Early Anomaly Detection

The PERS Sector for Maintenance and regional departments conduct daily visual inspections of state road categories I and II. The routine patrols are conducted not only for geohazard detection but also to detect pavement deterioration, road damage by traffic loads and accidents, falling objects from traffic, falling trees, and other obstacles. Photo 6.2 shows regular maintenance of a slope being undertaken on the Kraljevo–Raska road.

Photo 6.2 Maintenance Crew Clears Debris from Cut on the Kraljevo–Raska Road

Source: B. Abolmasov / Abolmasov et al. 2015.

6.2.2 Road Condition Emergency Information System, Including Early Warning or Precautionary Road Closure

In Serbia, the general public visits the websites of PERS and the Automobile and Motorcycle Association of Serbia (AMSS) for all the information on road closures and road traffic conditions. Road users can also call a toll-free information number (0800-111-004) to reach the information to and from PERS. In addition, the PERS Sector for Traffic Control and Information has a mobile application for Android smartphones and computers with nine functions—including online updated information on road closures and traffic conditions—and this information is shared with the AMSS, Ministry of Interior, and media outlets.

The Republic Hydrometeorological Service of Serbia (RHMZ) provides climatological data and warning alarms (red, orange, and yellow) on its website and through weather forecasts on television and radio every hour. Weather data information is shared with PERS and media outlets.

Under the established system for precautionary road closure, a road subsection is designated for traffic regulation. limited to the designated road subsections, depending on the traffic situation and the emergency need. The traffic closure is lifted when the situation improves to normal.

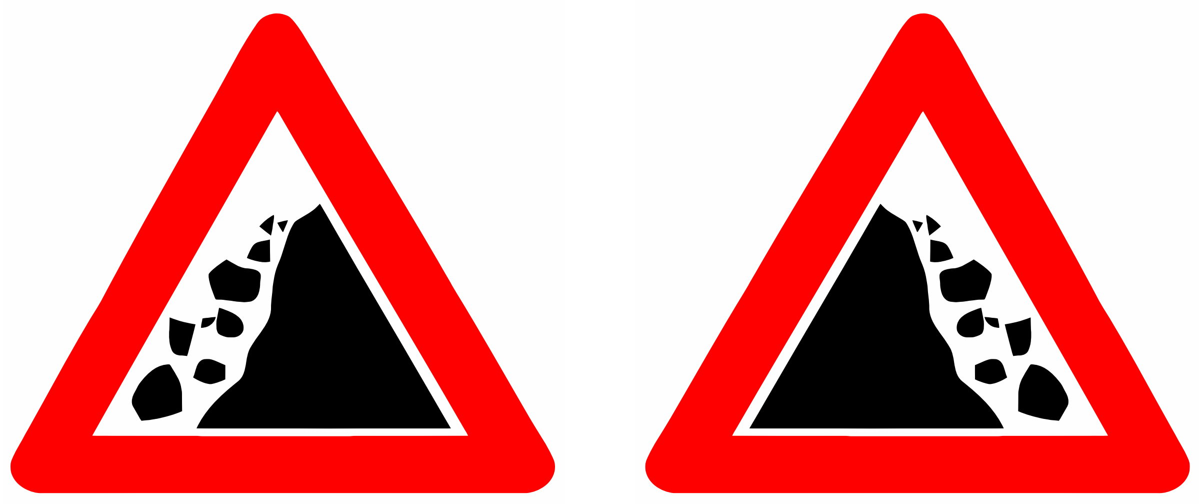
Traffic Signs to Raise Awareness

Road signs include danger warnings, regulatory notices. The danger of geohazard risk is indicated by warning signs for rockfalls and landslides (figure 6.1).

Figure 6.1 Road Geohazard Warning Signs

a. Landslide-prone road subsection

b. Rockfall danger



Source: Public Enterprise Roads of Serbia (PERS).

Awareness Raising and Training for Road Stakeholder Engagement

The Ministry of Construction, Transport and Infrastructure (MCTI) has produced a brochure for road stakeholders in case of road traffic accidents. In addition, the Ministry of Interior's Sector for Emergency Situations (SES) has published a booklet in various local languages to raise awareness on disaster risk management (DRM). The SES booklet outlines the hazards and how to protect oneself or take precautions during a disaster event or emergency.

6.2.3 Control of Road Disasters Caused by Human Activities

The extraction of sand and boulders from riverbanks, deforestation, or otherwise clearing of land for agriculture or settlement purposes increases road geohazard risk. Therefore, such human activities are forbidden in the road corridors under the Law of Public Roads. The MCTI regularly patrols to limit illegal human activities and protect roads. Of course, many geohazards extend well beyond the legal road corridor, and the ability to limit such activities on private land is an ongoing challenge.


50

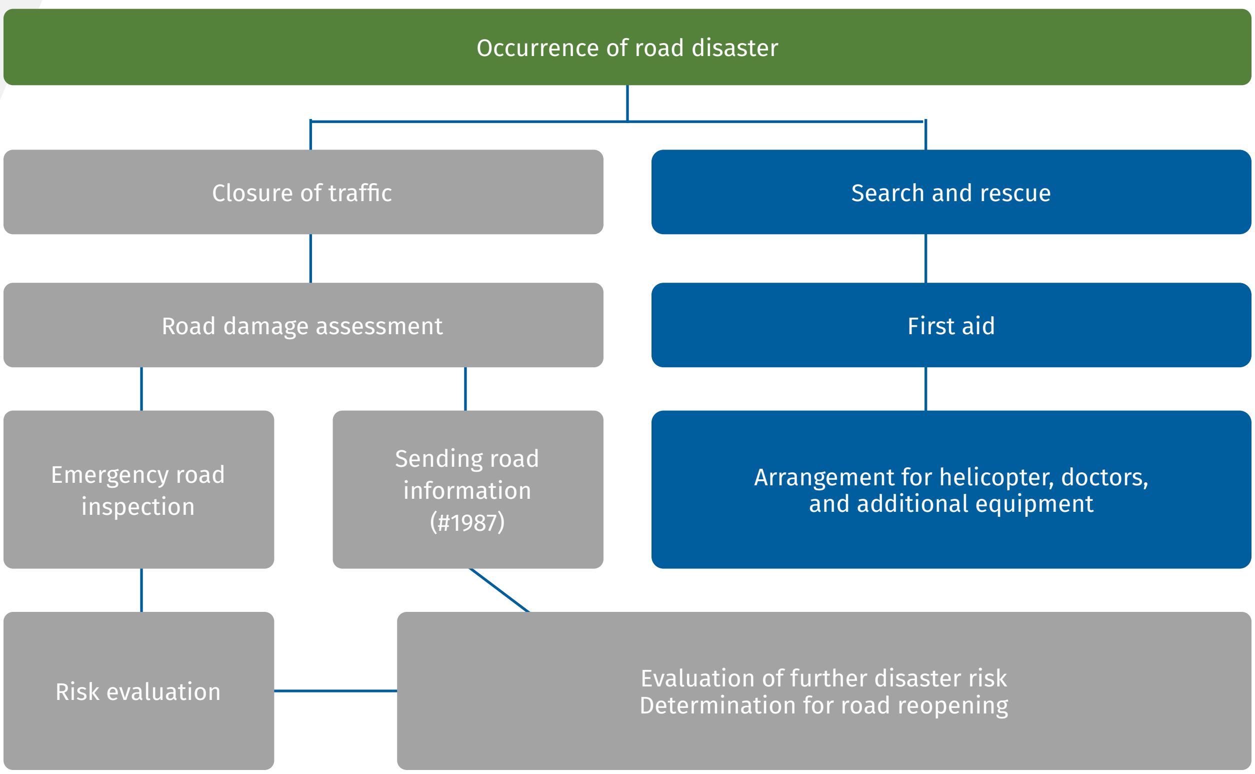
7 CONTINGENCY PROGRAMMING

7.1 Emergency Inspection and Postdisaster Needs Assessment

Postdisaster damage information is collected the same way as early anomaly detection and emergency information collection, and by the same staff at Public Enterprise Roads of Serbia (PERS) sectors and departments. If road users are injured or killed or vehicles damaged, the police also conduct inspections. The required emergency inspections and urgent measures are taken to protect road users and road structures from secondary damage.

The flowchart in figure 7.1 shows a general procedure for emergency inspections, including postdisaster needs assessment. The gray boxes show tasks of road management authorities, and the blue boxes show tasks of police or health and rescue officers. A rescue team evaluates the injured road users' needs for first aid and carries out the proper emergency treatment. The police team and road operation staff may request additional rescue teams or ambulances as well as additional equipment for cleaning endangered road sections.

Figure 7.1 General Procedure for Road Emergency Inspections



Note: Gray boxes indicate tasks of road management authorities; blue boxes indicate tasks of police or health and rescue officers

7.2 Emergency Traffic Regulation and Public Notice

The Ministry of Construction, Transport and Infrastructure (MCTI) road inspection results determine road traffic status as well as whether there will be a complete or partial halt of traffic in coordination with police and PERS staff. PERS sector and department staff place temporary barricades and traffic lights if the road is partially or fully closed. The MCTI is informed after state road closures are lifted by PERS staff.

Emergency information is made publicly available from the PERS Traffic Control and Information Sector through various media such as national and local television, radio, the internet, and the Automobile and Motorcycle Association of Serbia (AMSS) website. It is also available on the PERS Information Center web service and call center.

7.3 Reactive Measures

7.3.1 Emergency Recovery

In emergency recovery situations, all available technical support from public and private companies is mobilized for urgent countermeasures. This response is a part of the emergency situation response plan and activities managed by the Ministry of Interior's Sector for Emergency Situations (SES), as defined by the Law on Emergency Situations (further described in section 2.4). Responsible SES employees on the local, regional, and national levels are obligated to prepare a list of available public and private companies equipped for fast technical support and emergency response.

The SES data are available to PERS in case of emergency. Emergency inspection and postdisaster needs assessment, emergency recovery, and repairs are conducted by PERS maintenance staff on category I and II state roads. In case of major disasters such as the 2014 rainfall event, PERS helps local authorities responsible for local roads.

7.3.2 Repair and Risk Reduction

After inspection and risk evaluation of a geohazard event, PERS prepares implementation plans, time frames, and budget allocation for repair of structural countermeasures for category I and II state roads. The local authorities also follow the same procedure for local roads. The road repairs after minor road geohazard disturbances are conducted by technical support companies, such as road construction companies, upon demand by PERS, and these repairs are part of routine maintenance.

7.3.3 Rehabilitation

Rehabilitation involves engineering investigations and design. PERS prepares the norms and criteria for the rehabilitation of a prioritized location based on the field inspection data and according to the need, importance, and resources available. The design and construction works are closely managed, with the standard of construction specifications and other criteria defined during the road design and construction stages.

7.3.4 Reconstruction

Reconstruction takes into consideration the life-cycle costs, geohazard risk management costs, and costs to relocate or reroute the road section or subsection. Rerouting of the existing road to avoid a hazardous location is preferred for maintenance cost and safety reasons, and if the hazard is sufficiently active, the rerouting may also reduce life-cycle costs. Road reconstruction is defined by law during the road design and construction stage and follows all the same specifications and criteria for design and construction as for any road construction in Serbia.

7.3.5 Monitoring and Preparedness

Traffic flow is monitored using cameras on the state roads, although cameras do not cover the entire road length. Geohazard and natural hazard risks are monitored by visual inspection by road authority staff or through information received from local residents, road users, and other stakeholders. Installation of automatic weather stations on state roads is an ongoing process and will be effective for weather data monitoring and disaster risk preparedness in the country.

Geotechnical monitoring by inclinometer and piezometer, and geodetic marks during the design and construction stages, are required for many geohazard sites. An effective early warning system is not in place in Serbia; however, proactive nonstructural measures are being undertaken, such as implementation of road condition emergency information systems, including precautionary road closing as preparedness. As mentioned earlier, the routine visual road monitoring and inspection by PERS staffs takes place regularly.

7.3.6 Risk Sharing (Insurance and Reinsurance)

Owners of vehicles are obliged to pay an annual taxation fee for their car insurance. Part of that tax goes from the insurance company to share risk (pay the bills) in the case of a road accident, but it is not stated that coverage extends to geohazard events resulting in vehicle damage. Insurance and insurance rules are not clearly defined regarding geohazards, and no known insurance agencies provide such insurance for geohazard risk damage to private vehicles.

However, a program developed and issued by Europa Reinsurance Facility Ltd. (Europa Re) that helps protect Serbian farmers is promising and could be extended to road geohazard risk sharing. Europa Re's head of product development and country program manager for Serbia and North Macedonia discussed the disaster risk management solutions and financial instruments developed under the Europa Re catastrophe (re)insurance program at a June 2015 conference in Belgrade (Europa Re 2015).

The Municipality of Sremska Mitrovica became the first region in Serbia to benefit from the municipal Area Yield Index Insurance (AYII) policy, which was developed and issued under the Europa Re catastrophe risk market development program in Serbia. The Europa Re–endorsed AYII product protects farmers in the municipality of Sremska Mitrovica from the loss of crop yields due to extreme weather events such as drought, frost, windstorm, continuous excess rain damage, high temperatures, and catastrophic floods (Europa Re 2015).

REFERENCES

Abolmasov, B., S. Milenković, M. Marjanović, U. Đurić, and B. Jelisavac. 2015. "A Geotechnical Model of the Umka Landslide with Reference to Landslides in Weathered Neogene Marls in Serbia." Landslides 12 (4): 689–702. doi:10.1007/s10346-014-0499-4.

Cruden, D. M., and D. J. Varnes. 1996. "Landslide Types and Processes." In *Landslides, Investigations and Mitigation*, edited by K. Turner and L. R. Shuster, 36–75. Transportation Research Board Special Report 247. Washington, DC: National Academies Press.

Dragićević, S., D. Filipović, S. Kostadinov, R. Ristić, I. Novković, N. Živković, G. Anđelković, B. Abolmasov, V. Šećerov, and S. Đurđić. 2011. "Natural Hazard Assessment for Land-Use Planning in Serbia." *International Journal for Environmental Research* 5 (2): 371–80.

Europa Re. 2015. "Disaster Risk Management Conference in Serbia." Press release, June 4. http://www.europa-re.com/uploads/news/Press_Release_DRM_Conference_in_Serbia.pdf.

Jotić M., V. Vujanić, B. Jelisavac, M. Zlatković, and S. Milenković. 2015. "Klizišta i štete na saobraćajnoj infrastrukturi u Srbiji" [Slipways and Damage to the Traffic Infrastructure in Serbia]. [In Serbian.] *IZGRADNJA [Construction]* 69 (5–6): 215–24.

Milenković, S., M. Jotić, V. Vujanić, and B. Jelisavac. 2014. "Landslide Database on the Road Network in Serbia." In L*andslide and Flood Hazard Assessment: Proceedings of the 1st Regional Symposium on Landslides in the Adriatic-Balkan Region*, edited by S. M. Arbanas and Z. Arbanas, 199–202. Zagreb, Croatia: Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb; Faculty of Civil Engineering, University of Rijeka.

Republic of Serbia. 2010. "Spatial Plan of the Republic of Serbia: 2010–2014–2020, Abridged Version." National planning document, Ministry of Environment and Spatial Planning, Belgrade. http://195.222.96.93//media/zakoni/Spatial%20Plan%20of%20the%20Republic%20of%20Serbia_2010-2020_abridged%20(1).pdf.

Ristić, R., S. Kostadinov, B. Abolmasov, S. Dragićević, G. Trivan, B. Radić, M. Trifunović, and Z. Radosavljević. 2012. "Torrential Floods and Town and Country Planning in Serbia." *Natural Hazards and Earth System Sciences* 12 (1): 23–35. doi:10.5194/nhess-12-23-2012.

Schwab, Klaus, ed. 2015. *The Global Competitiveness Report 2015–2016*. Geneva: World Economic Forum.

Smailagić, J., A. Savović, D. Marković, D. Nešić, B. Drakula, M. Milenković, and S. Zdravković. 2013. "Climate Characteristics of Serbia." Analysis, Republic Hydrometeorological Service of Serbia (RHMZ), Belgrade.

UNDP (United Nations Development Programme). 2015. "Serbia Launches the National Disaster Management Program." Press Center article, March 4. http://www.rs.undp.org/content/serbia/en/home/presscenter/articles/2015/03/04/serbia-launches-the-national-disaster-management-program.html.

UNISDR (United Nations Office for Disaster Risk Reduction). 2004. *Living with Risk: A Global Review of Disaster Reduction Initiatives.* 2 vols. Geneva: UN Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN/ISDR).

United Nations (UN) Serbia, European Union (EU), and World Bank. 2014. "Serbia Floods 2014." Postdisaster needs assessment of the Government of the Republic of Serbia, Belgrade.

World Bank. 2012. "Project Information Document (PID), Concept Stage: Road Rehabilitation and Safety Project." Report No. PIDC523, World Bank, Washington, DC. http://documents.worldbank.org/curated/en/441751468757497624/pdf/PID0Print0P127876009252012013486213488 51.pdf.

World Bank. 2015. "Launch: Serbia National Disaster Risk Management Program." Event news article, March 4. http://www.worldbank.org/en/events/2015/03/06/launch-serbia-national-disaster-risk-management-program.

ROAD GEOHAZARD RISK MANAGEMENT

CASE STUDY OF BRAZIL

CONTENTS

FIGURES

TABLES

MAPS

ABBREVIATIONS

CEDEC	State Coordination of Civil Defense
CEMADEN	National Center for Natural Disaster Monitoring and Alerts
CENAD	National Center for Risk and Disaster Management
CPRM	Mineral Resources Research Company
DER-SP	Department of Roads of São Paulo
DNIT	National Department of Transportation Infrastructure
DOT	Department of Transportation (state)
DRM	disaster risk management
GDP	gross domestic product
GFDRR	Global Facility for Disaster Reduction and Recovery
IG	Geological Institute (São Paulo)
IPT	Institute of Technological Research of the State of São Paulo
PDN	State Program for the Prevention of Natural Disasters and Reduction of Geological Risks (São Paulo)
PEMC	State Policy on Climate Change (São Paulo)
PMRR	Municipal Risk Reduction Plan
PPDC	Preventive Plan of Civil Defense (São Paulo)
SINGREH	National Water Resources Management System
SINPDEC	National Civil Protection and Defense ... System
UBAs	basic territorial units
VMS	variable message sign

PART I

CASE STUDY SCOPE, BACKGROUND, AND GEOHAZARD ON ROADS IN BRAZIL

1 INTRODUCTION

1.1 Case Study Scope

This Brazil road geohazard risk management case study is designed to demonstrate the country's current situation and to offer a way forward for future development.

This case study summarizes the institutional capacities of geohazard risk management at the different government levels in Brazil, focusing particularly on the federal government and state government. The study selected the São Paulo state as a case study for two reasons: (a) it is a state vulnerable to landslide disasters, and (b) the Bank is implementing an investment operation in the road sector, including disaster risk management (World Bank 2013b).

Note that São Paulo state is considered a state with high institutional capacity within the Brazilian context. Therefore, not all aspects of this case study are reflected in practices across the remainder of Brazil.

The case study report includes

- Background on natural disasters, road systems, and geohazards on roads in Brazil;
- A review of the road geohazard risk management, with overviews of institutional capacity and coordination, systems planning, engineering designs, operations and maintenance, nonstructural measures, and contingency programming;
- Summaries of ongoing projects and programs related to geohazard risk management on roads; and
- Suggestions and recommendations for the next steps.

1.2 General Geographic Description

Brazil covers approximately 8.5 trillion square kilometers, occupying 47 percent of South America's surface area. The country is divided into five geographic regions (map 1.1) with specificities that differentiate them from each other. It is made up of 26 states and the Federal District, whose capital is Brasília. Brazil has a total population of more than 208 million inhabitants and a 2017 gross domestic product (GDP) of approximately US$2.2 million.

Map 1.1 Regions of Brazil

1.3 Background of Natural Disasters in Brazil

According to the "Disaster Losses in Brazil, 1995–2014" report, the events most frequently reported by the municipalities are related to droughts, followed by floods, flash floods, and windfalls (World Bank 2016). However, because of the country's great territorial extension, each region presents different characteristics regarding the frequency and magnitude of these disasters.

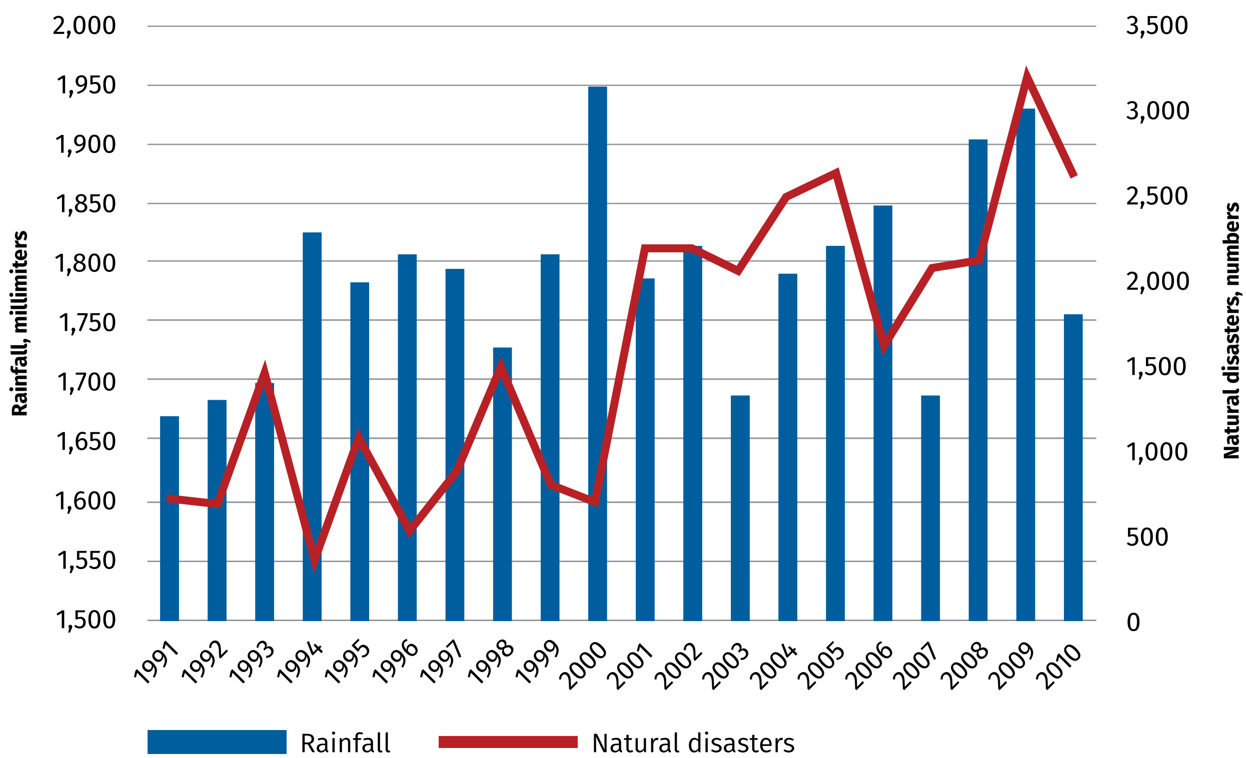
In terms of intensity, natural disasters in Brazil can be classified into four distinct levels:

- ***Level I:*** Small-scale events with minor damages and minor losses that can be overcome by the affected community. Here the situation of normality is restored without great difficulty, using the resources of the municipality itself.
- ***Level II:*** Medium-size events with damage of some importance and significant losses, but surmountable by well-prepared communities. At this level, the situation of normality is reestablished with a special mobilization of local resources.
- ***Level III:*** Events of great proportions and with enormous impact on infrastructure and society. To restore normality, local resources are used, reinforced by state and federal contributions in the National Civil Defense System (SINDEC).
- ***Level IV:*** Events of very serious proportions with very large damages and losses that cannot be overcome without help from outside the affected municipality. When the disaster is of such intensity, the situation will return to normality only if there is an articulated action of the three levels of SINDEC and possible help from international organizations.

Brazilian law also distinguishes between "emergencies" and "public calamities." An emergency situation is when the abnormal situation is caused by a disaster, with damages that can be overcome by the community; it is legally recognized as such by the government. A state of public calamity, in addition to being legally recognized as an abnormal situation caused by a disaster, seriously puts at risk the safety and life of the people of the community. The declaration of either an emergency situation or a state of public calamity must be approved by the state government, with this confirmation of the declaration having corresponding legal effects.

Climate is directly related to natural disasters in Brazil, as it is in many other parts of the world. With the amount of rainfall varying from year to year, the number of registered natural disasters has increased dramatically since a record-breaking annual rainfall of 1,948 millimeters in 2000, closely followed by 1,930 millimeters in 2009. From 2011 to 2015, the amount of annual rainfall kept decreasing, but no reliable data is given regarding the number of registered natural disasters found by the time this report was published. Figure 1.1 shows the sum of the annual rainfall in comparison with the number of registered natural disasters.

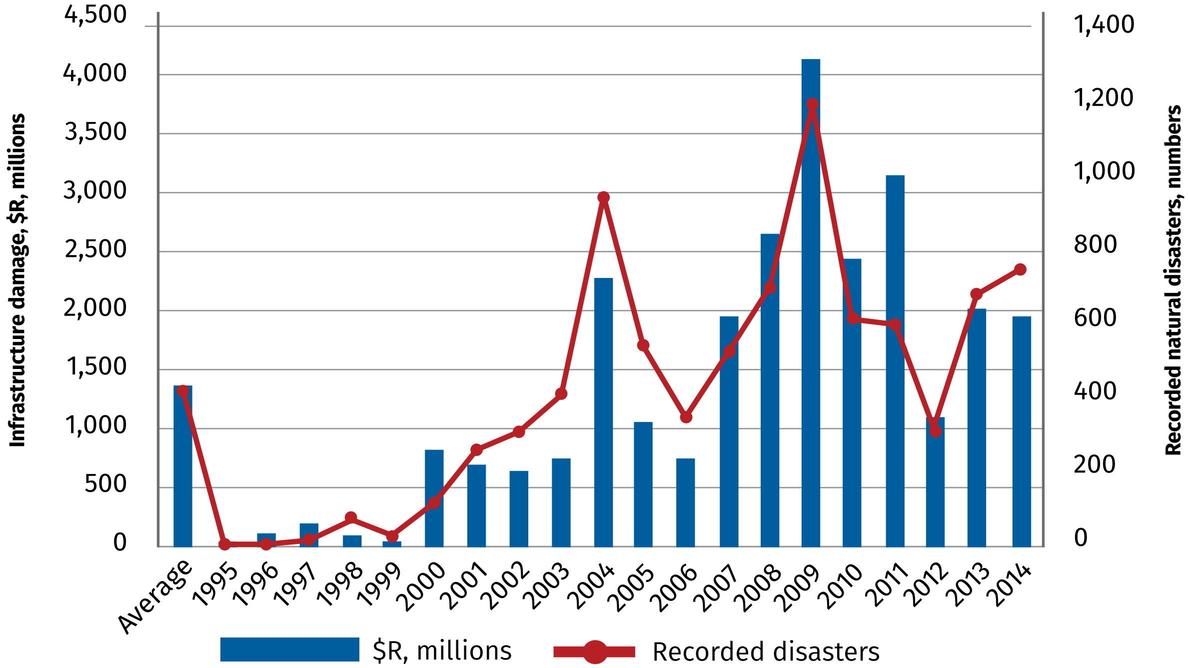
Figure 1.1 Annual Rainfall and Registered Natural Disasters in Brazil, 1991–2010



Source: World Bank Climate Change Knowledge Portal 2.0, http://sdwebx.worldbank.org/climateportal/.

Most of the disasters recorded in the North region are related to excess rainfall—the highest annual total in Brazil. The Northeast and South regions concentrate the highest occurrence of drought records (World Bank 2016). The semiarid region within the Northeast often faces long periods of drought. In the South, the western portion of the three states is more frequently affected by rainfall than the eastern portion. Figure 1.2 shows the number of natural disasters in Brazil and the corresponding cost of damage to infrastructure from 1995 through 2014 (World Bank 2016).

Figure 1.2 Annual Natural Disasters and Cost of Damage to Infrastructure in Brazil, 1995–2014



Source: World Bank 2016. / Note: R$ = Brazilian reais.

Although floods and flash floods appear as the most recurrent phenomena in the South and Southeast regions, events related to wind, hail, and landslides are also responsible for significant damage. Finally, the West Central region presents a more frequent recurrence of flood-related disasters than drought.

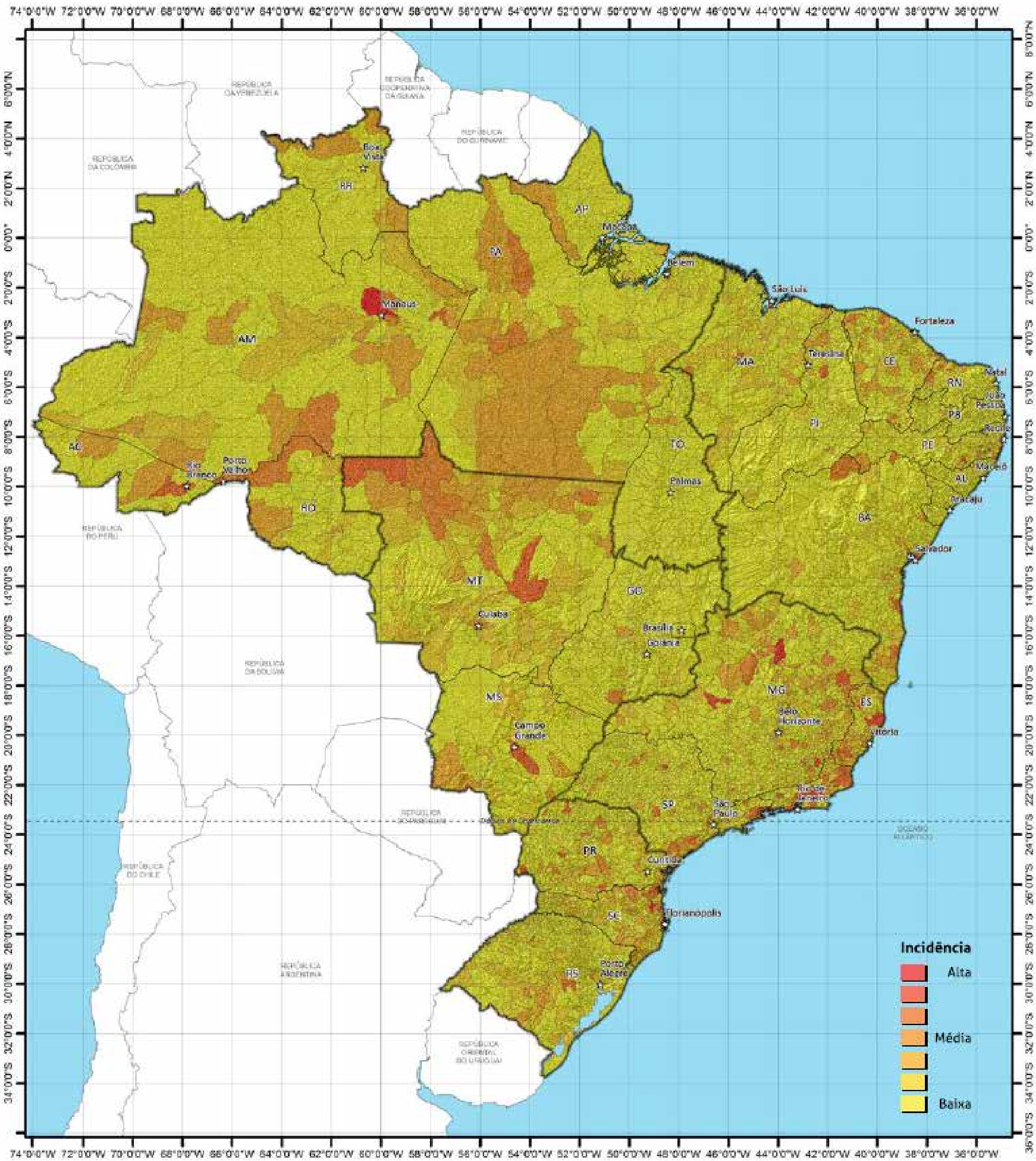
Landslides due to heavy rains have a significant impact on roads across Brazil. Map 1.2 shows the distribution of landslides from 1994 through 2012, where a clear polarization of the events toward southeastern Brazil can be observed. Most of the events materialized in the states of Rio de Janeiro (RJ), São Paulo (SP), and Minas Gerais (MG). The states of Santa Catarina (SC), Paraná (PR), Espiritu Santo (ES), and Bahia (BA) also suffered several landslides, although in a smaller proportion.

Map 1.2 Distribution of Landslides in Brazil, 1994–2012

Source: ©Center for Studies and Research in Engineering and Civil Defense, Federal University of Santa Catarina (CEPED UFSC 2013). Reproduced, with permission, from CEPED UFSC; further permission required for reuse.

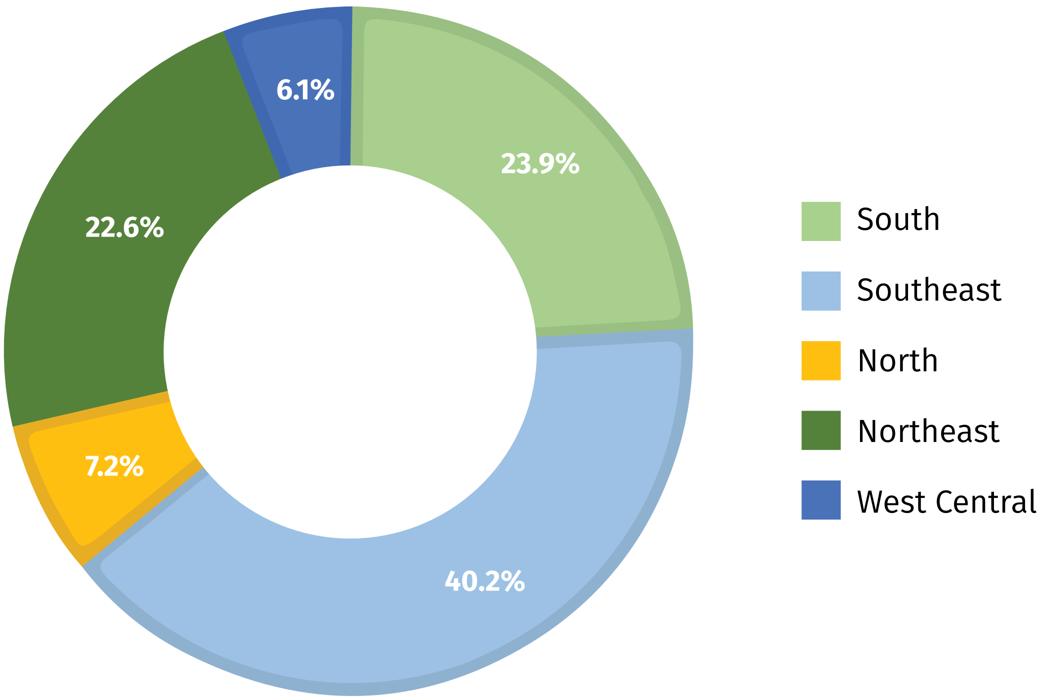
The way natural disasters are managed in Brazil has evolved throughout the years. The culture of monitoring and managing natural disasters has been ongoing since the 1940s, when Brazil implemented the first civil defense actions, structures, and strategies of protection and safety toward its citizens. Since then, the occurrence of numerous devastating natural disasters in the country has changed the way they are managed. Map 1.3 and figure 1.3 show the distribution and share of damage (R$, millions) to infrastructure by region.

Map 1.3 Distribution of Damage to Infrastructure in Brazil, 1995–2014



Source: World Bank 2016.

Figure 1.3 Share by Region of Damage to Infrastructure in Brazil, 1995–2014



Source: World Bank 2016.

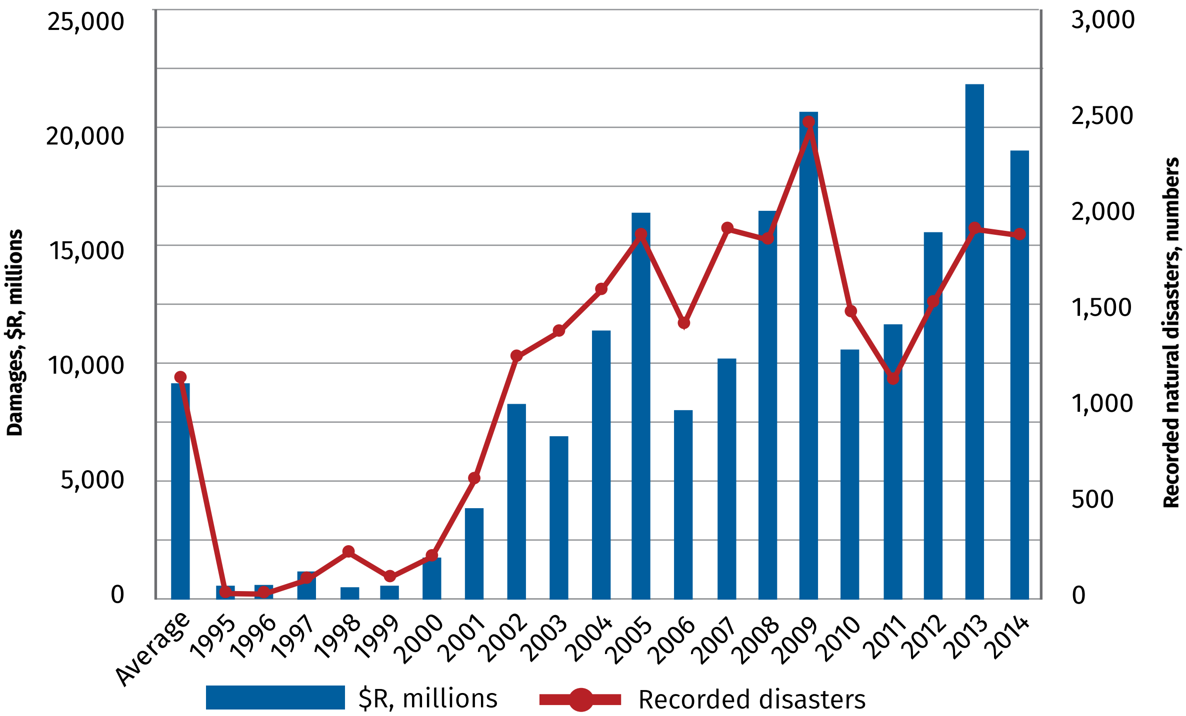
Although Brazil is the fifth largest country in the world, it has a relatively low number of natural hazards. However, its exposure to natural hazards has increased relative to other countries because of insufficient preventive actions in the past, resulting in more damage from natural hazards to both infrastructure and human lives than countries of comparable size would incur. For example, Brazilian building codes and maintenance of infrastructure are usually poor compared with other upper-middle-income countries, resulting in a disproportionally high amount of damage for a given severity of an event.

Catastrophic floods and landslides occurred in Santa Catarina in 2008, Pernambuco and Alagoas in 2010, and the Serrana region of Rio de Janeiro in 2011, resulting in combined estimated economic losses of about R$15.5 billion (US$4.2 billion). Even more worrisome, such results are partial in view of the limited data availability and the practical impossibility of evaluating all events recorded in a country (World Bank 2016).

More recently, the floods in the state of Paraná in 2016 affected 150,000 people; floods in Pernambuco and Alagoas in May 2017 forced a combined 69,000 people to leave their homes; and within the same week, floods in Rio Grande do Sul left more than 40,000 people homeless. This flooding is normally associated with intense and prolonged rainfall events during the rainy seasons: (a) summer in the South and Southeast regions, and (b) winter in the Northeast region. Figure 1.4 shows the total amount of damages and losses due to natural disasters from 1995 through 2014.

That economic losses were poorly accounted for in Brazil contributed to the idea that disasters were not a significant issue to be dealt with. Thus, Brazil has been considering floods and landslides as punctual problems that historically warranted a reactive approach, which consequently caused major setbacks for its regional and local sustainable development.

Figure 1.4 Total Annual Damages from Natural Disasters in Brazil, 1995–2014



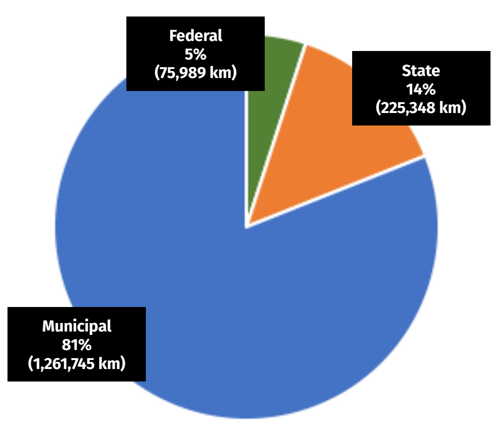
Source: World Bank 2016. / Note: R$ = Brazilian reais.

1.4 Road System in Brazil

The 2017–2018 Global Competitiveness Index Report by the World Economic Forum ranks Brazil 65th out of 137 countries in transport infrastructure development (WEF 2018). In spite of many government efforts and programs, Brazil's transportation matrix is still unbalanced, with 60 percent of goods transported by roads. Some of the core infrastructure has ended its useful life, and Brazil has opted for 20- to 30-year road concessions as a form of public-private partnership to remedy the situation.

Brazil is divided into federal, state, and municipal levels of government, and the road network is subdivided the same way, with each level of government having jurisdiction over its own road network. The country's overall road network is just over 1.5 million kilometers, distributed among government jurisdictions (Figure 1.5).

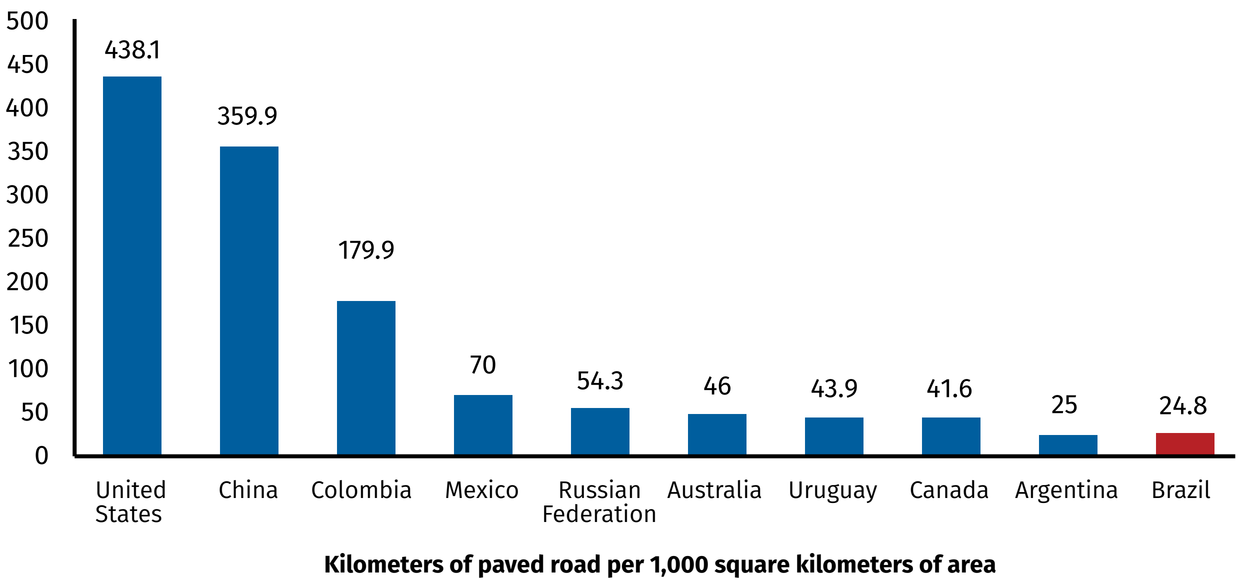
Figure 1.5 Road Network Distribution in Brazil, by Government Jurisdiction, 2015



Source: National Road System, National Department of Transportation Infrastructure (DNIT). https://www.dnit.gov.br/sistema-nacional-de-viacao/sistema-nacional-de-viacao.

Despite increasing numbers in recent years, the density of Brazil's total paved road network is still low, especially when compared with other countries of similar territorial size or even with some other Latin American countries. For example, Brazil has a density of approximately 24.8 kilometers of paved roads for every 1,000 square kilometers of area, a much lower road density than in China, Colombia, and the United States (figure 1.6) (CNT 2017).

Figure 1.6 Density of Paved Road Network, Selected Countries, 2017



Source: CNT 2017.

As noted earlier, some of the roads are operated and maintained by the private sector through concessions. As of 2016, about 20,000 kilometers of Brazilian roads (1.2 percent of the total road network) have been conceded to private investors (table 1.1). About half (10,000 kilometers) of the roads under concession are federal roads and belong to the federal highway system. This means that the equivalent of 15 percent of the federal road network has been conceded to the private sector. Photo 1.1 shows an example of a road under concession in Brazil.

Table 1.1 Total Brazilian Road Network, by Jurisdiction and Operation Status, 2016

Jurisdiction	Paved	Nonpaved	Total	Concessioned
Federal	55,817	11,459	67,276	10,123
State	110,424	105,601	225,348	9,323
Municipality	26,810	1,234,918	1,261,745	17
Planned links	—	—	157,309	—
Total	193,051	1,351,978	1,711,678	19,463

Source: World Bank. / Note: — = not available.

Photo 1.1 Example of a Road Concession in Brazil

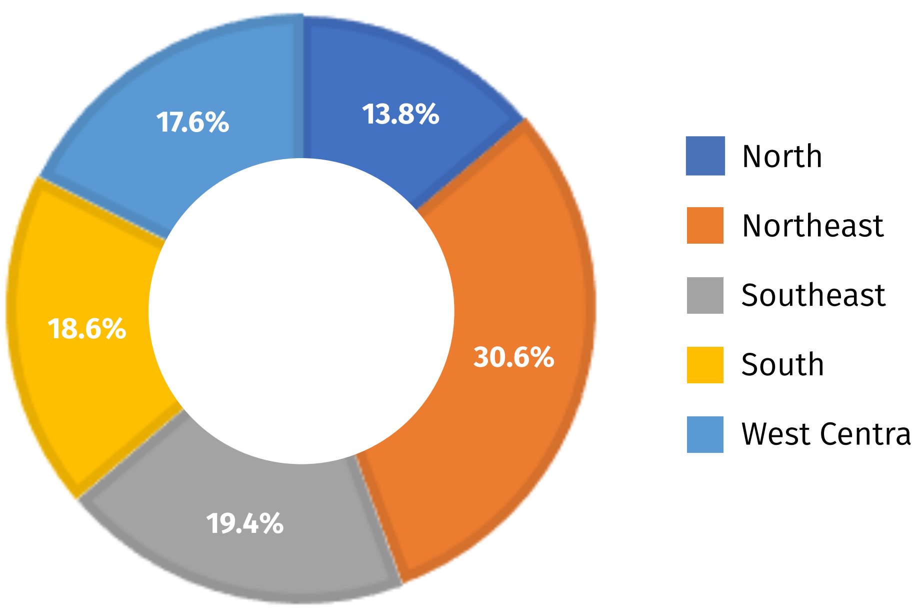
Source: ©Brazilian Association of Road Concessionaires (ABCR). Reproduced, with permission, from ABCR; further permission required for reuse. http://www.abcr.org.br:8090/pt/atuacao.html.

1.4.1 Federal Level

The National Department of Transportation Infrastructure (DNIT) is in charge of all nonconcession roads of the federal highway system, while the federal roads in concession are regulated by the National Agency for Ground Transportation (ANTT).

Of the total amount of the paved federal road network of 55,817 kilometers, the Northeast is the region with the largest extension of this type of infrastructure, with 19,865 kilometers, which represents 30.6 percent of the national total. The Southeast and South regions account for 12,565 kilometers and 12,039 kilometers, respectively, representing 19.4 percent and 18.6 percent of the federal paved highways (figure 1.7).

Figure 1.7 Share of Paved Federal Highway Extension in Brazil, by Region, 2017



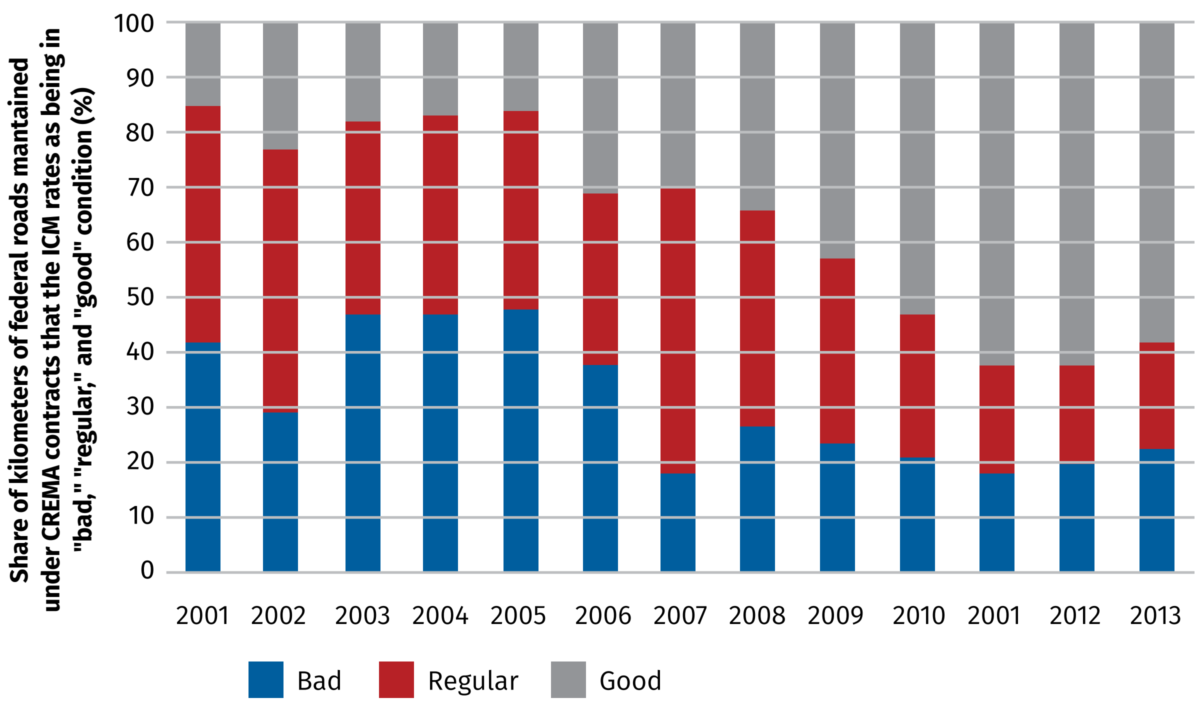
Source: CNT 2017.

Ninety-four percent of the DNIT paved road network is covered by different types of maintenance contracts that attend to pavement maintenance, rehabilitation, reconstruction, drainage, civil works, and projects under various programs. A Maintenance Condition Index (ICM) monitors the overall condition of the roads. Although these programs are not specifically designed for the prevention of natural disasters on roads, they directly or indirectly help to reduce the impact of natural disasters.

Following is a brief description of each program:

- ***Performance-Based Road Rehabilitation and Maintenance Contracts (CREMA).*** Since 2001 with the start of a pilot project, this program has attended to 101,643 kilometers of the federal paved road network. These contracts last from three to five years, during which the service level must be maintained (performance-based) even in the event of a natural disaster. The 2001–13 CREMA results indicate the overall condition of the paved road network attended to by the program (figure 1.8).

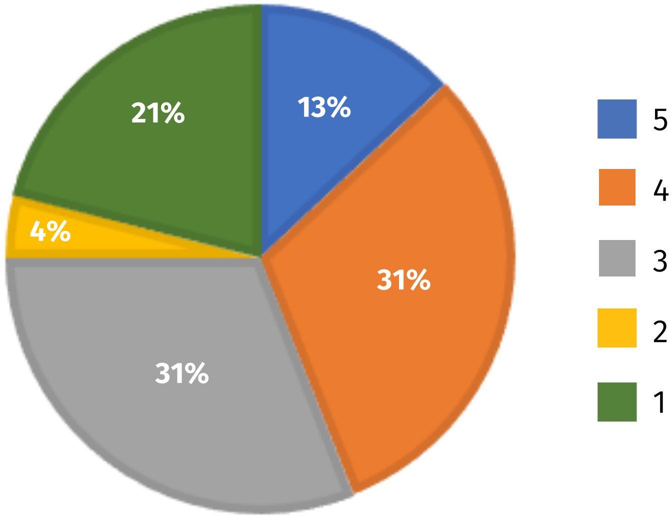
Figure 1.8 Condition of Brazilian Federal Roads Maintained under CREMA, 2001–13



Source: DNIT 2017.
Note: CREMA = Performance-Based Road Rehabilitation and Maintenance Contracts program. ICM = Maintenance Condition Index.

- ***Structural Maintenance and Rehabilitation Program (PROARTE).*** This program has the purpose of eliminating structural and functional deficiencies through rehabilitation and to make sure the structures meet life expectancy through ongoing maintenance. In addition to bridges, overpasses, and walkways, it also includes tunnels and retaining walls. The program has inspected 4,885 structures in 24 out of the 27 states (including the federal district) on the federal paved network. Figure 1.9 shows the ratings of the structures inspected, from 5 (best) to 1 (worst).
- ***Annual Work and Budget Plan (PATO).*** This program for routine and preventive maintenance also attends to drainage structures on the side of the road. The result of this program is an annual work plan that establishes the quantities of the work needed.

Figure 1.9 Distribution of PROARTE Ratings of Federal Road Network Structures in Brazil



Source: DNIT 2017.
Note: PROARTE = Structural Maintenance and Rehabilitation Program. Structural ratings range from 5 (best) to 1 (worst).

1.4.2 São Paulo State Level

The highway system of São Paulo is the largest statewide road transportation system in Brazil, with a total of 34,650 kilometers of roads comprising municipal (11,600 kilometers), state (22,000 kilometers), and federal (1,050 kilometers) roads. More than 90 percent of the population lives within 5 kilometers of a paved road. The state also has the largest number of two-, four-, and six-lane highways in Latin America. According to the National Confederation of Transport (CNT), São Paulo state has the best-maintained highway grid in the country, with 59.4 percent classified as excellent.

São Paulo state has a major component of a critical infrastructure, namely the link between Planalto and Baixada Santista (ligação Planalto–Baixada Santista). This is a complex highway network that connects the coastal region and the Port of Santos to the São Paulo metropolitan area. An estimated 25 percent of national GDP depends on the Anchieta-Imigrantes complex (map 1.4), and almost all passenger trips and 90 percent of freight shippers use it to move between the port and São Paulo.

Map 1.4 Anchieta-Imigrantes Complex of the Ligação Planalto–Baixada Santista Transportation Network, São Paulo State

Source: World Bank 2013a.

The São Paulo State Public Transportation Regulatory Agency (ARTESP) is a state authority responsible for regulating and supervising the Road Concession Program, the Intermunicipal Collective Transportation of Passengers, and all public transportation services delegated in the state of São Paulo. ARTESP was created in 2002, although the Road Concession Program for the state of São Paulo started in 1998 and was divided into two phases:

- ***Phase I (1998):*** Concession awarded to 12 road concessionaires responsible for a combined total of 3,600 kilometers over 20 years
- ***Phase II (2008):*** Concession awarded to five road concessionaires responsible for a combined total of 1,715 kilometers over 30 years.

1.4.3 Geohazards on Roads in Brazil

Brazil faces an increasing risk of natural disasters, in particular floods and landslides (photo 1.2). A recent Global Facility for Disaster Reduction and Recovery (GFDRR)-funded study showed that approximately US$5 billion was lost in the four major flood and landslide disasters in the past five years, with damage to transport infrastructure amounting to 20 percent (US$0.9 billion) of total costs (World Bank 2016).[1] Although insufficient data and studies prevent a complete understanding of disaster damages in the entire country, natural disaster incidents have increased for the past 10 years.

Photo 1.2 Landslide Damage to Mogi-Bertioga Road, São Paulo State, April 2018

Source: ©Jonny Ueda / ALESP / Dep. Gondim

Although road infrastructure is the most important transport mode in Brazil—transporting 95 percent of passenger trips and 61 percent of cargo—the country's disaster risk management (DRM) agenda is nascent, confined to a few specialized agencies (civil protection) and focusing only on emergency response.

Of the numerous transport projects that are developed in Brazil every year, few (if any) are strongly concerned about ensuring the application of DRM practices holistically. Some might consider common engineering approaches, such as the use of flood modeling information for the structural design of infrastructures, but a comprehensive approach under a DRM strategy is seldom observed.

The increasing frequency of natural disasters and their dramatic impact on infrastructure slowly raises awareness of the DRM agenda, on monitoring and prevention in particular, among transport infrastructure managers. Yet, there are strong needs to mainstream DRM practices during the planning and operating phases to deal with increasing natural disaster risks to mitigate huge potential economic losses.

[1] "Damage Report: Material Damages and Losses due to Natural Disasters in Brazil, 1995–2014" (World Bank 2016) intends to deepen the studies initiated by the World Bank and the Center for Studies and Research in Engineering and Civil Defense, Federal University of Santa Catarina (CEPED UFSC), organizing data on material damages and losses due to natural disasters in Brazil between 1995 and 2014 and based on the information reported by the municipalities to the states and the union.

PART II

ROAD GEOHAZARD RISK MANAGEMENT

2 INSTITUTIONAL CAPACITY AND COORDINATION

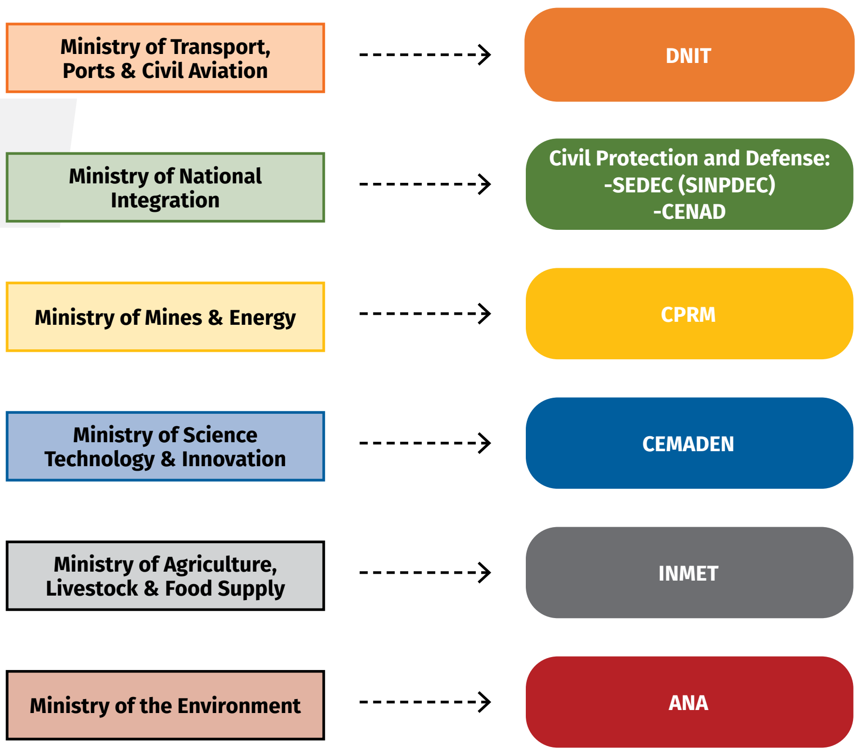
2.1 Institutional Framework

To understand the road geohazard risk management framework in Brazil, there is a need to first understand the different institutions involved in the process, both at the federal and São Paulo state levels. The federal government and its institutions are very different from the ones in any other state in Brazil, particularly from São Paulo state, which is considered one of the best states in Brazil in terms of institutional capacities.

2.1.1 Federal Level

The key federal entities involved in geohazard management and response are outlined in the figure 2.1 note, with further explanation of their roles below.

Figure 2.1 Federal Organizations with Roles in Road Geohazard Risk Management in Brazil



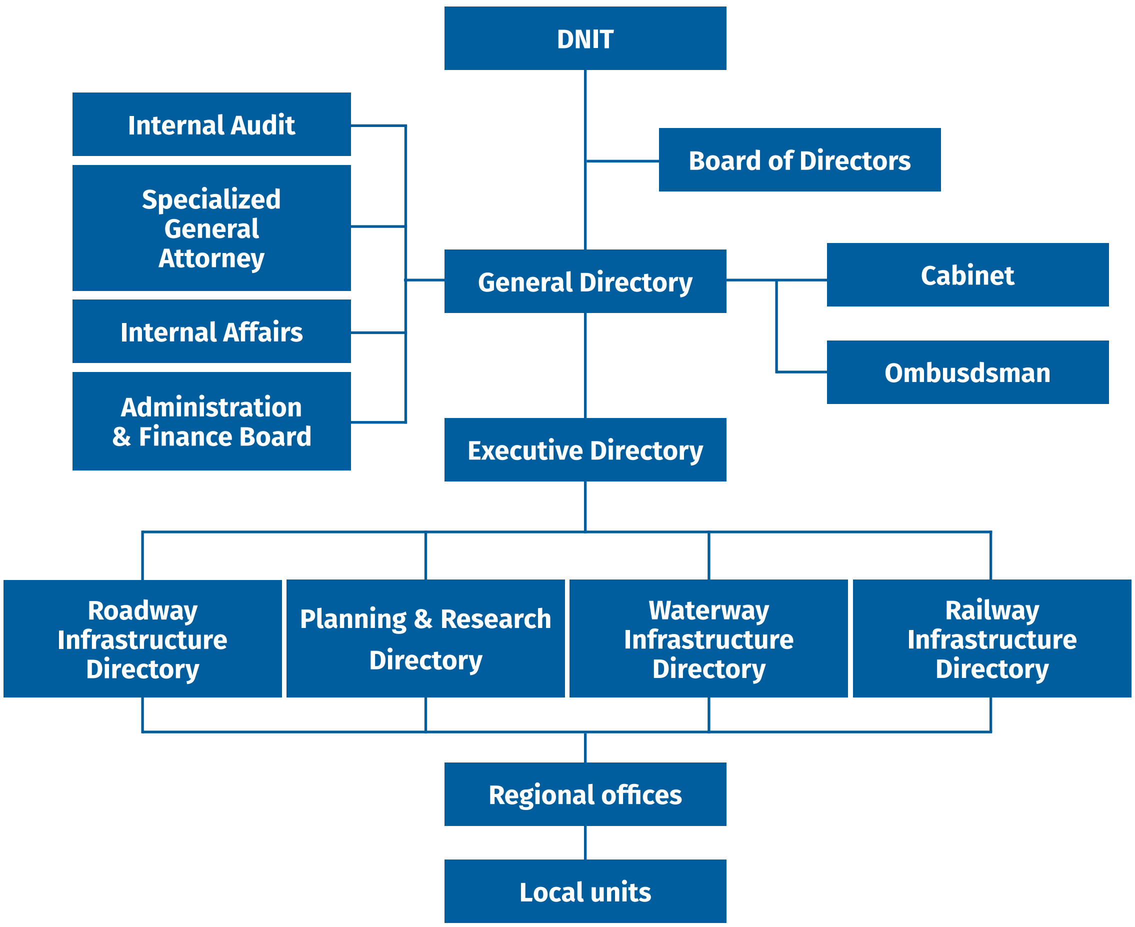
Note: ANA = National Water Agency. CEMADEN = National Center for Natural Disaster Monitoring and Alerts. CENAD = National Center for Risk and Disaster Management. CPRM = Mineral Resources Research Company. DNIT = National Department of Transportation Infrastructure. INMET = National Meteorological Institute. SEDEC = National Secretariat for Civil Protection and Defense. SINPDEC = National Civil Protection and Defense System.

National Department of Transport Infrastructure (DNIT). DNIT is a Brazilian federal authority under the Ministry of Transport, Ports and Civil Aviation. It was created by Law No. 10,233 of June 5, 2001, which restructured the land and water transportation system of Brazil and abolished the former National Department of Roadways (DNER).

The DNIT is responsible for the maintenance, expansion, construction, supervision, and preparation of technical studies for the resolution of problems related to the federal highway system, as well as for the multimodal traffic of people and goods in the modalities of roads, rails, and waterways.

There is a regional DNIT office in every state, including for the federal district where the DNIT headquarters is located, which is supported by the regional office from the state of Goiás. Each regional office is supported by strategically located local units throughout the state, where the number of units varies in accordance with the size of the federal road network. For example, the state of Sergipe has the smallest network with 319 kilometers and one local unit, while the state of Minas Gerais has the largest network with 8,711 kilometers and 18 local units throughout the state. These local units work as first responders to all transportation infrastructure issues under the DNIT's jurisdiction.

Figure 2.2 DNIT Organizational Chart



Source: Organizational chart, DNIT website: http://www.dnit.gov.br.
Note: DNIT = National Department of Transportation Infrastructure.

National Civil Protection and Defense System (SINPDEC). Civil protection and defense in Brazil, legally constituted by Law No. 12,608 of April 10, 2012, is organized in the form of SINPDEC, which comprises a set of multisectoral bodies that use a matrix concept with vertical and horizontal dynamics throughout the national territory.

National Secretariat for Civil Protection and Defense (SEDEC). SEDEC is the central body of SINPDEC, responsible for coordinating civil protection and defense actions throughout the national territory. Its aim is to reduce the risks of disasters. It also includes prevention, mitigation, preparedness, response, and recovery actions that take place in a multisectoral manner at the federal, state, and municipal levels of government, with broad community participation.

National Center for Risk and Disaster Management (CENAD). CENAD was created in February 2005, through Decree No. 5,376, to manage, with agility, strategic actions to prepare and respond to disasters in the national territory and, eventually, also internationally.

Coordinated by SEDEC within the Ministry of National Integration, the current structure of the organization has two work fronts: (a) "articulation, strategy, structuring, and continuous improvement"; and (b) "permanent action of monitoring, alert, information, mobilization, and response." The first is responsible for the preparation and response to disasters, and its main activity is the mobilization to care for the victims. The second work front corresponds to the constant monitoring of information about possible disasters in risk areas, with the objective of reducing impacts and preparing the population.

CENAD is responsible for consolidating information on risks in the country, such as maps of landslide and flood risk areas as well as data on the occurrence of natural and technological disasters and associated damages. Managing this information enables the center to support states and municipalities in disaster preparedness actions among the most vulnerable communities.

CENAD's operating dynamics consists of receiving information from various federal government agencies responsible for predicting time and temperature; assessing geological conditions in hazardous areas; monitoring the movement of tectonic plates; monitoring river basins; controlling forest fires; and transporting and storing hazardous products. CENAD evaluates and processes the information and forwards it to the civil protection and defense agencies of the states and municipalities under disaster risk.

CENAD is responsible for the federal coordination of disaster response actions within SINPDEC; its representativeness in committees and commissions related to risks and disasters has an important role in the planning and mobilization of response actions at the national level.

Mineral Resources Research Company (CPRM). CPRM is legally bound to act as Brazil's official agency for gathering data and information on Brazilian geology, minerals, and water resources. It manages a complex set of databases and theme-based georeferenced information systems as well as a vast collection of documents, maps, and images, which it puts at the public's disposal.

The company was set up in 1969 with a mix of state and private ownership. With the onset of challenging circumstances in the nation, especially as of the second half of the 1980s, CPRM underwent deep-rooted institutional changes that culminated in Law No. 8,970, of December 27, 1994, which made it entirely state-owned. This changed things on a practical level because all private service provision ceased, and the company took on its current role as the nation's geological survey. The focus shifted to basic geology and hydrology, with the concomitant development of different applications, such as environmental geology, hydrogeology, and geological hazards. All corporate activities were halted, and institutional partnerships with other federal, state, and local government agencies became the order of the day.

CPRM has operational offices throughout Brazil. Eight regional offices are located where projects are carried out and where most of the institution's operations are centered: in Manaus (Amazonas), Belém (Pará), Recife (Pernambuco), Goiânia (Goiás), Salvador (Bahia), Belo Horizonte (Minas Gerais), São Paulo (São Paulo), and Porto Alegre (Rio Grande do Sul). Another three smaller operation facilities are in Porto Velho (Rondônia), Teresina (Piauí), and Fortaleza (Ceará). Three support centers, or small offices, provide representation and operational support in Natal (Rio Grande do Norte), Cuiabá (Mato Grosso), and Criciúma (Santa Catarina). The company's political headquarters is in Brasília, while the main administrative office and technical departments are in Rio de Janeiro. CPRM's three training centers are in Apiaí (São Paulo), Morro do Chapéu (Bahia), and Caçapava do Sul (Rio Grande do Sul).

National Center for Natural Disaster Monitoring and Alerts (CEMADEN). CEMADEN is responsible for the prevention of natural disasters in Brazil and the management of governmental action when they do occur. This center is linked to the Ministry of Science, Technology, Innovation and Communication (MCTI).

Created in 2011 and installed in the city of Cachoeira Paulista, in the state of São Paulo, this center is responsible for managing the information emitted by meteorological radars, rain gauges, and data from climate forecasts. By passing information to competent bodies throughout Brazil, it aims to anticipate possible occurrences of meteorological conditions that could lead to a natural disaster.

CEMADEN became effectively operational on December 2, 2011, and has since issued alerts to CENAD. CEMADEN's researchers and technologists work with high-resolution satellite imagery and a host of high-tech equipment such as weather radars, data collection platforms, and soil analysis equipment to prevent events such as floods and landslides.

National Institute of Meteorology (INMET). INMET, Brazil's meteorological institute, is part of the Ministry of Agriculture, Livestock and Food Supply. Its mission is to provide meteorological information to Brazilian society and to influence the decision-making process, contributing to the country's sustainable development. This mission is achieved through monitoring, analysis, and prediction of weather and climate, which are based on applied research, working in partnership, and sharing knowledge, emphasizing practical and reliable results.

National Water Agency (ANA). ANA is legally liable for implementing the National Water Resources Management System (SINGREH) and was created to ensure the sustainable use of Brazilian rivers and lakes for the current and future generations.

This mission implies the regulation of water use according to the mechanisms established by Law No. 9,433 of 1997, among which the following stand out: (a) the granting of rights to the use of water resources aimed at disciplining the use of water bodies in relation to the collection of water and discharging of effluents; (b) inspection to ensure that the grants are licenses effectively respected and not mere notarial formalisms; and (c) the charge for use of water, to ensure that the water bodies are used with parsimony, in addition to enabling the generation of the necessary financial resources to recover and conserve rivers and lakes.

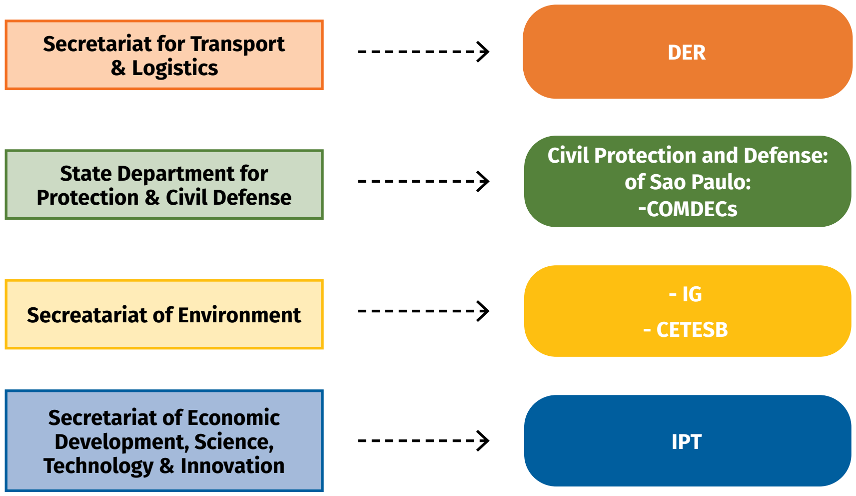
These three mechanisms have been implemented in an articulated manner in each river basin, which requires harmony between ANA and the water managing bodies and entities of the state governments, because Brazilian rivers are under the domain of both the federal government and the states.

However, ANA's regulatory scope reaches other management tools that are also relevant to the effective performance of SINGREH and represent the grounds for the good water management in Brazil. In this regard, the agency carries out actions of management support, monitoring, and planning of water resources, in addition to offering Information for improvement of the performance of the water resources management agencies and of the sectors that use these resources.

2.1.2 São Paulo State Level

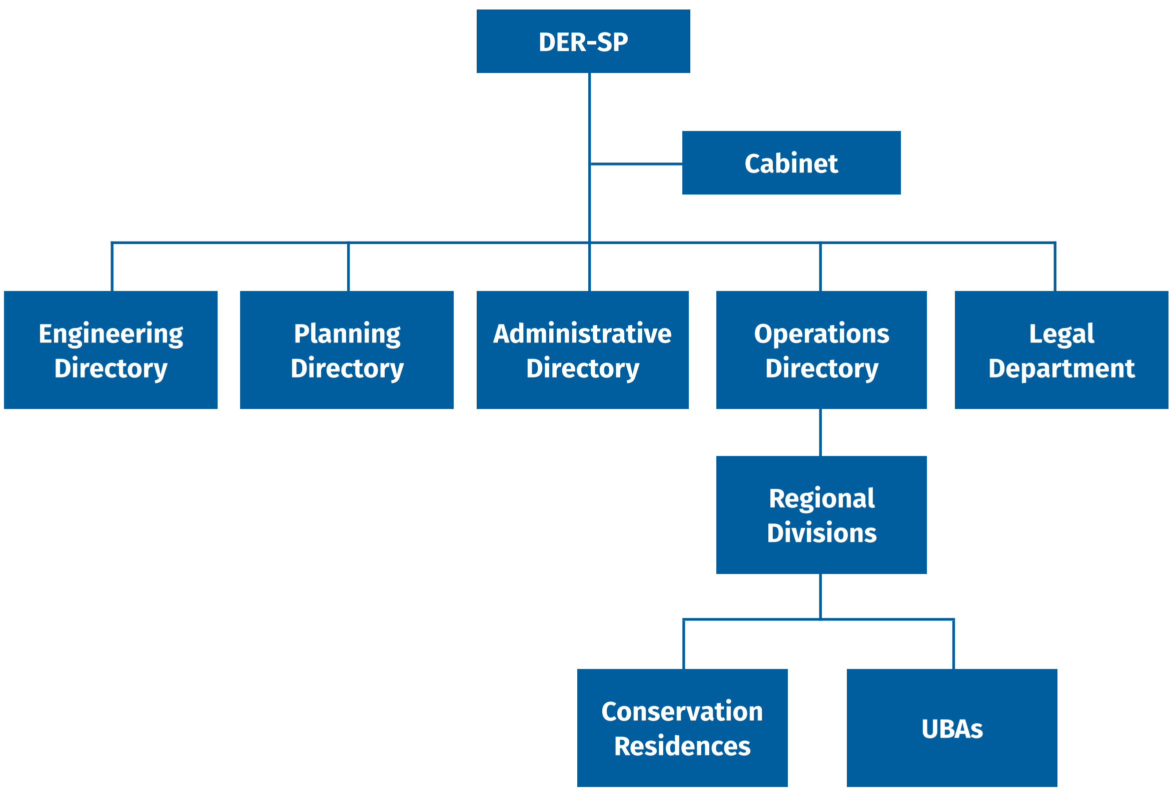
The state of São Paulo has its own institutions in charge of dealing with disaster risk management (DRM) in the transport sector. Figure 2.3 shows the relation between those key institutions, and each institution's responsibilities in the DRM context is also described below.

Figure 2.3 State of São Paulo Organizations with Roles in Road Geohazard Risk Management



Note: CETESB = Environmental Company of the State of São Paulo. COMDECs = Commissions of Civil Defense. DER = Department of Roads. IG = Geological Institute. IPT = Institute of Technological Research.

Figure 2.4 São Paulo DER Organizational Chart



Source: Source: Organizational chart, DNIT website: http://www.dnit.gov.br.
Note: DER-SP = Department of Roads of the State of São Paulo. UBAs = basic territorial units.

Department of Roads of São Paulo (DER-SP). As it happens at the federal level, the road agency is a key institution in the state of São Paulo. It is DER's mission to administer the state road network system, its integration with the municipal and federal highways, and its interaction with other modes of transportation, aiming at assisting users in the transportation of people and cargo. It operates under the Secretariat for Transport and Logistics of the state of São Paulo.

In 1999 the first basic territorial units (UBAs) were created. The UBAs' organizational structure sought to be compatible with the existing structure of the conservation residences of the DER's 14 regional divisions, incorporating user assistance services into the road operation ones. Figure 2.4 presents the organizational chart of the DER.

With preventive actions to ensure a gradual and systematic reduction of accidents, the UBAs aim at the full utilization of highway capacity, traffic flow, safety, and comfort to users. Through road inspection services, UBAs seek to detect and eliminate any pavement or signaling irregularities and other interferences on highways to restore their safety conditions.

Civil Protection and Defense of São Paulo (DC). Civil defense has state-level offices all over Brazil for a more efficient and effective response to disasters. In São Paulo, DC has continuing working relationships with the Environmental Company of the State of São Paulo (CETESB), the Geological Institute (IG), the Institute of Technological Research of the State of São Paulo (IPT), the Basic Sanitation Company of the State of São Paulo S.A (SABESP), and other state emergency response institutions like the police, fire department, and ambulance services. Some of these institutions are further described below.

In São Paulo, the heavy rains and the great flood of Caraguatatuba (1967) and the fires of the Andraus and Joelma Buildings (1972 and 1974, respectively) caused hundreds of deaths because of unpreparedness and lack of coordination. Thus, DC emerged as a coordinating body for disaster prevention and response, with the participation and involvement of government agencies and entities as well as the entire community.

In the municipalities of São Paulo, Municipal Commissions of Civil Defense (COMDECs) act locally. Among their duties are to (a) participate, together with the competent sectors, in the elaboration of municipal public policies for prevention, minimization, monitoring, and assistance of environmental impacts on private and public persons and collective goods; (b) elaborate and coordinate specific contingency plans for existing environmental risks in the city of São Paulo; (c) coordinate and supervise the actions of civil defense; and (d) keep information related to civil defense up-to-date and available.

Geological Institute of São Paulo (IG). The IG is a public agency of the state of São Paulo, responsible for conducting scientific research on geosciences and the environment, as well as for generating the necessary knowledge to implement public policies in the state. Since 1986, it has operated within the Secretariat of Environment of the state of São Paulo.

The IG, in line with the coordinating bodies of the State Environmental System, works mainly in the following areas: underground water, mineral resources, natural disasters, environmental pollution, territorial zoning, management of conservation units, basic surveys in geosciences, information management systems, and environmental education. The IG's research in the various areas is applied toward solving emerging environmental problems and providing services to the population. Its work is fundamental in issues related to territorial planning, land use and occupation, mining, geological hazards, and groundwater, among others.

Environmental Company of the State of São Paulo (CETESB). The CETESB is the government agency of the state of São Paulo responsible for the control, supervision, monitoring, and licensing of pollution-generating activities, fundamentally concerned with preserving and recovering the quality of water, air, and soil. Along with the IG, the CETESB works under the supervision of the Secretariat of Environment of the state of São Paulo.

Institute for Technological Research of the State of São Paulo (IPT). The IPT was founded in 1899 as the Office of Resistance of Materials of the Polytechnic School of the University of São Paulo. It is a public research institute under the Secretariat of Economic Development, Science, Technology and Innovation of the state of São Paulo and offers technological support to industry and public policies.

The institute has 38 laboratories working in four main areas: innovation, research, and development; technological services; metrological development and support; and information and technology education. It operates in a multidisciplinary way, covering sectors as diverse as energy, transport, oil and gas, environment, civil construction, cities, and security.

The IPT laboratories are organized in 12 technology centers. One of the laboratories focuses on IPT's Natural Investigations, Risks and Disasters Section (SIRDEN). Below we describe the two IPT centers most relevant to our topic:

- ***Center of Infrastructure Works Technology (CT-Obras):*** Provides technological support and solutions to problems related to different civil construction materials (concrete, asphalt, soil, and coatings); pathologies in the areas of pavements, structures, works of art and the like; and characterization and investigation of the geological-geotechnical availability of mineral resources.
- ***Center for Geoenvironmental Technologies (CTGeo):*** Provides technological solutions based on sustainability concepts, working mainly on environmental aspects of the physical environment. It focuses on the development of technologies and projects for environmental management, evaluation, and monitoring.

2.1.3 Municipal Level

Brazil has more than 5,570 municipalities, ranging in population from 834 (Borá) to 12.1 million (São Paulo) inhabitants. Owing to lack of resources and coordination, municipalities rely heavily on municipal Commissions of Civil Defense (COMDECs) to confront natural disasters.

COMDECs help municipalities articulate, coordinate, and manage civil defense actions in addition to promoting broad community participation, especially in planning, response, and reconstruction activities. They are key to interconnecting operation centers and increasing the monitoring, alerting, and alarming activities needed to optimize disaster prediction. COMDECs are also empowered to create civil defense districts—or corresponding bodies—that will integrate their own structure, defining assignments to articulate and execute civil defense actions in specific areas such as districts and neighborhoods.

2.2 Laws, Regulations, and Technical Standards

Brazil does not yet have a law or plan that relates and directly integrates DRM into the country's transport sector. However, there is a positive evolution in both areas that will facilitate their integration in the future. The key laws and regulations (at both federal and state levels) that changed how natural disasters are treated in Brazil, as well as the ones that have directly influenced the transport sector, are discussed below.

2.2.1 Federal Level

Transport institutions. In 1998, as part of a federal government effort to improve Brazil's transportation infrastructure, the National Department of Roadways (DNER) was authorized to contract, in the form of concession, the construction and conservation of roads. The same law (No. 10,233) that in 2001 replaced the DNER with the DNIT also created the National Agency for Ground Transportation (ANTT) and the National Agency for Waterway Transportation (ANTAQ) as regulating agencies under the Ministry of Transport, Ports and Civil Aviation.

National Environmental System (SISNAMA). SISNAMA was instituted by Law 6,938, dated August 31, 1981, and regulated by Decree 99.274 of June 6, 1990. The National Environmental Council (CONAMA) has representatives from five sectors: federal, state, and municipal agencies; business; and civil society. On December 19, 1997, through Resolution No. 237, CONAMA made it necessary for road constructions to have environmental licenses. In addition to road construction, this resolution applies to other modes of transportation and civil works in general, such as the following:

- Railroads, waterways, and metropolitan transport
- Dams and dikes
- Drainage channels
- Rectification of waterways
- Opening of channels and bars
- Transposition of watersheds.

To ensure that environmental impact will be minimal and consequently avoid road geohazards, the public agency responsible for issuing the licenses will do it in three stages:

1) ***Preliminary License (LP):*** In the preliminary phase of planning, approves the location and concept, attesting to its viability
2) ***Installation License (LI):*** Authorizes the installation of the works in accordance with the approved projects
3) ***Operation License (LO):*** Authorizes the operation of activities or works.

National Center for Risk and Disaster Management (CENAD). In 1988, the National System of Civil Defense (SINDEC) organized the civil defense in Brazil in a systemic way. SINDEC was reformulated in August 1993 and updated in February 2005 by Decree No. 5,376/05, with the creation of CENAD and the Disaster Support Group as well as the strengthening of civil defense in the municipalities. Decree No. 5,376/05 decentralized the actions of the civil defense. Responsibility began to be shared among federal, state, and municipal governments.

The current structure of the organization has two work fronts: "articulation, strategy, structuring and continuous improvement" and "permanent action of monitoring, alert, information, mobilization and response." The first is responsible for the preparation and response to disasters, and its main activity is the mobilization to assist the victims. The second work front corresponds to the constant monitoring of information about possible disasters in risk areas, with the purpose of reducing impacts and warning the population.

The establishment in 1994 of the National Council of Civil Defense (CONDEC) has broadened the scope of civil defense action in the country. In addition, in 2011, communities gained greater participation through Community Centers for Civil Defense (NUDECs), bringing about a cultural change in citizen awareness of the importance of increasing their own security.

National Policy on Climate Change (PNMC). The PNMC makes official Brazil's voluntary commitment to the United Nations (UN) Framework Convention on Climate Change to reduce greenhouse gas emissions by 36.1–38.9 percent of projected emissions by 2020, compared with the 2000 levels. Instituted in 2009 by Law No. 12,187, the PNMC seeks to ensure that economic and social development contribute to the protection of the global climate system.

Decree No. 7,390/2010, which regulates the PNMC, estimates the baseline greenhouse gas emissions for 2020 at 3,236 GtCO2-eq (gigatons of carbon dioxide equivalent). Thus, the corresponding absolute reduction was established between 1,168 GtCO2-eq and 1,259 GtCO2-eq, which amounts to 36.1 percent and 38.9 percent reduction of emissions, respectively. To help achieve the reduction targets, the law establishes the development of sectoral mitigation and adaptation plans at the local, regional, and national levels.

The goals achieved by the PNMC should be harmonized with sustainable development—seeking economic growth, eradicating poverty, and reducing social inequalities. To achieve these objectives, the law establishes some guidelines, such as promoting practices that effectively reduce greenhouse gas emissions and encouraging the adoption of low-emission activities and technologies as well as sustainable production and consumption patterns.

National Policy of Protection and Civil Defense (PNPDEC). Federal Law No. 12,608, dated April 4, 2012, establishes the National Policy of Protection and Civil Defense and authorizes the creation of an information system and a disaster monitoring system. The law provides for articulated action between the federal level, states, and municipalities; a systemic approach; prioritization of preventive actions; the adoption of river basins as a unit of analysis; planning based on research and studies; and the participation of civil society. The act's provisions cover natural hazards of geological and hydrological origin as well as biological, nuclear, and chemical hazards.

PNPDEC must institute and maintain a national register of municipalities with areas susceptible to high-impact landslides, sudden floods, or related geological or hydrological processes. States and municipalities should identify and map areas of risk and conduct studies to identify threats, susceptibilities, and vulnerabilities. This measure must be accompanied by meteorological, hydrological, and geological monitoring of risk areas.

It is compulsory for the registered municipalities to prepare geotechnical charts of suitability for urbanization, which would support the establishment of urban planning guidelines for the safety of new subdivisions and which will be a key element when the urban perimeter is expanded. These charts should be incorporated into the master plans of the municipalities, which should also contain the mapping of risk areas.

2.2.2 São Paulo State Level

Preventive Plan of Civil Defense (PPDC). Specifically to address landslides on the mountain ranges of the Serra do Mar in the state of São Paulo (State Decree No. 30,860, dated December 4, 1989, and redefined by State Decree No. 42,565, dated 12/01/1997), the PPDC began in the summers of 1988 and 1989, initially covering eight municipalities with territories in proximity to Serra do Mar.

The PPDC is an instrument for coexisting with risk. It aims to subsidize the preventive actions of the municipal and state public authorities regarding the mitigation of problems caused by occupation in risk areas. The main objective is to preserve life through the preventive and temporary evacuation of the population that occupies the risk areas before the landslides reach their dwellings.

This plan comes into operation annually in the summer (December to March), when more frequent and intense rains occur in the southeast region of the state. It works with four levels of operation—observation, attention, alert, and maximum alert—where the actions of each agent, at each level of operation, are broken down in detail. It involves actions to monitor the rainfall indexes and the meteorological forecast, as well as field surveys and emergency services. Currently, the PPDC is implemented in 129 municipalities and is coordinated by the State Coordination of Civil Defense (CEDEC).

State Policy on Climate Change (PEMC). In 2009, the state of São Paulo adopted the PEMC to establish the state's commitment to the challenges of climate change. It is one of the few laws in the world that addresses the importance of climate change in the political sphere in a progressive and inclusive way. It covers innovative ideas such as the “polluter pays” principle, civil society participation, government responsibility, international cooperation, transparency, links between the environment and poverty, and actions recommended to other secretariats in the context of climate change.

The PEMC’s objective is to establish the state's commitment to the challenge of global climate change, to provide the necessary conditions for adaptations to the impacts of climate change, and to contribute to reducing or stabilizing the concentration of greenhouse gases in the atmosphere. The law considers the following topics, among others: (a) strategic environmental assessment or ecological-economic zoning; (b) control of land use; (c) licensing, prevention, and control of environmental impacts; (d) sustainable transport; and (e) DRM.

State Program for the Prevention of Natural Disasters and Reduction of Geological Risks (PDN). As one of the applications of the PEMC, State Decree No. 57,512, of November 11, 2011, created the PDN to address disaster risk prevention in a broad and articulated way. It aims to reduce vulnerabilities, minimize losses, and increase the state’s capacity to cope with emergencies and existing risks. This program will be further explained in section 2.3.2.

2.3 National and Subnational Plans and Strategies

National and subnational plans and strategies have evolved together with the abovementioned laws and regulations. Every new plan at the federal and state level tries to improve how natural disasters and the transport sector are treated. Even though there is still missing a broad integrated plan that jointly embraces the transport sector and natural disaster risk management, the two areas are getting closer and closer with time. The key plans and strategies carried out by the federal and São Paulo state governments are described below.

2.3.1 Federal Level

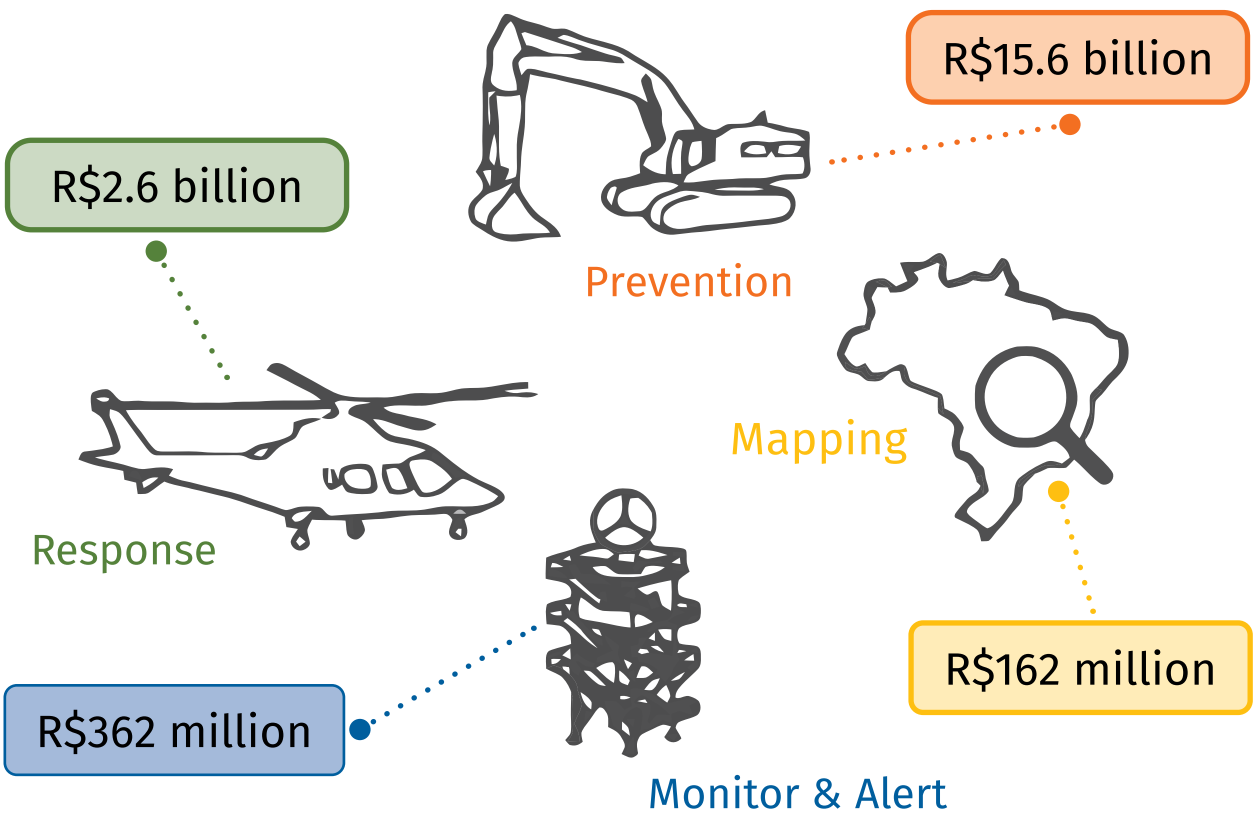
National Plan for Risk Management and Response to Natural Disasters. On August 2012, the president of the republic, Dilma Rousseff, launched the National Plan for Risk Management and Response to Natural Disasters 2012–2014, which provides for the identification of high-risk landslide, flood, and flash flood areas in 821 municipalities all over Brazil. The prioritization was made considering the areas that had suffered the most from natural disasters in the preceding 20 years.

According to the government, this mapping would prevent natural disaster-affected regions and would contribute to the assessment of the investments needed to avoid more tragedies.

The plan included (a) prevention, which includes works in more vulnerable municipalities, such as drainage; (b) mapping, surveying hazardous areas where landslides and floods could occur; (c) monitoring and alerting of climatic events; and (d) rescue, assistance, evacuation of areas.

In 2014, investments of nearly R$18.8 billion (US$4.8 billion) were planned in prevention works, purchase of equipment, monitoring of areas at risk, and issuing warnings about the proximity of a natural disaster (figure 2.5). The plan foresaw the expansion of the observation network with the acquisition of nine radars, 4,100 rain gauges, 286 hydrological stations, 100 agrometeorological stations, 286 geotechnical assemblies, and 500 soil moisture sensors.

Figure 2.5 Planned 2014 Investments of the National Plan for Risk Management and Response to Natural Disasters



In 2017, national efforts toward developing DRM continued. Twenty urban drainage projects were completed in critical municipalities, with a total value of R$594.87 million. Together with the 19 projects completed in 2016, a total of 39 projects were completed between 2016 and 2017. In addition, 155 drainage projects were in progress, totaling R$9 billion in investments.

As for alert and monitoring initiatives, CEMADEN made progress in identifying 98 percent of the triggering conditions of the natural disasters that had been recognized as emergency situations or states of public calamity by the Ministry of National Integration. In 2017, 151 maps were completed in support of natural disaster prevention.

National Adaptation Plan (PNA). The purpose of the Brazilian Federal Government's National Adaptation Plan (PNA) is to guide initiatives for management and reduction of long-term climate risks, as established in the Ministry of Environment (MMA) Order No. 150 of May 10, 2016, published in the Official Diary of the Union (DOU) of May 11, 2016. The plan was drawn up by the Executive Group of the Interministerial Committee on Climate Change (GEx-CIM) between 2013 and 2016, as provided for in the National Policy for Climate Change (PNMC, Law No. 12,187/09) and its enabling decree (Decree No. 7,390/10). The PNA was drawn up in consonance with the PNMC, with sectoral mitigation and adaptation plans, and with decisions on adaptation undertaken by Brazil within the framework of the Conference of the Parties (COP 21) of the UN Framework Convention on Climate Change.

Sectorization of high and very high risk of landslides and floods. Starting in 2012, the national and federal risk reduction policy began to develop a "high" and "very high" risk sectorization. This action had the main objective of subsidizing the alarm and warning systems of the municipalities and meeting the demands of newly created federal agencies such as CEMADEN and CENAD.

2.3.2 São Paulo State Level

Several risk management instruments have been implemented for over the past 25 years in the state of São Paulo, as described below.

State Program for the Prevention of Natural Disasters and Reduction of Geological Risks (PDN). As noted earlier, the PDN was created to broadly address disaster risk prevention. This public policy was pioneered in Brazil, creating innovative ways of dealing with problems related to the occurrence of natural disasters and geological risks, and indicating ways to avoid, reduce, manage, and mitigate risk situations. It articulates actions, programs, and projects of government secretariats and other public institutions of the state of São Paulo that are working on DRM. The PDN is coordinated by CEDEC and consists of a Deliberative Committee (composed of secretaries of state) and the Articulation Group for Executive Actions (GAAE-PDN) as a technical body (Vedovello et al. 2015).

Ecological-economic zoning of the State of São Paulo (ZEE). The State Coastal Management Plan established by Law No. 10,019 of March 7, 1998, set the objectives, guidelines, and instruments for the elaboration of ecological-economic zoning (ZEE) with the purpose of disciplining and rationalizing the use of natural resources to improve the quality of life of local populations and protect ecosystems. Later the State Policy on Climate Change (PEMC) (Law No. 1,378 of December 9, 2009) established that ZEE must discipline productive activities, rational use of natural resources, and use and occupation of the land of São Paulo, as a basis for a sustainable development.

The decree regulating the PEMC (State Decree No. 55,947 of June 24, 2010) characterizes ZEE as a basic and referential instrument for environmental planning and management of a development process. This important instrument on land use planning has been carried out by the Environmental Planning Coordination Office of the State Secretariat for Environment, including discussions to add the approach to natural and geological risks in the context of ZEE (Vedovello et al. 2015).

Mapping of areas at risk of landslides, flooding, and erosion. In 2004, CEDEC began mapping areas at risk of landslides, floods, and erosion. This effort aimed to diagnose risk situations in support of monitoring and other actions under the PPDC. It enables a better understanding of the problematic situations and their locations as well as the implementation of structural measures (such as works) and nonstructural measures (such as training, monitoring, and civil defense preventive plans) needed to reduce, mitigate, or eliminate risk. These studies have been carried out by CEDEC and later by the Ministry of Cities. The mapping focuses on the areas of risk generally indicated by municipal civil defense teams. These areas go through technical evaluation, differentiating them by the degree of risk varying from low to very high (Vedovello et al. 2015).

Municipal Risk Reduction Plan (PMRR). To help municipalities reduce risks in urban areas, the Ministry of Cities provided funding for the elaboration of PMRRs by municipalities. The PMRR has brought a breakthrough in DRM because it involves a number of actions linked to the mapping of risk areas. It includes a hierarchy of physical and financial needs for the implementation of structural and nonstructural measures in the risk areas, based mainly on the criticality of the risk.

The execution of a PMRR involves the following steps: (a) training of municipal teams for the elaboration of diagnosis, prevention, and risk management, including the mapping of risk areas in areas of irregular occupation of the municipality; (b) financial support for the prioritization and planning by the municipality; and (c) financial support for the development of slope restraint projects in priority risk areas identified in PMRRs (Vedovello et al. 2015).

Sectorization of high and very high risk of landslides and floods. In the state of São Paulo, these works have been elaborated expeditiously both to meet federal policy and to support CEDEC in monitoring the at-risk areas of municipalities operating under the PPDC.

Geotechnical cartography for the planning and management of land use and occupation. According to a 2012 survey, the Geotechnical Cartography Database of the Brazilian Association of Engineering and Environmental Geology (ABGE) contains about 151 studies in the state of São Paulo prepared by research institutes and universities (including the IG, IPT, CPRM, School of Engineering of São Carlos [EESC], Federal University of São Carlos [UFSCar], Paulista State University–Rio Claro Campus [UNESP–Rio Claro], and Ilha Solteira [UNESP– Ilha Solteira], among others) and available in the form of technical reports, theses, and scientific articles.

These studies cover 70 municipalities in the state of São Paulo (at least one study of 40 municipalities, and more than one study of some municipalities). In general, the scale ranges from 1:3,000 to 1:100,000. Of note is the Geotechnical Chart of the State of São Paulo, in the 1:500,000 scales, and dozens of municipalities mapped on the 1:50,000 to 1:10,000 scales (for example, Ubatuba, São Sebastião, Guarujá, and Ilhabela, among others) (Vedovello et al. 2015).

Training and dissemination of information. This instrument aims to promote the qualification of municipal teams and other agents with responsibilities in risk management. It also aims to disseminate information and knowledge about risk situations to the population, increasing risk awareness and community participation.

The various actions implemented to train municipal agents involving civil defense teams and other sectors of municipal governments, as well as school communities, to deal with risk situations, include the following (Vedovello et al. 2015):

- Training of municipal civil defense agents to monitor risk areas and operation of municipal civil defense plans

- Distance training courses for multiplier agents on disaster prevention (CEDEC agreement with Brazilian Virtual University Institute [UNIVESP])
- Civil defense course through interactive virtual game for elementary and secondary education of the state public school network
- Courses for the correct evaluation and mapping of areas at risk for landslides and flooding
- Courses to education professionals for awareness of geological hazards and risks
- Execution of simulated exercises to evacuate landslide risk areas.

Rainfall and fluviometry monitoring. A wide telemetric network is being implemented in the state, in a partnership between the Department of Water and Electric Power (DAEE), the Foundation Technological Center of Hydraulics (FCTH), and Foundation for Agricultural Research Support (FUNDAG)—collectively abbreviated as DAEEFCTH-FUNDAG. This network encompasses more than 280 fluviometric stations and rain gauges distributed by the state of São Paulo, providing real-time data. Four "situation rooms" are located in São Paulo, Registro, Taubaté, and Piracicaba. In Piracicaba, the system is conducted in partnership with FUNDAG, DAEE, the State Water Resources Fund (FEHIDRO), and the State Secretariat of Agriculture and Supply (SAA), with situation rooms in Piracicaba and Campinas. The network also includes 15 hydrological stations and 20 meteorological stations.

Environmental Data Infrastructure of the State of São Paulo (DATAGEO). The DATAGEO platform is being developed by the environmental planning coordinator of the State Environment Secretariat. It will enable the organization, standardization, and sharing of environmental information among the various institutions of the state. In this way, a great prototype of the planned PDN risk portal was launched in 2012, with the possibility of expansion and connection with other sectors such as natural disaster risk management, water resources, regional planning, and logistics and transportation, among others.

2.4 Mechanisms for Implementation

There is no standardized general methodology for identifying and evaluating potential road geohazard risks on either federal or state roads. The corresponding transport agencies responsible for the monitoring, conservation, repair, and construction of public roads have traditionally adopted a reactive approach to road geohazard risks affecting the right-of-way of their roads.

DNIT (for federal roads) and state Departments of Transportation (for state roads) have several maintenance contracts with the private sector. Maintenance companies are in charge of cleaning, repairing, or rehabilitating the roads if a natural disaster occurs, provided that the magnitude and impact of the occurrence is manageable. In the case of natural disasters that greatly affect a road or even the integrity of human lives, the emergency mechanism will be activated. Civil defense, police, firemen, and any agent that can help in a quick recovery of the situation would be involved.

Regarding federal, state, and municipal concession roads, concessionaires are responsible for all phases of the road geohazard risk management process.

2.5 Funding Mechanisms

Public roads are state property and therefore constructed, managed, and maintained with the budget from government revenue. This is the case for federal roads with DNIT (under the Ministry of Transport, Ports and Civil Aviation) and for São Paulo state roads with the DER (under the state Secretariat of Transport). Besides regular managerial activities, these two institutions are in charge of providing road geohazard risk evaluation, management, and planning; implementing proactive measures; and putting into action contingency and postdisaster plans in their jurisdictions.

The funds for these tasks are pulled from toll fees, financial loans, and the budget of the federal government of Brazil in the case of federal roads and from the government of São Paulo state for its state roads. As explained later in this case study, little to no funding is destined for road geohazard risk activity before contingency and after a disaster.

Funding for road geohazard risk evaluation. The funding sources for road geohazard risk evaluation differ for new roads and existing roads. For new road projects, geohazard risk evaluation is often included in the engineering design preparation by road administrators (DNIT or the subnational governments) at the conceptual and design stages. For existing roads, the budget is generally included in the operation and maintenance cost of existing roads by each road administration authority. These are financed through the general budget, not any specific budget for geohazard risk evaluation.

Funding for road geohazard risk management planning. The funding for road geohazard risk management planning is similar to risk evaluation. Risk management planning is also usually included in the design preparation processes, which are funded through the general budget of the road administrators. In the case of urban areas, to support municipalities in reducing risks, the Ministry of Cities provides funding for the elaboration of the PMRRs by municipalities. PMRR use has brought a breakthrough in DRM because it involves a number of actions linked to the mapping of risk areas. It includes a hierarchy of physical and financial needs for the implementation of structural and nonstructural measures in the risk areas, based mainly on the criticality of the risk.

Funding for proactive measures. Specific funding for preventive measures is almost nonexistent in the federal and state roads throughout Brazil. Road management authorities normally approve funds after an occurrence has already happened or when the imminence of occurrence is evident.

Funding for postdisaster activities and recovery. When extremely severe disasters occur in the transport sector—such as the floods and flash floods in 2016 and 2017, where human lives were at high risk—civil defense takes action, and emergency funds are allocated to help the municipality and state in rescue and reconstruction activities.

3 SYSTEMS PLANNING

3.1 Risk Identification, Assessment, and Evaluation

3.1.1 Existing Roads

The operation and maintenance department of the National Department of Transportation Infrastructure (DNIT) lacks a standardized methodology for identifying critical spots that could cause or worsen a potential natural disaster on federal roads (photo 3.1). It is the engineers of the local units themselves who supervise the stretches and identify the critical spots that would need rehabilitation, maintenance, or new investments within the DNIT´s right of way.

Photo 3.1 Critical Spots Identified during a Field Visit, Angra dos Reis, Brazil

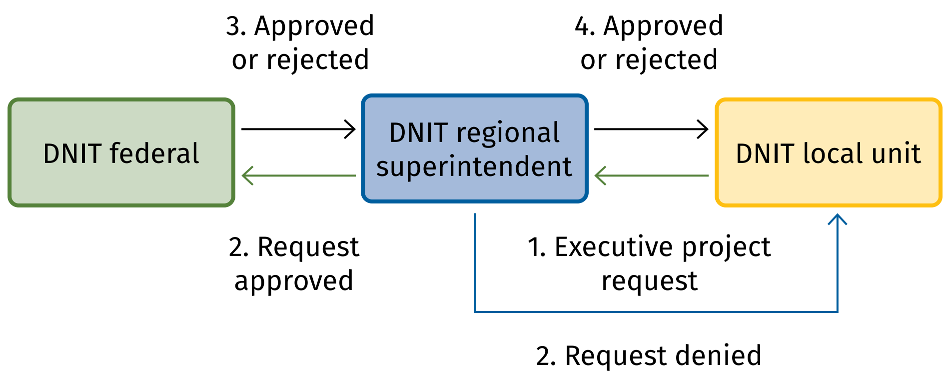
Source: © Javier Escudero Marroquin / World Bank. Further permission required for reuse.
Note: "Critical spots" are places that could cause or worsen a potential natural disaster on roads. Clockwise (from left): deteriorated drainage pipe, anchored curtain and bumps on the road due to land movements.

After the identification of any critical spots, they are then prioritized and addressed within the existing road maintenance contract of the road agency when the budget permits. Because the road agency lacks a standardized evaluation methodology or checklist, these assessments are based on the experiences of the engineer of the local office or hired consultants (geologist) who evaluate a specific condition. If the existing road maintenance contract cannot address the risk, then the local unit prepares a preliminary evaluation report and a proposal to remedy the situation, which are used to request funding for preparing a detailed design to the regional superintendent of the DNIT. Once the request is approved and the detailed design is ready, the DNIT´s regional superintendent sends the request to fund the work to DNIT headquarters in Brasília.

The headquarters office, once it has received petitions from the different regional units, prioritizes the demands based on the relevance of the road (volume of traffic, logistical importance, and so on) and determines which of those demands are approved based on the available budget. Many of them will not be approved, and even identified critical spots of risk will not be remedied because of severe budget constraints. The federal unit informs the regional unit about the decision made, and the regional unit forwards the decision to the corresponding local unit (figure 3.1).

The process for the state of São Paulo road network is similar. The risk identification in state roads is made by engineers of the Department of Roads of São Paulo (DER) working in their corresponding basic territorial units (UBAs). When the need for an intervention has been identified by the local unit, it is the central body of DER in São Paulo that prioritizes and eventually approves the works.

Figure 3.1 DNIT Decision-Making Process for Work to Remedy Critical Spots



Note: DNIT = National Department of Transportation Infrastructure. “Critical spots” are places that could cause or worsen a potential natural disaster on roads.

3.1.2 New Roads

The DNIT planning department is responsible for and coordinates the construction of new federal roads. As part of any road engineering project in Brazil, experts in geology and hydrology engineering are consulted during the planning and design stages of a new road to evaluate the viability of the project. This process will produce a “hazard-indicating map,” but it is not labeled as such and will be part of the preliminary studies of the project.

An ongoing example is the Mário Covas Beltway project, which is the metropolitan loop around greater São Paulo with an extension of 180 kilometers (map 3.1). The construction is divided into four segments. Work started in 1998, taking advantage of a section of an existing road, and the last segment should be delivered by 2019–20.

Map 3.1 Phases of the Mário Covas Beltway Project, São Paulo

Source: ©DERSA Road Development S.A. Reproduced, with permission, from DERSA; further permission required for reuse.
Note: Dark blue segment = southern project phase. Yellow segment = eastern project phase Red segment = northern project phase. Light blue segment = western project phase.

Map 3.2 and photo 3.2 illustrate the results of the geologic and hydrology studies as part of the geohazard risk evaluation that goes beyond the width of the right-of-way. Note that this is beyond a typical road project in Brazil, because of its magnitude and importance to the state of São Paulo and Brazil.

The same technical specifications used for the Mário Covas Beltway project are available for use by road agencies throughout Brazil.

Map 3.2 Tunnel and Intersection Locations, Mário Covas Beltway Project, São Paulo

Source: dos Santos et al. 2016.
Note: In yellow = the northern segment of the Mário Covas Beltway Project.

Photo 3.2 Mário Covas Beltway Tunnel Entrance under Construction

Source: ©DERSA Road Development S.A. Reproduced, with permission, from DERSA; further permission required for reuse.

A recent DNIT article—"Use of Small Drones as a Low-Cost Alternative for Topographic Characterization of the Transport Infrastructure in Brazil" (de Oliveira Borges et al. 2017)—evaluated the accuracy of using aerophotogrammetry with low-cost drones for the generation of models of terrain and the mosaic of orthorectified images compared with RTK (real-time kinematic) topographic surveys. As the authors mention, the results obtained from the pilot project are positive:

In general, the results obtained indicate an excellent cost-benefit ratio, given the low investment, fast processing time, and the reduction of the team required for its execution, as well as extremely consistent results for planning, monitoring, execution, and maintenance of road works in DNIT. Even with very promising results, inconsistent regions in the Digital Terrain Model (TDM) can be identified for the scale and accuracy achieved, a fact generally associated to the filtration of elevation points extracted in regions of dense vegetation and interpolation based on distant points, which can be complemented with GNSS/RTK points.

3.1.3 Risk Management Planning

The institution in charge of planning for interventions to reduce potential economic and social losses would be the DNIT when referring to federal roads and the DER for São Paulo state roads. For the time being, these two agencies do not work with a list of prioritized interventions for potential road geohazard risk reduction. Because it is considered as part of the day-to-day activity of a road agency, a calculation of potential economic loss due to a road geohazard condition is not calculated. It falls into the general road fund for a road maintenance contract within that given year.

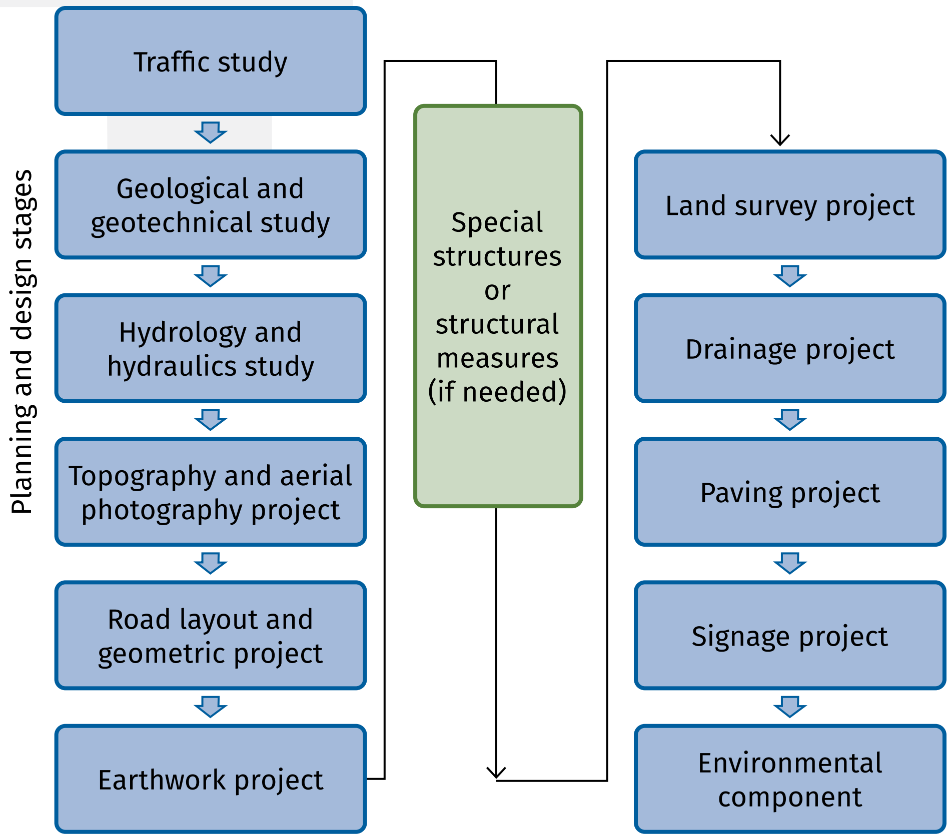
4 ENGINEERING AND DESIGN

4.1 Engineering Investigation and Study for Engineered Measures

The initial engineering investigation is done by the road agency and included in the project as part of the proposal, which will go out for bids to be executed by an engineering firm. As part of the planning and design stages (figure 4.1), the engineering firm will be responsible for the respective studies, tests, data collection, and analysis to be presented and evaluated by the road agency. This standard procedure is followed and needs to be approved before the beginning of construction.

For a new or existing road, all the appropriate phases regarding planning, design, and construction take place following the norms and specifications applicable to the project. The structural measures are part of the project as needed and are limited by available funds and thus not considered a priority, especially concerning works outside of the right-of-way. In other words, the structural measures become secondary to a project and are addressed only when issues arise.

Figure 4.1 General Planning and Design Flow of Road Construction



4.2 Types of Structural Measures and Design Considerations

Before the National Department of Transportation Infrastructure (DNIT) was created in 2002, the National Department of Roadways (DNER) operated as the national road agency for 65 years (1937 to 2002). Some of DNER's pre-2002 specifications are still in use today, including the following:

- DNER-ES 039/71—Retaining wall
- DNER-ES 044/71—Slope stability lining with soil-cement.

Both technical specifications above are from 1971 and are acceptable for their integrity, but they haven´t been updated with technology and materials over the years.

The Department of Roads of the state of São Paulo (DER-SP) was created in 1934 and has been continuously updating its technical specifications, like the ones shown below from 2006:

- ET-DE-G00/017—Retaining wall with bags of soil-cement
- ET-DE-G00/018—Gabion wall.

Municipalities throughout Brazil use the technical specifications provided by DNIT and state Departments of Transportation (DOTs). The types of structural countermeasures depend on different parameters, such as location, type and magnitude of hazardous event, type of road section or construction threatened, and the site geology and hydrology.

The structural countermeasure design consideration in Brazil is based on the result of engineering investigations. Although both the DNIT and DER-SP possess a technical manual with countermeasures to apply, the reality is that these manuals are barely used. Structural solutions for road geohazard risk are normally designed ad hoc or from first principles, rather than from adopting a standard solution.

Below are illustrations of some of the major types of engineering interventions aimed at restraining (mitigating or preventing) mass movements on Brazilian highways—for example, translational landslides, rotational landslides, block plummeting, block running, and debris run. The list of all types of interventions is more extensive, and any omission from this list does not mean that omitted types of intervention are not used in the restraints along the Brazilian road system, but they are not the most common ones.

Anchored curtain. Anchored curtains are containment structures that use tie rods. They are formed with a wall of reinforced concrete, generally 20–30 centimeters thick (depending on the loads on the rods) and fixed to the ground through pretensioned anchors (photo 4.1). This provides a structure with sufficient stiffness to minimize the shifting of the terrain.

Photo 4.1 Anchored Curtain Structure

Source: Collection of Fundação Geo-Rio. Reproduced, with permission, from Fundação Geo-Rio; further permission required for reuse.

Gabion wall. Gabions are metal cages made of galvanized steel wires and filled with manually arranged rocks, which must be uniform in size, with a diameter 1–2 times the size of the mesh (photo 4.2). For aesthetic reasons and space limitations, it is common for gabion walls to have a cross-section with a vertical outer face and steps in the internal face. However, from the standpoint of stability, steps can be built on the outer face, with a recoil between successive layers of gabions. Alternatively, the outer face may be constructed with a small slope (1H:5V to 1H:10V) relative to the vertical, toward the soil slope. This solution is widely used at the base of slopes and in the margins of channels.

Photo 4.2 Gabion Wall

Source: Reproduced, with permission, from the faculty of geology of the State University of Rio de Janeiro; further permission required for reuse.

Anchored grid. The anchored grid is a set of horizontal and vertical beams forming a reinforced concrete lattice, anchored at the intersections of the beams (photo 4.3). It can be used for containment of rock masses or for reinforcement of containment works, where anchors allow for increasing the stability of the slope, reducing the pressure and the rotations of unstable walls.

Photo 4.3 Anchored Grid Structure

Source: Collection of Ursula Guerra. Reproduced, with permission, from Ursula Guerra; further permission required for reuse.

Stapled soil coated with projected concrete (or revegetation). Stapled soil is an in situ reinforcement method used for stabilization of excavated or natural slopes. It is constituted from the introduction of semiflexible rods in the soil and, in most cases, by protecting the face of the slope, usually using projected concrete or soil biomantle (photo 4.4). Stapled soil structures are generally composed of steel bars (or other metal or synthetic fibers) surrounded by a cement mix. They must withstand tensile, shear, and bending moments.

The rods are introduced into the ground from a predrill run by a drill and are then wrapped by cement grout along their entire length. This set is often called a clamp. The staples are not prestressed, and the mobilization of the efforts is made from the movements of the soil mass. The distribution of the staples (density) on the face of the soil mass to be stabilized depends mainly on the slope geometry, the mechanical properties of the soil, and the mechanical properties of the staples themselves.

The execution of a work in stapled soil takes place in three distinct phases: excavation or regularization of the surface, installation of the first line of staples, and protection of the face of the slope. This sequence is repeated until the desired dimension is reached. In cases where the characteristics of the earthy material allow, the execution phases may vary.

The designed concrete is a mixture of cement, sand, water, and additives, propelled by compressed air from the projection equipment to the application site through a hose. To obtain a protective layer with good strength, durability, and great resistance to erosion, it is necessary to install drains and for the projected concrete layer to have an average thickness of 15 centimeters owing to the presence of the reinforcement screen of the clamps.

Photo 4.4 Stapled Soil Structure Coated with Concrete

Source: Collection of Fundação Geo-Rio. Reproduced, with permission, from Fundação Geo-Rio; further permission required for reuse.

Projected concrete. This solution is used in surface protection against erosion on soil slopes. The designed concrete is a mixture of cement, sand, water, and additives, propelled by compressed air from the projection equipment to the place of application through a hose on the slope over a steel mesh. To obtain a protective layer with good strength, durability, and high resistance to erosion, it is necessary to implant drains into the slope to reduce pore pressures (photo 4.5). The concrete layer typically has an average thickness of 9 centimeters.

Photo 4.5 Projected Concrete Structure

Source: Collection of Fundação Geo-Rio. Reproduced, with permission, from Fundação Geo-Rio; further permission required for reuse.

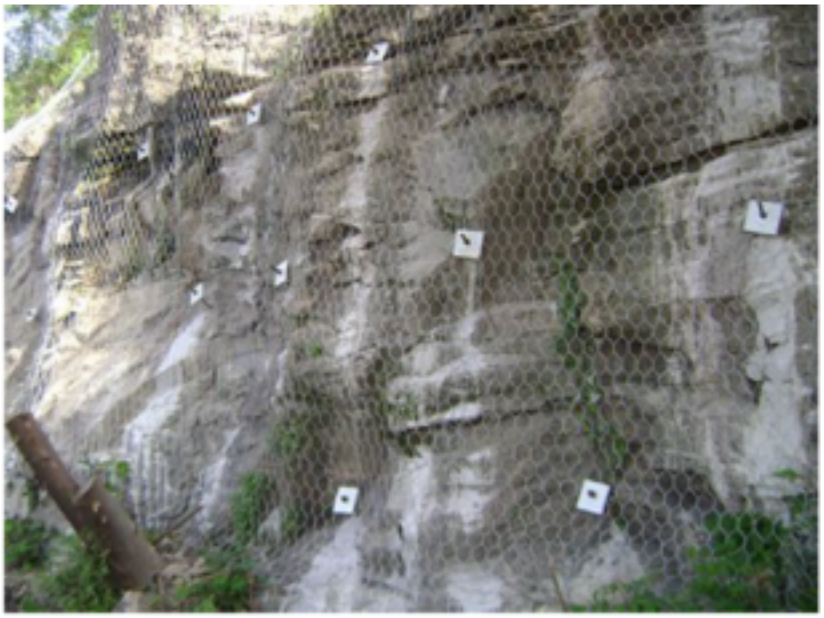
Photo 4.6 Slope Restoration with Berms

Slope restoration or berms. Slope restoration or berms are a solution that aims to provide greater stability to the slope by removing unstable soil or attenuating the slope of the terrain (photo 4.6).

Source: Reproduced, with permission, from students of agronomy, architecture and urbanism from the State University of Rio de Janeiro; further permission required for reuse.

High-strength steel mesh. Steel mesh is suitable for stabilizing steep slopes in soil, sediments, and rocks. The mesh adapts to the topography and prevents not only slides and deformations but also ruptures. The steel mesh is anchored with nails to the soil or rock behind the layer generated by the rupture surfaces (photo 4.7). Because the panel also fits the slope surface owing to pretensioning, it prevents a breakdown of land masses and pieces of rock.

Photo 4.7 Slope Stabilization with Steel Mesh



Source: Collection of Fundação Geo-Rio. Reproduced, with permission, from Fundação Geo-Rio; further permission required for reuse.

Isolated anchorage with or without a shield. This is the semirigid or flexible element installed in the soil or rock and capable of transmitting tensile forces between its ends. The anchor consists of three elements: the head, the anchor portion that transmits to the ground traction load, and the free section that transmits the load between the ends. The isolated anchors are intended to prevent the falling of blocks or splinters downstream of the slope (photo 4.8). In the case of ground anchorage, a reinforced concrete plate (usually 1.0 x 1.0 meters or 1.5 x 1.5 meters) should be included where the anchor head is supported.

This type of soil stabilization is commonly adopted when more conventional solutions, such as slope restoration and berms at the base, are not possible. Anchored plates are used when the terrain to be stabilized has a sloped and irregular surface, making it difficult to install vertical curtains. Another situation in which anchored plates are employed consists of slopes that have poor stability conditions and could be ruptured if cuts were made to the curtain wall.

Photo 4.8 Soil Stabilization with Isolated Ground Anchors (Foreground)

Source: Collection of Ursula Guerra. Reproduced, with permission, from Ursula Guerra; further permission required for reuse.

Impact wall. An impact wall is a rigid reinforced concrete structure that has the purpose of absorbing possible falls of small blocks and splinters or soil slides on the wall location. A high-resistance screen is installed on the wall to prevent the blocks from exceeding the structure (photo 4.9). During this type of solution, when possible, a damping trench must exist to reduce the impact of the blocks on the wall.

Photo 4.9 Impact Wall

Source: Collection of Fundação Geo-Rio. Reproduced, with permission, from Fundação Geo-Rio; further permission required for reuse.

Impact barrier. An impact barrier is a flexible structure built to retain rock blocks or landslides from slopes, absorbing the stresses and energy associated with movement and ensuring adequate safety to the area intended to be protected (photo 4.10). Usually this solution is adopted in situations involving rocky slopes where the complexity of the other containment structures would involve a large logistical apparatus and pose a high risk to the workers. Impact barriers should be designed to absorb such energies by statistically estimating where the trajectories of the objects along the slope will be. The statistical estimation determines the energy range and the maximum height required by the barrier.

Photo 4.10 Impact Barrier

Source: Collection of Fundação Geo-Rio. Reproduced, with permission, from Fundação Geo-Rio; further permission required for reuse.

Reinforced concrete wall with or without buttress. This is a containment solution in which a vertical panel of reinforced concrete contains reinforcements in the horizontal and vertical directions (photo 4.11). It is set at its base in the rock by means of steel anchors and is used to withstand the bending stresses due to the thrust of the raised soil. If necessary, it can use stiffening beams (buttresses) to strengthen the face. This containment aims to prevent material from sliding or falling from blocks reaching the slope downstream.

Photo 4.11 Reinforced Concrete Wall with Buttresses

Source: Collection of Fundação Geo-Rio. Reproduced, with permission, from Fundação Geo-Rio; further permission required for reuse.

Deep horizontal drains. Deep horizontal drains (DHPs) are devices along the body of slopes or hills that aim to provide flow for infiltrated water or groundwater so as to alleviate the existing pore pressure, improving the conditions of stability of slopes or hills (photo 4.12).

Photo 4.12 Deep Horizontal Drains

Source: Collection of Geoconcret. Reproduced, with permission, from Geoconcret; further permission required for reuse.

The DNIT may also intervene outside of the right-of-way (40 meters to each side of the road) depending on the severity of the occurrence or the location of the potential geohazard. These interventions are not contemplated by the regular DNIT operation but may take place after negotiations with the landowners or municipalities involved.

5 OPERATIONS AND MAINTENANCE

5.1 Road Disaster Awareness

5.1.1 Control of Road Disasters Caused by Human Activities

Beyond the natural susceptibility of roads to damage from droughts, floods, landslides, or other calamities, human activity has a considerable impact—potentially transforming what could be a minor inconvenience into a catastrophe. Examples of human activities that could activate or enormously intensify road geohazard risk include construction of precarious housing on inadequate sites, near slopes, or in flooding locations; development of superpopulated, waterproof metropolises that do not drain rainwater; or even much smaller actions like blocking roadside drainage.

An important factor, which must be considered as a human activity that contributes to road disaster, is the roadside presence of shantytowns (photo 5.1).

Photo 5.1 Roadside Shantytowns in Brazil

Source: Stock photos.

5.1.2 Traffic Signs to Raise Awareness

Brazil's National Department of Traffic (DENATRAN) is the agency responsible for setting the norms and specifications for road signs, including regulatory, warning, identification and orientation, educational and auxiliary, tourist attraction, works, and other types of signs.

Two DENATRAN warning signs make road users aware of potential road geohazards and natural disasters (figure 5.1): (a) Area with Rockfall (Sign Code A-270); and (b) Crosswind Area (Sign Code A-44).

Figure 5.1 Warning Signs to Raise Road User Awareness

a. Area with rockfall

b. Crosswind area

Source: National Department of Traffic (DENATRAN).

In addition to using electronic variable message signs (VMS) to raise road user awareness of local conditions, road authorities at a local level create their own signs (photo 5.2 and photo 5.3).

Photo 5.2 Local Traffic Sign: "Attention: Area Subjected to Flooding"

Source: Stock photo.

Photo 5.3 Local Traffic Sign: "Area Subjected to Flooding"

Source: Stock photo.

5.1.3 Awareness Raising and Training for Road Stakeholder Engagement

For many years, awareness raising and training on disaster risk management (DRM) had not involved road agencies and the transport sector in Brazil. In May 2017, in addition to the work by the civil defense on natural disaster awareness and training, the World Bank's DRM team sponsored two day-long workshops: one in Brasília and another in São Paulo. These events were the first ever in Brazil to formally bring awareness of DRM to the transport sector, as described below.

Brasília. The Brasília workshop brought together representatives from the Ministry of Cities, Ministry of Transport, National Agency for Ground Transportation (ANTT), National Department of Transportation Infrastructure (DNIT), University of Brasília, and Japan International Cooperation Agency (JICA) to share their experiences and discuss how to introduce DRM into the transport sector.

São Paulo. The São Paulo workshop brought together São Paulo state agencies. Attendees representing the Department of Roads of São Paulo (DER), Geological Institute, environmental institutions, and Civil Protection and Defense of São Paulo (DC) shared their experiences and discussed how to introduce DRM in the transport sector. The next day, a field visit included the civil defense headquarters, the offices of road concessionaire Ecovias, and a tour of basic territorial units (UBAs) (photo 5.4)

Photo 5.4 Field Visit to Civil Defense, Road Concessionaire, and UBAs, São Paulo, May 2017

Source: ©World Bank. Further permission required for reuse.

5.2 Nonstructural Measures

5.2.1 Monitoring and Early Anomaly Detection

Except for road concessionaries that, under contract, are obligated to monitor roads and roadsides using cameras, the remaining road network in Brazil (more than 1.5 million kilometers) is monitored by visual inspection—the performance of which varies greatly on the federal, state, and municipal road networks. Depending on the size of the road network to be inspected, this visual inspection may happen daily, weekly, or monthly. In some cases, if a road segment poses any danger, especially during the rainy season, it is monitored 24 hours a day.

As mentioned earlier, this visual inspection is not exclusive to the detection of road geohazards but also of any distress or defect within the road's right-of-way. If a road geohazard is identified and poses a potential high risk to road users, a team of road engineers and geologists (sometimes with support from the civil defense) are dispatched to the location to evaluate the situation on foot and report with support of visual aids like photos and videos. No other detection devices such as wired geofence, closed-circuit television (CCTV), or alarms are used.

5.2.2 Emergency Information Collection

Today, with the widespread use of cell phones, it is easy for road users to call an emergency number to report an abnormal situation on the road. Depending on the reported situation, the responsible agency attends to the emergency as a first responder.

Taking advantage of the evolution of smartphones, the DNIT and other state Departments of Transportation (DOTs) such as DER-SP have developed apps to inform road users about road conditions by uploading georeferenced pictures (figure 5.2).

Figure 5.2 Launch Screens of DNIT Móvel and São Paulo DER Smartphone Apps

Sources: National Department of Transportation Infrastructure (DNIT) and São Paulo Department of Roads (DER) websites.

5.2.3 Road Condition Emergency Information System, Including Early Warning or Precautionary Road Closure

All traffic regulations that allow for road agencies to legally protect road users are listed in the Brazilian Traffic Code (CBT). The first CBT was published in 1941, but today it is based on the Federal Constitution and respects the Vienna Convention and Southern Common Market Agreement (Mercosur).

Because rainfall is the main indicator of potential road geohazards in Brazil, road agencies monitor meteorological conditions to first warn drivers about reducing travel speeds and later to focus on critical geohazard locations previously identified. However, rain gauges and automatic monitoring systems in general are not common in Brazil; thus, not every critical area in the country is covered.

Any early warning systems for road users, like VMSs—also known as changeable, electronic, or dynamic message signs—are found on roads operated under concessions. They can be placed on overpasses, bridges, and sometimes on trailers along the roadside, especially to warn drivers about construction zones (photo 5.5).

Photo 5.5 Variable Message Signs on Brazilian Roads Operated under Road Concessions

Source: Stock photos.

Under their contracts, road concessionaires monitor their roads and roadsides 24 hours a day through video cameras and maintenance crews doing their day-to-day activities. Using VMSs they are able to warn drivers with emergency information and precautionary road closures, regardless of the reason that caused them.

Road agencies at the federal and state levels create seasonal campaigns to raise road users' awareness about the increased risk that heavy rainfalls carry, mostly in the four months of summer (November, December, January, and February). Prevention and warning plans like "Plano Verão" (Summer Plan) in Petrópolis, Rio de Janeiro state, tend to reduce consequences and accelerate the response to potential natural disasters.

The Plano Verão includes a model called the "Family Contingency Plan," which seeks to organize family members in advance—including domestic animals—in the event of a tragedy. This plan provides for an advanced civil defense office in Itaipava, which will operate at the Citizenship Center in a room provided by the Secretariat of Social Assistance. It will be possible, among other services, to find reports of occurrences and make requests for preventive surveys and emergency care. Five contingency plans were also developed by organizing the response to landslides, floods, rock blockages, gales, and lightning storms.

5.2.4 Development and Implementation of an Emergency Preparedness and Response Plan

Any emergency preparedness and response plan is part of the road agency's scope of work, but because road agencies have lately reduced their equipment, machinery, and staff to attend to their road networks, they do emergency preparedness and response through a contractor. Once again, this is specific to road maintenance within the right-of-way. Any other effort regarding a major road disaster is coordinated by the civil defense.

5.2.5 Road Asset Management

At the federal level, the DNIT has created a road asset database that works as an interactive georeferenced inventory map. The Geographic Information Viewer (VGEO) uses layers that users can superimpose depending on their interests (map 5.1). The VGEO shows information about DNIT local units, ongoing road projects, and the condition of the road network, among others. This tool, despite being essential for successful road asset management, does not yet include road geohazard risk-related information.

In the São Paulo state, the DER-SP developed two road management systems of the state and municipal roads: (a) the Rural Roads' Cadastral System (SICAR), including a database of road inventory with basic physical characteristics; and (b) the roads mapping and georeferencing system (SIRGeo). However, at this moment, these systems are not used for road geohazard risk management.

Map 5.1 Screen Shot of DNIT Geographic Information Viewer (VGEO)

Source: Geographic Information Viewer (VGEO), National Department of Transportation Infrastructure (DNIT) http://servicos.dnit.gov.br/vgeo/. ©DNIT. Reproduced, with permission, from DNIT; further permission required for reuse.

5.3 Maintenance of Structural Measures

In Brazil, road agencies have ongoing road maintenance contracts and are responsible for maintaining a certain level of service, including routine, preventive, and rehabilitation services. The existing road maintenance contracts with the private sector are limited to the width of the right-of-way, thus limiting the maintenance to the pavement surface, drainage, debris removal, and small-slope reinforcement.

Structural measures beyond routine maintenance and rehabilitation need to be constructed through a separate contract or emergency funding. This would preclude the road agency from starting a bidding process until funds are available. Therefore, this process is used only when major structural measure maintenance is needed after a natural disaster.

5.3.1 Local and Institutional Partnerships for Geohazard Risk Management

In general, the Brazilian population is well versed in reaching out to the civil defense at the municipal, state, and federal levels. Most calls concern urban populated areas, possibly involving a bridge or segment of road, because fewer people live outside of these areas and consequently a disaster's impact on human lives would be lower.

After a natural disaster has occured or is considered imminent, road agencies at the federal and state levels coordinate with civil defense, firefighters, ambulances, and any service that can contribute to a better recovery from the occurrence. This relationship of the road agency with the different bodies involved is normal throughout Brazil.


100 m

6 CONTINGENCY PROGRAMMING

6.1 Predisaster and Emergency Preparedness

When imminent emergencies are detected on either federal or state roads, road agencies lack a formal protocol for determining the appropriate action. Normally, they rely on their personal assessment of the situation to decide the actions to take. For example, in the municipality of Angra dos Reis (Rio de Janeiro state), when a road agency detects that the falling rain could trigger a natural disaster, it usually notifies the contracted maintenance company to be attentive and prepare to clear the road as soon as possible and thus restore normal operation. The civil defense itself is also on notice to be able to respond as quickly as possible in case the maintenance company could not handle the situation on its own. Firefighters, ambulances, and any service that can contribute to a better recovery of the occurrence, will be on notice. It is worth mentioning that the procedures in the Angra dos Reis area cannot be extrapolated to every region in Brazil. With specific characteristics like accommodating the only two nuclear plants in Brazil, the region of Angra dos Reis is a good-practices example but does not show the real situation of Brazil.

6.2 Postdisaster Response and Recovery

6.2.1 Emergency Inspection and Postdisaster Needs Assessment

Postdisaster damage information is collected by visual inspection, usually by the same staff responsible for road maintenance. This information gathering process may vary greatly because each agency (federal, state, or municipal) is responsible for its own postdisaster activities and reactive measures on roads. In some cases, depending on the magnitude of the road geohazard, no further assessment takes place.

If injuries or fatalities of road users (and in surrounding communities) are involved, the event is considered a natural disaster and follows the civil defense procedures to possibly warrant a police investigation. Depending on the results of this investigation, the road agency responsible may or may not be accountable for it, and consequently, a judicial process takes place. For roads under concessions, the process works the same as if the liability involved a private business; insurance companies are also called to do an assessment.

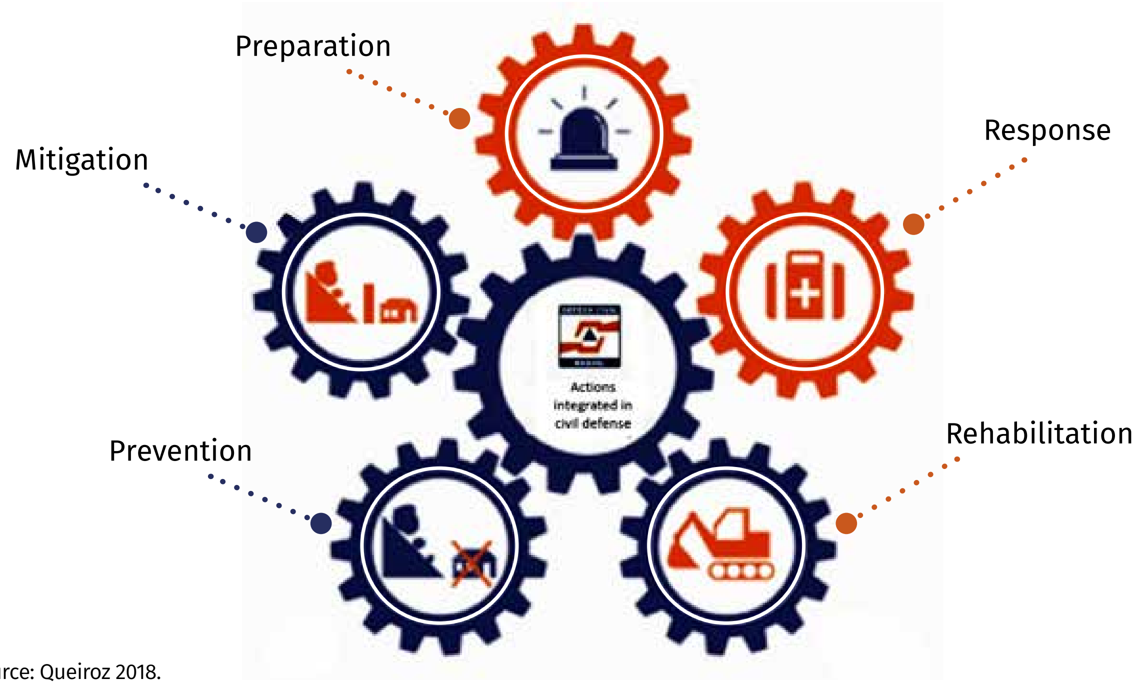
In São Paulo state, after a road disaster, several agencies are dispatched to the location to evaluate the situation. A road user could summon help using any of the following emergency phone numbers:

- 190: Military Police
- 191: Federal Highway Police
- 192: Ambulance
- 193: Fire Department
- 197: Civil Police
- 198: State Highway Police
- 199: Civil Defense.

Although having these many options for emergency phone numbers can be cumbersome, Civil Protection and Defense of São Paulo (DC) can redirect a call to the police, fire department, or ambulance if the emergency does not warrant its support. Discussions to turn all these numbers into one emergency phone number have taken place, but no progress has been made.

Each agency, when dispatched to a road disaster, has its function based on what it has been trained to do. Of course, standard procedures will be followed to keep the victims and the area safe, but all the while under the coordination of the state's civil defense agency (figure 6.1).

Figure 6.1 Emergency Inspection and Postdisaster Needs Assessment Process in Brazil



Source: Queiroz 2018.

6.2.2 Emergency Traffic Regulation and Public Notice

Any emergency traffic regulation is executed by the police and the Department of Transportation (DOT), even if coordinated (or not) by the civil defense, because they have the appropriate equipment to set barricades to block off an area or lane until the situation is resolved.

In addition to the television, radio, and internet, public notices can now be shared through navigation devices, smartphone applications, and electronic logging devices for commercial vehicles in real time. Some of these work with georeferences to alert drivers of potential road geohazard areas.

6.2.3 Reactive Measures

Reactive measures are subdivided into emergency recovery, repair, rehabilitation, and reconstruction, as follows:

- ***Emergency recovery:*** Federal and state road agencies are no longer construction powerhouses, which in the past took care of day-to-day activities like removing debris and road rehabilitation. Today these agencies have three- to five-year road maintenance private contracts that need to maintain a level of service and be on call 24 hours a day. Local road management authorities—like the regional superintendents (for the National Department of Transportation Infrastructure [DNIT]) and basic territorial units ([UBAs] for the São Paulo DOT)—coordinate these emergency recovery efforts on the road network under their jurisdictions. This network may vary greatly in extension, thus forcing the local road management authorities to prioritize among different road disasters.
- ***Repair:*** This is part of the emergency recovery, which could take place at the same time or be part of a routine or preventive maintenance.
- ***Rehabilitation:*** Rehabilitation is part of a road maintenance program, which is usually planned by the road agency and supervised by the local road authority but executed by the private sector under a specific contract.

- ***Reconstruction:*** Reconstruction works much the same way as rehabilitation, but because it requires more funds to be executed, it is part of a road maintenance program or qualifies for emergency funding if needed because of a natural disaster.

6.3 Postdisaster Risk Funding and Management

The federal government can approve two types of funds: voluntary transfers and mandatory transfers. Voluntary transfers are funds that states request from the federal government if there is a need to rehabilitate or reconstruct infrastructure after a disaster. Mandatory transfers are funds that the federal government must approve through a provisional measure (MP) when an emergency is identified, and funds are requested by the affected state or municipality.

Under the Brazilian constitutional law, an MP is a one-person act of the president of the republic, with the immediate force of law, without the participation of the legislative branch, which will be called upon to discuss and approve it later. The assumption of the MP, according to Article 62 of the Federal Constitution, is cumulative urgency and relevance. The executive does not always respect this criterion of relevance and urgency when editing an MP.

The MP, therefore, although it has an immediate force of law, is not really a law in the strict technical sense of the term, because no legislative process preceded its formation; the legislative process occurs later.

In the face of a severe disaster, the civil defense is responsible for the coordination of all bodies (DNIT, police, firemen, and so on) to respond as quickly and efficiently as possible to disasters. Civil defenses at the state level respond to state emergencies. Some states have a fund linked to their civil defense where they put a percentage of the annual budget to cover future emergencies. Santa Catarina state's emergency fund is a good example.

7 ONGOING PROJECTS AND PROGRAMS

Environmental and transport-related issues have been treated separately over the years in both the federal and state contexts. Currently there are not many projects or programs trying to bridge this gap in Brazil.

Nevertheless, given that the state of São Paulo is in the lead of disaster risk management (DRM) in Brazil, the World Bank has financed a collaborative project between the Department of Roads of São Paulo (DER-SP) and the Geological Institute (IG) to advance the development of road geohazard risk management. At the same time, a federal activity is currently being carried out between the World Bank, the Global Facility for Disaster Reduction and Recovery (GFDRR), and the National Department of Transportation Infrastructure (DNIT) to strengthen natural disaster resilience of federal highway infrastructure in Brazil.

These two activities are further explained below, together with other federal level projects that, even if they are not specific to road geohazard risk management, can contribute indirectly to its development.

7.1 São Paulo State Project

The São Paulo State Sustainable Transport Project was approved in 2013 with the objective of contributing to the improvement of the state's transport and logistics efficiency and safety while enhancing the state's capacity in environmental and DRM. The project coordination is under the responsibility of the DER-SP and has the participation of other institutions such as the Secretariat of Logistics and Transport (SLT), Secretariat of Planning and Management (GSP), Secretariat of Environment (SMA), and Environmental Company of the State of São Paulo (CETESB).

Since 2013, the objective is being achieved by

- Upgrading selected key transport corridors, including their rehabilitation and expansion, and mainstreaming transport planning and management;
- Building capacity in land use planning, territorial management, and regulation focusing on addressing environmental impacts in support of a greener and more inclusive growth; and
- Improving the state's capacity to manage disaster risk, particularly risks linked to climate change in the transport sector.

Although road geohazard risk minimization is not a common practice among road agencies in Brazil, the DOT has joined with the IG to share information regarding geohazard risk management, and not only for new roads. This arrangement has been encouraged by the state's capacity to manage disaster risk and is divided into the two subcomponents described below.

Mainstreaming DRM in the transport sector. Mainstreaming DRM in the state's transport planning and work execution through carrying out studies, small works, and the acquisition of goods to the benefit of the IG, aimed at, among other things,

- Mainstreaming disaster and climate change risk in the state's transport and logistic master plan, including the evaluation of the transport sector's vulnerability to natural hazards and potential socioeconomic impacts, notably resulting from climate events, and developing integrated disaster response plans for the transport sector in the selected region; and
- Supporting the review of technical specifications for road design and operations to improve resiliency of road infrastructure exposed to disaster risk.

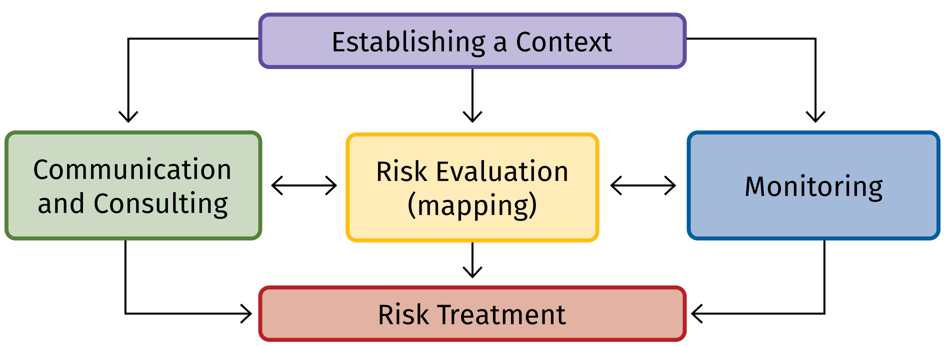
Enhancing DRM policy and institutional capacity. Strengthening the state's capacity for DRM through studies, capacity building activities, and the acquisition of goods to upgrade and support the implementation of the State Program for the Prevention of Natural Disasters and Reduction of Geological Risks (PDN) to the benefit of the IG, including, among other things,

- Mainstreaming DRM practices at the planning level by (a) supporting the design of DRM frameworks and a comprehensive conceptual and practical understanding of hazards, vulnerabilities, and risks; (b) assessing economic and social impacts of particular disasters; and (c) supporting the state's initiatives to establish a framework for the resettlement of populations in the immitigable high-risk areas; and
- Improving policies and procedures to better and more effectively respond to disasters through the development of monitoring and early warning systems, methodologies, and sharing of information and knowledge.

7.2 Ongoing State-Level Activities

In agreement with the objectives and components described earlier, there are four ongoing activities toward solving some of the fundamental DRM issues regarding the state roads of São Paulo. Each activity is described below. Figure 7.1 shows the conceptual model for DRM used by IG in São Paulo.

Figure 7.1 IG Conceptual Model for DRM



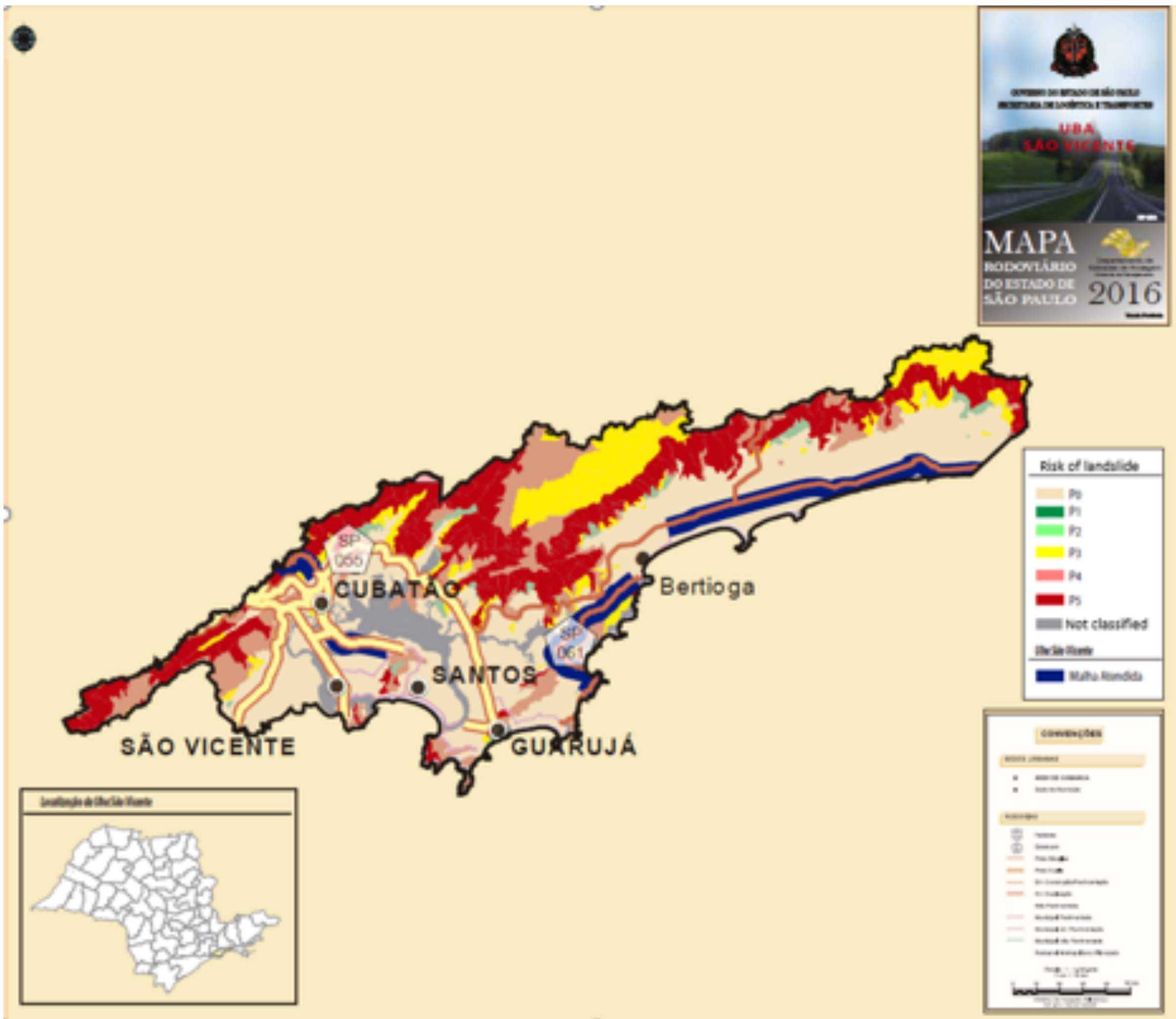
Source: ©Geological Institute of São Paulo (IG). Reproduced, with permission, from IG; further permission required for reuse.
Note: DRM = disaster risk management. IG = Geological Institute, São Paulo.

Elaboration of contingency plans against risks of geodynamic events in road sections. São Paulo decided to use its basic territorial units (UBAs), which were created in 1998, as part of a preventive effort toward major road accidents and assistance to road users. Although there are 57 UBAs that cover 645 municipalities, the state has selected three UBAs for a pilot project to test this concept: the municipalities of Mogi das Cruzes, São Vicente, and Caraguatatuba.

In this project, a contingency plan is created to allow the state to combine areas of natural disasters with the road network, enabling the minimization of road geohazards. The contingency plan applied to roads is an instrument to coexist with risk and has the objective of guaranteeing traffic safety and preventing, preparing, and mitigating the impacts of geodynamic events on the roads. It will therefore allow the DER-SP to manage risk conditions in periods of extreme rainfall, promoting the adoption of previous safety measures in the event of a disaster.

Risk analysis and mapping (as shown in map 7.1, for the São Vicente UBA)—which generate knowledge of the conditions of hazardous processes and of vulnerability and exposure of the roads—has two main applications: (a) to size the types of works necessary to reduce risk, avoiding or reducing impacts of geodynamic processes; and (b) to serve as a unit of analysis for the dynamic monitoring of contingency plans.

Map 7.1 Road Geohazard Mapping of São Vicente UBA, São Paulo State



Source: ©Department of Roads of São Paulo (DER-SP). Reproduced, with permission, from DER-SP; further permission required for reuse
Note: UBA = basic territorial unit. Code of colors range from low risk (P0) to very high risk (P5) as specified in the legend.

Georeferenced registration of geodynamic events. The IG carried out a georeferenced registration of geodynamic events over a 21-year period (1993 through 2013) in 50 municipalities of the São Paulo and Baixada Santista metropolitan regions plus the municipalities of Caraguatatuba, São Sebastião, and Ubatuba.

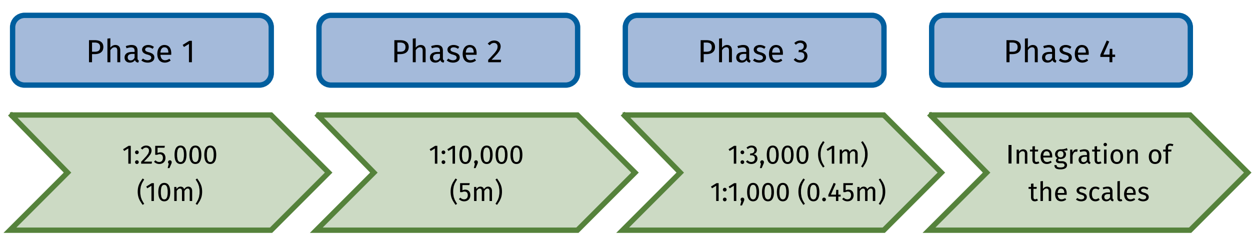
The objective of this activity was to promote the incorporation DRM parameters and attributes of geodynamic events into the strategic, managerial, and operational plans of the logistics and transport sector, as well as to promote the efficient implementation of the PDN geological survey of the state of São Paulo (Decree No. 57.512 of 2011). Map 7.2 shows the location of 38,134 geodynamic events in the surveyed areas from 1993 through 2013.

Map 7.2 Geodynamic Events in the State of São Paulo, 1993–2013

Source: Brollo and Ferreira 2016.
Note: Each color denotes a specific reliability of the recorded event. From most to less reliable, they are: green, yellow, red, and blue.

Risk assessment and mapping. The IG has proposed the performance of risk assessment and mapping on four scales: 1:25,000; 1:10,000; 1:3,000; and 1:1,000 (figure 7.2) that focus on both landslides (and mass movements in general) and floods (and related processes). All of these support strategic planning, the managerial and operational aspects of the transport sector, and the implementation of the PDN for risk management in residential areas.

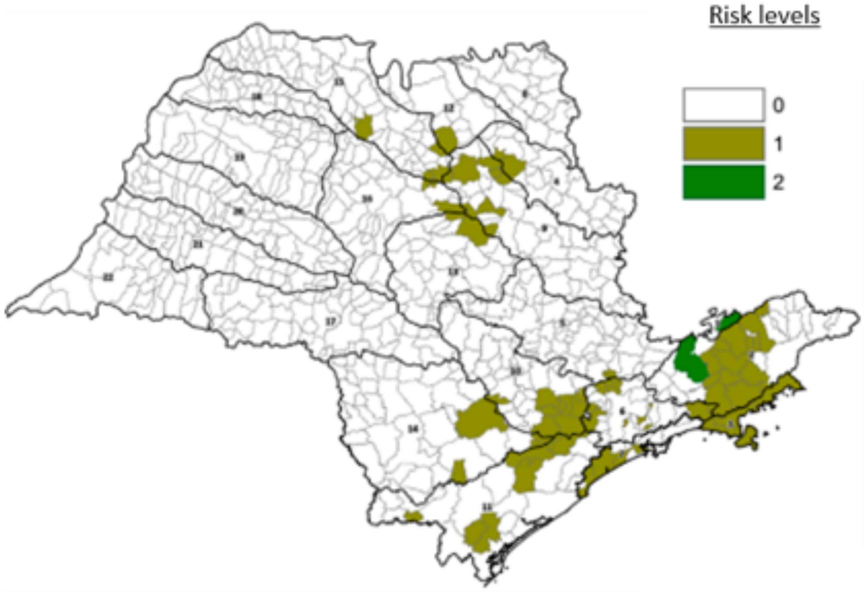
Figure 7.2 IG's Proposed Four-Phase Map Scale for Risk Assessment



Source: ©Geological Institute of São Paulo (IG). Reproduced, with permission, from IG; further permission required for reuse.
Note: IG = Geological Institute of São Paulo.

The studies cover the area of 50 contiguous municipalities (map 7.3) of the São Paulo metropolitan region as well as the Planalto Paulistano–Baixada Santista interconnection (further described in chapter 1), which includes the Anchieta-Imigrantes system (highways SP 150, SP 160, and SP 055) and the UBAs of São Vicente, Caraguatatuba, and Mogi das Cruzes. These three UBAs include the municipalities of Santos (partial), Bertioga, São Sebastião, Caraguatatuba, and Ubatuba.

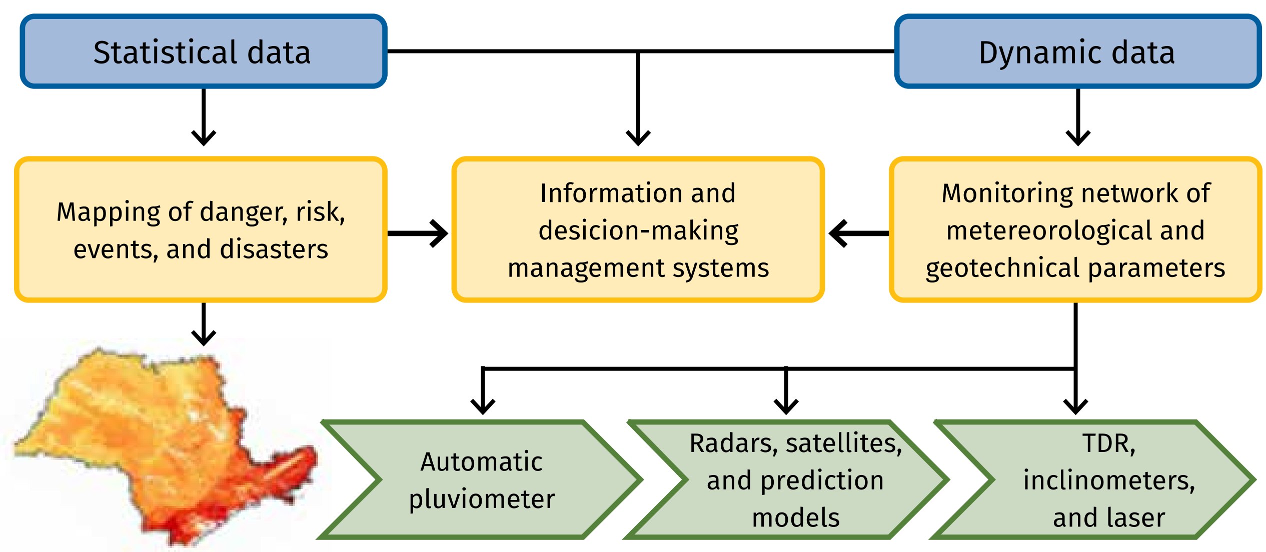
Map 7.3 Risk Mapping of São Paulo State, by Municipality, 2016



Source: ©Geological Institute of São Paulo (IG). Reproduced, with permission, from IG; further permission required for reuse.
Note: Numbers in the map refer to hydrographic units in São Paulo State. Colored risk levels: 0 = low risk, 1 = some risk, 2 = high risk.

DRM platform and laboratory. The implementation of a platform and laboratory for disaster risk information management will integrate information from the actions of disaster inventory, risk mapping, and real-time monitoring of dynamic meteorological and geotechnical variables, among others (figure 7.3). It requires (a) definition of protocols for obtaining, storing, and transmitting geological risk data; and (b) information technology for the systematization, integration, and georeferencing of data related to risks in the web network. The DRM platform and laboratory are already being implemented.

Figure 7.3 IG's Proposed Monitoring Process



Source: ©Geological Institute of São Paulo (IG). Reproduced, with permission, from IG; further permission required for reuse.
Note: IG = Geological Institute of São Paulo. TDR = time-domain reflectometry.

7.3 Improving Climate Resilience of Federal Road Networks in Brazil

In partnership with the GFDRR, the World Bank is developing an ongoing activity to strengthen the natural disaster resilience of Brazil's federal highway infrastructure through preliminary DRM diagnostics on the federal road infrastructure. For a complete understanding of the current situation, information will be collected through the DNIT (road administrator); Ministry of Transport, National Agency for Ground Transportation (ANTT, the highway concession regulator); Ministry of Integration (civil defense for emergency response); National Institute of Meteorology (INMET); and National Water Agency (ANA) (metrological agencies), among others.

The project will produce a diagnosis on the current design of the DRM framework (risk identification, risk reduction, preparedness, and financial protection) for road infrastructure from the engineering, regulatory, and institutional aspects. Based on the previous information, a pilot analysis of vulnerability and criticality in a selected federal road network and a pilot economic evaluation of road resilience will be carried out to identify priority actions to increase the climate resilience of road infrastructure.

To conclude, the project will share international best practices on climate resilience of road infrastructure with the Brazilian authorities through workshops and other dissemination or awareness activities on climate resilience in the road sector.

The abovementioned activities will help identify the main gaps and issues related to DRM in the transport sector in Brazil and help improve DRM for federal roads in the future.

7.4 Findings, Recommendations, and Next Steps

Based on the above reviews, the following summarizes this case study's findings and recommendations to enhance road geohazard risk management in Brazil and open a path for future actions.

1. No systematic approach to road geohazard risk management. There is no comprehensive approach to road geohazard risk management, including risk identification and assessment, planning measures, and contingency programming to protect road infrastructure from geohazard events. Such an approach should be coordinated and implemented by relevant stakeholders. However, road administrators and other relevant institutions often work individually; any official coordination mechanism on geohazard risk does not exist. An integrated, multi-institutional approach is essential to enhance geohazard risk management of road infrastructure.

2. Ad hoc methodology for geohazard risk assessment. Road administrators are identifying and assessing road geohazard risk substantially depending on the experiences of local engineers, normally through visual inspection of roads. Though the experiences in local situations help to identify problems, this approach has certain limitations, not being based on any geological or statistical assessments. For example, it is difficult for the local unit of road administrators to conduct a proper geological survey or inspection of risky slopes. Many of the occurrences start outside of the right-of-way or are in inaccessible areas where the human eye cannot observe. This obstacle could be overcome by using advanced technology—for example, unmanned aerial vehicles (UAVs) to observe the terrain and identify critical spots. Furthermore, an additional assessment by experts in geology with the support of local geological institutes would enrich the engineer's evaluation and provide a better solution, combining the transport and geological points of view.

3. Lack of norms and technical specifications for preventing geohazard risks. The Brazilian road sector has its own construction norms and specifications, many of which are based on North American and European standards. Technical specifications of good quality are widely available for transport infrastructure in Brazil. However, most of these norms and specifications have been designed solely for the construction of engineering structures (pavement, for example); lacking are norms and specifications specifically designed for natural disaster prevention on roads. Having a wide variety of natural disaster prevention norms and technical standards would support the use of preventive structural measures and thus reduce the number of natural disasters.

4. No cost-benefit assessment for geohazard mitigation measures. Although geohazard mitigation could bring a substantial economic benefit by preventing a chronic need for the recuperation of roads after disasters, economic assessment of geohazard mitigation measures from the life-cycle viewpoint has rarely been conducted, and as a result, such benefits are not clearly demonstrated. This often leads to a low priority of these works given the serious budget constraints.

5. Road asset management system not used for geohazard risk management. Though some road agencies own basic road inventory systems, the detailed data of road structures such as bridges, culverts, and protection walls are not in the inventory. Having such an inventory will improve the management capacity of the geohazard mitigation measures and make it possible to maintain these structures more efficiently.

6. Little data sharing among stakeholders in geohazard management. Environmental and geohazard risk-related information is not yet integrated with the transport sector. Each branch has been considered separately over the years without looking at each other's data or information. For successful road geohazard risk management, data is one of the most valuable assets and, as such, it becomes fundamental that every institution involved in the area is aware and knowledgeable about all the available data. A more developed collaboration among the different stakeholders involved in the road geohazard risk management would increase the impact of preventive countermeasures on roads while reducing the response time after a natural disaster happens. A successful example of this collaboration, in the state of São Paulo, is the integrated and coordinated relationship between the IG and the Civil Protection and Defense of São Paulo. Sharing key information, being aware of the other institutions' actions and plans, and keeping a fluid and continuous relationship are fundamental for effective prevention of and rapid response to natural disasters.

7. Inefficient collection of disaster event data. Road agencies and civil defense lack a digital standardized database to keep records of road geohazards. Data is key when assessing road geohazard risk or when developing economic analysis. To overcome this issue, a more complete, standardized, and easily shareable road geohazard occurrence database would not only help manage risks but also provide important information regarding the efficient allocation of governmental funds.

8. Lack of monitoring and maintenance. Regular road monitoring and maintenance are fundamental for lengthening the useful life of road assets. In Brazil, routine monitoring and maintenance of the federal and state roads is common practice. However, the inspections and other actions are limited to the main road structures such as pavement. For road geohazard prevention, continuous monitoring and maintenance of the surroundings of the roads—for example, retaining walls or drainage systems on slopes—are needed to avoid or minimize the impact of natural disasters. In some cases, even monitoring and performing maintenance works beyond the right-of-way of a road would dramatically reduce the probability of a natural disaster and thus prolong the life cycle of the road agency's assets.

9. Inadequate scope of routine road maintenance. To enhance monitoring and maintain the key structures to mitigate geohazard risk for road users, the scope of routine road maintenance can be broadened. Normally roads in Brazil are maintained under one-year or longer routine maintenance (conservation) contracts or Performance-Based Road Rehabilitation and Maintenance Contracts

(CREMA). These contracts, as stated previously, mainly deal with pavement structures. To reduce geohazard risk, broadening the scope of maintenance contracts to include structures for geohazard mitigation (including retaining walls or slope protection and so on) is recommended.

10. No strategic contingency program. Although a certain protocol exists at the local unit level of road agencies for preparing for geohazard events, no official and written procedures, or contingency plan, is developed, which is a key to reduce potential losses of life or assets under a natural disaster threat. Such a contingency plan should (a) include preparedness and early warning systems; (b) define the roles and responsibilities of every stakeholder, including road agencies, local municipalities, civil defenses, police, and so forth; and (c) describe the required preparatory actions for effective and quick responses to disasters. For example, the plan needs to clarify under what conditions a road agency needs to close a road and consider the risk to human lives. A more standardized and protocolized contingency plan is recommended to establish clear guidelines and criteria of the preparedness actions based on the historical disaster data. The plan will be able to promote close coordination between the involved stakeholders to carry out the appropriate actions in the most efficient way possible.

REFERENCES

Brollo, Maria José, and Ferreira, Cláudio José. 2016. "Risk and Disaster Management from Geodynamic Phenomena in the State of São Paulo: 2000–2015 Scenarios." Bulletin of the Geologic Institute 67: 1–70.

CNT (National Transportation Confederation). 2017. "CNT Highways Survey 2017." 22nd ed. Annual survey report, CNT, Brasília. http://pesquisarodovias.cnt.org.br/Edicoes.

de Oliveira Borges, Raphael, Lucas Tavares Sobral, Antonio Juliano Fazan, Roberto de Figueiredo Ribeiro, Daniel Santana Lanza, and Marcelle da Silva Calil. 2017. "Use of Small Drones as a Low-Cost Alternative for Topographic Characterization of the Transport Infrastructure in Brazil." Paper presented at the 27th Brazilian Congress of Cartography, Rio de Janeiro. November 6–9. http://www.cartografia.org.br/cbc/2017/trabalhos/4/635.html.

dos Santos, Daniela, Isabella Montanari, Sabrina Pereira, Fernando Lavoie, and José Avesani Neto. 2016. "Contenção de Encostas com Uso de Tirantes: Estudo de Caso" [Containment of Slopes with the Use of Tie Rods: Case Study]. Study presented at the XVIII Brazilian Congress of Soil Mechanics and Engineering (COBRAMSEG 2016), Belo Horizonte, Minas Gerais, Brazil. October 19–22.

Federal Government of Brazil. 2012. "National Plan for Risk Management and Response to Natural Disasters 2012–2104." Investment report, Federal Government of Brazil, Brasília. http://www.pac.gov.br/pub/up/relatorio/d0d2a5b6f24df2fea75e7f5401c70e0d.pdf.

Queiroz, Major. 2018. "Gestão em Proteção e Defesa Civil" [Civil Protection and Defense Management].

Vedovello, Ricardo, Lidia Tominaga, Maria José Brollo, and Walter Nyakas Jr. 2015. "Management of Natural Disaster Risk in the State of São Paulo." Paper submitted for the 15th Brazilian Congress of Engineering and Environmental Geology, Bento Gonçalves City, Brazil. October 18–21.

WEF (World Economic Forum). 2018. "Brazil: The Global Competitiveness Index 2017–2018 Edition." Country statistical report 80th/137, WEF, Geneva.

World Bank. 2013a. "Incorporating Disaster Risk Management in the Transport Sector in Brazil: Challenges and Opportunities." Working Paper No. 82542, World Bank, Washington, DC.

World Bank. 2013b. "Project Appraisal Document on a Proposed Loan in the Amount of US$300 Million to the State of São Paulo with the Guarantee of the Federative Republic of Brazil for a São Paulo Sustainable Transport Project." Project Appraisal Document (PAD) No. PAD258, World Bank, Washington, DC.

World Bank. 2016. "Damage Report: Material Damages and Losses due to Natural Disasters in Brazil, 1995–2014." Working Paper No. 111703, (in Portuguese), World Bank, Brasília.

CONTACT

The Global Facility for Disaster Reduction and Recovery (GFDRR)

Email: gfdrr@worldbank.org

Website: https://www.gfdrr.org/

GFDRR is a global partnership that helps developing countries better understand and reduce their vulnerabilities to natural hazards and adapt to climate change. Working with over 400 sub-national, national, regional, and international partners, GFDRR provides grant financing, technical assistance, training, and knowledge sharing activities to mainstream disaster and climate risk management in policies and strategies. Managed by the World Bank, GFDRR is supported by 37 countries and 11 international organizations.

World Bank Disaster Risk Management Hub, Tokyo

Phone: +81-(0)3–3597–1320

Email: drmhubtokyo@worldbank.org

Website: http://www.worldbank.org/drmhubtokyo

The World Bank Tokyo Disaster Risk Management (DRM) Hub supports developing countries to mainstream DRM in national development planning and investment programs. As part of the Global Facility for Disaster Reduction and Recovery, the DRM Hub provides technical assistance grants and connects Japanese and global DRM expertise and solutions with World Bank teams and government officials. The DRM Hub was established in 2014 through the Japan-World Bank Program for Mainstreaming DRM in Developing Countries – a partnership between Japan's Ministry of Finance and the World Bank.

Layout/graphic design by Carlos Plaza Design Studio.

GFDRR Global Facility for Disaster Reduction and Recovery

THE WORLD BANK IBRD • IDA | WORLD BANK GROUP