APPENDIX XVIII

ESTIMATING LOSSES IN THE DRINKING WATER AND SANITATION SECTOR CAUSED BY THE JANUARY 13, 2001, EARTHQUAKE IN EL SALVADOR2

On January 13, 2001, an earthquake that registered 7.6 on the Richter scale struck El Salvador. Its epicenter was located off the Pacific coast, approximately 100 kilometers southeast of the city of San Miguel. The quake was felt throughout El Salvador and in some neighboring countries, but the regions suffering the greatest damage were the departments of Usulután, La Paz and San Vicente.

The earthquake, which was followed by numerous and powerful aftershocks, took a significant toll on the poorest segments of the population, especially their housing, basic services, education and access to healthcare. All productive sectors and the country's basic infrastructure were affected.

Most of the information required for evaluating the water and sanitation sector was provided by the Administración Nacional de Acueductos y Alcantarillados (ANDA), the Pan - American Health Organization/World Health Organization and the Ministry for Public Health and Social Services.

1. Drinking water and sanitation

Prior to the earthquake, El Salvador supplied potable water to 86.8% of the urban population (2,951,565 inhabitants) and to 25.3% of its rural residents (830,130 inhabitants). Sanitation services were available to 85.9% of urban residents (2,727,160 inhabitants) and to 50.3% of the rural population[3-4].

The above service breakdown implies overall (urban and rural) coverage of 60.4% for drinking water and 68.3% for sanitation. Such services are supplied by ANDA, municipal governments and the health ministry, as well as local and international NGOs that are largely focused on covering demand in rural areas.

a) Drinking water supply

According to ANDA damage reports, water storage tanks and distribution systems were the components of urban service networks hardest hit by the quake. The extent of damage varied widely, ranging from cracked walls, weakened support structures (beams, towers) and the settling of surface-level facilities.[5]

2 ECLAC, *El terremoto del 13 de Enero de 2001 en El Salvador. Impacto socioeconómico y ambiental*, Mexico City, February 2001.
3 Dirección de Planificación, *Boletín estadístico* Nº21, ANDA, San Salvador, 1999.
4 OPS/OMS – UNICEF, *Evaluación global de los servicios de agua y saneamiento – Informe analítico*, San Salvador, July 2000.
5 ANDA, *Información preliminar de agua potable y alcantarillado sanitario a nivel nacional – Ocasionado por el sismo del 13/01/2001*, San Salvador, 2001.

In the San Salvador metropolitan area and other regions serviced by ANDA, varied degrees of impact on flows from wells and pumping stations were reported. Meanwhile, weakened slopes and the resulting landslides led to ruptured water mains, especially near hillsides, and water supply was suspended for days or even weeks before the breaks were repaired. There were also reports of damage to electric equipment and water treatment plants, but in most cases these were repaired and service was reestablished quickly.

Unfortunately, it was not possible to obtain information on the extent to which services were suspended or impaired in municipalities not covered by the ANDA system.

Thirty-two out of approximately 400 rural drinking water systems reported varying degrees of damage that largely consisted of the uncoupling or breaking of water mains, especially near inclines and ravines or in areas where the land was otherwise unstable. Where the walls of shallow wells were damaged, they had to be cleaned or alternate water sources had to be found. According to estimates, approximately 10 400 household shallow wells were in need of repair or reconstruction after the quake, and most of those were to be found in the countryside or in marginal urban neighborhoods.

According to data from ANDA and other relevant institutions, roughly 500 000 urban residents temporarily lost access to drinking water; that is equivalent to 15% of those normally receiving this service. In rural areas, 9.1% of service recipients, or 75 626 inhabitants,[6] were similarly affected.

During the emergency stage, tanker trucks were used to deliver properly chlorinated water, and portable water treatment equipment was deployed to areas where normal service had been affected. By February 8, tanker trucks had distributed 18 968 cubic meters of drinking water.

In addition to the emergency measures cited above, ANDA, municipal authorities and local water boards went to work inmeddiatly of the quake to restore damaged networks, prioritizing those supplying urban areas and those rural systems for which the cost of repairs could be immediately covered by local water boards or ANDA. Work was strictly focused on restoring service as quickly as possible, so some repairs further magnified vulnerability, especially along ravines where there were reports of landslides. Some inclines that were left unstable by the quake remain highly susceptible to future tremors, human intervention and rainfall that could inflict damage as great or greater than that of the original earthquake.

b) Sanitation systems

While ANDA reported no damage to wastewater disposal facilities and municipalities have yet to publish any relevant information in this regard, the assessment team assumed that any damage would become apparent over the course of sanitation-system operations. Depending on where sewerage lines ran, and their proximity to water mains, there was a remote possibility that potable water could have been contaminated.

6 Gerencia de Sistemas Rurales, *Informe de daños a sistemas rurales de agua potable hasta el 29/01/2001*, ANDA, San Salvador, 2001.

Latrines, which are the main form of sanitation system in the rural sector and in marginal urban communities, sustained considerable damage or were totally destroyed, especially in the hardest hit areas. According to data on the number of rural dwellings that were destroyed and the extent of such sanitation systems in the countryside, it was estimate that approximately 63 000 latrines were damaged.

c) Solid waste disposal

Municipalities provide solid waste collection and disposal services. During the field visits it was impossible to obtain any information concerning the state of these services. COMURES (the National Council of Municipalities of El Salvador) intends to collect information on this matter sometime in the future.

2. Estimated damage and losses

Direct damage to drinking water and sanitation systems was estimated at 13.1 million dollars. Indirect losses –which involve greater expenses and fewer revenues for the sector's utilities– were estimated at 3.3 million dollars. Total damages and losses thus reached 16.3 million dollars. The international community provided one million dollars in emergency assistance. Meanwhile, the temporary suspension of service implied estimated savings of approximately 525 000 dollars in state subsidies to ANDA (see table 1 below).

Table 1

SUMMARY OF DAMAGE AND LOSSES IN THE SAN SALVADOR EARTHQUAKE OF JANUARY 2001
(Thousands of US dollars)

Item	Total damage	Direct damage	Indirect losses	Impact on balance of payments
Total	16,340.0	13,062.0	3,278.0	8,500.0
1. Urban systems	8,363.0	6,200.0	2,163.0	5,000.0
- Infrastructure damage [7]		6,200.0		
- Emergency relief [8]			663.0	
- Low income			1,500.0	
2. Rural systems	7,977.0	6,862.0	1,215.0	3,500.0
- Damage to rural water systems		362.0		
- Emergency relief [7]			1,215.0	
- Damage to shallow wells		500.0		

7 Reconstruction costs include those for repairing public sector buildings damaged by the earthquake.
8 Includes an increase in operational expenses.

III. TRANSPORT AND COMMUNICATIONS

A. INTRODUCTION

This chapter concentrates on assessing the impact of a disaster on the transport and communications systems of a country or region with special reference to road transportation and its infrastructure, the hardest hit subsector in the events analyzed by ECLAC in the last 30 years. We also take up the telecommunications and coastal infrastructure subsegments.

A handbook of this type obviously cannot anticipate all possible types of damage to the transport and communications sector. Infrastructure and services vary greatly from country to country, as do the characteristics of the phenomena that cause disasters. Therefore, this Handbook describes the general assessment procedure for the sector, which the transport and communications specialist must adapt to the specific conditions of each case.

The general rule that the assessment only be conducted after the emergency stage proper is especially important for transport and communications. During the emergency phase, counterpart personnel for the assessment are usually busy trying to solve more urgent problems and have yet to amass the necessary information. In addition, a completely valid assessment is not possible until the natural phenomenon has concluded. An earthquake assessment must contemplate the effects of aftershocks, which can provoke considerable damage of their own. The impact of protracted flooding –as in the case of the El Niño phenomenon in countries located along the Pacific coast of South America– cannot be fully gauged until floodwaters have completely receded.

Once the assessment mission has begun, the transport and communications specialist must meet his/her counterparts from the country or region where the disaster has occurred –including representatives of civil defense organizations or their equivalent, the ministry of public works or transportation, the affected municipalities, etc.– in order to carry out the following tasks:

- Obtain detailed information on the characteristics of the disaster;
- Determine the geographic scope of damage to the sector;
- Provisionally identify the administrative agency or agencies responsible for transportation and communications infrastructure, whether public or private; and
- Make initial contact with officials of local organizations who may be able to assist in the collection of the basic information essential for impact assessment.

Periodic coordination meetings of the assessment team can allow the transport and communications specialist to obtain necessary information from other team members and ensure that there is no evaluation duplication between sectors. This last point is of special importance in the transport sector, whose use by agriculture and industry increases the threat of double accounting.

Field visits to affected areas are essential. While it is important to consult official aerial photographs to get an initial idea of the scope of the damage (these are usually available before the assessment begins), on - site inspections are key to a thorough analysis. When confronted by such obstacles as collapsed bridges, eroded roadbeds and flood waters, analysts may have to complement overland visits with an overflight of less accessible areas in a helicopter or light plane.

B. QUANTIFICATION OF DAMAGE

1. The road network and ground transportation

The road network is often the sector's primary disaster-damage recipient. National or local authorities make at least a preliminary evaluation of direct damages to road infrastructure. These usually include cost estimates of emergency repairs to re-establish minimum communication and access; the rehabilitation of infrastructure to pre-disaster conditions or to the state it should have been in if proper maintenance had been provided; and improvements, such as new detours or the construction of new bridges with longer spans than those destroyed. The costs of works under the first two categories are directly related to direct damage assessment, whereas those under the last category are important for formulating reconstruction projects, an issue with which the transport and communications specialist will become involved after concluding the damage assessment.

The analyst must closely scrutinize any official direct-damage estimates issued by national or local authorities. Such numbers may be incomplete or not entirely reliable, for several reasons:

- Impassable sections of road may have prevented the detection and assessment of damage to other strips of road located further upstream;
- Local or national authorities may have overestimated the value of damage in an attempt to increase reconstruction funding;
- Inadequate maintenance may have led to considerable pre-disaster damage;
- The estimates may have overlooked some reconstruction costs, such as the value of the full-time labor for which relevant institutions and organizations had already budgeted;
- National authorities may not have taken into consideration damage to locally administered or privately concessioned infrastructure; and
- Such estimates almost never take into account damage to privately owned vehicles.

Therefore, the transport and communications specialist must first check that official estimates contemplate all the necessary elements and correctly quantify the costs. Table 1 provides information on unit costs for some typical assets.

Table 1

TYPICAL VALUES OF CERTAIN UNIT DIRECT COSTS

Item	Price in USD
New light utility vehicle (average)	10 000
New small car (average)	10 000
New truck, rigid frame (average)	60 000
New urban bus (average)	100 000
New inter-urban bus (average)	150 000
New bicycle (average)	150
New motorcycle (average)	500
Km. of dirt road, flat/undulating land (reconstruction)	10 000
Km. of dirt road, undulating/mountainous land (reconstruction)	20 000
Km. of hardcore road, flat/undulating land (reconstruction)	50 000
Km. of hardcore road, undulating/mountainous land (reconstruction)	75 000
Km. of paved road, one lane each way, flat/undulating land (reconstruction)	100 000
Km. of paved road, one lane each way, flat/undulating land (reconstruction)	150 000
Km. of paved road (rehabilitation)	25 000
Km. of hardcore road (rehabilitation)	15 000
Km. of dirt road (rehabilitation)	5 000
Mend potholes in paved road, one lane each way, per km.	2 500
Bailey bridge, 20 meter span, CIF importing country	200 000
Reconditioned 2500 hp diesel locomotive	750 000
Reconditioned 750 hp diesel locomotive	450 000
New railway truck	85 000
New railway carriage	500 000
Km. of railway, one way (reconstruction)	100 000
New light aircraft 500 000	500 000
50-seat propeller-driven aircraft, new	15 000 000
150-seat turbine aircraft, reconditioned	20 000 000
20-metre fishing boat, wood, new	65 000
25-metre fishing boat, metal, new	200 000
Grader, reconditioned	75 000

Experience has shown that national or local authorities do not assess indirect losses (the largest damage component in the transport and communications sector), as they are mainly focused on determining the affected road network's reconstruction needs.

Disasters usually provoke a reduction in the volume of incoming and outgoing transportation. In this regard, it is not sufficient to estimate the difference between pre-disaster and post-disaster transportation unit costs and then multiply it by normal transportation volume; this would overestimate indirect disaster costs. Neither is it valid to multiply the difference in the volume of post-disaster transportation, because this would underestimate indirect damage.

The transport and communications specialist should revise and update the direct damage estimates made by local authorities, but when it comes to estimating indirect losses, the specialist must practically begin from scratch and conduct his/her own assessment.

Indirect loss assessment requires the quantification (in monetary terms) of the increase in the operational costs of vehicular traffic on a road network damaged by a disaster, as compared to costs under a normal situation. Such a calculation must also contemplate any surplus lost due to trips not made because of impassable roads or the heightened cost of driving on them.

The following generic formula may be used for this purpose. (Note that this formula does not take into consideration some factors that, time permitting, should be included in the calculation, such as the effect of taxes on vehicular operating costs.)

$$\text{Indirect cost} = \int_{q_1}^{q_0} p.\partial q - p_0(q_0 - q_1) + q_1(p_1 - p_0) \quad (1)$$

where:

q_o	=	the volume of traffic under normal conditions;
q_1	=	the volume of traffic after the disaster;
p_o	=	the cost of transportation in normal conditions; and
p_1	=	the cost of transportation after the disaster.

How this formula is applied depends on the circumstances, especially on the availability of basic information. It should usually be applied for each affected section of road, even if this might involve some inconsistencies such as differences between the volume of traffic on one section and that of the next or the previous one. Note that transportation costs should include the cost of travelers' personal time.

Typically, sufficient information is available to apply the formula separately for light vehicles, buses and trucks.

The usual procedure to be applied is as follows:

1. In consultation with local road engineers, estimate the pre-disaster international roughness index (IRI) of each affected section of the road;

2. Estimate the pre-disaster operational costs for each affected section by type of vehicle as a function of the IRI, referring for example to the results of similar applications made by applying the World Bank's Highway Design Model in the country affected by the disaster or in another comparable country;

3. Repeat the two previous steps to estimate the post-disaster IRI and operational costs for the same sections of the network;

4. After obtaining data for pre-disaster traffic volumes and estimating the elasticity between the traffic volume and operational costs, use a simple mathematical formula to calculate post-disaster volumes: q = kpe (where q = traffic volume, k = a calibration determinant and e = elasticity).

Data on pre-disaster traffic volumes for each section of the network can be obtained from traffic surveys or by consulting local road engineers familiar with the normal volumes by road and vehicle type. The transport and communications specialist must usually estimate elasticity based on his/her own experience. However, when information is available on post-disaster traffic volumes (q_1 in formula 1), they may be calculated on an approximate basis.

5. Finally apply formula 1.

Calculations made using formula 1 must be supplemented with additional estimates when one or more of the following situations arise:

- A bridge has totally collapsed. In such instances, one must take into account potential costs associatied with trucks and their crews being left idle on either side of the river, the operation of either ferries or a railway shuttle established on a parallel bridge, and trucks having to take long detours along alternative routes.
- Truck or bus traffic is replaced by air transport. In this case, the above formula can still be used, with the difference that the values for $\mathbf{q_1}$ and $\mathbf{p_1}$ must refer to a non-overland means of transport.
- Traffic is detoured over longer routes. Costs include the longer distance to be covered and the higher unit cost of transportation per kilometer.

Clearly, the sector specialist must estimate how long the road network is likely to remain in disrepair. National authorities are often too optimistic in this regard, so the transport and communications specialist must make his/her own estimations, taking into account the productivity of the available machinery and labor, the length of the affected road network and a reasonable rehabilitation schedule. The indirect cost estimate must be expressed in current values while applying the corresponding discount rate to future costs.

Indirect costs are normally lower for other transport subsectors than for roads. Although the same concepts described above can be used for assessment, additional considerations apply. For example, a part of normal railway transportation interrupted by a natural disaster will probably be diverted to other means of transportation, such as roads, whereas another part will simply not take place. When applying formula 1 to such a case, $\mathbf{p_o}$ costs refer to the railroad, and $\mathbf{p_1}$ costs to the alternate means of transportation. Rail-freight charges, especially those of private companies, are normally higher than short-term marginal transport costs.

The values of $\mathbf{p_o}$ must reflect the freight paid by customers; the loss to rail customers can then be estimated by applying formula 1. One must include the loss sustained by the railway company (roughly equivalent to foregone profits), which can be estimated by means of the following formula:

$$(q_0-q_1)(f_0-c_0) + q_1(c_1-c_0) \qquad (2)$$

Where

f_o = the value of the freight charged, by unit of traffic;
c_o = the marginal cost of transportation before the disaster, by unit of traffic; and
c_1 = The marginal cost of transportation after the disaster, by unit of traffic.

In normal circumstances $\mathbf{p_o \neq f_o}$, because the values for $\mathbf{p_o}$ include additional cost elements charged to rail users, such as that of truck transport to the rail station.

It is impossible to include in this Handbook examples of calculations needed for every conceivable scenario, as each disaster has its own peculiarities. The transport and communications specialist must use his/her criteria and experience to adapt the above guidelines to each case.

The growing trend toward the privatization of transportation in Latin America and the Caribbean adds dimensions to the damage assessment. The management of the busiest communications infrastructure –highways, ports, railways, etc.– are increasingly in the hands of private companies, who sometimes also own the facilities and equipment.

These companies are usually more reluctant than government institutions to provide basic information, unless they realize that by doing so they help themselves to obtain financial support. Moreover, corporate offices are often much more geographically disperse than those of ministries or other official bodies, making on-site visits all the more challenging.

In the event of damage to concessioned transport infrastructure priced by tolls, losses may accrue to both users and concessionaires. Formula 1 can be used in principle to estimate losses to users, inserting values for $\mathbf{p_o}$ and $\mathbf{p_1}$ that reflect tolls paid by users instead of the marginal or direct cost of providing the service. To estimate the losses of the concessionaire, formula 2 can be used.

2. Water and air transport and their infrastructure

Analysis of the air and water sub sectors is essentially no different from that of the road sub sector, especially where direct damages are concerned. However, indirect loss analysis must be adapted for the specifics of each subsector. The problems involved in assessing indirect losses for water and air transport are similar to those of the telecommunications subsector, which we take up later in this chapter.

A disaster's impact on roads often expands the operational costs of trucks and cars, but air, rivers and seas are often essentially unchanged. Water levels may rise above normal, but this does not necessarily affect the operational costs of vessels. Specific water or air routes might be canceled in the wake of a disaster, but if not, operational costs will probably be the same as before. Exceptions include cases in which diminished river levels require the use of smaller water craft or a damaged landing strip calls for smaller aircraft, thus expanding unit transport costs. Formula 1 can be directly applied in such cases.

When water or air transport is canceled owing to adverse weather or damage to terminal facilities, it is sometimes very difficult to determine the values of $\mathbf{p_1}$, that is post-disaster unit transport costs, including components paid by users in addition to the fare or freight rate, such as the value of personal time devoted to the trip. The resulting shortfall or absence of transport on some routes can reduce total transport costs. (If there is no post-disaster transport, the value of $\mathbf{q_1}$ is **0**, meaning that the component $\mathbf{q_1\ (p_1\text{-}p_0)}$ in formula 1 is also **0**, as long as the value of $\mathbf{p_1}$ is not infinite.) The specialist must estimate this diminished cost while taking into account that some cost elements, such as part of depreciation, labor and administration, would not change. It must be remembered that some transport that does not take place during or immediately after the disaster may be undertaken afterwards, demanding an intensified schedule of service to compensate for demand not fulfilled during the paralysis.

In the case of a cargo shipment delayed for some weeks by the temporary lack of transport services, cost $\mathbf{p_1}$ should include interest, which can be estimated quite easily, as well as the cost of deterioration of goods, which can be more difficult to quantify. The failure of cargo to arrive on time can have high-cost consequences, such as increased human suffering when medicines fail to reach their intended destination or factories grinding to a halt owing to a lack of materials. The sectoral specialists must assess these consequences. In the case of delayed personal trips, cost $\mathbf{p_1}$ must include an estimate of the cost of the inconvenience involved. Only surveys —which are never possible as part of disaster assessment— can satisfactorily quantify this inconvenience, but one must try. In the following section, we propose a method for making such a calculation, albeit one that is not intellectually satisfying.

3. Telecommunications

The telecommunications sector contemplates the full range of telephony services including fax and Internet and e-mail access. In principle, it also extends to radio and television broadcasting. As with other sectors, we divide damages into direct and indirect categories.

We approach the telecommunications sector in a similar fashion as we would the transportation industry, especially concessioned transport, since most telecommunications enterprises are now privately owned. Direct costs may involve the value of repairing losses to three categories of infrastructure: the installations from which telecommunications are managed; transmission or broadcast facilities; and equipment used to send or receive messages. The first of the above categories comprises administrative offices, repair facilities, laboratories, and so forth. The second category consists primarily of antennas and cable lines and theoretically extends to the air through which short wave signals carry wireless phone messages. The third category includes wired and mobile handsets, computers and fax machines.

Estimating the costs of repairing services and replacing all three types of infrastructure following a disaster basically consists of an exercise in accounting similar to one that would commonly be applied to road and rail transportation. Nevertheless, it is necessary to take into account the very fast-paced process of technological innovation that swept the telecommunications sector in the last years of the twentieth century and continues into the twenty-first century. This progress translates into premature obsolescence and accelerated depreciation for some types of infrastructure, thereby implying that the value of infrastructure in company balance sheets may be exaggerated.

Clearly, if a flood were to wipe out an analog switching station or destroy a phone with a rotary dialer, the real cost of replacement would be quite low, since those units have been superseded by digital technologies. It is thus important to assess the current market value of infrastructure at the time of the disaster. In the event that there is no market in the affected country for specific types of infrastructure, the analyst must make an assessment based on a realistic evaluation of the economic life of each type of equipment, together with a profile of the average age and nature of the equipment or installations that have been destroyed.

Sometimes it is not economically viable to repair the damaged equipment since the next generation of devices provides enhanced productivity at a lower cost. Instead of contemplating the replacement cost, in such situations the analyst could use the following formula:

(cost of new equipment) x (productivity of the old equipment) x (productivity of the new equipment) $^{-1}$ – (the residual value of the analog equipment).

Nevertheless, each case is unique, so the analyst must bring his or her own professional experience and judgment to bear.

As for indirect damages, disasters tend to generate costs for both users and service providers just as in the case of privatized railroads. It is usually relatively easy to quantify the losses of service providers using formula 2. As we explain below, however, it is much more difficult to estimate losses to users.

Telecommunications systems can be easily damaged, thereby frustrating any efforts to place a phone call or to send a fax or e-mail message. In that case it is very difficult to assign a value to $\mathbf{p_1}$ when using formula 1. Here we encounter parallels between the telecommunications industry and air or water transportation (to be analyzed in the second section of this piece) in that it is simply impossible, at any cost, to establish contact between some points immediately after a disaster.

Thus the average value of the calls, faxes and e-mail messages that could not be made as a result of the disaster must be estimated. In practical terms, the specialist will lack conceptually satisfactory formulas for making such an assessment and may simply value the call at twice the amount the user would normally pay.

This involves trying to guess the value of the call in a totally arbitrary manner, but better options are rarely available. Ideally, one would have access to industry studies identifying the nature of the demand for phone calls, faxes and e-mail messages, and then link the number or volume of calls with the relevant charging rates.

Occasionally one may encounter data that makes it possible to estimate the function of call demand (phone, e-mail, etc.) based on the communications response of catastrophe victims. For example, we determine that in a given city some $\mathbf{q_0}$ calls are normally made from either fixed-line or wireless calls at a price of $\mathbf{p_0}$ to the user. During a disaster phase when neither wired nor wireless service is available, those same citizens will make only q_1 calls from emergency booths set up by the army at a price of $\mathbf{p_0}$, plus a wait of three hours. An estimate of the value of the personal time of local inhabitants would make it possible to calculate and apply the value of $\mathbf{p_1}$ in formula 1. Each case is different, requiring that the analyst decide what methodological variant is most applicable.

Telecommunications services are normally suspended for a relatively brief period. That is particularly true today, now that underground or elevated cable lines can be at least temporarily replaced by wireless alternatives.

4. Coastal infrastructure

This part of the chapter focuses on the impacts of a disaster on coastal infrastructure. Its relevance is of greatest significance for small island developing states (SIDS), where natural phenomena such as hurricanes take a can a very high toll, but it also applies to the coasts of the continental mainland.

Coastal zones represent a disproportionately large part of the landmass of SIDS. To make matters worse, most infrastructure is often concentrated in the coastal zone: urban developments (including critical infrastructure such as hospitals, police stations, and utilities); industrial centers; port infrastructure; marinas; fishing communities; and tourism developments, among others. In the Caribbean, and in particular in the Lesser Antilles, the islands generally are either volcanic in origin or composed of coral caps. The mountainous terrain of volcanic islands generally means that most development is confined to a relatively narrow strip along the coastline, whereas on coral caps development tends to be spread more evenly across the island landscape. In both instances, coastal roads tend to serve as the main links between urban centers and tourism developments. Damage to such infrastructure can be devastating to the small island economies, producing significant hardship during the first year or more of rehabilitation.

a) Information requirements

i) Coastal roads. The following minimum information should be obtained:

- The agency or agencies that deal with the construction and/or repair of main and arterial roads;
- The physical extent of damaged roadways;
- The actual volume of roadway material removed or destroyed;

- The importance of the damaged road to the road network linking towns and rural centers;
- The volume and types of traffic that would typically use this road;
- The extent of any utilities that may have been damaged as a result of the disaster;
- Knowledge of the general topography and seabed bathymetry of the area;
- Knowledge of the hurricane wave conditions that may have caused the damage;
- Knowledge of building code requirements and the criteria for design of coastal infrastructure (in the Caribbean the 1-in-50-year hurricane cycle is typically used as the design criterion for non-essential infrastructure); and
- An estimation of the need for coastal defense works in the rehabilitation exercise.

ii) Harbors and marinas. In response to a growing tourism sector, many harbor facilities have been developed to handle the cruise shipping industry in the Caribbean basin. In some instances, cruise - ship facilities have been combined, in the same port area, with other general port operations. Marinas catering to the yachting fraternity have also appeared across the region. These marinas vary greatly in size and can offer berthing facilities for vessels ranging from dinghies to mega-yachts. Harbors or marinas are often sheltered against waves by breakwater-type structures unless located in a naturally sheltered site.

Data requirements in the assessment of damages to these facilities include the following:

- Knowledge of the agency in charge of port operations;
- Plans or maps showing the pre-disaster layout of facilities;
- The physical extent of the damage;
- An inventory of damage to specific equipment, if applicable;
- An inventory of damage to berthing structures;
- Knowledge of the hurricane storm-wave conditions leading to the disaster;
- General knowledge of the local seabed bathymetry;
- Rehabilitation/repair requirements, including the appropriate type of structure and the approximate quantities of materials involved;
- Availability of materials to be used in the reconstruction process; and
- Reconstruction needs for imported materials, labor and special equipment.

iii) Beach and shoreline erosion. The existence and preservation of beaches and shoreline is of paramount importance to the tourism sector and to a number of ecological systems. When a beach suffers massive erosion from tropical storms or hurricanes, infrastructure located near the beach is also exposed. Such infrastructure is usually tourism related, but it could also be residential or industrial. Non-beach shorelines may experience damage to seawalls and/or revetments. On the ecological side, beaches may often serve as nesting sites for endangered turtles. When massive beach erosion takes place, the displaced sand may smother offshore sea grass beds and/or coral reefs. Beach recovery occurs naturally, although it may have to be helped along in the rehabilitation process.

Damage assessment requires a variety of data:

- Knowledge of any set-back regulations required by the local environmental planning agency;
- Physical extent of shoreline damage;
- Volume of beach material lost and/or volume of shoreline eroded;
- General idea of the fate of the eroded material;
- General knowledge of local seabed bathymetry and prevailing coastal processes;
- General background of prevailing wave climate;
- Storm wave action that resulted in the shoreline damage;
- Appropriate types of rehabilitation strategies, including the "do-nothing" approach;
- Local availability of dredging equipment, or the need to import;
- Availability of quarried armor stone, which may be required in the construction of special structures to ensure future beach and/or shoreline stability;
- General knowledge of coral reefs and sea grass beds in the vicinity of the damaged shoreline; and
- Approximate evaluation of habitat loss.

iv) Water intake and effluent outlet structures. Many coastal areas and islands must extract drinking water from brackish or salt water due to a lack of adequate rainfall or ground water resources. In some places, desalination plants have been established that require inflows of brackish water and discharge a brine solution that is piped into the ground or out to sea. In addition, wastewater treatment at a municipal or project-specific level often involves discharging treated effluent into the sea. Wastewater that is effectively treated only at a primary level is often discharged through a deep-sea outfall, whereas wastewater that is treated to a secondary or tertiary level is occasionally discharged into the sea, but very often is recycled for irrigation. Damage to effluent-discharge or to water-intake structures can have serious consequences for a community, whether large or small, significantly affecting the community's post-disaster health.

In assessing damage to this type of infrastructure, the following information and data should be obtained:

- Knowledge of the local agency dealing with water and sanitation;
- The physical extent of the damage, either on land or on the seabed;
- The type and quantities of piping and/or other equipment damaged;
- The user base of the damaged facilities (e.g., municipal treatment plant serving a community or a desalination plant for a hotel);
- General knowledge of the hurricane-wave and surge conditions that would have led to the damage;
- General knowledge of the repair or rehabilitation works required;
- The local availability of materials needed to carry out the repairs; and
- Any need to import construction materials, specialized labor or special equipment in order to carry out the repairs.

b) Sources of information

The following institutions are valuable sources of the information required for the assessment:

- Public works departments and transport ministries;
- Public utilities;
- Port authorities;
- Surveying departments;
- Engineering regulatory institutions;
- Contractors;
- Quarry operators;
- Material suppliers;
- Hotel and tourism agencies;
- Water and sewerage agencies; and
- Environmental regulatory agencies.

c) Description of damages

i) Direct damage

Coastal roads

- Damage to the road and sub-base;
- Damage to any sea defense structures associated with the road; and
- Damage to any utilities linked with the road.

Harbors and marinas

- Damage to any protective breakwater structures at the marina or marina entrance;
- Damage to berthing structures within the berthing area, including docks and wharves;
- Damage to specific equipment associated with the operation of the harbor or marina; and
- Damage to walkways and landside facilities or infrastructure associated with the marina.

Beaches and shorelines

- Volume of beach erosion;
- Damage to infrastructure in the back of beach area (including tourism infrastructure);
- Damage to utilities in the back of beach area;
- Damage to any existing shoreline protection works; and
- Loss of ecosystems habitat.

Water intake/effluent outfall pipes

- Damage to sections of intake or outfall pipes;
- Damage to anchors for pipes; and
- Damage to associated equipment and plant on the shoreline.

ii) Indirect losses

Coastal roads

- Loss of productivity as a result of people not being able to travel from rural to urban centers;
- Increased costs of transport as a result of commuters having to take alternative roads;
- Loss of income as a result of busses and taxis not being able to operate on the affected roads; and
- Possible loss of revenue from damaged utilities.

Harbors and marinas

- Loss of revenue from cruise ships that would have docked had there been no disaster;
- Loss of income from the support services associated with the operation of a harbor; and
- Loss of income from the provisioning services accorded to a marina facility,

Beaches and coastlines

- Loss of income derived from the recreational value of the beach;
- Potential loss of income from hotels or other tourism - related interests, as a result of closure of these facilities following the loss of beach and incursion of water and waves; and
- Loss of sand - producing potential as a result of the smothering of critical ecosystem habitat.

Water intake/effluent outfall pipes

- Losses through income not received as a result of plant not being able to operate;
- Impacts on the health sector as a result of reduced sewage treatment capabilities; and
- Rehabilitation activities.

d) Quantification of damage and losses

i) Direct damages. In quantifying damage during the assessment process, the coastal infrastructure specialist must liaise with counterpart personnel from the local agencies involved in rehabilitation or repair work, or with agencies that are directly involved with the operation of the damaged facilities. This will facilitate a better estimate of the actual volume of material that was damaged or that needs to be brought in for repair work.

We recommend the following procedure to quantify direct damages to coastal roads, harbors and marinas, beaches and shorelines, and intake/outlet structures.

- Obtain up-to-date survey maps, at a scale ranging from 1:25,000 to 1:2,500, depending on the country in question;
- Determine the extent of the damage in conjunction with relevant local personnel and through field visits;
- Compute the actual volumes of road and sub-base damaged or destroyed;
- Estimate whether repairs are possible or whether total replacement will be required;
- Evaluate the repair/replacement costs, incorporating a factor to account for partial repairs, where applicable;
- Evaluate the cost of rehabilitation, using the cost of similar roadwork within the affected country or region using as a guide;
- Evaluate whether sea defense works will have to be incorporated into the rehabilitation procedure. If yes, then:
- Estimate the design wave height at the shoreline, and estimate the required size and volume of sea defense works required. and
- Estimate the requirement for repair and/or replacement of damaged utilities.

In addition to the items listed above, the following information should be sought for harbors and marinas:

- Obtain an up-to-date survey mapping of the harbor or marina area, preferably at a scale of 1:2,500;
- Obtain seabed bathymetric data for the affected area;
- Determine the physical extent of damage in conjunction with relevant local personnel and through field visits;
- Evaluate the actual damage suffered on an area-by-area basis (e.g., for breakwater and berthing areas, landside facilities, etc.);
- Estimate whether repairs are possible or whether total replacement will be required; and
- Estimate the cost of the replacement works based on discussions with local contractors and government agencies, and through evaluation of the cost of similar repairs elsewhere in the region.

For beaches and shorelines, quantification of damage should include the following:

- Volume of beach lost;
- Cost of replacing beach, probably through dredging of sand from an identified offshore reserve and placing this sand onto the damaged shoreline; and
- The need for any hard engineering structures to ensure shoreline stability, such as revetments and/or seawalls.

Finally, for intake and/or outflow structures, estimation of direct damage will include:

- Size of damaged piping;
- Length of pipe damaged;
- Associated infrastructure on land that may also have been damaged; and
- Anchoring systems for the pipe that may have been ripped out as a result of the disaster.

ii) Indirect losses. Indirect losses are likely during the assessment, repair and rehabilitation period. Quantification of these losses will require data from a number of sources as outlined previously, and it requires that the coastal infrastructure specialist target the proper sources of data within a fairly short period of time.

Information required for the quantification of indirect losses for the types of coastal infrastructure described includes the following items:

- Pre-disaster traffic flows along the affected roadway;
- Typical commuter fares, cost of petrol or diesel and typical number of commuters who would normally travel the affected route;
- Estimates of loss of income at affected utilities;
- Typical number of cruise - ship port calls prior to the disaster;
- Number of visitors typically expected during each cruise ship visit;
- Cruise shipping fees and average spending rate per visitor;
- Number of general cargo or container vessels that would ordinarily call at port;
- Tariffs or dues typically payable;
- Loss of revenue estimates from shipping lines;
- Number of yachts that would typically moor in the marina;
- Average berthing fees;
- Loss of revenue estimates from vendors who would provision the yachts;
- Number of vendors and water sports operators who would normally operate on a beach, along with loss of revenue estimates from them;
- Number of hotel or tourism - related staff that may be out of work while the rehabilitation works are being carried out, along with estimates of average earning rates;
- Loss of revenue estimates from water supply companies, where desalination intake lines have been damaged;
- Loss of income estimates from water and sewerage officials when effluent discharge lines have been damaged; and
- Cost of providing alternative water supply or sewage disposal.

The above section includes and describes methodologies for estimating damage and losses to all types of coastal infrastructure and facilities many of which correspond to other sectors. For example, damage to drinking water and wastewater facilities should be included in the water and sanitation sector; damage and losses at tourism facilities should be reflected in the assessment of the tourism sector; damage to natural resources –such as beaches and coral reefs– should be included in the environmental assessment. Special care should be exercised to avoid double accounting in such cases. Damage and losses sustained by roadways, landing strips and airports, harbors, piers and marinas, and so forth, should be estimated and accounted for under the transport and communications sector, however.

5. Other effects

As in other sectors, the transport and communications sector requires the breakdown of damage and losses into the public and private sectors, either because the treatment of rehabilitation and reconstruction might involve different modalities or because reconstruction may take advantage of the differential impact of the disaster on women, for example. Therefore, the transport and communications specialist must indicate the amount of direct and indirect damage for each sector.

Likewise, damage to transport and communications may have effects on the country's macroeconomic performance. The foreign sector might be harmed by increased imports of machinery, equipment and materials needed for reconstruction, as well as by exports not made due to the lack of connectivity or lost because perishable goods in transport at the moment of the disaster did not reach lost their destination in good condition. Even when machinery and other goods required for reconstruction are produced within the affected country, they normally include some imported components. In addition, the consumption of national resources for reconstruction may reduce exportable supply, as in the case of oil used in the rehabilitation stages after a disaster in an oil-producing country.

Public sector finances may also be affected -and fiscal deficits aggravated- by the revenue shortfalls arising out of diminished billing for public-sector services, decreases in the collection of service taxes and unforeseen spending for the emergency and rehabilitation works. All this information, estimated by the transport and communications specialist, must be delivered to the macroeconomics specialist for due consideration.

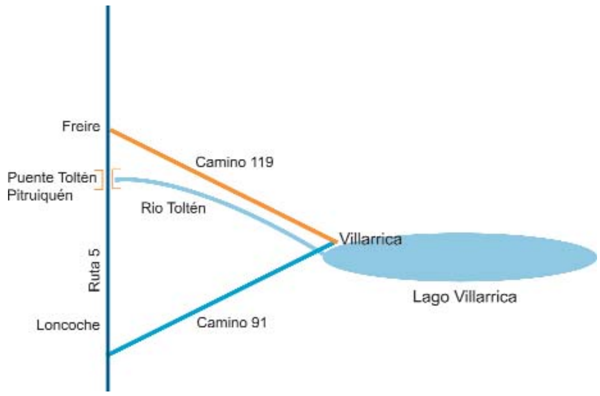
Unemployment and income loss within the sector may occur if transport and communications operations are suspended for long periods. One must estimate how much of the sector's services belong to women, as well as the percentage of potential employment and income losses corresponding to women (see the chapter on the impact of the disasters on women in Volume Four). The transport and communications specialist must ensure that the corresponding estimates are made in close cooperation with the employment and gender specialists.

The following appendix offers an example of how the methodology described above was applied to a typical disaster in the region.

APPENDIX XIX

ESTIMATES OF THE SOCIO-ECONOMIC COSTS CAUSED BY THE WEAKENING OF A HIGHWAY BRIDGE BY A FLOODED RIVER

Geographic location. The main Chilean highway, known as Route 5, runs a little more than three thousand kilometers from Arica through Santiago to Puerto Montt. Route 5 crosses the Toltén river, just north of the town of Pitrufquén, 30 km south of the regional capital of Temuco and 677 km south of Santiago. The highway bridge over the river was built in 1935, many years before the route was paved, and its central section was weakened July 8, 1993, when the river broke its banks. The analysis summarized here in a simplified fashion was produced to estimate the socio-economic cost of the damage caused by the interruption to traffic and to determine whether a bridge inspection program should be carried out along Route 5 to minimize the risk of interruptions on other occasions.



Description of the damage and its consequences. Immediately after the bridge was weakened, the police closed it to vehicular and pedestrian traffic. Drivers had to choose between canceling their trips and making a 46 km longer detour along a route we will call the Villarica road (see the schematic map above). Local traffic faced up to a 700% cost increase. However, most of the total costs arising out of damage to the bridge resulted from the longer distances traveled until a Bailey bridge was put in place on September 16, and the increased vehicle operating cost of normal traffic on the Villarica road after the heavy traffic diverted onto that alternative route deteriorated the quality of the pavement. Pedestrian traffic was handled by a shuttle-type train service on the (undamaged) railway bridge located a few meters to the west of the highway bridge. This service was maintained until a walkway was installed July 12.

Costs and benefits. Ministry of Public Works investments went toward the installation of the Bailey bridge; the definitive repair of the fixed bridge; and the Villarica road, which was the subject of an engineering study, emergency repairs (partially compensated for by lowering routine maintenance costs on Route 5) and reconstruction works. The increased costs to users were estimated in a breakdown, taking into account the following points:

- The costs of operating trains in the emergency period;
- The costs of post-emergency train service;
- The increased operating costs for vehicles making the long detour;
- Profits forgone due to cancelled long-distance trips;
- Greater operating costs for local traffic;
- Loss of profits due to local trips cancelled;
- Greater operating costs due to damage to the surface of the alternative road;
- Greater journey times for people who changed from buses to trains;
- Reduced operating costs for buses due to transfers to trains during the emergency; and
- Reduced operating costs for buses due to transfers to trains in the post-emergency stage.

Loss estimate. Lost profits were roughly estimated using the following formula:

$$\int_{q_i 1}^{q_i 0} c_i \cdot \delta q$$

where: $q_i 0$ = volume of traffic before the disaster, i-type vehicles;
$q_i 1$ = volume of traffic after the disaster, i-type vehicles;
c_i = cost of traffic, i-type vehicles.

In general, it was assumed $\mathbf{q = k_i c^e_i}$, where $\mathbf{k_i}$ is a constant (calibrated in each case), and **e** is a measure of elasticity, chosen in each case by the analyst to reflect the fact that the flow of certain types of vehicles, such as trucks on long-distance trips, would be more resistant to the greater costs arising out of using the alternative bridge than would other types of vehicles, such as cars, especially when they were not making trips related to economic activities. The elasticity coefficients chosen in the study summarized here varied between -1.00 and -0.25.

Strictly speaking, calculations should recognize differences between the costs perceived by travelers and those of resources consumed. The former differ from the latter because they include taxes, for example, and would consider that travelers often incorrectly interpret cost elements such as vehicle maintenance.

Results and conclusions. The present value of the socio-economic cost of the damage to the bridge, in December 1994 Chilean pesos, was estimated at 5.619 billion, comprising mainly the increased operating costs of long-distance road transport (29%), increased operating costs on the alternative route due to damage to the surface (24%) and progress in the reconstruction of the Villarica road (20%). The present value of an annual bridge inspection program would have been approximately 800 million pesos, and the cost of repairing the section of the bridge weakened by the water, had the damage been identified in time, would have been 250 million pesos.

In other words, socio-economic damage totaling 5.619 billion pesos could have been avoided with an investment of approximately 1.050 billion pesos- and that is without taking into account the other bridges along Route 5.

Therefore, we concluded that it would be very beneficial to establish a bridge inspection service.