



 United States Department of Transportation

**Organization of American States
Unit for Sustainable Development
and Environment**

**General Study on the Vulnerability
of Road Segments to Natural Hazards
of the Pan American Highway and its
Complementary Corridors in
Central America**

Working Document

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PREFACE

Central America is one of the regions most vulnerable to the threat of natural disasters because of its geographic location. Situated in the circum-Pacific “Rim of Fire,” it is narrow, bordered by the Pacific Ocean on the west and the Atlantic on the east. It is a diverse habitat that includes high mountain ranges and volcanoes, valleys, and coastal and alluvial plains. The region’s geography predisposes it to a large number of atmospheric, hydrologic, and geological threats. Furthermore, the presence of two major tectonic plates--Coco and the Caribbean--and the numerous local and regional fault lines that crisscross the region, constantly releasing energy through subduction, subject it to frequent seismic and volcanic episodes.

There is an extreme diversity of weather patterns, with different rainy and dry seasons caused by the double oceanic effect, the intermittent El Niño phenomenon, and the constant change in the location of the intertropical convergence line. These, combined with high mountain ranges, numerous river basins and broad plains, render Central America the perfect setting for repeated floods, landslides, and droughts. In addition, the fact that many of the Central American countries are in the Caribbean Basin exposes them to a constant threat of hurricanes and tropical storms that originate there or in the Atlantic when they are pummeled each year between June and November.

Other factors to be considered are the manmade phenomena that have been brought on by development, bad management of environmental risk, an absence of criteria and codes for the building of regional transportation infrastructure, and others. All these threats constantly affect the regional infrastructure of the transportation sector, particularly roads, and because of its vital role in production and sustainable development, arduous efforts have been made to reduce its vulnerability.

The USDE, formerly called the Department of Regional Development and Environment (DRDE), was created in June 1963 to provide technical assistance to the member states of the OAS, which became the main inter-American forum for the development of regional policies on sustainable development and the environment.

Since 1983 the USDE has assisted countries and sectors in reducing the vulnerability of the Central American population and socioeconomic infrastructure to natural disasters. And since 1992, in cooperation with the Center for the Coordination of Natural Disaster Prevention in Central America (CEPREDENAC), the USDE has promoted the development and implementation of programs to reduce vulnerability in the productive and social sectors.

In the case of the transportation sector, two sets of activities currently exist. The first consists of activities that the USDE has been organizing in conjunction with various Central American institutions, as described below:

- The OAS, through the USDE, has supported the development of the Central America Regional Disaster Reduction Plan coordinated by CEPREDENAC. Specifically, it has given financial and technical support to “institutional” strategies in the areas of energy, education, telecommunications and transportation, agriculture and housing. Currently, USDE is supporting the Regional Plan’s development of its Basic Plan.
- In 1994, the USDE organized the Inter-American Seminar on Transportation Infrastructure as a Factor in Integration, which stated that “the Region must have a transportation system with high standards of efficiency that meets the levels of competitiveness required worldwide.” It was also decided that investment in transportation infrastructure must be based on the needs of trade and integration. The seminar covered topics such as the integration of the transportation system, the transportation services sector, the development and financing of the transportation infrastructure, and the evaluation of the impact of environment and natural disasters on the development of the transportation infrastructure.¹
- In 1995, with the support of the European Community Humanitarian Office (ECHO) and the Pan American Institute of Highways (PIH), the OAS implemented the Project for the Reduction of the Highway Transportation System to Natural Disasters, which has as an objective the development of a methodology compatible with other road-planning instruments for the preparation of vulnerability profiles, to train representatives of the sector in vulnerability analysis and mitigation techniques through the collaborating centers in the Pan American Institute of Highways (PIH) network, to include courses on vulnerability reduction in the PIH’s annual program, and to strengthen the sector’s ability to work with national disaster management agencies and emergency preparedness and response.
- As part of this project, the USDE, in cooperation with the PIH, focused on reducing highway vulnerability to disasters by incorporating mitigation techniques in to road construction, reconstruction, maintenance, and repair programs through the development and distribution of the PerfilMap program. This consists of a computer program based on geographic information systems (GIS) that enables information on natural hazards to be superimposed on the road infrastructure, generating vulnerability profiles. Currently, PerfilMap libraries are being updated for future use in the creation of vulnerability profiles. The OAS supported workshops in the use of this program.
- In 1998, through the Executive Secretariat for Integral Development, and with the technical assistance of the USDE an agreement was drafted with the National University of Cuyo in Argentina to develop the Natural Disasters

¹ Seminario Interamericano de Infraestructura de Transporte como Factor de Integración. Washington, DC, Organización de los Estados Americanos, 1995.

Vulnerability Reduction Project in the MERCOSUR Transportation System. The Center of Territorial Strategies for MERCOSUR (CETEM), which is part of the Geography Department of the Faculty of Philosophy and Letters of the University, is the organization responsible for its implementation. Its objective was to make the commercial road system of MERCOSUR (Argentina, Brazil, Paraguay, and Uruguay) more efficient by reducing its vulnerability to natural disasters, thus making roads a contributor to sustainable development. This was a two-phase project; the first took place in 1998, and the second is still in process. This project also had the participation of the Empresa Brasileira de Planeamiento de Transporte (GEIPOT) and the National Bureau of Roads of Paraguay (DNV).

- Similarly, the USDE has been participating in the follow-up of actions related to the Plan of Action of Santa Cruz, which are aimed at incorporating the environment into integrated development. In 1998, with the cooperation of other international organizations, it held a series of regional workshops on sustainable cities and trade corridors: Natural Disaster Vulnerability Reduction and Mandates and Future Actions in Central America, the Andean Region, and the Southern Cone. The Central American workshop took place in San José, Costa Rica, with the collaboration of SIECA, the United Nations International Decade for Natural Disaster Reduction (IDNDR), and the Pan American Health Organization (PAHO) in October 1998, immediately preceding Hurricane Mitch.

- In July 1999 the United States Permanent Mission to the OAS approved the Program for Training and Research of the Trade Corridor Development (PROCORREDOR), which has two main components: research on methodologies for the development of trade corridors and training in activities related to the review and refinement of methodologies and techniques of analysis.

The impact of Hurricane Mitch during the last week of October 1998, which affected all of Central America, has made it necessary that all efforts in the area be directed towards economic reconstruction and revival and giving impetus to the reduction of vulnerability to natural disasters. The most important activities are the following:

- To support the Secretariat for Central American Economic Integration (SIECA), in its capacity as a technical secretariat of the Sectoral Council of Ministers of Transport of Central America (COMITRAN) in dealing with the effects of natural disasters on the transportation infrastructure, the USDE began to work with SIECA and COMITRAN, in coordination with CEPREDENAC, on technical assistance directed toward analyzing the vulnerability of the Central American Highway and proposed regional transportation corridors to natural hazards.

- On October 18 and 19, 1999, the presidents of Costa Rica, El Salvador, Guatemala, Honduras, and Nicaragua, and the First Vice President of Panama, met in Guatemala City, Guatemala, with the Vice President of the Dominican Republic and the Vice Prime Minister of Belize as observers. From this meeting emerged the Declaration of Guatemala II, in which CEPREDENAC was assigned to coordinate the Five-Year Central American Project for the Reduction of Disaster Vulnerability and Impact 2000-2004. During this time the presidents will concentrate their efforts on the transformation and the search for sustainable development, in which they hope for assistance from the international community.
- In the same Agreement it was decided: "To adopt the Strategic Framework for the Reduction of Vulnerability and Disasters in Central America, which is part of the process of transformation and sustainable development in the region for the next millennium and includes the basic guidelines for preventive measures and mitigation of damage, together with actions concerning preparedness and emergency management, with special attention to the most vulnerable groups and sectors of society, especially the poor and the marginalized with a focus on gender."²
- Owing to drastic political and economic changes in Central America, the Central American Transportation Study (ECAT) carried out between 1974 and 1976, was unable to meet its projections for economic development.³ As a result, it became necessary to conduct a new study, which would cover the events of the past 20 years, the current economic, infrastructure and transportation situation and the various policies in effect in the region. As a result of the 17th COMITRAN meeting held in April 1997, it was decided to update ECAT and designated SIECA as the agency in charge. This project will lay groundwork for the proposal of a 2001-2010 Master Plan for Regional Transportation Development that will make the Central American transportation sector integrated, efficient and competitive.
- Currently, SIECA and the U.S. Agency for International Development (USAID) are preparing a study on norms and criteria for highway design, construction and maintenance in the region. The region has also drafted two projects for the Third Meeting of the Consultative Group on Central American Reconstruction and Transformation, which will take place in Madrid, Spain in 2001, with a view to obtaining international assistance. These projects are The Central American Logistical Corridor and The Transportation Sector in the Regional Disaster Reduction Plan.

² "Plan Regional de Reducción de Desastres: Plan Básico," Sistema de la Integración Centroamericana, Centro de Coordinación para la Prevención de los Desastres Naturales en América Central, 2000.

³ "Estudio Centroamericano de Transporte," Secretaría de Integración Económica Centroamericana Draft Final Report, Part 2, Summary, BCEOM, 2000.

- The transportation ministers of the Americas met in New Orleans on December 16, 1998, to consolidate their commitment to the creation of an integrated transportation structure in the Western Hemisphere that will serve to increase economic and social development, trade, tourism, and cooperation among the nations of the region and the equitable distribution of and participation in the benefits of the system among the member states during the 21st century. The ministers agreed that this call for action and decided to revitalize the Western Hemisphere Transportation Initiative (WHTI), launched at the Meeting of Western Hemisphere Transportation Ministers in 1996, so as to create an integrated transportation system for the 21st century and support the initiatives agreed upon at the Summit of the Americas in Bolivia, and those related to the Free Trade Area of the Americas (FTAA). One of the suggested plans of action emerging from the New Orleans meeting was the Disaster Response Plan, in which the ministers stated:

We understand that the destruction of the essential transportation infrastructure caused by weather phenomena or other natural causes, disables rescue efforts after such disasters and that the reconstruction of such infrastructure is crucial for the economic recovery of the nations affected. Therefore, we agree to develop a Western Hemisphere Transportation Disaster Response Plan that will be aimed at responding more effectively to weather and other disasters at a regional and subregional level.

The USDE has provided support to WHTI during its various different stages of development.

- Recently the National Laboratory for Materials and Methods of the University of Costa Rica (LANAMME) has joined the PROCORREDOR consortium created by the USDE to strengthen research and training in the field of trade-corridor development, particularly environmental management of transportation corridors. The USDOT participated in the first PROCORREDOR research workshop and commented on the need of studies on the vulnerability of multi-modal transportation.

The impact of Hurricane Mitch has made even more evident the need for specific studies on the region's road transportation system and the need for strengthening emergency response as a team effort in coordination with CEPREDENAC and the national civil defense and transportation mechanisms.

In response to this need and because of its active role in vulnerability reduction, the USDE with financing from USDOT OET was asked to coordinate the drafting of the present document on the Central America Pan American Highway and its complementary corridor vulnerability study and to identify the necessary mitigation work.

ACRONYMS

ALCA	Area de Libre Comercio de las Américas
BCEOM	Sociedad Francesa de Ingeniería
CECC	Coordinación Educativa y Cultural Centroamericana
CEPREDENAC	Centro de Prevención de Desastres Naturales de América Central
CETEM	Centro de Estrategias Territoriales para el Mercosur (Universidad de Cuyo, Argentina)
CIG	Centro de Investigaciones Geotécnicas (El Salvador)
COEN	Comité de Emergencia Nacional (El Salvador)
COMITRAN	Consejo Sectorial de Ministros de Transporte de Centroamérica
DDRMA	Departamento de Desarrollo Regional y Medio Ambiente
DGC	Dirección General de Caminos (Guatemala)
DNV	Dirección Nacional de Vialidad (Paraguay)
ECAT	Estudio Centroamericano de Transporte (SIECA)
ECHO	Oficina Humanitaria de Comisión Europea
FHIS	Fondo Hondureño de Inversión Social
GEIPOT	Empresa Brasileira de Planeamiento de Transportes
GPS	Sistema de Posición Geográfica
IGN	Instituto Geográfico Nacional (Guatemala)
IGNTG	Instituto Geográfico Nacional Tommy Guardia (Panamá)
INETER	Instituto Nicaragüense de Estudios Territoriales
INSIVUMEH	Instituto de Sismología, Vulcanología, Meteorología e Hidrología (Guatemala)
IPC	Instituto Panamericano de Carreteras
ITHO	Iniciativa de Transporte del Hemisferio Occidental
LANAMME	Laboratorio Nacional de Materiales y Modelos Estructurales (Universidad de Costa Rica)
MARN	Ministerio de Medio Ambiente y Recursos Naturales (El Salvador)
MCyV	Ministerio de Comunicaciones, Infraestructura y Vivienda (Guatemala)
MTI	Ministerio de Transporte e Infraestructura (Nicaragua)
MOPT	Ministerio de Obras Públicas y Transporte (Costa Rica)
MOP	Ministerio de Obras Públicas de (El Salvador)
OEA	Organización de los Estados Americanos
OET	Office of Emergency Transportation (Estados Unidos)
OPS	Organización Panamericana de la Salud
PROCORREDOR	Programa de Capacitación e investigación sobre el desarrollo de Corredores de Comercio
REP	Reglamento Estructural Panameño
SERNA	Secretaría de Recursos Naturales y Ambiente (Honduras)
SIECA	Secretaría de Integración Económica Centroamericana
SIG	Sistema de Información Geográfica
SINAPROC	Sistema Nacional de Protección Civil (Panamá)
SOPTRAVI	Sistema de Obras Públicas, Transporte y Vivienda (Honduras)
TPDA	Tránsito Promedio Diario Anual
UDSMA	Unidad de Desarrollo Sostenible y Medio Ambiente (OEA)
UN-DIRNDN	Naciones Unidas-Década Internacional de Reducción de Desastres Naturales
UPEG	Unidad de Planeamiento y Evaluación de la Gestión (SOPTRAVI, Honduras)
USAID	United States Agency for International Development
USDOT	United States Department of Transportation

INTRODUCTION

The Pan American Highway is of great economic, political and social importance on both the regional and hemispheric levels. In the case of Central America, the Pan American Highway's geographic, atmospheric and meteorological context, as well as its design parameters and its maintenance make it more vulnerable to natural hazards. As a consequence of this vulnerability, there are substantial damages to the transportation infrastructure in the region, therefore producing serious effects on the production and social sectors and the populated areas both near and far.

The transportation infrastructure in the Central America region includes not only the following corridors: Natural Highway Corridor (Pacific), Alternative A (Central) and Alternative B (Atlantic), but also some connections that are the main entrances to important ports. The Alternative A corridor is also called the Pan American Highway and has its own nomenclature in each country (see Figure 1).

Figure 1. Nomenclature of the Pan American Highway and its Complementary Corridors of the Highway Network in Central America

Corridor	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panamá
Pan American Highway, Alternative A Corridor or Central Corridor	Pan American Highway CRN1 and CRN2	CA-1	CA-01	Alternate A Corridor	Pan American Highway	Pan American Highway
Alternative B Corridor or Atlantic Corridor	Alternative B Corridor or Atlantic Corridor	Alternative B Corridor or Atlantic Corridor	Alternative B corridor or Atlantic Corridor	Alternative B Corridor or Atlantic Corridor	Alternative B Corridor or Atlantic Corridor	Alternative B Corridor or Atlantic Corridor
Natural Highway Corridor or Pacific Corridor	Natural Highway Corridor or Pacific Corridor	Natural Highway Corridor or Pacific Corridor	Natural Highway Corridor or Pacific Corridor	Natural Highway Corridor or Pacific Corridor	Natural Highway Corridor or Pacific Corridor	Natural Highway Corridor or Pacific Corridor
Corridors mentioned in this document in addition to the Pan American Highway	Coastal Highway	Littoral Highway or CA-2 Coastal Highway (Pan American Highway Alternate Corridor)	<ul style="list-style-type: none"> • Western Intertronal Corridor (CITO) • CA-09 South • National Route 16 (RN 16) • CA-02 (Alternate Corridor of the Pan American Highway) 	<ul style="list-style-type: none"> • Natural Highway Corridor • Alternate B Corridor or Atlantic Corridor • Several connections 	Non existent	Non existent

Source: OAS/USDE based on national reports

The objective of this document is to present information on the vulnerability of road segments on the Pan American Highway and when available, information on its alternate or complementary corridors in Central America. The document also contains information about the vulnerability of each section of the Pan American Highway, the natural hazards to which it is prone, the length of each vulnerable road segment, the lists of vulnerability reduction measures taken, and the history of disasters it has suffered (where information was available). This information is based on Central American vulnerability profile studies carried out by technical teams from the Central American countries and with international coordination by the USDE. The USDE has coordinated these efforts and has been working on the development of vulnerability studies since March 2000.

The vulnerability profiles cover the geographic area known as the Central American Framework, which consists of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama. The national institutions that served as focal points for each study are the following:

Costa Rica: Dirección de Planificación, Ministerio de Obras Públicas y Transporte (MOP)

El Salvador: Unidad de Planificación Vial, Ministerio de Obras Públicas (MOP)

Guatemala: División Planificación y Estudios, Dirección General de Caminos (DGC)

Honduras: Unidad de Planeamiento y Evaluación de Gestión, Sistema de Obras Públicas, Transporte y Vivienda (SOPTRAVI)

Nicaragua: Administración Vial y Dirección de Vialidad, Ministerio de Transporte e Infraestructura (MTI)

Panama: Dirección Nacional, Instituto Geográfico Nacional "Tommy Guardia" (IGNTG), Ministerio de Obras Públicas

The following points should be kept in mind as a general summary of this document:

- The vulnerability studies of the road segments of the Pan American Highway and its complementary corridors that each of the countries prepared correspond to a first approach and therefore are presented as the beginning of a process that should be continually updated and broadened.
- This document is presented keeping in mind that the institutions that coordinated the vulnerability studies in each of the countries are responsible for its publication and discussion.

- The national technical teams were the principal actors at the initiation of the vulnerability studies. The contents of these studies reflect the availability of information, the actual conceptual focus and the conditions in which the public sector operates with support from consultants.
- The purpose of requiring the type and quantity of the mitigation work on the most vulnerable road segments of the corridors is to support the vulnerability evaluation process of the highway transportation corridors for vulnerability investment and its incorporation into the planning of the transportation sector.
- The lack of sufficient and complete information about natural hazards, the quantity and value of priority mitigation projects to reduce vulnerability indicates the necessity to reinforce activities of the sector in order to produce the missing information.
- The results of the national studies are directly linked to the mutual assistance theme in the case of damages to the infrastructure of highway transportation in the region and implicate a need for additional training of specialists on the subject in both the private and public sectors.

Before describing the structure of this document, it is necessary to explain certain basic concepts that will aid in its comprehension:

- Natural hazards are those geological, atmospheric or meteorological processes that threaten human life and that are caused by forces beyond their control (OAS/DRDE, 1991 and 1993). In this document the natural hazards described are those that most affect the Central American region are earthquakes, hurricanes, floods, landslides and volcanic eruptions.
- Natural hazard evaluation is an evaluation of the location, severity, and the possibility that a natural event may occur within a specific period of time (OAS/DRDE, 1991).
- Vulnerability evaluation is the damage/loss estimate that can be the consequence of a natural hazard event of a specific severity, including construction damages, personal damages, and the interruption of economic services and everyday community activities (OAS/DRDE, 1991).
- In the context of this document, the term “natural hazard” refers to all atmospheric, hydrological and geological phenomena that due to the location, severity and frequency may adversely affect the infrastructure of the highway transportation sector.
- In some nations, the term “natural threat” is used instead of natural hazard.
- When the term “vulnerability profile” is used in this document, it refers to a general study about the transportation road segments that are vulnerable to natural hazards in a specific geographical area.

Based on these definitions, this document contains three chapters, which are briefly described below:

Chapter One, General Study on the Vulnerability to Natural Hazards of the Pan American Highway and its Complementary Corridors, describes vulnerability

studies carried out by the technical teams. It includes the vulnerability road segments of the Pan American Highway and their lengths and the methodology and concepts that were used to determine each vulnerability profile. Such information was gathered from the national profiles sent to the USDE by each focal point, and will be a helpful reference and orientation tool for successful regional highway planning and subsequently the reduction of the effects of natural hazards.

Chapter Two, Relationships of the Activities Regarding Vulnerability Reduction to Natural Hazards of the Central American Transportation Sector presents information relating products and activities generated by this document to the regional studies on vulnerability reduction that are programmed or actually being carried out in the region.

Chapter Three, Conclusions and Recommendations, presents broader comments regarding the reach and usefulness of this information in helping to determine future courses of action in the transportation sector.

In addition, this document has a series of appendices with associated tools that refer to the road segment vulnerability studies carried out in each of the countries and provide a better understanding of the work itself. One of the annexes contains the general format that each country used as a guideline to carry out its study. A similar format was created for bridges related to the road segments previously mentioned (where information was available) in order to study their vulnerability to natural hazards.

Almost all of the information provided in this document comes from national studies carried out by the respective technical groups. In some cases it includes information that comes from other sources, which are duly cited.

PART 1: GENERAL SUMMARY ON THE VULNERABILITY TO NATURAL HAZARDS OF THE PAN AMERICAN HIGHWAY AND ITS COMPLEMENTARY CORRIDORS

Pan American Highway vulnerability to natural hazards

Central America is one of the most vulnerable regions of the world to natural hazards affecting, among other things, the economic infrastructure and therefore the region's sustainable development. For this reason the planning units of the ministries of transportation have initiated vulnerability reduction measures in order to reduce the risk of damages caused by such hazards. Since this document is aimed at the vulnerability reduction of the regional highway transportation sector, specifically the Pan American Highway, the terms and methodology mentioned will exclusively refer to this and, when information is available, it will also refer to alternate corridors identified by the countries that participated in this study.

Some of the most frequent natural hazards affecting Central America today are earthquakes, floods, landslides, and volcanic activity.

Earthquakes

Earthquakes are caused by the sudden release of energy that slowly accumulates along fault lines in the Earth's surface. They represent a particularly severe threat because of the irregular time lapses between episodes, the lack of adequate prediction techniques, and the hazards associated with each event, such as ground tremors, surface faulting, landslides, liquefaction of unsettled matter, sink holes and tsunamis or tidal waves.

Floods

Two types of floods exist: (1) Land floods or river floods, brought on by too much rain and the resulting excessive water flows; and (2) coastal floods caused by the raising of the sea level, frequently worsened by heavy downpours that occur in the higher reaches of the affected basins (OAS/DRDE, 1993).

Landslides

Landslides are associated with various types of natural processes and/or population-generated effects that result in sudden or slow horizontal or vertical movement of material. They may be brought on by earthquakes, volcanic eruptions, ground saturated by excessive rainfalls or by the sudden raising to the surface of the phreatic layer and erosion caused by riverbeds. Landslides are composed of the falling and flow of unsettled ground materials.

Volcanic eruptions

The hazards associated with volcanic eruptions include lava flows, ash and projected material downpours, mudslides and toxic fumes. Volcanic activity can also cause other natural hazards such as local tidal waves, the alteration of the surrounding terrain, the obstruction of rivers, causing floods and landslides provoked by the tremors.

The Pan American Highway vulnerability to natural hazards

In order to organize the information related to the vulnerability to natural hazards of the Pan American Highway and its complementary corridors, the USDE created a matrix-style presentation format that has been named the OAS-USDOT format. The technical information contained in this format is as follows:

- Name or identification code of each road segment at the national level
- Origin
- Destination
- Name of bridge (if one exists)
- Length of road segment in kilometers
- Information of specific threats. This aspect contains four variables: the location of each road segment identified as vulnerable, the length of the vulnerable road segment, the frequency or probability of the occurrence of the phenomenon and its severity. Each natural hazard that affects a specific country have been classified according to these variables
- The highway features: type of pavement, type of soil, actual physical state of the road, annual daily average transit (ADAT), type of cargo transported, and volume of such cargo
- The general natural disaster history of the country

Annex A contains the OAS-UDSOT format for both pavements and bridges, while Annex B contains the matrices about the vulnerability of the Pan American Highway and its complementary corridors (where available) developed by each national technical team.

Figure 2 lists the titles for each vulnerability report and for the focal point for each country. All the reference maps on the location of the described road segments of the Pan American Highway as well as is complementary corridors are available in these reports, which may be obtained through the focal points.

In order for a regional vulnerability profile study to be useful, independent of the type of natural hazards being studied, it is necessary to have standard criteria that will allow for a quick visualization and comprehension of the vulnerability characteristics of a specific infrastructure. For this reason, in addition the OAS-USDOT format, the USDE met with the focal points of each country and their technical teams to clarify and unify criteria in respect to the information to be gathered, especially the frequency and the severity of the phenomena. The following concepts were taken into account:

- In the case of earthquakes, frequency may be taken into account as the probability of occurrence of a certain event of certain severity for a given period of time. Severity can be determined in function of the expected acceleration in zoning, historical acceleration, expected intensity and/or historical intensity. In the event that the historical data is not available, the magnitude of the earthquake measured by the Richter scale is used.
- In the case of floods, frequency has been determined by the number of floods that occur during a specified time period, the severity as calculated over the size of the area, the depth, or the length of time of the event.
- In the case of landslides, frequency has been defined as the volume and type of material that has fallen over a determined time period and the severity of each occurrence have been left to the discretion of its counterparts since there is no standard parameter for measurement.
- In the case of volcanic eruptions, frequency has been defined as the number of eruptions that affect a highway over a determined time period and the severity in terms of the existence or rivers of mud and type of flow, lava flows and volcanic ashes.
- In the case of other threats that may have been included, these will be mentioned along with the frequency and severity evaluation criteria that have been adopted.
- When speaking of the area or radius of influence of a road segment, it refers to one in addition to the actual segment, be it on the left or right side, that are taken into account when performing the study.
- Identification of vulnerable road segments was done based on national road maps as well as national thematic maps on natural hazards. Depending on availability, these maps were used on paper or digital media (on which the Geographical Information Systems (GIS) were used).

Since some national reports provide information on proposed construction for vulnerability reduction in the local currency, the value of such works has been determined in U.S. dollars by USDE based on economic indicators in the month during which this document was drafted.

Figure 2. National Studies and Coordination Focal Points

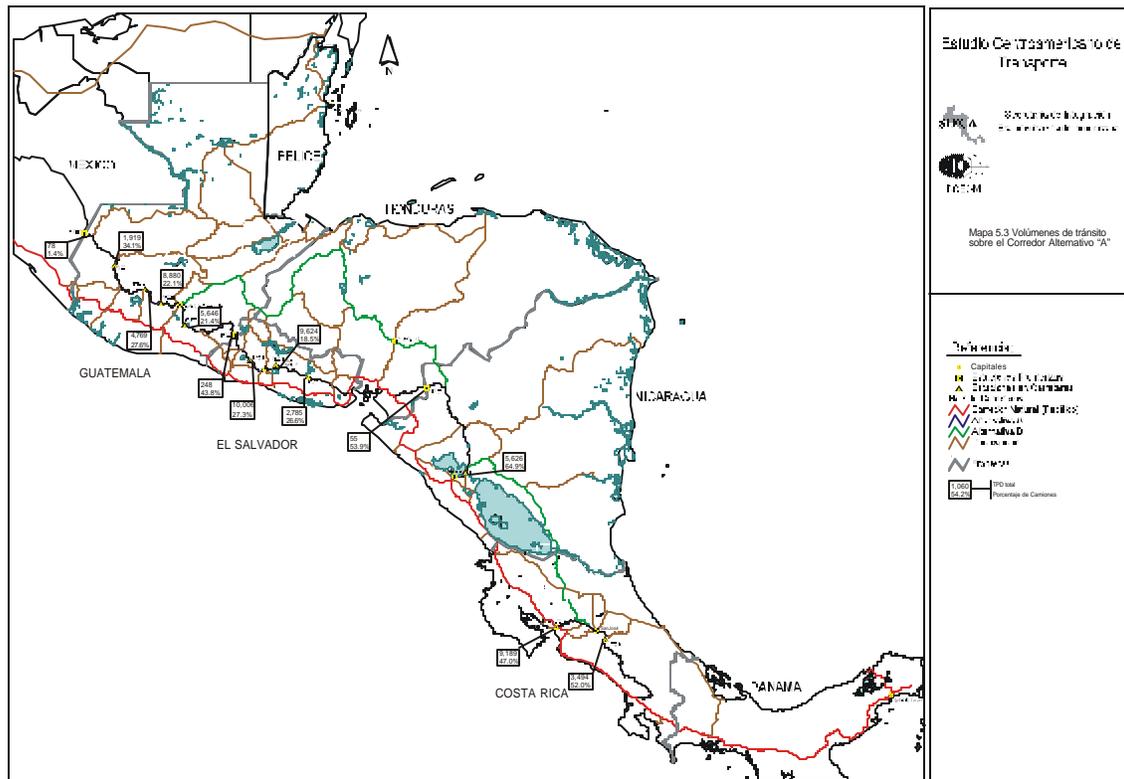
Country	Title of Study	Focal point
Costa Rica	Inter-American Highway Vulnerability Profile	Dirección de Planificación, Ministerio de Obras Públicas y Transporte (MOPT)
El Salvador	Pan American Highway and Alternate Corridor Vulnerability Profile Coastal Highway	Unidad de Planificación Vial, Ministerio de Obras Públicas (MOP)
Guatemala	Recognizance Level Pan American Route Vulnerability Study (CA-01)	División Planificación y Estudios, Dirección General de Caminos (DGC)
Honduras	Pan American Highway and Alternate Corridor Vulnerability Profile in the Republic of Honduras	Unidad de Planeamiento y Evaluación de Gestión, Sistema de Obras Públicas, Transporte y Vivienda (SOPTRAVI)
Nicaragua	Pan American Highway and Alternate Corridor Vulnerability Profile in the Republic of Nicaragua	Administración Vial y Dirección General de Vialidad, Ministerio de Transporte e Infraestructura (MTI)
Panama	Pan American Highway and Alternate Corridor Vulnerability Profile in the Republic of Panama	Dirección Nacional, Instituto Geográfico Nacional "Tommy Guardia" (IGNTG), Ministerio de Obras Públicas

Source: OAS/USDE based on national reports

National reports on the vulnerability to natural hazards of the Pan American Highway in Central America

The map below presents the participating countries in the OAS-USDOT project with their corresponding corridors, Natural Corridor or Pacific Corridor, Alternative A or Pan American Corridor, Alternative B or Atlantic Corridor and connections.

Source: SIECA and BCEOM, 2001



Considering the entire Central American region, Figures 3 and 4 present for each country, the length of road segments vulnerable to each of the hazards and the equivalent percentage, and the cost in U.S. dollars necessary for investment in identified civil works for vulnerability reduction.

Figure 3. Vulnerable Distance to Natural Hazards in the Pan American Highway

País	Longitud de carretera km	Longitud vulnerable (km.)				
		Deslizamientos	Inundaciones	Hundimientos y erosión	Sismos*	Erupciones volcánicas
Costa Rica	647.64	41.75	74.90	No reportado	No reportado	No reportado
El Salvador	307.55	11.40	7.60	No reportado	No reportado	No reportado
Guatemala	462.00	79.00	124.00	141.00	No reportado	No reportado
Honduras	64.90	0.59	0.00	No reportado	0.08	No reportado
Nicaragua	391.34	145.68	100.87	No reportado	355.78	161.87
Panamá	674.90	0.610	0.850	No reportado	391.71	261.12
Total	2548.33	279.03	308.22	141.00	747.57	422.99
Porcentaje	100.00	11	12	5.5	29.34	16.60

*Includes geological faults

Source: USDE/OAS based on national reports

Figure 4. Total Cost in U.S. Dollars of the Identified Labor in Vulnerability Reduction of the Pan American Highway

País	Costo total US\$
Costa Rica	387.000,00
El Salvador	46.780.053,00
Guatemala	2.711.800,00
Honduras	5.165.285,00
Nicaragua	26.202.260,00
Panamá	No reportado
Total	80.859.398,00

Source: USDE/OAS based on national reports

The Pan American Highway in every country has been affected by landslide and in the majority of the countries, it has been affected by floods with the exception of Honduras. Nonetheless, an execution report prepared in 1999 by the General Directorate for the Conservation of Highways and Airports of SOPTRAVI reported occasional damage from Hurricane Mitch to the transportation infrastructure of that country.

Notwithstanding the instability of the soils in Central America, only Guatemala reported segments of the Pan American Highway to sinking and erosion.

Taking into account the total length of the Pan American Highway, the largest reported quantity of vulnerable highway segments was for earthquakes, 747.49 km of which 391.71 km and 355.78 km pertain to vulnerable highway segments in Panama and Nicaragua, respectively.

Given the high seismicity of the Central America region, only Honduras, Nicaragua and Panama reported vulnerable road segments of the Pan American Highway to earthquakes. Cases such as El Salvador, which recently experienced earthquake activity, should consider a study to qualify and quantify the length of highway segments vulnerable to this type of hazard.

PART 2: RELATIONSHIPS OF ACTIVITIES REGARDING VULNERABILITY REDUCTION TO NATURAL HAZARDS OF THE CENTRAL AMERICAN TRANSPORTATION SECTOR

The impact of natural hazards in Central America such as Hurricane Mitch has negatively affected the different sectors of the region, including highway transportation and its infrastructure. These natural hazards have created incentives for the USDE and other national and regional institutions to prepare steps to reduce the vulnerability specifically of the highway transportation sector to natural hazards.

Given the economic and social importance on a regional level of having a safe and secure transportation infrastructure, and to enforce the subject of vulnerability reduction to natural hazards, USDE has promoted the efforts of regional organizations such as SIECA, COMITRAN, COCATRAM and CEPREDENAC to include vulnerability reduction in projects related to the highway transportation sector.

Among the recent USDE activities related to vulnerability reduction in the transportation sector is the OAS-USDOT Transportation Vulnerability Reduction Project for Central America, which consists of three components:

1. General Study on Vulnerability Reduction of Road Segments to Natural Hazards on the Pan American Highway and its Complementary Corridors in Central America
2. Mechanisms for Mutual Assistance in Case of Damage and Vulnerability Reduction of Transportation Infrastructure in Central America
3. Training on the Use of Information on Natural Hazards for the Formulation and Evaluation of Investment Projects in the Highway Transportation Sector

This document is part of the first component of the OAS-USDOT project and has as its objective to serve as a technical guide to the planning directorates of the ministries of transportation in the region and/or regional or international organizations that are developing or executing projects related to the highway transportation sector.

The objective of this chapter is to identify the products of each of the components of the OAS-USDOT project, and to associate these with the products of the regional institutions SIECA and CEPREDENAC, since they are directly linked to products of the OAS-USDOT project. With this USDE intends for the regional organizations previously mentioned, as well as other organizations interested in the subject, to be able to identify in an efficient way, the usefulness of the information presented by all projects.

On the international level, it is understood that due to the impact caused by Hurricane Mitch on the regional economic and social level, the international community started on a series of efforts to attend to emergency and rehabilitation needs. On December 10, 1998, in Washington DC, the Inter-American Development Bank (IDB) called a meeting to determine the rehabilitation and reconstruction international cooperation needs. In order to tackle the subjects of reconstruction and vulnerability reduction at the same time, another meeting of the Consultative Group for the Transformation and Reconstruction of Central America was held in Stockholm, Sweden on May 25-28, 1999, which was also called for by the IDB.

During this meeting the governments of Central America countries and the international community decided to share responsibility of the reconstruction and transformation of the affected countries, starting a long-term association guided by priorities as defined by the Central American countries and based on the following principles and objectives (Stockholm Declaration, 1999):

1. To reduce the ecological and social vulnerability of the region, as the main objective.
2. Rebuild and transform Central America based on an integrated approach with transparency and governability.
3. To consolidate democracy and governability, enforcing the de-centralization of government functions and its span of responsibility, with the active participation of the civilian population.
4. To promote the respect of human rights as a permanent objective. The promotion of equal rights regardless of gender, ethnic group or minority and the rights of children must be a priority.
5. To coordinate the efforts of donors, guided by the priorities established by the countries receiving the aid.
6. To intensify efforts to reduce the foreign debt of the countries in the region.

In addition to the national efforts for reconstruction that are supported by the international community, the presidents of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and the First Vice President of Panama, accompanied by the Vice Prime Minister of Belize and the Vice President of the Dominican Republic serving as observers, held the 20th Presidential Summit from October 18-19, 1999 in Guatemala City, Guatemala. In this summit they started a regional effort and focused the subjects on the improvement of the quality of life of the inhabitants of the region and the creation of new development opportunities. With this they created the Declaration of Guatemala II, in which they mentioned the following issue among others (Declaration of Guatemala, Guatemala City, October 19, 1999):

The devastating consequences of the different natural phenomena that have affected this region have made more evident its

vulnerability, and placed under risk the unique richness of Central America's bio-diversity, which represents 10% of the world's total.

With this Declaration the Presidents agreed on specific actions that focused on the vulnerability reduction of natural disasters in all social and economic sectors. The specific actions are as follows:

- To adopt the Strategic Framework for the Reduction of Vulnerability and Disaster in Central American, which is part of the region's transformation and sustainable development process for the next millennium, and that includes the basic guidelines on prevention measures and damage control, as well as readiness and emergency prevention measures, giving special attention to the most vulnerable groups and sections of society, especially on the levels of poverty and marginality focused on gender. The Strategic Framework, which is an integral part of this Declaration, is the gauge for the elaboration, actualization, habilitation, and development of regional plans on the subject of the Reduction of Vulnerability and Disasters, Integrated Management and Preservation of Water Resources, and Prevention and Control of Forest Fires.
- To establish the Five-Year Central American Project for the Reduction of Disaster Vulnerability and Impact 2000-2004, during which efforts will have to concentrate on the transformation and search for sustainable development in our societies, for which the extra aid by the international community is desired. To assign CEPREDENAC to coordinate this five-year effort.
- To instruct the Council of Ministers of External Relations and the Council of Ministers in general and other corresponding sector groups, so that with the aid of the General Secretariat of SICA and in alliance with the specialized regional institutions will complete and maintain a close following of the developments of the Strategic Framework.
- To instruct the Central American Security Commission so that it will, in alliance with the respective national authorities, establish in the shortest time frame possible the joint action mechanisms, and that these mechanisms be transparent and share in the region's risk prevention and disaster mitigation, with the help of the corresponding regional institutions.
- To assign, according to the possibilities of each country, the internal financial resources needed for such initiatives; to emphasize the call to the cooperating international community so they it contributes in its effort to reduce the level of vulnerability in case of disasters in the region. And to instruct the Council of Ministers of External Relations to, with the aid of the General Secretariat of SICA, coordinate the management of international technical and financial international resources that are required for the completion of these projects on a regional level, while the respective government agencies will do the same on a national level.

During the 20th Presidential Summit the Presidents also analyzed the possibility of having a new meeting of the Regional Consultative Group in Madrid,

Spain, to examine the possibilities of cooperating to support Central America in its medium and long-term transformation and modernization.

A direct response to these mandates is the OAS-USDOT project, as well as the activities that SIECA and CEPREDENAC have performed or are performing related to the vulnerability reduction of the Central American highway transportation sector.

Figure 5, from the Spanish version of this document, presents three columns of which the first describes the products of which the OAS-USDOT project is comprised, the second presents products under SIECA's coordination and related to the vulnerability reduction of the highway transportation sector. These projects correspond to the "Master Plan for Regional Transportation for the 2001-2010 Decade" (Central American Transportation Study, ECAT), "Improved Regional Capacity to Mitigate the Effects of Transnational Disasters," and "The Transportation Sector in the Regional Plan for Disaster Reduction," and the "Central American Logistical Corridor." The third column presents the products of the Basic Plan of the Regional Plan for Disaster Reduction (PRRD) and are linked to the principal export trade corridors that are directly related to each of the three components of the OAS-USDOT project. CEPREDENAC created PRRD as one of its initiatives to establish a Central American strategy to reduce the societal impact of disasters.

As can be observed in Figure 5 the three components of the OAS-USDOT project provide useful information to the regional activities of the transportation sector. These activities are under the coordination of SIECA and CEPREDENAC given that they have in common disaster prevention and mitigation of the regional road segments in the transportation sector.

Cuadro 5. Aportes de los Proyectos de la OEA-USDOT sobre la Reducción de Vulnerabilidad del Sector Transporte a los Productos de las Actividades Regionales de SIECA y CEPREDENAC

Figure 5. Contributions of the OAS–USDOT Project on Vulnerability Reduction of the Transportation Sector to SIECA and CEPREDENAC Regional Activities

<p>Proyecto OEA-USDOT sobre la Reducción de Vulnerabilidad del Sector Transporte en Centro América</p> <p><i>OAS-USDOT/Project on Vulnerability Reduction of the Transportation Sector in Central America</i></p>	<p>SIECA</p> <p>Proyectos Regionales del Sector Transporte</p> <p><i>Transportation Sector Regional Projects</i></p>	<p>CEPREDENAC</p> <p>Plan Básico del Plan Regional de Reducción de Desastres(PRRD)</p> <p><i>Basic Plan for the Regional Plan for Disaster Reduction</i></p>
<p>1. Estudio General sobre los Tramos Vulnerables a los Peligros Naturales de la Carretera Panamericana y sus Corredores Complementarios en Centroamérica</p> <p><i>General Study on the Vulnerability of Road Segments to Natural Hazards of the Pan American Highway and its Complementary Corridors in Central America</i></p> <p>Los temas que abarca el estudio se presentan a continuación, mencionando el material que se encuentra disponible en los estudios nacionales de cada uno de los países que participaron en el proyecto (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua y Panamá), a menos que se indique lo contrario:</p> <p><i>The subjects covered by the study are listed below, including material that is available in each of the national studies of the countries that participated in the project (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panamá), unless otherwise indicated:</i></p>	<p>1. Proyecto SIECA “Plan Maestro de Transporte Regional para la Década 2001–2010” (Estudio Centroamericano de Transporte, ECAT)</p> <p><i>SIECA Project “Masterplan for Regional Transportation for the 2001-2010 Decade” (Central American Transportation Study, ECAT)</i></p> <ul style="list-style-type: none"> • Bases para fortalecer y organizar el desarrollo del sector transporte de Centroamérica con proyectos que ayuden a lograr mayores niveles de competencia, eficiencia y sostenibilidad, que reducen los costos y que permiten la participación del sector privado en la ejecución y financiamiento de los proyectos <p><i>Basis for strengthening and organizing the development of the transportation sector in Central America with projects that will help achieve higher levels of competitiveness, efficiency and sustainability, that reduce costs, and that permit the participation of the private sector in the execution and financing of the projects</i></p> <ul style="list-style-type: none"> • Listado detallado de proyectos y programas en ejecución y por ejecutarse 	<p>1. Plan Básico del Plan Regional de Reducción de Desastres(PRRD)</p> <p><i>Basic Plan for the Regional Plan for Disaster Reduction</i></p> <p>Documento preparado por LANAMME por encargo de CEPREDENAC titulado “Estrategia del Sector Transporte para su Incorporación en el Plan Básico del Plan Regional de Reducción de Desastres.” Este documento hace relación a los principales corredores de exportación.</p> <p><i>Document prepared by LANAMME at the request of CEPREDENAC entitled, “Transportation Sector Strategy for Incorporation in the Basic Plan of the Regional Plan for Disaster Reduction” The document relates to the principal export corridors.</i></p>

<ul style="list-style-type: none"> • Longitud en kilómetros de la Carretera Panamericana vulnerable a los peligros naturales <i>Length in kilometers of the Pan American Highway vulnerable to natural hazards</i> • Metodologías utilizadas para la identificación y cálculo de la longitud de tramos de Carretera Panamericana vulnerables a peligros naturales <i>Methods used for the identification and calculation of the length of segments of the Pan American highway vulnerable to natural hazards</i> • Obras de reducción de vulnerabilidad y sus costos aproximados en US\$. Los informes presentados por Costa Rica y Panamá están limitados a la identificación de las obras y sus costos no se incluyen <i>Vulnerability reduction works and their estimated costs in US\$. The reports presented by Costa Rica and Panama are limited in the presentation of works and the associated costs are not included.</i> 	<p><i>Detailed list of projects and programs in execution and to be executed</i></p> <ul style="list-style-type: none"> • Definición de la estrategia de desarrollo, de financiamiento y el monto de los recursos requeridos para el desarrollo del transporte de la región <i>Definition of the development strategy, financing and amount of resources required to develop transportation in the region</i> • Establecimiento de las prioridades en la ejecución de proyectos nacionales y regionales en el sector transporte <i>Establishment of the priorities for the execution of projects in the national and regional transportation sector</i> • Recomendación de las modalidades para la participación del sector privado en los proyectos que financieramente sean de particular interés <i>Recommend models for the participation of the private sector in the projects that are of particular financial interest</i> • Base de datos para actualizar el plan maestro de transporte regional en forma regular y permanente, especificando la adquisición de equipo de cómputo y de software para los sistemas de información <i>Data base for updating in a regular and permanent way the masterplan, specifying the acquisition of computer equipment and software for information systems</i> • Actividades de divulgación y entrenamiento sobre los resultados del estudio, con la participación de los involucrados con el desarrollo del nuevo modelo de transporte en cada país 	<ul style="list-style-type: none"> • Evaluación del riesgo: comprende reducción de la vulnerabilidad de la infraestructura y población expuestas al riesgo <i>Evaluation of risk: covers vulnerability reduction of exposed infrastructure and population</i> • Evaluación de la amenaza: comprende mapas de amenaza, parámetros para diseño general o valores específicos para un sitio determinado <i>Evaluation of hazards: covers hazard maps, general design parameters and specific values for an identified site</i> • Evaluación de la vulnerabilidad: comprende vulnerabilidad física y vulnerabilidad funcional <i>Evaluation of the vulnerability: covers physical and functional vulnerability</i>
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	<p><i>Dissemination and training activities related to the results of the study with the participation of those involved in the development of the new model for transportation in each country</i></p> <p>2. Proyecto SIECA–USAID “Mejor Capacidad de la Región para Mitigar los Efectos Transnacionales de Desastres”</p> <p><i>SIECA–USAID Project “Improved Regional Capacity to Mitigate the Effects of Transnational Disasters”</i></p> <ul style="list-style-type: none">• Manual Centroamericano de Especificaciones para la Construcción de Carreteras y Puentes Regionales <i>Central American Manual of Specifications for the Construction of Regional Highways and Bridges</i>• Manual Centroamericano de Especificaciones para el Diseño Geométrico de Carreteras Regionales <i>Central American Manual of Specifications for Geometric Design of Regional Highways</i>• Manual de Mantenimiento Vial <i>Manual for Highway Maintenance</i> <p>3. Proyecto SIECA “El Sector Transporte en el Plan Regional de Reducción de Desastres”</p> <p><i>SIECA Project “The Transportation Sector in the Regional Plan for Disaster Reduction”</i></p> <ul style="list-style-type: none">• Evaluación del riesgo (evaluación de amenaza, evaluación de la vulnerabilidad, contraste amenaza/vulnerabilidad) <i>Risk evaluation (evaluation of hazard, evaluation of vulnerability, comparison of hazard and vulnerability)</i>	
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	<ul style="list-style-type: none">• Identificación y formulación de proyectos específicos (perfiles de proyectos que requieren ejecución, con énfasis en los puntos históricos de alta vulnerabilidad e infraestructura expuesta; priorización de inversiones a partir de un análisis de costo/beneficio, medidas estructurales para corregir vulnerabilidad física, medidas no estructurales para corregir vulnerabilidad institucional) <i>Identification and formulation of specific projects (profiles of projects that require execution, with emphasis on the historic places of high vulnerability and exposed infrastructure, prioritization of investments based on a cost/benefit analysis, structural measures to correct physical vulnerability, non-structural measures to correct institutional vulnerability)</i>• Ejecución, seguimiento y evaluación de proyectos (bases de datos actualizadas sobre la vulnerabilidad existente; carteras de proyectos y obras en ejecución; inclusión de los conceptos de amenaza, vulnerabilidad y análisis de riesgo en futuros proyectos; inversión en readecuación; preparación para contingencias, estricto control de calidad y mantenimiento apropiado; investigación científica para el ajuste y readecuación de los diseños y códigos; adaptación de avances tecnológicos; capacitación y educación del personal involucrado) <i>Execution, follow up and evaluation of projects (updated data bases on existing vulnerability; portfolios of projects and works in execution; inclusion of concepts of hazard, vulnerability and analysis of risk in future projects; investment in retrofitting; preparation for contingencies, strict control of quality and appropriate maintenance; scientific research to adjust and retrofit designs and codes; adaptation of technological advances; training and education of involved personnel)</i>	
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	<p>4. Proyecto SIECA “Corredor Logístico Centroamericano”</p> <p><i>SIECA Project “Central American Logistical Corridor”</i></p> <ul style="list-style-type: none">• Mejoramiento de la eficiencia de los sistemas de transporte <p><i>Improvement in the efficiency of the transportation systems</i></p>	
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<p>Proyecto OEA-USDOT sobre la Reducción de Vulnerabilidad del Sector Transporte en Centro América</p> <p><i>OAS-USDOT/Project on Vulnerability Reduction of the Transportation Sector in Central America</i></p>	<p>SIECA</p> <p>Proyectos Regionales del Sector Transporte</p> <p><i>Transportation Sector Regional Projects</i></p>	<p>CEPRENAC</p> <p>Plan Básico del Plan Regional de Reducción de Desastres (PRRD)</p> <p><i>Basic Plan for the Regional Plan for Disaster Reduction</i></p>
<p>2. Mecanismos de Asistencia para Daños y Reducción de Vulnerabilidad de la Infraestructura del Sector Transporte en Centroamérica ante la Ocurrencia de Desastres Naturales</p> <p><i>Mechanisms for Mutual Assistance in Case of Damage and Vulnerability Reduction of Transportation Infrastructure in Central America</i></p> <p>El documento presenta un análisis de la situación actual y propuesta de la utilización de mecanismos formales por parte del sector público y privado. Se presenta la siguiente información:</p> <p><i>The document presents an analysis of the actual and proposed state of utilization of formal mechanisms by the public and private sectors. The following information is presented:</i></p> <ul style="list-style-type: none"> Identificación de los componentes de la infraestructura de cada uno de los modos de transporte, (terrestres, aéreo y marítimo), más vulnerable a los peligros naturales. Esta identificación fue dada a conocer por cada una de las autoridades de transporte respectivas. 	<p>1. Proyecto “Plan Maestro de Transporte regional para la Década 2001 – 2010” (Estudio Centroamericano de Transporte, ECAT)</p> <p><i>SIECA Project “Masterplan for Regional Transportation for the 2001-2010 Decade” (Central American Transportation Study, ECAT)</i></p> <ul style="list-style-type: none"> Bases para fortalecer y organizar el desarrollo del sector transporte de Centroamérica con proyectos que ayuden a lograr mayores niveles de competencia, eficiencia y sostenibilidad, que reduzca los costos y que permita la participación del sector privado en la ejecución y financiamiento de los proyectos <p><i>Basis for strengthening and organizing the development of the transportation sector in Central America with projects that will help achieve higher levels of competitiveness, efficiency and sustainability, that reduce costs and permit the participation of the private sector in the execution and financing of the projects</i></p> <ul style="list-style-type: none"> Recomendación de las modalidades para la participación del sector privado en los proyectos que financieramente sean de particular interés <p><i>Recommendation of models for the participation of the private sector in the projects that are of particular financial interest</i></p> <ul style="list-style-type: none"> Base de datos para actualizar el plan maestro de 	

<p><i>Identification of the infrastructure components for each of the transportation modes (air, maritime and land) most vulnerable to natural hazards. This identification was made known by the respective authorities of each mode.</i></p> <ul style="list-style-type: none"> • Identificación de las prioridades en cuanto a asistencia requerida en caso de daños a la infraestructura de transporte <p><i>Identification of priorities as to assistance needs in case of damage to transportation infrastructure</i></p> <ul style="list-style-type: none"> • Identificación de las necesidades en cuanto a la reducción de vulnerabilidad de la Infraestructura de transporte <p><i>Identification of needs as to vulnerability reduction of vulnerable transportation infrastructure</i></p> <ul style="list-style-type: none"> • Identificación y propuestas para el uso de mecanismos existentes para mejorar asistencia y mejorar coordinación <p><i>Identification and proposals for the use of existing mechanisms to better assistance and improve coordination</i></p> <ul style="list-style-type: none"> • Propuestas de nuevos mecanismos para la ampliación de recursos y mejorar implementación <p><i>Proposals for new mechanisms for expanding resources and improving implementation</i></p>	<p>transporte regional en forma regular y permanente, especificando la adquisición de equipo de cómputo y de software para los sistemas de información</p> <p><i>Data base for updating in a regular and permanent way the masterplan, specifying the acquisition of computer equipment and software for information systems</i></p> <p>2. Proyecto SIECA–USAID, “Mejor Capacidad de la Región para Mitigar los Efectos Transnacionales de Desastres”</p> <p><i>SIECA–USAID Project “Improved Regional Capacity to Mitigate the Effects of Transnational Disasters”</i></p> <ul style="list-style-type: none"> • Acuerdo Centroamericano de Circulación por Carretera <p><i>Central American Agreement on Highway Transit</i></p> <ul style="list-style-type: none"> • Manual Centroamericano de Especificaciones para la Construcción de Carreteras y Puentes Regionales <p><i>Central American Manual on Specifications for Construction of Regional Highways and Bridges</i></p> <ul style="list-style-type: none"> • Manual de Mantenimiento Vial <p><i>Manual on Highway Maintenance</i></p> <p>3. Proyecto SIECA “El Sector Transporte en el Plan Regional de Reducción de Desastres”</p> <p><i>SIECA Project “The Transportation Sector in the Regional Plan for Disaster Reduction”</i></p> <ul style="list-style-type: none"> • Identificación y formulación de proyectos específicos (perfiles de proyectos que requieren ejecución con énfasis en los puntos históricos de alta vulnerabilidad e infraestructura expuesta, priorización de inversiones a partir de un análisis de costo/beneficio, medidas 	
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	<p>estructurales para corregir vulnerabilidad física, medidas no estructurales para corregir vulnerabilidad institucional)</p> <p><i>Identification and formulation of specific projects (profiles of projects that require execution, with emphasis on the historic places of high vulnerability and exposed infrastructure, prioritization of investments based on a cost/benefit analysis, structural measures to correct physical vulnerability, non-structural measures to correct institutional vulnerability</i></p> <ul style="list-style-type: none">• Ejecución, seguimiento y evaluación de proyectos (Bases de datos actualizadas sobre la vulnerabilidad existente, carteras de proyectos y obras en ejecución, Inclusión de los conceptos de amenaza, vulnerabilidad y análisis de riesgo en futuros proyectos, inversión en readecuación, preparación para contingencias, estricto control de calidad y mantenimiento apropiado, investigación científica para el ajuste y readecuación de los diseños y códigos, adaptación de avances tecnológicos; capacitación y educación del personal involucrado) <p><i>Execution, follow up and evaluation of projects (updated data bases on existing vulnerability; portfolios of projects and works in execution; inclusion of concepts of hazard, vulnerability and analysis of risk in future projects; investment in retrofitting; preparation for contingencies, strict control of quality and appropriate maintenance; scientific research to adjust and retrofit designs and codes; adaption of technological advances; training and education of involved personnel)</i></p>	
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	<p>4. Proyecto SIECA “Corredor Logístico Centroamericano”</p> <p><i>SIECA Project “Central American Logistical Corridor”</i></p> <ul style="list-style-type: none">• Fomento de la inversión en el sector <i>Promote investment in the sector</i>• Mejoramiento de la eficiencia de los sistemas de transporte <i>Improve the efficiency of transportation systems</i>• Mayor eficiencia en la logística comercial internacional para que desarrolle la provisión de insumos con la producción, la comercialización, la distribución y el consumo <i>Better efficiency in international commercial logistics so that the provision of inputs is developed with the production, commercialization, distribution and consumption</i>• Participación efectiva del sector privado <i>Effective participation of the private sector</i>	
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<p>Proyecto OEA-USDOT sobre la Reducción de Vulnerabilidad del Sector Transporte en Centro América</p> <p><i>OAS-USDOT/Project on Vulnerability Reduction of the Transportation Sector in Central America</i></p>	<p>SIECA</p> <p>Proyectos Regionales del Sector Transporte</p> <p><i>Transportation Sector Regional Projects</i></p>	<p>CEPRENAC</p> <p>Plan Básico del Plan Regional de Reducción de Desastres (PRRD)</p> <p><i>Basic Plan for the Regional Plan for Disaster Reduction</i></p>
<p>3. Capacitación en el Uso de Información sobre Peligros Naturales para la Formulación y Evaluación de Proyectos de Inversión en el Sector Transporte Vial</p> <p><i>Training in the Use of Natural Hazard Information in the Formulation and Evaluation of Investment Projects in the Road Transportation Sector</i></p> <p>Presentación del curso y su manual de capacitación regional del cual se tienen básicamente los siguientes resultados:</p> <p><i>Course presentation and its manual for regional training with the following results:</i></p> <ul style="list-style-type: none"> • Personal técnico de la región capacitado para formular y evaluar proyectos de inversión para el sector transporte vial, enfocando en el uso de información sobre peligros naturales <p><i>Technical personnel from the region trained in the formulation and evaluation of investment projects in the road transportation sector, focusing on the use of natural hazard information</i></p> <ul style="list-style-type: none"> • Manual de curso con descripción, estructura y contenido de sesiones, ejercicios, bibliografía y estudios de caso (“Uso de Información sobre Peligros Naturales en la Formulación y Evaluación de Proyectos de Inversión del 	<p>1. Proyecto SIECA “Plan Maestro de Transporte regional para la Década 2001 – 2010” (Estudio Centroamericano de Transporte, ECAT)</p> <p><i>SIECA Project “Masterplan for Regional Transportation for the 2001-2010 Decade” (Central American Transportation Study, ECAT)</i></p> <ul style="list-style-type: none"> • Actividades de divulgación y entrenamiento sobre los resultados del estudio, con la participación de los involucrados con el desarrollo del nuevo modelo de transporte en cada país <p><i>Dissemination and training activities related to the results of the study with the participation of those involved in the development of the new model for transportation in each country</i></p> <p>2 Proyecto SIECA-USAID “Mejor Capacidad de la Región para Mitigar los Efectos Transnacionales de Desastres”</p> <p><i>SIECA-USAID Project “Improved Regional Capacity to Mitigate the Effects of Transnational Disasters”</i></p> <ul style="list-style-type: none"> • Identificación y formulación de proyectos específicos (Perfiles de proyectos que requieren ejecución con énfasis en los puntos históricos de alta vulnerabilidad e infraestructura expuesta, Priorización de inversiones a partir de un análisis de costo / beneficio, Medidas estructurales para corregir vulnerabilidad física, Medidas no estructurales para corregir vulnerabilidad institucional) 	

<p>Sector Transporte Vial¹⁹⁾</p> <p><i>Course manual with description, structure and content of sessions, exercises, bibliography and case studies (“Use of Natural Hazard Information in the Formulation and Evaluation of Investment Projects in the Road Transportation Sector”)</i></p>	<p><i>Identification and formulation of specific projects (profiles of projects that require execution, with emphasis on the historic places of high vulnerability and exposed infrastructure, prioritization of investments based on a cost/benefit analysis, structural measures to correct physical vulnerability, non-structural measures to correct institutional vulnerability)</i></p> <ul style="list-style-type: none"> • Ejecución, seguimiento y evaluación de proyectos (Bases de datos actualizadas sobre la vulnerabilidad existente, carteras de proyectos y obras en ejecución, Inclusión de los conceptos de amenaza, vulnerabilidad y análisis de riesgo en futuros proyectos, Inversión en readecuación, preparación para contingencias, estricto control de calidad y mantenimiento apropiado, Investigación científica para el ajuste y readecuación de los diseños y códigos, adaptación de avances tecnológico y capacitación y educación del personal involucrado) <p><i>Execution, follow up and evaluation of projects (updated data bases on existing vulnerability; portfolios of projects and works in execution; inclusion of concepts of hazard, vulnerability and analysis of risk in future projects; investment in retrofitting; preparation for contingencies, strict control of quality and appropriate maintenance; scientific research to adjust and retrofit designs and codes; adaptation of technological advances; training and education of involved personnel)</i></p>	
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Fuente: UDSMA/OEA basado en informes nacionales y regionales.
USDE/OAS based on national and regional reports.

PART 3: CONCLUSIONS AND RECOMMENDATIONS

As was referred to in the Introduction, the intention of this document is to present the information from the national studies on the vulnerability of road segments to natural hazards of the Pan American Highway and its complementary corridors in Central America, and to note the contribution of the OAS-USDOT project to existing and future activities under the coordination of SIECA and CEPREDENAC in Central America.

The objective of presenting the conclusions and recommendations noted below are to highlight what has been learned from the national vulnerability studies, the process that produced the studies, and the preparation of this document. It is hoped that the recommendations identified will promote natural hazard vulnerability reduction in the highway transportation sector.

The elaboration of national vulnerability studies to natural hazards of the Pan American Highway and evaluation methodologies

Conclusions

- The possibility of creating in a planned, and therefore sustainable ways, the maximum regional and national benefits from not only passengers but also freight transportation, depends on the security, effectiveness and efficiency of road corridors, particularly if the corridor is as important as the Pan American Highway.
- A transport system that is safe, efficient and less vulnerable to natural hazards generates confidence in its users, strengthening exports, and thereby the economic growth of the country.
- From the national studies and the vulnerability matrices, the most important regional corridors are the three commercial corridors: Pan American Highway / Corridor Alternative A or Central Corridor; Atlantic Corridor or Corridor Alternative B; and Natural Highway Corridor or Pacific Corridor and their different connections. These are the main roads of the Central American road transportation network, and they link the principal cities with the hinterland of the region, and they are keys in the regional commerce.
- There exists no regional criterion on acceptable levels of vulnerability in the highway transportation sector.
- The lack of training in vulnerability reduction and risk management in Central America is reflected in the lack of experience of systematic incorporation of natural hazards information in the preparation of investments projects.
- The use of information about natural hazards is a new focus for the region to reduce vulnerability and raise the profitability of the sector.
- Reflecting on the experience of coordinating the national studies, highway planning and vulnerability reduction to natural hazards activities are managed in separate ways. They are complementary because vulnerability reduction is

a part of transportation planning that has not been used much until now, but is very useful for inventory control of road infrastructure. Vulnerability studies also contribute to the definition of the civil works and the budget needed for normal corridor functioning.

- The absence of interaction and information exchange about the generation, distribution and use of natural hazard data between national institutions has been observable in the preparation of the national studies. Among the aspects that made difficult the preparation of studies is the limited information about natural hazards that affect road networks; weak training of technical staff and decision makers on management, methodology and vulnerability evaluation; the absence of national natural hazards maps such as flood maps, seismic zoning maps for expected acceleration, historic acceleration and/or expected intensity or historic intensity; and volcanic hazard zoning in terms of lava flows, projectiles and gases.
- Because of the lack of information about natural hazards some countries depend on direct observation in order to determine the vulnerable road segments, which increases the cost of the studies to be carried out.
- Because of the lack of information about natural hazards that threaten the corridors in each country, some of the vulnerability matrices do not present all requested data.
- Based on the information presented in the national studies, and considering the entire Central American region, the Pan American Highway is vulnerable to landslide and floods, excepting Honduras, although, the transportation infrastructure of this country was affected by Hurricane Mitch.
- Despite soil instability in Central America, only Guatemala reported the existence of road segments vulnerable to land subsidence and erosion.
- Considering all the vulnerable segments of the Pan American Highway, the great majority of vulnerable road segments to earthquakes belong to Panama 391.71 km. and to Nicaragua 355.78 km.
- In spite of the high seismic activity in El Salvador, the vulnerable segments to this hazard of the corridors studied were not identified.
- The technical teams from the six Central American nations were the main actors at the beginning of the preparation of the vulnerability studies. The studies reflect the information available about natural hazards in each country, the current conceptual approaches, and also the situation of the public sector in dealing with private sector consultants, as the case may be.

Recommendations

- Given the time and the spatial constancy of vulnerability in Central America, it is highly recommended that the national studies vulnerability to natural hazards be updated annually. Moreover they should include not only the Pan American Highway but also the alternative and complementary corridors. The preparation of these annual studies supports the Guatemala Declaration II, through contributing to the elaboration, updating, adaptation and development of the regional plans on vulnerability reduction and disasters.

- A vulnerability study should include the identification of the vulnerability reduction work needed for the rehabilitation or reconstruction for specific kinds of structures. Because of this, it is also necessary to identify alternative transportation infrastructure that could be used during the rehabilitation period of the principal transportation infrastructure. It is recommended that the countries complement, as soon as possible, the information on the Pan American Highway with that on complementary corridors, if they have not yet done so.
- It is recommended that the departments of highway planning or their equivalents in the transportation ministries in Central America include the use of information on natural hazards in the formulation and evaluation processes of investments in transportation projects.
- It is necessary that each country, according to its vulnerability study and current situation, complement the existing information on the vulnerable road segments of the Pan American Highway and its complementary corridors. Examples are Costa Rica and El Salvador, which did not present the vulnerable road segments to land subsidence and erosion, nor to seismic nor to volcanic threats; Guatemala did not present the vulnerable road segments neither to seismic nor to volcanic eruptions; Honduras did not report vulnerable road segments to floods, land subsidence, to erosion and to volcanic eruptions; and finally Panama and Nicaragua did not present the vulnerable road segment for land subsidence and erosion.
- At the national level it is recommended the adoption of acceptable levels of vulnerability to natural hazards be based on regional agreements concerning the development of the transportation corridors, highways development and maintenance.
- It is necessary that the highway planning units strengthen training in risk management of both the technical staff and the decision-makers, and in vulnerability reduction of the highway transportation sector. Their active participation in courses on information management of natural hazards, and formulating and evaluating investment projects on vulnerability reduction of the transportation sector is desirable.
- From the national studies it appears that there is no standard methodology for evaluating vulnerability in the region. Therefore the development of this methodology is recommended, incorporating actions and commitments for its implementation.
- The feasibility studies for highway project investments must include vulnerability studies in order to establish the geographical areas with the most potential for the development projects and to determine if the areas are situated in vulnerable zones, conditioning the feasibility of the project. Thus, vulnerability studies are tools to determine the project viability.
- It is recommended that in the future the vulnerability studies be made with available scientific information, such as geological, geomorphologic or land maps, weather and hydrological facts, topographic maps, air photographs and satellite images. Just as important is the need to characterize the potential

natural hazard events, and historic information in oral or written from the habitants of the threaten areas.

- With the objective of recognizing the vulnerability of the highway transportation infrastructure in its regional context, is recommended that vulnerability evaluation and management be multimodal. This means that in the context of the transportation sector, land, sea, air and railway transportation modes are analyzed in relation to all economic sectors of the region, such as the agriculture, energy and tourism sectors.
- National and regional transportation sector institutions should recognize the economic and social importance of vulnerability studies and create measures that demand the systematic and frequently distribution of information on transportation infrastructure in the region.

Civil Mitigation Works

Conclusions

- From the national studies it appears that El Salvador is the country that, until now, has identified the largest sums for proposed investments in vulnerability reduction works for the Pan American Highway. The most common works consist of road surface restitution, slope stabilization with wire mesh and grass, reforestation, bridge construction and realignment of the road at the Laguna de Aramuaca site.
- Referring to the Pan-America road mitigation works in other countries, Costa Rica developed specific project profiles to reduce vulnerability in the Buenos Aires - Palmar road segment. Guatemala mentioned needed vulnerability reduction studies covering geological, geotechnical, and hydrological and hydraulic aspects. Honduras mentioned works such as embankment back-fill; slope cutting; base, sub-base and soil material replacement; and drainage works. Among the mitigation works mentioned by Nicaragua are monitoring unstable slopes, reforestation programs, construction of groin and stone walls in flood plains, slopes stabilization, drainage maintenance, etc. Panama identified works such as reforestation, slopes stabilization, construction of stone walls for retaining structures, use of geotextiles, stream maintenance, and channeling of rivers and creeks.
- Mitigation measures such as watershed maintenance are applicable to all countries of the region, with the objective of avoiding sedimentation and erosion that cause floods.
- According to the mitigation works described by the countries, some road segments of the Pan American Highway do not meet the technical design criteria that allows for maintaining safe, efficient and competitive highway transportation.

Recommendations

- It is recommended to include in the budget of the sector the associated costs with the identified vulnerability reduction works, considering the cost-benefit ratio given that damages caused by natural hazards present higher costs than the direct reconstruction or rehabilitation costs.
- In the future the project profiles for land transportation must reflect a balance between infrastructure investment and low vulnerability to natural hazards, and the impact on productive activities, the supply of services and resources management in case of damages caused by natural hazards.
- Since vulnerability reduction civil work have the same importance as highway development works, is recommended that mitigation project profiles are prepared in a systematic way, applying professional techniques of project evaluation, and that they include the costs associated with the civil works.
- Is recommended that once the mitigation civil works are established in the vulnerability study, priorities are established and work began immediately in order to assure resistance to possible impacts. When these civil works are finished, the countries should continue a maintenance program and quality control by verifying their design norms.
- Is recommended the elaboration of design codes or some technical specifications of road construction that include vulnerability reduction in a regional context.
- It is recommended that the national coordinators of the vulnerability studies exchange information and experiences, based on the preparation of these studies and their updates in the future, in order to strengthen and broaden the vulnerability evaluation process.

Activities towards the reduction of natural hazard vulnerability in Central America

Conclusions

- Base on the projects mentioned in Chapter 2, there is observed increasingly interest in vulnerability reduction of the road transportation infrastructure in the reconstruction and in modernization investment projects of transportation sector, as well as in joint efforts of the regional institutions in supporting these activities.

Recommendations

- Proposals for vulnerability reduction of the transportation sector to natural hazards should recognize the evolution of the institutional situation, both at national and local level, in the region and the development of vulnerability study methodologies.

- Technical training and continuous strengthening of the development of vulnerability reduction indicators to be included in highway planning of national and local investment projects is recommended.
- Strengthening the coordination mechanism for projects at the sectoral level in order to take advantage of efforts for the efficient exchange of information is recommended.
- Ministries of transport should provide for infrastructure vulnerability studies as an essential part of the design and civil works that they develop.

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Annex A

OAS-USDOT FORMAT

Annex B

Matrices on the Vulnerability of the Pan American Highway and its Complementary Corridors Presented in the National Reports

The matrices are available for Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama. In order to receive a copy, please contact the respective Ministries.