Handbook

for Estimating the Socio - economic and Environmental Effects of **Disasters**

Economic Commission for Latin America and the Caribbean
ECLAC

Section Three
Infrastructure

Introductory note: Three main infrastructure sectors are included in this section: energy (both the electric power and oil segment), drinking water and sanitation, and transport and communications.

I. ENERGY

A. INTRODUCTION

Energy, like all other sectors, sustains direct damages and indirect losses during and after disasters, and their macroeconomic impact must also be ascertained. Direct damages refer to the immediate damage or destruction of physical infrastructure and inventories available at the time of the disaster. Indirect losses refer to the costs of satisfying demand for energy during the recovery period, as well as the net income or profit that is not received in said period. These indirect losses are used to separately assess the macroeconomic effects.

One must determine the repair or reconstruction costs required to reestablish pre-disaster operating capacity. A decision must be taken as to whether the new operating capacity should be equal to the one in place prior to the disaster or incorporate updated efficiency and security standards. Valuation criteria at current replacement cost –including technological innovations– will provide a more accurate cost of the works to be carried out in practice and the financial resources they will require.

The cost estimate must take into consideration the time needed for repair work to be completed and the costs of meeting temporary needs, as explained below in the section on indirect losses.

It is much easier to estimate stocks of equipment, materials and raw materials that were damaged or destroyed by the disaster, with replacement costs at current market prices. If at the time of the assessment, there are no equal goods available in the market, it is necessary to use the cost of the most similar goods in order to obtain equivalent or approximate results.

The quantification of indirect losses is a more complex task because it is based to a greater degree on estimates. On the one hand, the behavior of supply and demand during the rehabilitation period must be estimated; on the other, the financial results that will actually be obtained over the same period must be compared to those that would have been obtained if the disaster had not occurred. In the projection of what will happen after the disaster, results will clearly be lower than those estimated before the disaster, because large consumers will have reduced their energy demands. Though it is less likely, energy demand could increase if large amounts of energy are required for repair works. Both situations may actually occur concurrently, in which case a quantification of the net results must be made.

Once the analyst has determined post-disaster demand –which can be equal to, smaller than or greater than normal demand– the means to properly meet it must be identified. As a general criterion, assume that demand for energy will be met somehow. Then estimate the required capital and operating costs, based on how long it takes to rehabilitate all facilities. Capital costs essentially refer to the purchase of equipment, while operating costs consist of labor and materials. Personnel costs should include salaries of plant personnel temporarily laid off for any reasons arising out of the disaster.

Finally, indirect losses must be estimated. Begin by estimating the net income that can be obtained during the rehabilitation period. Then subtract the cost of temporary energy supplies in addition to the company's operational costs during the rehabilitation period from estimated income from energy sales in the same period. Keep in mind that net income thus estimated might be negative depending on the post-disaster purchasing capacity of consumers. Second, estimate the net income that would have been obtained had the disaster not occurred by subtracting total cost from gross income, just as was done in the previous example. This information is often available in the records of companies that manage the sector, especially in their respective short- and medium-term planning departments. The amount of total indirect losses can be determined by the algebraic difference –applicable in cases of real negative income– between the two previously estimated net incomes. These indirect losses would already include the additional costs of temporarily meeting demand, as well as the income that will not be received because of the disaster.

The previous estimates of costs stemming from direct and indirect damage should be broken down, on the one hand, into local and foreign currency components so that they may be used for the overall balance-of-payments calculations. On the other hand, distinctions must be made with regard to damage and losses corresponding to the public sector and to private enterprises, with a view to their utilization in subsequent estimates of national accounts for the calculation of macroeconomic effects.

We recommend the following assessment methodology for the electricity and oil sectors.

B. ELECTRICAL SECTOR

1. Direct damage

Direct damages in the electrical sector usually affect the following three major components of the system: electricity generation plants; transmission lines and distribution grids; and power distribution centers.

a) Electricity generation plants

Electrical energy is generated by hydroelectric and geothermal power plants, as well as by conventional thermal power plants driven by steam, diesel and gas turbines. For the purposes of this Handbook and in light of their special characteristics, consideration is given first to civil works required for the generation of the hydroelectric and geothermal energy. Second, we deal with the power generation plants, where the equipment to transform raw energy into electricity is located.

In connection with hydropower generation, water resource development may require a wide range of works such as diversion and storage dams, channels, tunnels, oscillation chambers and pressurized pipelines. Damage to these facilities must be repaired in order to restore the water supply required for electricity generation; failure to do so would result in the power plant becoming non-operational, and the entire electrical system would be affected. The aforementioned facilities are often located some distance from the main communication routes, so access can be difficult, at least during certain times of the year. In these cases, the direct effects should include any additional costs to repair communication routes; this should not be included in the damage quantified for the transportation sector to avoid double accounting.

To assess the cost of rehabilitation and/or reconstruction of the affected facilities, first an estimate must be made of the following units involved: cubic meters of earth to be removed, including specifications of the type of material involved; amounts of concrete that may be required, broken down by type and strength; the length and other characteristics of water conveyance lines; and the main mechanical components and special facilities. Then an estimate of costs should be made based on current unit values for each type of component. Alternatively, depending on the basic information available, a more detailed procedure can be followed that would consider labor needs by specialty, the amounts of raw materials, the time of use of construction equipment and the unit costs for each of these components. In both cases, the type of damage sustained by the facility, access to basic construction materials -earth, sand and gravel- and the availability of both unskilled and specialized labor will have a direct bearing on the estimation of direct costs. In this regard, cost estimates and bidding proposals made by contractors that have had recent experience in the affected area or in regions with similar conditions will be a valuable source of information.

When considering geothermal power generation, resource extraction and management includes deep wells, conveyance pipe systems and specialized equipment for the processing and collecting of steam. Any estimate of damage to the availability of geothermal power falls outside the scope of the present Handbook and will require the assistance of experts and field research. However, the electrical sector specialist might try to make order-of-magnitude estimates based on updated average costs of drilling deep wells in the area under consideration or in other areas having similar geological characteristics. The alternative procedures that have already been described for hydropower plants should be followed to estimate costs for any remaining generation facilities.

The remaining components for electricity generation refer to the power plants themselves, including the building and a wide array of mechanical, electrical and electronic equipment. An analyst should first focus on equipment and machinery that deliver power to the generator; this basically covers equipment to collect hydraulic energy in hydroelectric power plants and equipment that uses heat energy through boilers, pressure tanks and steam and gas turbines. The former are individually designed to match the characteristics of the hydroelectric site, and their replacement must follow a similar procedure. However, their costs can be estimated by updating the original investment using indexes that reflect the trend in international prices of similar equipment. Manufacturers’ catalogues and statistics that show the costs of equipment to collect hydraulic energy in hydroelectric power plants by range of water height (meters) and flow (m^3/sec) of the water resource may also be used.

Equipment used for the mechanical processing of energy obtained from steam and from burning oil derivatives is more standardized, although it has specific characteristics depending on the size and type of facility. This includes geothermal as well as conventional power plants classified –depending on the fuel used– as steam-, diesel-, and gas- driven plants.

Their replacement costs can be estimated following the general procedures mentioned above for hydroelectric power plants, which normally are easier to estimate because the equipment is more standardized. Power plants use a range of largely electromechanical equipment to convert raw energy forms –hydraulic, geothermal and those derived from oil derivatives– into electricity. This equipment is generally similar for different types of power plants, but it may vary depending on how up-to-date the plants are and on their specialized functions. The determination of replacement costs first takes into account investments for the original purchase –especially if this was done recently– updated to account for international inflation. A second alternative is to consult cost catalogues published by the manufacturers of this equipment or costs statistics available in specialized publications.

The above comments refer to cases in which installations must be totally replaced. When damage is less severe and only repairs or rehabilitation are required, the cost estimate must be preceded by a technical assessment of the scale of the damage and the real chance of repair. This work will require the participation of specialized personnel having wide experience in the repair and maintenance of this type of equipment. Laboratory tests of the affected equipment will be required to obtain more exact estimates, something that cannot be done in the relatively short time usually available to the disaster assessment team.

The buildings that house all generating equipment must also be assessed. The assessment of their direct damage will follow the same procedures as described for other buildings, as explained below.

b) Transmission and distribution systems

This heading includes transmission, subtransmission and distribution lines and grids, as well as all electrical substations that may be directly related to transporting the electrical power from the generation plants to final consumers.

High-voltage lines that use large and expensive pylons should be assessed first. To do this, field surveys will be required, making use of fast means of transportation such as automobiles when the lines are near to passable routes and light aircraft or helicopters in the case of cross-country lines. It is necessary to estimate the number of damaged pylons, the different types of pylon, and the length of affected electrical cables. In the case of lines that use uniformly distributed posts, only the number of kilometers of affected lines will be needed, with an indication of whether the damage is limited to the pylons or whether it also includes considerable lengths of cables. In addition, transformers and other equipment located along affected distribution lines must also be determined.

Thereafter, a list should be made of affected electrical substations, using the most precise indications possible of all equipment that has sustained any damage, including open-air facilities and equipment located in the main substations.

Estimates of the corresponding costs should be made on the basis of the results obtained from the inspection of the facilities described above. These should take into account all information available on affected power companies or those in neighboring areas. Because these data are frequently used, they should be readily obtainable. As in the case for electrical generation facilities, overall or broken-down costs could also be used, such as data from local or international contractors with experience applicable to the affected area, lists of equipment costs and catalogues.

The above comments on estimating damage in partially affected installations, in contrast to those that must be totally replaced, are also applicable to power transmission and distribution facilities.

c) Energy distribution centers and other works

Electricity measurement and dispatch centers and buildings for administrative offices are also of relevance in the electrical sector. The former are buildings that house a whole range of equipment to monitor and control electricity flows between power generation plants and the main consumption areas. These facilities may range from the most elemental, using manual controls, to the most sophisticated, employing modern remote-measuring and electronic computing systems with a high degree of automated and optimized basic functions. When total reconstruction of these facilities is required, cost estimates should be based on the comprehensive estimates of the energy distribution enterprise. An inventory of the respective parts and an estimate of the extent and magnitude of the damage are necessary in the case of partially damaged equipment and structures; experts should be engaged when specialized equipment is involved.

Damage to administrative buildings and other facilities that might be affected by a disaster can be assessed relatively easily because the characteristics of such structures and constructions are well known. Average prices by unit of floor area or total horizontal space should be ascertained. For a more accurate estimate, unit prices should be estimated for the main elements that comprise such buildings, such as panels, walls, ceilings, window frames and so on.

2. Indirect losses

As previously noted, indirect losses include the additional cost of meeting interim energy demands during the rehabilitation period when affected installations are under repair; they also include net income or profits not received by the power companies during the same period.

a) Temporary supply of electricity

The calculation of the additional cost involved in the temporary supply of electricity will first require an estimate of the time required to rehabilitate the damaged infrastructure. The length of this period will essentially depend on the extent and magnitude of the disaster, and it must be determined on the basis of the assessment of direct damages. Next, it is necessary to estimate electrical demand during the rehabilitation period.

This involves determining the effect that the disaster had on the power company's main customers (generally consisting of industry, commerce and the residential sector). Residential demand projections should contemplate the number of unaffected dwellings; projections of industrial demand should reflect the number of facilities that are in a position to continue operating (including estimated demand for their products); and commercial demand estimates should take into account the operating capacity of the establishments in the affected area. Assumptions must be made for all sectors as to the purchasing power of customers in the period after the disaster to anticipate that potential source of demand constraints. These factors should make it possible to calculate the magnitude and characteristics of the total demand for power.

The electricity sector specialist should then examine alternative ways of supplying the estimated temporary demand. As was said above, this will generally be lower than if the disaster had not occurred, although some customers may tend to increase their use. This review should also contemplate possible solutions for ensuring a rapid re-establishment of electrical service.

In the case of systems in remote locations, all-in-one equipment solutions that can be mobilized and installed quickly in the main load centers should be considered. Their cost can be obtained relatively easily from specialized catalogues or based on recent purchases of such equipment for special needs, such as backup generators for industrial centers or for isolated populations not connected to the national power grid.

Operating costs can be estimated on the basis of specific fuel consumption requirements and the cost of delivery to the area that may be chosen for the temporary generators, which should preferably be located as close as possible to the centers of demand. Estimates of operational costs should be completed by adding labor and materials expenditures, which are normally obtainable from the cost accounting maintained by power companies for the operation of equal or similar equipment.

In the case of damaged systems that are not connected to the national power grid and that are located close to neighboring undamaged systems, the cost of temporarily providing electricity can be estimated quite easily. First, a determination must be made as to whether the undamaged neighboring systems have the capacity to provide the additional power and energy requirements. The cost of interconnection must then be calculated, including the cost of items such as lengths of transmission line, substation equipment and so forth. The rates at which the required power could be provided should be estimated next. If there are no existing agreements established for such emergencies, a reasonable rate based on the additional operating costs to be faced by the system chosen to temporarily provide the power supply should be estimated. In other cases, neighboring systems might be capable of supplying only part of the demand. In this case, the procedures indicated above for isolated and stand-alone systems should be used, in proportion to each one's contribution. Note that because the intention is to establish the additional costs of the provisional service, any reduction in operating costs compared to those the company incurs under normal conditions (such as the variable expenses of generating units that cease to operate because of the disaster) must be deducted from the aforementioned estimates for all alternatives considered.

b) Other indirect losses

Profits not received by the electrical utility during the rehabilitation period (after which demand would tend to normalize) are also indirect losses. It may be assumed that during this period the post-disaster reduction in income will limit the payment abilities of many consumers who need energy to speed up the recovery of their activities; such considerations can be reflected in a provisionally lower rate. It is possible to use such a provisional rate to estimate the gross income and real demand discussed in the previous section. Total costs during the interim period, including additional charges implied by interim service and the company's costs under normal conditions, should be deducted from the gross income thus calculated. This will yield an estimate of the net income during the period in question, which could be negative if there is an increase in expenses along with a reduction in income.

Net income should then be estimated as though the disaster had not occurred. On the one hand, expected income should be considered by applying estimated average income to the normal projection of electricity demand. On the other hand, an estimate of anticipated costs based on recent historic behavior, including direct and indirect costs, should be made in order to calculate normal income for the utility. Power utilities usually employ the expected surplus to cover capital investments made to adequately and opportunely meet future demand. Any significant reduction in operational surpluses would entail new loans that will only be granted if the respective company is financially profitable. Estimates for this second scenario are normally available in power utilities, which constantly require updated short- and medium-term planning.

Indirect losses –which in this case would be equal to the profits not made due to the disaster– would be estimated as the algebraic difference between net income calculated for a normal scenario, with no disaster, and net income estimated for the disaster scenario, including any additional costs of supplying power during the rehabilitation period. Note that when net income is negative in the latter scenario, it must be added to the estimated net income for the normal scenario to obtain the total decrease in profits due to the disaster.

3. Imported content and breakdown of costs

The effects of the disaster on the balance of payments and national accounts may be ascertained from separating direct damages and indirect losses into foreign and national - currency spending requirements, on the one hand, and into public and private - sector spending, on the other. As far as direct damages are concerned, foreign-currency spending should include all equipment, materials and specialized labor that must be imported for the rehabilitation of facilities and machinery.

Local spending refers mainly to construction and repair costs, such as surveying work, earth removal, construction of structures and so forth. However, these items may also include significant foreign-currency spending on specialized equipment such as tractors, trucks and cranes that must be imported. The cost accounting records of power companies or those of contractors with recent experience in the region should prove useful for these estimations.

As far as the foreign-currency component of indirect costs is concerned, one should estimate the expense of temporarily meeting electricity demands in function of the equipment and materials that must be imported for such purposes. The costs of importing electricity from other countries should be included, when applicable.

The separation or breakdown of costs into public and private sectors depends on whether the affected power utility is state or private owned. In addition, when the government provides power services, participation by private companies in related activities, normally in reconstruction or repair contracts for the affected installations, must be taken into consideration.

C. OIL SECTOR

1. Direct damages

a) Production facilities

Oil production involves the drilling of deep wells on land or at sea and the extraction of crude oil. Oil transportation and storage, either for domestic refinement or for export to external markets, fall within the transport sector and should be estimated therewith.

Structures, equipment and facilities that are tailor-made to the needs and characteristics of the geographic environment are used to drill and operate the production wells. They include control rigs, deep drilling rigs, offshore platforms and a wide array of pipelines and equipment to handle the resulting flows of oil. When access to the underground oil deposits has been hampered by a disaster, estimation of damages requires that highly specialized personnel carry out field research.

Such activities are beyond the scope of this Handbook, which refers to estimates that can be carried out in a very short period of time. In the case of total destruction of a given well, the amount of investments already made, updated as of the date of the disaster, would provide a first estimate of direct damage. An approximation of indirect losses would be provided by the net commercial value of production lost during the rehabilitation period. This could then be refined through estimates of damage to such installations as rigs, drilling machinery and auxiliary equipment.

When such facilities have to be replaced because of total destruction, estimates can be made using (updated) standard costs that are normally available in the oil companies' files. Information on costs can also be obtained from manufacturers' catalogues in the case of industrial equipment. Contractors with relevant experience can also be approached. If damaged facilities and equipment can be repaired, it is necessary to assess the magnitude and extent of damage; such estimates require specialized experts with broad experience in repair and maintenance works, preferably familiar with the affected installations.

b) Oil refineries

Refining facilities may be simple when they only cover the stages of primary distillation, but they may be rather complex when they handle more processed products or remove harmful substances such as sulphur. Refineries generally include different kinds of processing towers, storage tanks and a wide array of pipes of differing diameters with various categories of valves and other fittings for managing fluids. Assessing disaster damage at oil refineries should follow the same or similar procedures as those described in the previous chapter for thermal power plants, as they often employ somewhat similar installations.

c) Distribution facilities

The distribution and sale of oil derivatives can be broken down according to the main user sectors as follows: gas for domestic and industrial use; liquid fuels for road, sea and air transport; and bituminous residues that are normally used in road construction. Basic distribution facilities include pipelines, storage tanks, pumping stations (which really belong to the transportation or industrial sectors) and standard service stations that supply fuel to automobiles and small vessels. Damage assessment for service stations involves procedures mentioned earlier in this section.

d) Other facilities

This item includes buildings used for administrative purposes and recreational centers for company personnel. Such facilities are common to all sectors, and their damage assessment requires the techniques described for the housing and human settlements sector.

2. Indirect losses

Indirect losses include the additional cost of providing oil and oil derivatives to meet energy requirements during the rehabilitation of affected facilities. It also includes net income not received during the same period, including the additional costs mentioned above.

a) Temporary supply of oil and oil derivatives

The estimate of costs to temporarily provide oil products must be based on the magnitude and nature of the damage sustained and on the duration of rehabilitation work. These two factors would have already been determined by the time the assessment of direct damage is made. Then the demand for oil and oil derivatives needed to replace lost production capacity and for the reconstruction process should be estimated. This calculation should take into account the extent to which the disaster may affect demand among leading residential, commercial and industrial consumers, all types of functioning automobiles and other vehicles, and roads that have to be constructed or repaired with bituminous material. New demand, in terms of volume and type of oil derivates, should be estimated based on the above factors and with due consideration for the diminished purchasing power of affected consumers.

Once new demand levels are projected, the analyst should consider alternative means for fulfilling that need. Several possibilities may arise, depending on the availability and location of existing resources and the facilities available for transportation and transfer. Tanker trucks should be used to meet small demands near deposits. Active and abandoned pipelines can be used for pumping fuel across greater distances, or new pipelines can be built if their investment can be justified. Finally, tanker ships, such as those commonly used commercially to ship oil and oil derivatives around the world, can be pressed into service using either existing facilities if available or, in their absence, provisional installations adapted to emergency situations.

The corresponding costs should be estimated based on the above considerations and after the most economical and feasible alternative has been selected. In any event, this type of activity falls within the transport and communications sector, and it should be recorded as such. Data on capital and operational costs must be calculated, including the purchase cost of oil and oil-derivatives, which is easily obtained since they are sold at international prices.

b) Other indirect losses

As explained in greater detail in the section on the electrical sector, indirect effects due to lost income can be quantified in the following manner. The net income is determined for the post-disaster scenario. Note that gross income is expected to fall, whereas costs should rise as the greater cost of temporary supply is included. Results will very probably be negative. Then the net income that the company under study would have obtained if the disaster had not occurred is determined. This information can be obtained from the files or forecasts of the oil company itself. In those rare cases when records are not available, estimates can be made based on the files of similar companies. The algebraic difference between net income under normal conditions minus income in the post-disaster situation should yield the total indirect loss, which would be equal to the profit not received by the oil company as a result of the disaster.

3. Breakdown of damages and losses

As in the case of the electrical sector, direct damages and indirect losses are broken down, on the one hand, into domestic and foreign currency for purposes of the balance of payments and on the other, into public and private - sector costs for purposes of national accounts. In the case of the oil sector, the macroeconomic effects might be significant, especially in those cases where the country affected is a net oil and oil derivatives exporter, requiring a much more detailed analysis of the indirect and macroeconomic effects by the energy sector specialist, in close cooperation with the macroeconomics specialist.

4. Effects on employment and on women

The electrical and oil sectors employ a limited number of personnel in view of their relatively high dependency on technology, so these industries tend to have limited repercussions on personal income levels following a disaster. For the very same reasons, no significant differential impact on women is expected to arise from these sectors.

5. Impact on the environment

This setcion describes the main links between assessing damage to the energy - sector and assessing that to the environment. The energy specialist is also referred to the chapter on environmental assessment included in Volume Four of this Handbook.

Some environmental changes related to water resources have a negative impact on hydroelectric power generation. Leaving aside droughts, whose effects are obvious, other disasters –such as floods and landslides– may also affect the availability and quality of water. Landslides can result in the obstruction and diversion of water flows that feed dams, thus affecting resource availability for electrical generation. Floods can increase the silting rates of reservoirs, giving rise to a reduction in their storage capacity and, therefore, in their useful life.

When a watercourse is diverted, river training works are required, and their expenditure should be recorded as indirect damages in the energy sector. A decision to omit such works for technical or financial reasons will compromise the future energy production capacity of the hydropower plant and should be registered as direct damage; this can be estimated as the present value of the difference in net income flows resulting from the disaster. When silting reduces the useful life of a reservoir, the approach is very similar, and damage should be estimated as the present value of the lost net income flow associated with the years of lost production. It must be pointed out, however, that estimation of silt deposition volumes requires lengthy field surveys whose results will not be available at the time of the assessment.

Oil is a non-renewable natural resource that is a part of a country's natural capital. Oil spills of significant proportions are registered as direct damage in the energy sector based on market prices. The environmental assessment seeks to identify the share of these damages that correspond to the contribution of natural capital, isolated from contributions of human capital and other assets such as infrastructure, machinery and equipment. This contribution may be estimated using an economic rent concept that, in the case of underground assets, has methodological difficulties. It will therefore be necessary to use estimates from other sources.[1] To avoid double accounting, these estimates will not be included in the damage overview.

Oil spills and the release of other toxic substances into the environment are another usual effect of disasters. Breakage in oil pipelines is one of the major risks associated with earthquakes. Toxic substances (such as sulphur and other compounds associated with geothermal production) may also be released when their collection and disposal systems are damaged or destroyed.

1 For example, Kunte et al. "Estimating National Wealth: Methodology and Results", Discussion Paper, the Environment Department of the World Bank, Washington, 1998.

In general, these direct damages and indirect effects are accounted for either in the energy or in the transport sector. The environmental specialist should work closely with other members of the assessment team to ensure appropriate damage accounting, especially of the expenses required to restore the environment to pre-disaster conditions.[2] In cases where natural areas are affected by these events, the environmental specialist will most likely be put in charge of calculating those damages. The preferred method for assessing these damages is the restoration cost method described in the chapter on environmental assessment in Volume Four.

An example of how the assessment of the energy sector should be carried out is presented in the following appendix.

APPENDIX VII

DAMAGE TO THE ENERGY SECTOR CAUSED BY THE MARCH 1987 EARTHQUAKE IN ECUADOR

A major disaster occurred in Ecuador in March 1987, caused by a series of earthquakes whose epicenter was located in the northeastern region of the country. The disaster badly affected the living conditions of low-income population groups, destroying their homes and basic services. More serious damage was inflicted on the transport infrastructure used by key sectors of the economy, undermining the country's ability to export and generate foreign currency.

1. Electrical sector

The earthquakes, mudslides and floods caused direct damage to some power plants, national-grid transmission lines and two hydroelectric power plants that were still under construction. They also caused indirect losses because the supply of had to be temporarily suspended in some cities, hydroelectric production had to be replaced with higher-cost energy produced in thermal plants, and the unit operational costs of thermoelectric power plants rose due to an increase in the cost of the transportation of diesel fuel.

The repair of power plants and electricity transmission systems was estimated on the basis of costs provided by the companies that operate them, as were the costs to repair and rebuild the camps at the power plants under construction. Direct total damages were estimated at 3.5 million dollars.

Indirect losses included increased costs in the dams that were under construction, higher electricity production costs because thermoelectric plants were used, and lost revenue at utility companies. Total indirect losses were estimated at 0.3 million dollars.

2 Although the energy specialist may have assessed direct and indirect damages caused by these events, environmental restoration measures may be under the responsibility of institutions not directly related to this sector. In such a case, , it is likely that these expenses would not have been accounted for in the energy sector especially if the solution to the problem depends on the environmental authorities.

Therefore, total damages and losses sustained by the energy sector as a result of the disaster were estimated at 3.8 million dollars. Since most of the equipment and materials to be replaced are not produced domestically, a negative effect on the balance of payments was projected of 2.2 million dollars .

Table 1
SUMMARY OF DAMAGE AND LOSSES CAUSED BY THE EARTHQUAKE IN ECUADOR 1987

Item	Damage, millions of dollars			Effect on the balance of payments[3]
	Total	Direct	Indirec	
Total	3.80	3.51	0.29	2.18
Production infrastructure	0.13	0.13		...
Lines and substations	0.12	0.12		...
Construction work camps	3.26	3.26	--	2.18
Greater generating costs and reduced income from billing	0.29		0.29	--

Source: ECLAC, based on official figures.

2. Oil sector

Although no physical damage was detected in the oil-producing wells, mudflows and floods cut the Trans-Equatorial oil pipeline that links the production area located in Lago Agrio to the refinery and oil and oil derivatives export terminal located in Esmeraldas. The flow of crude from the eastern area, which accounts for 99.6% of national oil production, was interrupted, and approximately 100,000 barrels of oil were spilled. The breaks in the pipeline, of different diameters, covered a total length of approximately 78 kilometers, and civil works at some pumping stations were damaged.

Direct damage to pipelines and related works and the value of the oil spilled was estimated at a cost of 120 million dollars. Reconstruction of the pipeline, following the same route of the previous one to facilitate matters, required a four-month period, and indirect losses were much greater than direct damages (see Table 2).

These indirect losses had domestic and external repercussions on the country's economic performance. They refer to a significant decrease in foreign currency earnings from oil exports throughout the reconstruction period, and to higher costs incurred to meet the domestic demand for oil derivatives.

Domestically, higher costs were incurred to supply liquid gas to the capital city of Quito, owing to the broken pipeline, as alternative routes and means with higher operational costs were used. In addition, the internal demand for oil derivatives had to be met by combining a temporary loan of such products from Venezuela and the building of an alternative pipeline to Colombia in order to extract limited amounts of oil, which were then transported by ship to the Ecuadorian refinery at Esmeraldas.

Oil exports had to be suspended until the pipeline was rebuilt, even though temporary loans from Venezuela and Nigeria made it possible to comply with some foreign commitments. Losses were thus spread over a longer time period than that required for the reconstruction of the pipeline.

3 The value of the components that will have to be imported because they are not produced domestically.

In addition to the above, the Ecuadorian State Oil Corporation (Corporación Estatal Petrolera Ecuatoriana – CEPE) sustained losses due to the reduction in domestic consumption of gasoline, and refineries (private and state) processed a lower volume of oil in their facilities. This loss of profits increased indirect losses caused by the disaster.

In sum, the earthquake caused direct damage to the sector's infrastructure totaling 121.7 million dollars and indirect losses worth 766.7 million, resulting in total damage and losses of 888.4 million dollars. Moreover, the country's balance of payments was affected with a negative impact of around 815 million dollars, caused by the fall in oil exports and the increase in imports required for domestic consumption.

Table 2

DIRECT DAMAGE AND INDIRECT LOSSES CAUSED BY THE I987 EARTHQUAKE IN ECUADOR

Item	Damage, millions of dollars			Effect on the balance of payments
	Total	Direct	Indirect	
Total	888.42	121.67	766.89	815.6
Reconstruction of pipelines, pumping stations, and cost of oil spilled	121.67	121.67	--	66.0
Greated costs for internal supply	90.17	--	90.17	87.3
- Investment in pipeline to Colombia	17.05		17.05	
- Greater transportation costs	15.69		15.69	
- Cost of replacement oil	54.56		54.56	
- Greater liquid gas transportation costs	0.87		0.87	
- Greater transportation costs of derivatives to Oriente	2.00		2.00	
Export losses	662.30		662.30	662.3
- lost exports	64.27	--	64.27	
- chaters of loaned oil	19,60		19,60	
Lost profits	14.28		14.28	
- Reduced consumption	5.27	--	5.27	--
- Reduced processsing in refineries	9.01		9.01	

Source: ECLAC, based on official figures.

The March 1987 earthquake caused 892 million dollars in total damages and losses to Ecuador's energy sector. Of this amount, only 14% are direct damages to the sector's infrastructure, and the remaining 86% are indirect losses. In addition, the disaster had an 818 million dollar negative impact on the balance of payments, mainly due to the inability to meet oil sale commitments abroad. This aggravated the economic situation in the country at the time, which had already been weakened largely as a result of a previous fall in world oil prices.

II. DRINKING WATER AND SANITATION

A. INTRODUCTION

In light of the region's epidemiological indicators, mortality rates are closely related to infectious diseases that, to a large degree, depend on the quality of water consumed and on access to adequate sanitation services. When this situation turns critical during disasters, post-disaster activities must concentrate on rehabilitating services that might otherwise constitute sources of epidemics; special attention must be paid to water quality, sanitary removal of excreta and solid waste management.

The search for solutions to restoring water supply must take into account each potential resource, its capacity, its proximity to a drainage system and all potential causes of chemical contamination.

Under normal circumstances, inadequate human waste treatment methods negatively affect the health of the population. In a disaster, removal and treatment of human waste acquires increased relevance in avoiding the transmission of infectious diseases, and it constitutes a public health priority.

Damage in this sector depends not only on the intensity of the disaster, but also on vulnerability, a special characteristic of each component of the entire system. To put it differently, a disaster of a given magnitude and type may cause very different damage to different systems, or to different components of one system. The vulnerability of a system basically depends on four factors: its geographical location, the quality of engineering design, the quality of construction (including technology, equipment and materials used) and the quality of facility operation and maintenance.

Most components of water and sanitation systems require proper operation and systematic maintenance over time; their absence would make the systems less resistant to damage and would hinder repairs when a disaster occurs. In turn, good operating and maintenance require effective organization, with workshops, spare parts and drainage layout plans, which significantly help to size, assess and repair more quickly and at a lower cost any damage produced by a disaster. Hence, operating and maintenance departments of affected systems will be a key source of information for the assessment team.

B. ASSESSMENT PROCEDURE

The assessment process requires, as a prerequisite, the definition of the area affected by the disaster. The water and sanitation specialist must also determine what institutions are involved in the sector and the role each of them plays. The water and sanitation sector requires a multi-disciplinary and holistic approach to the dialectic relationships among its component elements. At the same time, each service or subsector (water supply, sanitary sewage disposal and solid waste collection and disposal) requires special assessment procedures. The assessment team must obtain information on the individual policies to be applied in each of the subsectors, as well as each one's degree of development.

On the technical level, the assessment team should collect basic information and detailed maps of the affected systems, which will be essential for the necessary field evaluations and verifications. After the assessment is concluded, it should be possible for the water and sanitation specialist to prepare a table showing the most accurate and summarized information on damage and losses to the subsystems, as indicated in the following table.

Table 1
DAMAGE AN LOSSES IN THE WATER AND SANITATION SECTOR
(In thousands of dollars)

Component	Damage			Sector		Effect on the balance of payments
	Total	Direct	Indirect	Public	Private	
Total						
Water supply systems						
Urban systems						
Infrastructure						
Rehabilitation expenses						
Diminished utility revenue						
Higher production costs						
Rural systems						
Infrastructure						
Rehabilitation expenses						
Waste water disposal systems						
Infrastructure						
Rehabilitation expenses						
Diminished utility income						
Higher production costs						
Rural systems						
Infrastructure						
Rehabilitation expenses						
Wells and latrines						
Solid waste systems						
Rehabilitation expenses						
Diminished utility revenue						

C. INFORMATION REQUIREMENTS

The water and sanitation specialist should strive to obtain all available information on the subjects listed below as a basis for the assessment.

1. Drinking water supply systems

- Organization of the entire water supply subsector: service provider utilities, municipalities and regulatory and governing bodies;
- Pre-disaster water service coverage levels (urban and rural);
- Breakdown of the population served by collective and individual systems (such as collective water systems, individual wells, multi-family systems);
- Identification of the urban and rural systems affected by the disaster;
- Determination of whether the disaster affected the water supply treatment process and identification of any resulting need for additional chemicals/reagents or equipment;

- Characteristics of the systems affected by the disaster:

  - Population served before the disaster (number of domestic connections, average levels of water consumption, etc.);
  - Water supply rates, existing subsidies, billing collection effectiveness, etc.;
  - Pre-disaster production levels;
  - Water production capacity after the disaster; and
  - Estimated time required for rehabilitating all affected systems;

- Blueprints of all affected systems;
- Characteristics of damage sustained by all affected systems:

  - Description of damage sustained by different equipment/components of the affected systems;
  - Construction techniques and materials used in the systems' components; and
  - Accessibility to different components in the affected systems;

- Temporary organization of the water and sanitation service provider utilities, to meet population's needs until full services are re-established;
- Identification of measures undertaken to rehabilitate systems; and
- Costs of materials, construction, equipment, chemicals/reagents and other inputs required for the rehabilitation and reconstruction of systems.

2. Wastewater disposal systems

- Organization of the sewage disposal subsector: service provider utility, municipalities, etc;
- Coverage levels of the urban and rural sewage disposal and sanitation systems prevailing before the disaster;
- Breakdown of the population served by collective and individual systems (latrines and septic tanks);
- Identification of urban and rural systems affected by the disaster;
- Characteristics of the systems affected by the disaster;
  - Population served before the disaster (number of household connections,etc.);
  - Sewage disposal rates, subsidies and billing effectiveness (include any link to billing for drinking water);
  - Pre-disaster wastewater treatment levels;
  - Post-disaster treatment capacity; and
  - Estimated time required to rehabilitate affected systems.
- Characteristics of damage to the affected systems:
  - Description of damage to equipment/components of the affected systems;
  - Construction techniques and materials used in sanitation systems; and
  - Accessibility of affected systems;
- Temporary organization of water and sanitation utilities for meeting the population's needs until services are re-established;
- Identification of measures required for the rehabilitation of systems; and
- Costs of materials, construction, equipment, chemicals/reagents and other inputs needed for system rehabilitation and reconstruction.

3. Solid waste collection and disposal

- Description of existing local utility for the collection, processing and final disposal of solid domestic waste;
- Characteristics of damage to the service's assets (trucks, access roads to towns and dumps, etc);
- Geographical coverage and beneficiaries of these services before the disaster;
- Identification of measures required for the rehabilitation of affected systems; and
- Costs of materials, construction, equipment, chemicals/reagents and other inputs needed for system rehabilitation and reconstruction.

D. SOURCES OF INFORMATION

The water and sanitation specialist should enlist the assistance of all institutions and sources that may have basic information required for the damage and loss assessment, such as the following:

- Governing bodies and regulatory institutions, and water and sanitation services provider utilities:
    - Municipalities responsible for operating and maintaining water and sanitation systems and services; and
    - Ministry of health, housing or public works, when they have jurisdiction over the water and sanitation sector;
- National or departmental associations of municipalities.
- Water and sanitation utilities whether national, state, municipal, private, mixed or community managed:
    - Their annual reports in particularly;
    - Local water and sanitation management boards,
- Non-governmental organizations (NGOs) that usually construct rural water systems (CARE, Save the Children, OXFAM, Catholic Relief Services, etc.) and then transfer the systems to be self-managed by the community itself;
- National Chapters of the Inter-American Association of Sanitary and Environmental Engineering (AIDIS);
- UNDP, UNICEF and PAHO/WHO reports on the state and coverage of water and sanitation services, normally issued once every ten years.

E. DESCRIPTION OF DAMAGE

1. Direct damages

The water supply and sanitation specialist should be able to describe all direct damages sustained by the systems that make up the sector, as described below.

Drinking water supply systems. Ascertain the following:

- Damage to infrastructure and equipment of urban systems, preferably broken down by component;

- Damage to infrastructure and equipment of rural systems, preferably broken down by component; and
- Loss of stocks (chemicals, stored water, spare parts, other assets).

Wastewater disposal systems. Obtain the following information:

- Damage to infrastructure and equipment of urban systems, preferably broken down by component;
- Damage to infrastructure and equipment of rural systems, preferably broken down by component; and
- Loss of stocks (chemicals, spare parts, equipment, etc.).

Solid waste disposal systems. Ascertain the following information:

- Damage to infrastructure and equipment;
- Damage to access routes to facilities or dumps for final waste disposal; and
- Impact on waste disposal dumps.

2. Indirect losses

Here again, the water and sanitation specialist should obtain all information relevant for estimating indirect losses in the three subsectors.

Drinking water supply systems. The following data would be required:

- Activities related to rehabilitation (distribution of water by tanker truck or other means, purchase of equipment and machinery, repairs, changes in water treatment processes, use of materials and inputs kept in stock ready for rehabilitation efforts, personnel overtime);
- Reductions in potable water output (as it relates to intake, treatment, storage or distribution facilities);
- Reduction of operational costs due to the partial functioning of systems;
- Increase in potable water production costs;
- Losses due to income not received (water not billed, suspension of service, etc.); and
- Insurance coverage.

Wastewater disposal systems. The following information is essential for estimating indirect losses:

- Activities related to rehabilitation (network inspection work, acquisition of equipment and machinery, repairs, etc.);
- Reduction in wastewater treatment capacity;
- Increases in wastewater treatment costs;
- Losses due to income not received; and
- Insurance coverage.

Solid waste disposal systems

- Losses due to income not received
- Decrease in solid waste collection and disposal costs; and
- Insurance coverage.

F. QUANTIFICATION OF DAMAGE AND LOSSES

1. Direct damages

To facilitate their quantification, we suggest that damages be grouped in accordance with the following components.

- First damage should be identifird by type of system:
  - Potable water supply systems;
  - Wastewater disposal systems; and
  - Solid waste disposal systems.
- Second within each city and individual system, damage should be grouped by component or subsystem; for example, for the potable water supply system of a city:

  - Water intake facilities (intake A, intake B, etc.);
  - Pumping stations (station 1, station 2, etc.);
  - Water treatment plants (plant 1, plant 2, etc.);
  - Main lines to storage tanks;
  - Storage tanks (tank A, tank B, etc.);
  - Distribution networks; and
  - Other components, to be defined in each case.

The total damage to the potable water system of each city may then be obtained by summing the individual component damages.

A list of damage sustained by each subsector (water supply, wastewater disposal, and solid waste disposal) should be prepared, with a breakdown by materials, equipment or facilities. A procedure similar to the one described below could be adopted:

- A summary description for each damaged component should be made including its main elements, the type of damage and the approximate amount of work or material affected, in appropriate measurement units. For each damaged component, the following should be indicated:
  - Type of work and/or materials required;
  - Unit construction prices at replacement value (UP); and
  - Cost of repairs, estimated as a percentage (R%) of the unit reconstruction price described above.

- The estimate of the percentage (R%) to which facilities, materials or equipment may be damaged should be obtained directly from the service provider utility, or on the basis of a weighted estimate that would take into consideration whether the facility, material or equipment can be repaired or partially reconstructed or must be totally reconstructed or replaced. If there is a chance that the damage can be repaired, the cost of the damage should be estimated as a percentage (R%) of the total cost of said facility, material or equipment. If the facility has to be totally rebuilt or replaced, R should be taken to be 100%.

- The initial R% can be based on estimates provided by personnel from the utility that is responsible for each system, or from other sources, but the final figures adopted should be those calculated by the water and sanitation specialist on the assessment team on the basis of information he/she collected during the field mission.

In addition, one must take into account the cost of demolition, dismantling and debris removal in the manner described below.

- For each system component (identified in accordance with the above recommendations), a determination must be made as to whether reconstruction or repair will be required prior to demolition, dismantling or debris extraction. If such prior work is needed, an indication should be made of the approximate amount of work or material to be demolished and removed, in the appropriate unit of measurement, which as far as possible should be the same unit as the one used to quantify the damage to this item.

- A description should be made of the work or main activities considered part of demolition, dismantling and debris removal (adopting a single unit price for each item).

- The degree of difficulty and costs involved in work and materials should be taken into consideration. For example, distinctions should be made between the "demolition" of a reinforced concrete storage facility and the "dismantling" of asbestos cement pipes, whose joints can be much easier to take apart and which could be partially recovered and re-used.

- If an accurate estimate of prices under this heading is not possible, a criterion similar to that indicated in the previous point should be adopted, where the cost of "demolition and removal of debris" should be expressed as D% of the unit price. However, D% is not necessarily equal for each item, owing to the varying degrees of difficulty of demolition or removal.

- If part of the material can be recovered as a result of demolition or dismantling, whether for re-use by the same utility or for sale, its remaining value should be estimated as a percentage (V%) of the unit price of said material when new. These results should be deducted from demolition, dismantling and debris-removal costs.

If the disaster directly affects the warehouses or other storage facilities where spare parts, chemicals, reagents and water tanks are kept, this must be taken into consideration. The water and sanitation specialist should consider all available sources to ascertain the amount and unit prices of the materials in question.

Unit prices to be used in damage assessment can usually be obtained from recent feasibility studies or from the unit price lists normally used by the utility that provides the affected services. In this case, the date the lists were made should be ascertained so that, when necessary, adjustments for inflation can be made. The unit prices to be used can also be based on estimated unit prices derived from direct surveys or suitable local sources. "Comparative unit prices" available for the region that can also be used for comparisons with the two previous points, and used instead of them, when necessary.

No matter where the list or estimate of unit prices is obtained, it should include the labor content and the percentage of domestic and imported materials as a percentage of total unit prices. This will make it possible to distinguish the total amount of direct damage, the value of imports and their corresponding effect on the balance of payments.

Water supply, wastewater disposal and storm drainage systems include a wide array of facilities, materials and equipment. The cost of some of these facilities may easily be estimated on the basis of unit price lists. Such is the case of water pipes, whose unit price can be expressed in linear meters either for the simple purchase of the pipe or for their complete installation. The costs of other types of facilities (e.g., potable water treatment plants) that include components employing varied technologies and prices should be estimated based on a total price for the facility.

2. Indirect losses

Indirect disaster effects usually last throughout the rehabilitation and reconstruction period or until facilities return to normal operation. These effects include the water supply utilities' income shortfall (owing to reduced billings as they supply less water) and to increased water leakage from yet-to-be- repaired pipelines. They also extend to the higher operational costs the utility must assume to ensure the temporary provision of water until normal service is re-established. The negative impact on health should also be included. An agreement should be reached with the health sector specialist in order to avoid duplications or omissions in this regard.

a) Drinking water supply systems

i) Rehabilitation of normal operations. Depending on its magnitude, a natural disaster may affect very large geographical areas that might include cities of various sizes, towns and rural areas. The random nature of the disaster and its ramifications might require a broad range of activities for rehabilitating services; these involve costs that should be included as indirect damage (in addition to the repairs of direct damage). These rehabilitation activities include the following:

- Pipeline repairs, using plastic patches or jackets, provisional by-pass pipelines and also works to divert flows away from holes in order to avoid losses of water in damaged pipe networks;

- Use of existing stocks or reserves of equipment, materials, chemicals and reagents;
- Increased chlorine concentration in already chlorinated water, with temporary functioning of chlorination facilities for untreated water and for storage tanks and preventive chlorination in deep and shallow wells in both urban and rural areas;
- Use of other existing potable water sources such as the deep wells of private factories, businesses or sports facilities (this calculation includes water connections to the network, the supply of power to pumping equipment, etc.);
- Temporary conversion of existing water storage facilities –such as swimming pools, factory and business storage tanks– as well as fiberglass and plastic tanks to store and distribute drinking water;
- Temporary use of tanker trucks or other vehicles pressed into service for delivering drinking water to the population;
- Activities required to implement, when necessary and possible, temporary rationing of drinking water in the network;
- Increasing water pressure in the network to avoid contamination of the potable water, which might be essential even in the event of increased water leakage;
- Preparation and delivery of instructions to the population on preventive measures for the use of water (boiling, for example), rationing timetables, tanker truck routes, water distribution points, etc; and
- The cost of alternative means for the public to acquire/purchase water (e.g.; the premium paid for such water, health problems).

ii) Estimating the cost of rehabilitating services. Rehabilitation activities vary greatly owing to the wide range of potential disasters and the peculiarities of each region. In order to simplify matters, one should begin by grouping these costs into a limited number of categories:

Increased labor costs. This item includes any increases in costs of professional, technical, administrative and manual labor employed in rehabilitation operations, over and above the normal payroll levels. They may be estimated as follows, bearing in mind that the affected utility company would already have some estimates on the matter:

- Prepare a simplified list of personnel categories employed in this type work, indicating their unit cost in each category (person-months, person-days, as applicable);
- Estimate the “number of person-units” in each category that will be required for the rehabilitation operations during the entire period they are expected to last; and
- Multiply these values and add the subtotals to obtain total losses.

Estimated cost of works and repairs. This point includes any costs not included under the previous item. It should include all materials, transport, fuel and so forth, that may be used in works and repairs. Only a fraction of the total value of equipment, machinery, pipe and valves installed on a temporary basis is to be included in these estimates, which would include an amortization estimate (r%), whose value will depend on the use made of such elements during the rehabilitation.

A list of the main material works performed should be made, including a summarized description of each work or other material costs; the approximate volume of each work, materials or item; the unit price of each; and any overhead expenses and profits (where appropriate).

Estimated cost of using water sources or intake works not belonging to the public water utility. This involves expenses that have to be paid in accordance with special agreements with third parties.

Use of tanker trucks for drinking water distribution. Tanker trucks may deliver water in order to alleviate problems in those areas where the disaster disrupted normal service. Estimates should take into account such factors as the capacity of trucks engaged to deliver water and the rates charged per delivery.

iii) Reductions in drinking water production. The disaster may reduce the volume of water tapped from any source for treatment and delivery to the public. This shortfall may be the result of direct damages such as:

- A drought-induced decrease in water availability;
- Contamination of water sources; and/or
- Damage to intake facilities, pumping stations or other equipment.

iv) Reductions in the distribution capacity of drinking water systems. Damage to major pipelines that convey drinking water to cities or intermediate facilities (such as treatment plants, pumping stations, storage reservoirs, etc.) may impair the system's overall delivery capacity. Damage to secondary pipelines or to distribution networks may partially affect drinking water distribution capacity. Damage to domestic connections and or interior networks of buildings, houses, factories, markets and the like may curtail local delivery capacity. Damage to pumping stations may also affect the system's total or partial water conveyance capacity.

v) Reductions in the regulation and storage capacity of drinking water systems. Any reduction in water regulation capacity diminishes the ability of a system to meet demand over time and avoid losses to water sources. This item includes any damage to a system's regulation and/or storage capacity, as well as damage to minor, industrial, commercial or domestic reservoirs.

vi) Reduced consumption of drinking water. Consumption in affected cities and towns may be partially or totally curtailed by the supply constraints noted above (e.g., direct damage to the potable water supply system) and/or the displacement of the consuming public. Should the sanitary quality of the water be undermined, residents would be forced to boil water. Obviously, a fall in supply and/or demand would reduce utility billings and revenues.

vii) Increased water production costs. These usually result from an elevation of existing water intake points or the need to draw on alternative sources; an increase in the daily volume of water production to compensate for leakage in either the main pipelines or in the distribution networks; and/or higher power and other input costs.

viii) Lost income (water not billed, temporary suspension of supply, etc.). To estimate the extent to which billings have declined (or the probable reduction in water sold to consumers in cities and towns located in the disaster area), one must determine the main factors responsible for the shortfall.

ix) Impact on public health because water flows have become inadequate, inconsistent or of inferior quality. The impact on health, particularly on that of children and the elderly, can vary and should be analyzed under the health sector.

b) Wastewater disposal systems

Three main types of indirect losses may be sustained, by wastewater disposal and storm drainage systems.[1]

i) Increased health-risk levels and reduced quality of life. Apart from the fall in the level of hygiene that may result from the lack of sufficient drinking water, the lack of sanitary or storm drainage may pose significant public-health risks for the following reasons:

- Wastewater disposal systems cannot be used in those areas that do not have a potable water supply because water is essential to flush away excreta and other waste;
- Breaks and blockages in the sewage disposal network will likely result in wastewater flowing to the surface of streets, increasing the risk of disease and epidemics either by direct contamination or by the action of vectors.
- Any problems at wastewater treatment plants might further pollute the water resources into which effluents are discharged; and
- The risk of flooding increases when rainwater drains are damaged.

ii) Rehabilitation involves a wide array of activities including pipe repairs, the laying of provisional pipelines or drains and the digging of drainage ditches. These also may include maneuvers involving valves, gates and other facilities to divert flows from wastewater or rainwater pumping stations and to expel wastewater that has flooded plants, chambers or ditches. The cost of maneuvers and rehabilitation works for sewers should be estimated in the same fashion as drinking water.

1 In some instances, the same system is used to evacuate both wastewater and storm runoff. In other localities, separate systems exist.

iii) Decreased income from wastewater billings. How the disaster affects billings for wastewater disposal services depends on how billing is normally done in the affected cities. Where the charge is computed as a percentage of water supply billings, losses should be estimated using the following formula:

I_t = total decrease in water supply billings in the city;
a% = percentage (%) overcharge in water supply bills included to pay for the wastewater disposal service;
s% = percentage of population having both water supply and wastewater system in relation to the total population having water supply connection.

Hence, the decrease in billing for wastewater disposal services will be obtained as

$$\triangle f_a = I_t \text{ x } (a\%) \text{ x } (S\%).$$

However, there could also be an additional segment of the population that cannot make use of the wastewater disposal service because it is broken. This loss might be estimated as an additional percentage (Z%) to the one indicated above, in the following manner:

$$\triangle f'_a = (Z\%) \text{ x (Normal billing for waste water disposal service)}$$

When the cost for use of the wastewater disposal service is a flat rate for connecting to the system, the loss in billings can be estimated by applying a percentage to the overall billing for the city.

Given:

F_a = total monthly billing for wastewater disposal service for the entire city;
$F_a/30$ = average daily billing;
g% = estimated billing percentage not charged due to the disaster;
p = length of the period during which irregular or no service is provided, in days

Then:

$$\triangle f_a = (g\%) \text{ x } p \text{ x } (F_a/30)\text{, in US\$/period}$$

Where no charge is made for wastewater disposal service, the utility's revenues would not be affected.

G. MACROECONOMIC EFFECTS

All items, information, background and procedures necessary to asses the water supply and sanitation sector's impact on the country's macroeconomic performance are described below.

1. Effects on gross domestic product

a) Reduced output

This refers to the reduction in production of water that occurs from the time the disaster occurs until normal production capacity is restored. The lost production should be estimated as the shortfall in utility revenues resulting from the reduced volume of water billed to the users, plus any increase in the cost of providing the service because of water produced that fails to reach consumers due to leaks in networks or other reasons.

It is possible to estimate how long it will take to resume normal supply and billings in light of the scale and characteristics of direct damages and the financial, repair and reconstruction capacity of the corresponding water-supply utilities.

A table should be prepared for each affected city and/or utility, the following data:

- The reduction in drinking water volumes billed each month to users from the time of the disaster until service is likely to be normalized;
- Any variations in average rates charged to the public for the volume of drinking water delivered;
- The shortfall in the utility's monthly revenue (the difference between pre- and postdisaster billings); and
- Any added costs associated with the population having to acquire water by other means.

b) Projected sector performance prior to the disaster

The macroeconomic specialist may have access to such data for the entire country and the affected area. However, in Latin America and the Caribbean, the only such projections normally to be found involve the volume of water tapped, treated or lost through network leaks in urban areas, so it might be more practical to estimate the sector's GDP based on the volume of water billed to consumers. We recommend that the water and sanitation specialist, in close cooperation with the macroeconomics specialist, carry out the following tasks;

- Analyze national accounts and consult all institutions overseeing the sector in order to obtain, where possible, data on changes in GDP for the previous five years, together with a forecast by the corresponding officials on the sector's expected performance for the current year had the disaster not occurred; and
- Analyze any changes in the sector's strategies that would allow the service to be restored and further developed.

2. Effects on gross investment

These include the following three items:

a) Projects under execution and other projected investments that must be suspended or postponed, or whose funds must be reassigned to meet disaster-related needs

This information should be summarized in a table identifying the main projects affected and the investment envisaged for each one. Finally, an estimate is to be made of the expected reductions in investment for each project as a result of the disaster, in the current and succeeding years.

b) Losses of stock

A table must be prepared showing losses of stock (such as water stored in reservoirs and/or in storage tanks, chemicals and reagents for the treatment of water), as well as losses of materials and spare parts stored and/or available in facilities that were under construction.

c) Financial requirements for repair or reconstruction

The background for developing this item will mainly come from the direct damage lists and assessment, providing total and itemized costs for the damage. Based on that information, a table comprising the following information can be prepared:

- A list of affected works, broken down by systems, subsystems and main facilities and indicating the overall cost of the damage to each one. This list should separately identify works in the different cities and companies (if there is more than one responsible for the service in the same city), as well as for rural areas.
- A forecast of investment needed in the succeeding years for repairing said damages. The forecast should reflect the relative urgency of the respective works, the engineering capacity of the country and/or utility, and possible sources of financing. Special regard should be given to weighing the relation between national project execution capacity and new construction demands, and domestic capacity for covering the post-disaster surge in demand for reconstruction-related inputs vis-à-vis imports.

The water and sanitation specialist should make special reference to any expected requirement and capacity limitations for reconstruction and repair and make appropriate recommendations (as time and information limitations permit).

3. Effect on the balance of payments

The water and sanitation specialist should provide basic information on indirect losses so that the macroeconomic specialist may calculate the effects of the disaster on the current account. The information listed below should be included.

a) Decreased exports of goods and services

Since drinking water is very rarely exported, this item would not normally be taken into consideration. However, if an affected country normally exports engineering services related to the sector, the increased internal demand determined by the disaster might reduce or eliminate the export capacity for such services over a period of time. The reduced value of this export should be expressed as follows:

M$s = decreased value of exports of services, in a given period;
MsO = decreased value of exports of services, in the year of the disaster;
Ms1 = idem for the year following the disaster; and
Ms2 = idem for the second year following the disaster

Therefore: M$s = (MsO + Ms1 + Ms2)

b) Increased imports

To estimate the value of this item, imports required for rehabilitation and reconstruction of direct damages should be taken into consideration. Such imports may be obtained from the summation of the imported components of direct damage estimates made previously.

To estimate increased imports, the following procedure might be used:

Given:
Idd = increased imports as a result of direct damage;
Idd0 = idem, during the year of the disaster;
Idd1 = idem, during the year following the disaster; and
Idd2 = idem, during the second year (etc.) following the disaster (as applicable)

Thus: Idd = Idd0 + Idd1 + Idd2

c) Donations

This item includes international assistance for the sector consisting of donations in kind, equipment, materials and machinery. Although these donations will probably occur in the period immediately after the disaster (year 0), there should be an indication of whether donations are expected in the following years.

d) Reductions in international debt servicing

If a reduction in interest payments has been granted by creditors, due note should be made of it under the year in which it occurs.

e) Insurance and re-insurance

Increasingly, both the assets and revenues of the water and sanitation sector are domestically insured against disaster risks. Should that be the case, estimates must be made of insurance payments due after the disaster, as well as the expected amounts of reinsurance to be received from abroad, since these will have an effect on the country's balance of payment.

4. Effects on public finances

A disaster might disrupt public finances in several ways, as described below.

a) Decline in tax revenues due to lower production of goods and services

If water and sanitation billings are subject to taxation and if, utility revenues decline as a result of the disaster, the corresponding fiscal or municipal revenue will also diminish. To estimate these tax revenue shortfalls, due consideration should be given to the following:

- Declines in revenues due to decreased billing and water losses; and
- Information on the percentage (p%) and value of said taxes as estimated by the utilities.
- The value of lower taxes may then be estimated as follows:

  Mi = Mi0 + Mi1 + Mi2 = lower tax revenue in years 0, 1 and 2.

b) Decline in public utility revenues

Lower billings due to a decreased supply of drinking water, as indicated above, results in decreased revenues for the affected utilities.

Thus:

Mf = Mf0 + Mf1 + Mf2 = Lower billing for years 0, 1 and 2.

c) Increased outlays for reconstruction and damage repair

Information required to estimate this effect on public finances should be obtained from tables included in the previous example on gross investment.

Let: Mgi = higher outlays in reconstruction investment.
Then: Mgi = Mgi0 + Mgi1 + Mgi2 = idem, year 0 + year 1 + year 2

5. Effects on prices and inflation

Damage caused by the disaster may have a bearing on changes in the prices of water and construction materials required to repair damages in the sector. This would depend on several factors, including the magnitude of the disaster and the amount of damage caused.

a) Possible change in the price of water

The cost of water may vary as a result of a disaster for several reasons. Among them:

- Water production costs may vary owins to the need to change the place or type of water resource intake, the type or types of treatment plants or the conveyance or elevation of the water, or because of a drawdown in groundwater levels;
- If the resulting difference in costs compared to those before the disaster is absorbed by the utility through subsidies, there should be no effect on the price to the public.

Information on these matters should be provided by the water utility. However, it is unlikely that they could be reasonably certain of the exact impact on pricing so soon after the disaster, so the analyst must also make possible trend projections. If the cost increases as a result of the factors indicated above, the relationship between the new cost per cubic meter and the previous cost, or the expected variation in the new price to the public, should be indicated.

b) Possible effects on the price of construction materials.

Heightened demand for construction materials in this sector and throughout the economy in the wake of a disaster is likely to exert significant pricing pressures. Therefore, the assessment team as a whole should analyze the situation concerning a possible increase in construction material prices.

From the point of view of the water and sanitation sector, it would be useful to have an estimate of the increased demand for the main materials that will be involved in repair and reconstruction during the years following the disaster. The specialist should also develop an idea of the domestic production capacity, its relation to the increased demand and the capacity to import said materials. In addition, consideration should be given to possible price controls adopted by the government.

H. OTHER EFFECTS

1. Possible effects on employment

As in the case of the energy sector, the growing use of technology and equipment impliest that the water and sanitation sector employs a limited amount of personnel for the operation of its networks. A disaster is thus likely to have a very limited effect on employment and personal income in this sector. In fact, personal income of utility enterprises may actually increase during the rehabilitation period due to the payment of overtime.

The water and sanitation specialist should work in close cooperation with the employment specialist of the assessment team to arrive at the overall effects that the disaster may have on employment and income, ensuring that figures for the water and sanitation sector are duly included and not duplicated in the latter's global estimates.

The following paragraphs describe possible effects on employment for the sector.

a) Effects due to replacement of facilities and infrastructure

Since availability of drinking water is essential to the population, destroyed facilities and other infrastructure must be replaced as quickly as possible. The technology and design of the new facilities might require a different number or type of personnel for purposes of operation and maintenance. Any differences in employment arising from technological changes must be duly noted.

b) Effects occurring during the reconstruction and repair stage

Employment requirements during the emergency phase fall outside the scope of the assessment described in this Handbook. However, any of the following possible impacts on employment during the reconstruction process should be indicated:

- Employment levels could remain unchanged if reconstruction efforts absorb workers who were laid off when projects begun prior to the disaster were cancelled or suspended;
- Employment could increase if normal projects and activities are maintained while additional workers are hired for reconstruction and rehabilitation projects; or
- The employment scenario could be mixed, with only a percentage of pre-disaster development projects being canceled or postponed.

The disaster may have an impact on the investment decisions of government officials and the drinking water utilities, so the water and sanitation specialist should obtain the relevant information from these institutions for estimating any variations in employment for years 0 1, and 2 (if reconstruction works require more time, more years must be added).

These employment projections must be consistent with the time-frames and investment projections made earlier with regard to reconstruction requirements.

2. Differential effects on women

Any damage to drinking water systems in rural and marginal urban areas has a differential effect on women, who generally bear the burden of obtaining water for household consumption where no domestic water connections are available.

When a family or community well or spring is rendered useless as a source of drinking water because of contamination or silting, women are forced to dedicate greater time and effort to obtaining water from more distant locations, thus increasing their reproductive workload.

The section on the differential impact of disasters on women in Volume Four of this Handbook explains in detail how this increase in reproductive work can be estimated through field surveys. The water and sanitation specialist should work in close cooperation with the gender specialist in making such estimates.

3. Impact on the environment

Any change in the availability or quality of the water resource used by the drinking water supply system constitutes an environmental modification that has negative effects on people's health and well-being. The same is true of sanitation problems caused by disruption of wastewater disposal and solid waste management systems. While the chapter on environmental matters in Volume Four deals with these issues, the estimation of related costs falls within the purview of the water and sanitation specialist, who should coordinate with the environment specialist to ensure that all the relevant information is effectively obtained and that there is no double accounting.

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 $\mathbf{p_o} \neq \mathbf{f_o}$, 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:

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

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.

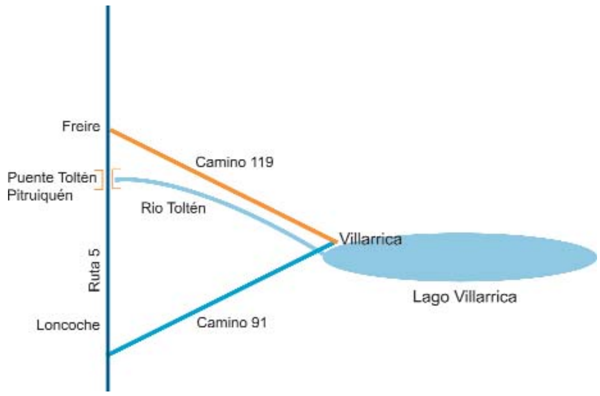
Unemployment and income loss within the sector may occur if transport and communications operations are suspended for long periods. One must estimate how much of the sector's services belong to women, as well as the percentage of potential employment and income losses corresponding to women (see the 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.