

## **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.