PN-ACA-267
93375

PRIDE Project in Development and the Environment

The Role of Risk Analysis in Environmental Management

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A Special PRIDE Technical Report Prepared for the AID/NE Bureau
Environmental and Natural Resource Workshop

Cairo, Egypt

February 28 - March 3, 1993

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As the Near East countries strengthen their environmental management capabilities, they face the double challenges of correctly identifying environmental problems and implementing effective solutions to those problems. This paper will focus on the identification of environmental problems, in particular, the application of risk analysis to establish priorities for the employment of scarce public funds to solve those problems.

Measuring Environmental Damage

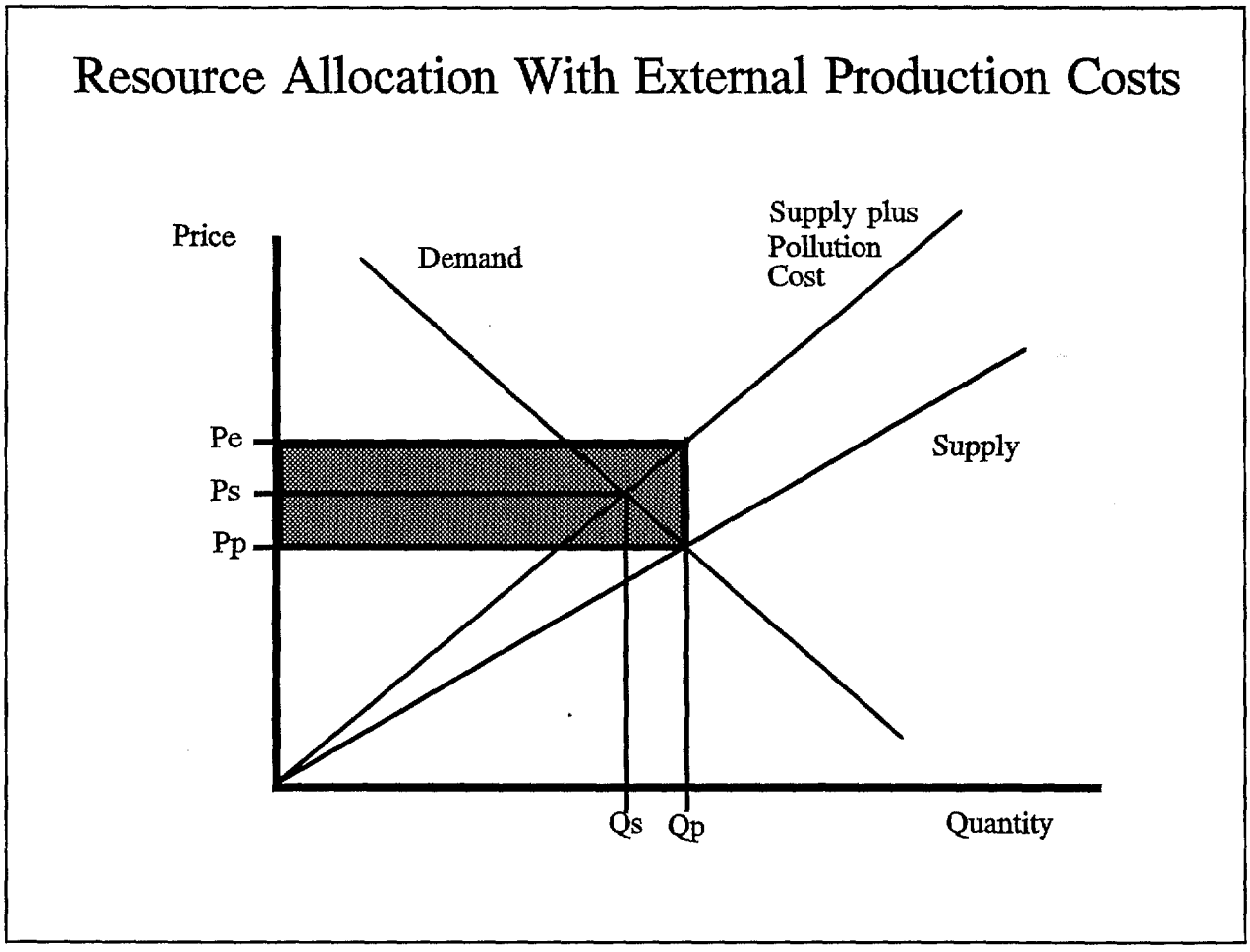
The failure to price water at its approximate social cost has led to severe water overuse which, in turn, has aggravated much of the Near East's water-based environmental damage. This problem is well known throughout the region, but there has been no concerted effort to analyze the problem in terms balancing the costs of eliminating water overuse with the resulting benefits or savings from forestalled environmental damage. Beyond the pricing issue, the absence of an analytical framework has meant that basic economic analysis is not being used to evaluate tradeoffs between the costs and benefits of environmental policy options. More generally, the analytical framework requires translation of physical damage caused by pollution into a monetary cost, which is then compared with the monetary cost of removing or reducing the pollution source.

The market-based approach to estimating environmental damage is demonstrated in exhibit 1. Suppose that the demand and supply of some manufactured good, such as paint, establishes a market-clearing price and quantity of Pp and Qp, respectively. This market equilibrium defines the equality of marginal social benefits (demand) with marginal private costs of production (supply). Note that the demand curve is assumed to represent the absence of consumption externalities. However, the private production costs of paint do not cover the full social costs of production, estimated to be a unit price of Pe. Although Qp units of paint are sold for a unit price of Pp, the paint-related environmental damage is Pe-Pp per unit of paint produced. The unit price, Pe, represents the full social cost of paint production, including the full private costs of paint production, plus the damage to health and other economic activities caused by air and water pollution from the paint manufacturing process.

The rectangle defined by Pe-Pp, Qp-0 represents an estimate of the external, pollution costs of paint production that are not included in normal market transactions. Since most pollution processes involve public goods and common property issues, markets rarely include these costs in paint prices because the pollution victims are usually not key interest groups in the paint market. Even if the paint pollution victims can be identified, it is often very difficult to precisely measure the magnitude of the paint-related damages, in both physical and monetary terms.

But, if the pollution processes could be precisely defined, exhibit 2 demonstrates the essential economic relationships required to apply these analyses to a comprehensive environmental quality management program. This framework is an economic

Exhibit 1



version of the risk assessment model explained below, and the production externality problem described above in exhibit 1. Panel (a) assesses the relationship between observable levels of pollution and physical damage to the environment; in the Near East, virtually no effort has been devoted to this issue. At best, sporadic information has been assembled on levels of pollution. One of the most comprehensive environmental monitoring programs is being managed by the Egyptian Ministry of Public Works and Water Resources' Water Research Center. Physical damage, such as incidence of disease, agricultural production losses, and manufacturing losses, have not been systematically related to alternative levels of water and air pollution.

Panel (b) determines the costs of estimated physical damage estimated in the first panel in terms of medical expenses, income lost from health problems, losses in agricultural and industrial productivity, and damages to property. Again, Near East environmental agencies are not studying this relationship to solve any major pollution problem.

Panel (c) links Panels (a) and (b) to produce a total pollution damage cost function, where

the total cost of pollution damage relates to respective levels of observed pollution. These costs should vary directly according to the level of pollution.

Panel (d) estimates the cost of abating or controlling pollution for alternative levels of pollution. This very difficult task often is abandoned in favor of a few lumpy approximations of the smooth curve of an infinity of abatement costs at respective levels of pollution.

Panel (e) determines the optimum level of pollution or environmental quality. The total cost of both pollution damage and abatement is minimized by combining panels (c) and (d) and summing the damage and abatement cost functions. These relationships show that at a relatively high level of pollution (low level of environmental quality), the total cost to society is high, and due almost entirely to the cost of damage caused by the pollutant. In contrast, at low levels of pollution (high environmental quality) total cost is also high, and attributable almost entirely to the cost of abatement. Between these two extremes, the total cost of the combined damage and abatement costs reaches a minimum, which can be described as the "optimum" level of pollution or environmental quality.

The Risk Assessment Framework

The environmental risk assessment framework that has evolved from U.S. experience over the last two decades has become a critical tool in any effective environmental management program. This framework involves applications of risk ranking and risk assessment methodologies to demonstrate physical and economic costs of environmental damage, and prioritize alternative pollution abatement options. The following sub-sections summarize these methodologies and demonstrate to employ them to improve Egyptian environmental management.

Risk Ranking

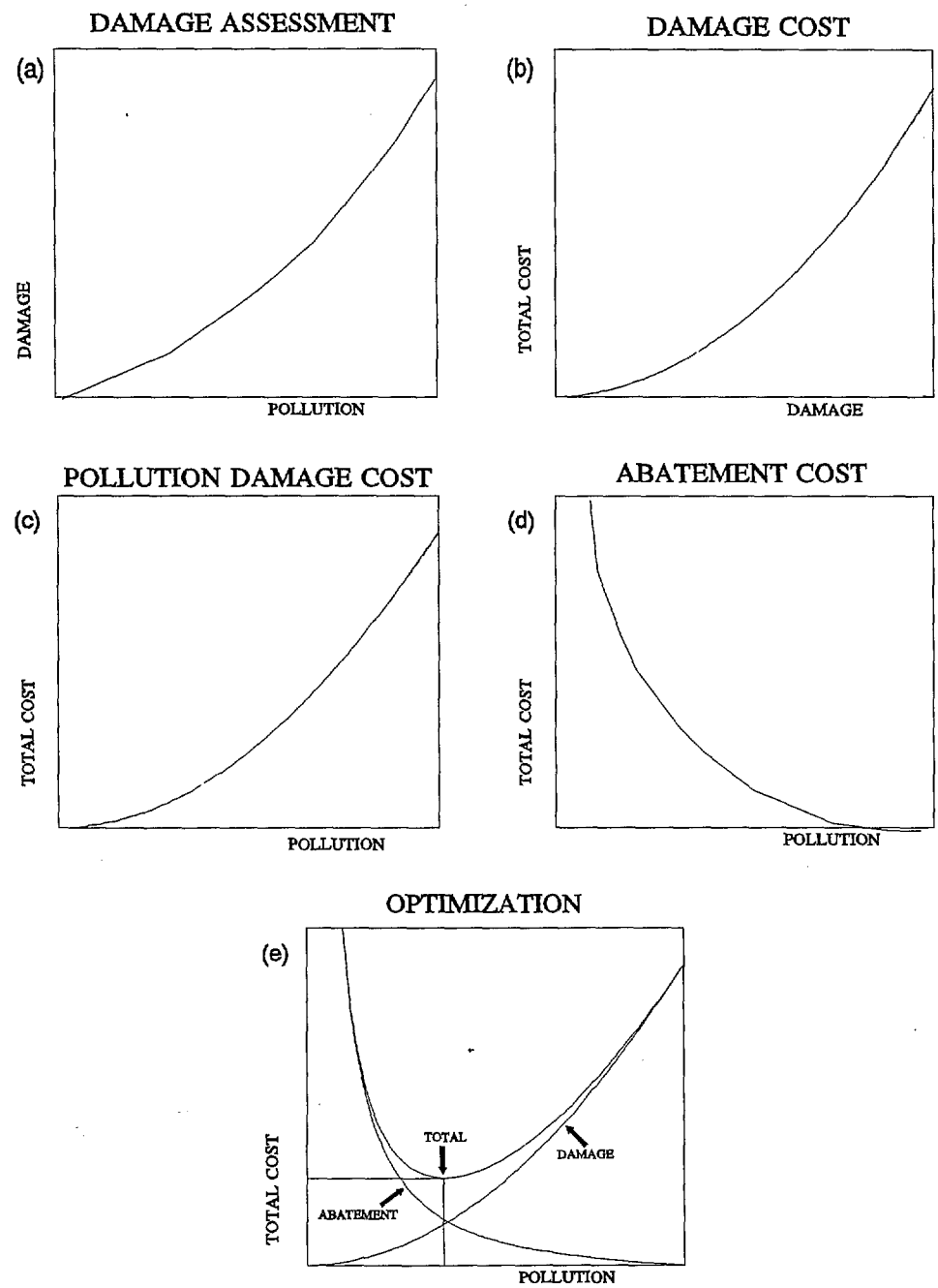
To effectively allocate scarce resources (money, personnel, time) toward alleviation of significant environmental problems, it is necessary to rank those problems according to the nature and magnitude of their detrimental effects. This ranking process is risk analysis.

Three types of risks must be considered: human health risks; ecological risks; and social and economic effects.

Human health risks involve actual or estimated cases of human disease or injury caused by anthropogenic environmental problems. Ecological risks involve actual, estimated, or anticipated damages to the structure and function of natural ecosystems and their components. Social and economic effects address losses in the social and economic quality of human life caused by environmental problems, such as increased maintenance cost of paint and reduced recreational use of water bodies.

Exhibit 2

Management of Environmental Quality



Risk analysis involves four steps: identify all significant environmental problems; characterize each problem in terms of the detrimental effects; estimate the magnitude of damages associated with each environmental effect; and rank the environmental problems on the basis of the damage estimates.

In the first step, it is important to identify both existing environmental problems and potential future problems. The second step involves identifying the environmental effects associated with each problem, such as cancers and related deaths, pulmonary-related illnesses and deaths, and trees blighted.

In the third step, quantitative damages are estimated for the magnitude and associated costs of each environmental effect identified in Step 2. Examples would be number of cancers and associated cancers, number of pulmonary-related illnesses and deaths, number of trees blighted, increase in health care costs, lost wages, value of lost timber or tourism.

The fourth step requires the ranking of environmental problems according to the damage estimates established in Step 3. This step typically involves judgmental decisions because different types of costs often are involved, *e.g.*, are ten cancer-related deaths equivalent to one million blighted trees? For this reason, the ranking process may be limited to assigning the problems to risk-level groups, such as high, medium, and low risk.

Risk analyses in developing countries such as the Near East region, are usually more limited than analyses conducted in the United States. This occurs because data of sufficient quality are seldom available for characterizing the environmental problems. Consequently, estimates must be made by extrapolating from data for comparable situations in the United States or other developed countries.

Near East countries lack continuous, systematic monitoring data; however, Egypt's scientific community has made a useful first effort to use available data to estimate environmental damage for the Egyptian environmental master plan. Because the plan will be used to solicit aid from donor countries, risks have not been ranked. However, the Egyptians' damage estimates provide a useful context for assessing the significance of projects that donors may consider undertaking.

Risk Sequence

When selecting among projects to address existing or potential environmental problems, it is important to consider the risk sequence associated with each problem. Each environmental problem can be viewed as the outcome of the six-step sequence depicted in exhibit 3. Viewing the problem within the context of the risk sequence is important because the appropriate remedy changes at each point of the sequence.

Ideally, projects should focus on the step in the risk sequence at which greatest payoff can be achieved for the least cost. In nearly all cases, cost efficiency decreases as one

moves long the risk sequence.

In addition, the Mission may prefer to undertake some types of projects and to refrain from undertaking others. In this case, the risk sequence can help determine at which step such projects will be most useful.

The activity of transporting people can be used to illustrate the six steps of the risk sequence (exhibit 3).

The first step in the risk sequence (Step 1) is the activity being undertaken, which in this case is people transport. The activity level is measured in people-kilometers. The activity mode can be individual or mass transport via land, air, or water. The choice of activity mode is important. For example, comparing mass transit using buses with private automobile transit, the former achieves more people-kilometers with less pollution than the latter because of the equipment characteristics, even though the two may employ the same technology.

Several technologies can be employed (Step 2), including automobiles, buses, rail, or water transport. In each case, the engine used to provide motive power can vary. Alternatives include internal combustion engines using gasoline, diesel fuel, natural gas, or LPG as fuel; electric power; coal boilers; or sail. The pollutants generated vary by species and quantity with the technology and fuel used and with the efficiency at which the technology is applied. Efficiency varies with the intrinsic characteristics of the technology, quality of equipment, and level of maintenance.

Once the pollutants have been generated, the goal becomes to capture, treat, and dispose of them before they are released (Step 3). In the internal combustion engine case, treatment can be accomplished by use of catalytic convertors, which convert fuel components in engine exhaust. In the case of chemical plants, treatment includes waste water treatment, neutralization of acidic waste streams, incineration of organic wastes, and other technologies.

Once the pollutants are released, they are transferred through the environment (Step 4) until they reach their final repository. In the case of air releases, pollutants are chemically converted over time, deposited on land, added to the atmospheric level of that material (*e.g.*, carbon dioxide), or they migrate to the stratosphere (chlorofluorocarbons). Emissions from vehicles include nitrogen oxides that contribute to ozone formation, volatile organic compounds (VOC's) that contribute to smog formation, and lead that is land deposited. The transfer path for air releases is affected by terrain and meteorological conditions.

During the transfer process, people and the environment may be exposed to the released pollutants or their conversion products (Step 5). In the case of airborne vehicle pollutants, the extent of exposure depends upon population location and density and the location of sensitive ecosystems.

Exhibit 3

ENVIRONMENTAL RISK SEQUENCE FRAMEWORK

Activity	Technology/ Pollutants	Control/ Release	Transfer	Exposure	Effects (Risk)
* Function * Activity Level	* Technology * Efficiency * Species * Quantity	* Treatment/ Control Mechanism * Release Mechanism * Concentration	* Transfer Path * Species Conversion/ Dilution * Intermedia Transfer	* Population * Environment	* Human Health * Environment * Economic or Social Loss

Intervention Mode

Behavior Adjustment	Pollution Prevention	Treatment/ Control	Chemical Use Constraints	Location Constraints	Mitigation

Illustrative Examples

Increased Mass Transit Driving Constraints	Auto CAFE Stds Electric Power	Incineration Neutralization	CFCs DDT	Restricted Industry Siting	Sunscreens Different Plant Species

Finally, the amount of damage (Step 6) attributable to this exposure depends upon the pollutant species characteristics, intensity and extent of exposure, and characteristics of the receptor, i.e., child, elderly, pregnant, or fragile ecosystem.

The risks associated with a given sequence result from the behavioral characteristics defined in the preceding steps. Thus, in the automobile exhaust example, the effects (damages) depend not only on the receptor characteristics (Step 6), but also on population and sensitive ecosystem locations (Step 5); transfer path characteristics (Step 4); whether a catalytic converter was employed as a control mechanism (Step 3); the type and efficiency of the engine and the type of fuel employed (Step 2); and the extent to which mass transit or private vehicles are employed (Step 1).

In nearly all cases it is less costly to address environmental problems at the earlier steps of the risk sequence (Exhibit 3). Activity modes can be adjusted by behavior modification, *e.g.*, increasing the use of mass transit. Technology can be dealt with by pollution prevention actions, which include source reduction and recycling, recovery, and reuse. Source reduction means elimination of pollution at the source, *i.e.*, before it is generated. In the people transport case, significant source reduction could be achieved by switching to electric power, using natural gas fuel, using unleaded fuel, or adequately maintaining the vehicle fleet.

Once the pollutants are generated, they can be controlled to some extent in the gasoline engine example by use of catalytic converters. However, such an approach does not deal with lead compounds, nitrogen oxides, or carbon dioxide generation. In dealing with a given level of pollutant release, transfer path and exposure can be affected by locating the road system away from population centers (or vice versa).

Once exposure occurs, it is possible only to mitigate the potential effects. For example, sensitive populations can be kept indoors during high ozone concentration periods (although this has been found to be of limited benefit).

These steps follow the recommendations of the EPA Science Advisory Board's, 1990 report, *Reducing Risk: Setting Priorities and Strategies for Environmental Protection*. Good examples of applied risk analysis are found in two recent studies sponsored by USAID and EPA. A 1990 study by Abt Associates and Sokotka & Co. for USAID and EPA, entitled, *Ranking Environmental Health Risks in Bangkok, Thailand*, has been instrumental in helping the Government of Thailand introduce a comprehensive analytical approach to its environmental problems. A 1992 report by Industrial Economics, Inc., and Sullivan Environmental Consulting, Inc. for EPA, entitled, *Project Silesia Comparative Risk Screening Analysis*, provides an application of risk analysis of Czechoslovakian environmental problems as the basis for a training manual.

Based upon the foregoing description of the sequence, USAID can be most cost-effective by focusing on the first two steps of the process. The third step of the sequence is

a less cost-effective alternative. This is because control methods, often termed end-of-the-pipe treatment, inevitably cost money, while pollution prevention actions often pay for themselves or even return a profit. This attribute is especially valuable in situations where limited pricing flexibility is available, as is the case in much of the region's public industry sector.

The latter three risk steps are difficult to affect, and generally fall within the province of each country's internal planning process. USAID might, however, provide expertise to strengthen the planning process to adopt and implement a practical application of the risk assessment methodology.

Environmental Project Accounting System

The risk sequence perspective offers a practical framework for assessing the current availability of environmental risk information and identifying USAID environmental project opportunities. As USAID establishes a more explicit environmental emphasis to its project selection process, an Environmental Project Accounting System (EPAS) becomes desirable. EPAS both furnishes organized management information for project oversight and reporting purposes, and provides the data needed to assess new projects in terms of their consistency with ongoing USAID activities. An EPAS should contain the following information for each project: geographic region affected; economic sector; environmental media involved; pollutant generation being affected; types of environmental impact occurring; estimated magnitude and costs of these impacts; remediation approach being employed (designated by risk sequence step); and overview comments on the project. An illustrative printout of EPAS data is given in exhibit 5 for the people transportation case discussed in the preceding risk assessment subsection.

Assembly of an EPAS for a USAID mission is a manageable endeavor. It involves a systemic review of all USAID projects from an environmental perspective. All projects have environmental implications if viewed broadly enough. While identifying these implications may seem an academic exercise in many cases, in other cases this analysis will provide valuable insights.

Most projects probably will be found to be generating a net environmental benefit. In some cases, however, projects may be found to be exacerbating an existing environmental problem or contributing to the potential emergence of a new problem. The Mission must be aware of the environmental implications of the latter type of projects. Once EPAS is assembled, the mission will be able to provide a well founded summary of the environmental implications of all its project activities.

Exhibit 4

RISK SEQUENCE: ILLUSTRATIVE EXAMPLE

(LEAD EMMISSIONS IN CAIRO ASSOCIATED WITH VEHICULAR TRAFFIC)

Activity	Technology/ Pollutants	Control/ Release	Transfer	Exposure	Effects (Risk)
* Function Transport - People * Activity Level Person-miles	* Technology Auto - IC Engine - Leaded Gasoline * Pollutants CO_2 Lead CO Waste Oil	* No Control * Air Release	* Air Transport * Dilution/No Conversion * Transfer to Land via Rain	* Cairo Pop. varies w/location * Land Depositing	* Hypertension Heart Attacks Strokes Reduced Mental Cap. * Environment (to be identified) * Health Costs Lost Wk Days
Restrict Vehicle Use	Switch to Unleaded Gasoline Increase Engine Efficiency	Lead Screening Filter (not currently feasible)	Switch to Unleaded Fuel	Restricted Traffic Patterns	Blood Platlet Scrubbing (not currently feasible)

Illustrative Interventions

Exhibit 5

Environmental Project Accounting System (EPAS) Framework

Region	Sector	Medium	Pollutant	Types of Impact	Estimated Magnitude	Remedial Approach	Comment
Egypt	Transporta-tion	Air	Lead	Hypertension	X Cases/Yr	Switch to Unleaded Fuel	Can Draw Upon U.S. Experience in Switching to Unleaded Fuel
	People			Stroke	Y Cases/Yr		
				Heart Attacks	Z Cases/Yr		
				Reduced Mental Capacity	Avg. IQ Declines		
				Health Costs	$/Yr		
				Lost Work Days	No. Days/Yr, $/Yr		
				Reduced Effectiveness	Reduced Productivity		

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