ANNEX III.23.1.- HANDOUT ON NATURAL HAZARDS AND PROJECT EVALUATION

USE OF NATURAL HAZARD INFORMATION IN THE ECONOMIC ANALYSIS OF AGRICULTURAL SECTOR PROJECTS

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I. Objective

Natural hazards can have devastating and long lasting impacts on the economies of developing countries. The impacts are often severe for the agricultural sector which in many cases is the most critical sector in terms of employment, income, and export earnings. Therefore, economic analysis of agricultural projects should take into account the potential effects of natural hazards.

Major types of natural hazards periodically buffeting agriculture in developing countries include droughts, hurricanes, volcanic eruptions, earthquakes, tsunamis, and other floods. All of these natural hazards are probabilistic in nature, that is, they occur with a certain frequency. In many cases it may be possible to relate information about the frequency, severity and duration of natural hazards to economic impacts. Therefore, natural hazard information can be used in the development planning process, particularly in assessing the feasibility of alternative investments.

This chapter discusses some of the economic impacts of natural hazards in developing countries. Emphasis is placed on the agricultural sector. Next, some risk and natural hazard concepts are defined and discussed. This is followed by a review of project analysis procedures. Several means of introducing natural hazard considerations into project analysis are presented and information requirements are discussed. It is argued that the presentation of risk information in project analysis can help decision makers assess the potential impacts of natural hazards on project outcomes. The overall objective of the chapter is to present guidelines for incorporating natural hazard information into economic analysis of agricultural sector projects.

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II. Economic Impacts of Natural Hazards

Agriculture in developing countries is particularly subject to natural hazards for two reasons. First, data from a variety of sources indicate that most natural disasters, approximately 90% of the global total, occur in developing countries.[1] Second, agriculture in developing countries is less protected from natural hazards by risk reducing institutions and infrastructure than in developed countries. In the United States, for example, risk protection is provided to farmers by institutions such as government sponsored crop insurance and disaster loans, and infrastructure such as the massive flood control civil works along the Mississippi River.

By the very nature of natural hazards, the economic damages they inflict are erratic and thus difficult to plan for. Because agriculture is the basic sector in many developing countries, disruptions caused by natural hazards can have far reaching consequences. In any country with a sizeable agricultural sector, serious shortfalls in the agricultural production can have ripple effects throughout the economy, affecting spending and employment in other sectors as well as available food supplies.

Consider some recent examples. When hurricanes David and Frederick struck the Dominican Repbulic in 1979, they caused an estimated $342 million in damage to the agricultural sector.[2] In a country where agricultural products account for 37 percent of Gross Domestic Product, and agriculture employs 40 percent of the labor force, these hurricanes destroyed 80 percent of all crops, and 100 percent of the banana crop. Agricultural production fell 26 percent in 1979, and continued to be down 16 percent in 1980.[3] In 1984, the worst floods in Colombia in a decade caused an estimated $400 million in damage to crops and livestock, while floods in Ecuador in 1982 and 1983 caused the value of the banana crop to decrease by $4.3 million.[4] These are only a few examples of the magnitude of direct agricultural losses resulting from natural disasters.

In addition to the direct impact on a nation's economy, disasters can affect employment, balance of trade, foreign indebtedness, and competition for scarce development funds. After Hurricane Fifi struck Honduras in 1973, employment in the agricultural sector decreased by 70 percent.[5] These sorts of effects have led

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[1] Frank Long, "The Impact of Natural Disasters on Third World Agriculture," American Journal of Economics and Sociology, Vol. 37, No. 2, April 1978, pp. 149-162.

[2] United Nations, "Case Report on Hurricanes David and Frederick in the Dominican Republic," Geneva, 1980, p. 6. (UNDRO)

[3] U.S. Agency for International Development, Office of Disaster Assistance. Countries of the Carribean Community. Washington, D.C., 1982, p. 209.

[4] United Nations, Economic Council on Latin America. Ecuador: Evaluation of the Effects of the 1982/83 Floods on Economic and Social Development. May 1983.

one observer to conclude that "the effects of natural disasters in disaster prone development countries tend to cancel out real growth in the countries."[6]

There are two types of measures which can be taken to mitigate the effects of natural disasters on the agricultural sector -- structural and nonstructural. (See Table 1.) Structural mitigation measures are physical measures or standards which lessen the vulnerability to natural hazards. For example, reservoirs can be constructed to store excess storm water. If linked to irrigation networks, the storage facilities can also be used to alleviate drought conditions. Nonstructural measures are practices and policies which reduce vulnerability. Examples of nonstructural practices include crop diversification and use of drought resistant varieties. There are a number of nonstructural ways that governments can encourage hazard mitigation including land use zoning, protection of coastal wetlands, relocation programs, and establishment of forecasting and warning systems.

If natural hazard mitigation is practiced, benefits can include:

- increased agricultural output and stability
- more efficient use of agricultural technology
- greater foreign exchange earnings
- improved development planning due to greater stability.[7]

This is not meant to suggest that every available natural hazard mitigation measure should be implemented. From an economist's point of view, mitigation should be practiced only as long as the benefits from doing so exceed the costs.

III. Risk and Natural Hazard Concepts

In order to facilitate discussion of economic methods to analyze natural hazards and their mitigation, several concepts are defined and explained below.

A. Probability

Probability is the likelihood of the occurrence of a particular event. This is often based on historical frequency, e.g., the probability of a hurricane striking an island this year could be considered to be 0.1 because hurricanes have struck in 2 of the past 20 years. Probabilities used in decisions, however, are rarely based strictly on historical information. Decision makers will usually adjust historical frequencies based on available current information; these are referred to as subjective probabilities. For example, an individual observing that tropical storms have recently occurred in other parts of the world, may want to assign a higher subjective probability to a local storm event than would be indicated by the historical frequency.

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[5] World Bank, "Memorandum on Recent Economic Development and Prospects of Honduras," 1979, p. 37.

[6] Long, "The Impact of Natural Disasters," p. 156.

[7] Long, "The Impact of Natural Disasters," pp. 160-161.

Table 1. Mitigation Measures for Agriculture

Mitigation Measure	Hazard	Structural	Non-Structural
Afforestation	Drought/Desertification Wind	X	
Animal Shelters	Hurricane Wind	X	
Coastal Break-Waters	Hurricane Tsunami	X	
Coastal Wet-Lands Protection	Hurricane Tsunami		X
Construction and Protection of Retention Basins	Hurricane Flood	X	
Contour Farming	Drought/Desertification Flood		X
Crop Diversification	All hazards		X
Crop and Live-stock Insurance	All hazards		X
Dam Construction and Inspection	Flood	X	
Forecasting and Warning	All hazards		X
Improved and Resistant Crop Varieties	Flood Wind Drought/Desertification		X
Land Use Zoning	Hurricane Flood Earthquake Drought/Desertification		X X
Maintenance of Natural Runoff	Flood Drought/Desertification		X
Reforestation and Prevention of Deforestation	Wind Drought/Desertification Hurricane		X
Relocation	All hazards		X

Table 1 Continued.

Mitigation Measure	Hazard	Structural	Non-Structural
Stabilization Slopes	Landslide	X	
	Floods		
Stream Chanelization	Flood	X	
Terracing	Flood Drought/Desertification	X	
Windbreaks (natural and structural)	Hurricane Wind	X	

Source: Compiled by authors.

B. Risk

Risk is generally referred to as the probability of loss. In economic terms this would refer to declines in income, say, due to crop losses resulting from a natural hazard. In this chapter risk will also be used more generally to refer to uncertainty in key variables used in economic planning. For example, when assessing the benefits and costs of a planned irrigation project, it should be recognized that the prices and yields of agricultural crops may fluctuate over a wide range during the life of the project. These fluctuations can be caused by natural hazards but can also be caused by changing market conditions and weather cycles.

C. Risk Aversion

Risk aversion refers to an individual's attitude toward risk. Risk aversion is simply the desire to avoid taking risk. A risk averse individual is willing to sacrifice some amount of money to avoid risk. Risk averse farmers, for example, may purchase hail insurance for their crops if premiums are at "reasonable" levels. However, a risk averse individual will elect to take risks if the cost of avoidance is too high. Empirical evidence indicates that most, but not all people, are risk averse, but there is a wide range in the degree of risk aversion.* In other words, for a given level of risk, some people would pay more than others to avoid the risk. The question of whether a government should be risk averse will be discussed later.

D. Risk Assessment

Risk assessment refers to the quantification of a risk. It requires a determination of both the consequences of an event and the likelihood of its occurrence. For example, in considering the potential economic effects of an earthquake on an agricultural project, risk assessment would require a determination of (a) the impacts of the earthquake on agricultural activity and the structural components of the project (e.g., would crops be lost? would irrigation canals be destroyed?), and (b) the probability of an earthquake occurring in the region during the life of the project.

E. Risk Management

Risk management refers to actions taken to reduce the consequences or likelihood of unfavorable outcomes. Similarly, natural hazard management refers to activities intended to reduce the negative effects of natural hazards. A farmer may choose to plant a windbreak along his field to reduce the chances of wind damage to his sugar cane crop. While this may reduce his average income if land must be removed from production, it may still be undertaken as insurance against an uncertain but potentially costly event -- a major storm.

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* Hans P. Binswanger, "Attitudes Toward Risk: Experimental Measurement in Rural India." American Journal of Agricultural Economics, 62(1980):395-407; Douglas L. Young, "Risk Preferences of Agricultural Producers: Their Use in Extension and Research." American Journal of Agricultural Economics, 61(1979):1063-1070.

IV. Natural Hazards and Development Planning

A. Project Planning

An agricultural project is an investment of capital to create assets capable of generating a stream of benefits over time. Types of agricultural projects are as diverse as land settlement, rural education, irrigation, and soil conservation to name only a few. The project may be independent or a part of a package of projects comprising a multisectoral development effort. Although implementation of a project is perhaps the most difficult aspect of development administration, careful project planning is also of critical importance:

> for most agricultural development activities, careful project preparation in advance of expenditure is, if not absolutely essential, at least the best available means to ensure efficient, economic use of capital funds and to increase the chances of implementation on schedule.[9]

The primary aspects of project planning can be described in three parts: project profile, prefeasibility analysis, and feasibility analysis.[10] (Refer to Chapter One.)

1. Project Profile

This is a preliminary project proposal in which overall costs and benefits for a specific project are roughly estimated and alternative approaches are identified.

2. Prefeasibility Analysis

This is a preliminary evaluation of the technical and economic viability of a proposed project. Comparison of alternative approaches to various project elements are made and less promising alternatives are recommended for elimination. Development and operation costs are estimated for the project and benefits are assessed so that economic feasibility criteria can be evaluated.

3. Feasibility Analysis

This is the final determination of the viability of a proposed investment project. The need for the project is analyzed along with resource availability. Every aspect of the project plan is reexamined. Refined estimates are made of project benefits, costs (construction, operation and

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[9] J. Price Gittinger, Economic Analysis of Agricultural Projects, 2nd ed., Baltimore: Johns Hopkins University Press, 1982, p. 3.

[10] Organization of American States. Integrated Regional Development Planning: Guidelines and Case Studies from O.A.S. Experience, Department of Regional Development, January 1984, pp. 226-227.

maintenance), and evaluative criteria, that is, net present value, internal rate of return, and benefit-cost ratio.

B. Use of Natural Hazard Information

Although not widely done, project planning could be improved if analysts would incorporate natural hazard information at each project development stage. In a brief survey of current project formulation and development guidelines utilized by several development organizations and private lending institutions, the lack of risk information, especially about natural hazards, was evident. Most institutions do not require risk information in project preparation guidelines, except for engineering projects. Risk to the environment appears to be more of a concern than risk from the environment.

It is important to introduce risk information at the earliest levels of project planning. When this information is included at project formulation levels, the entire project design can be altered to accommodate the risk factors. If the risks are too great, an alternative project may be chosen. Risk information may be included at the project analysis stage, just before the project is implemented, but at this stage it may only be possible to take limited remedial action.

Natural hazards can be considered first at the profile stage. Risk maps and hazard event frequencies can be consulted. For example, a flood plain map produced by use of remote sensing techniques would depict areas that are prone to severe flooding. From the start of project planning, planners might want to avoid designating these flood-prone areas for agricultural activities requiring extensive capital investments such as buildings. Instead, an alternative land use, less sensitive to flooding, such as rice production could be considered. In view of the high flooding probability, the planner also might want to consider hazard mitigation practices which could reduce risk to acceptable levels.

At the prefeasibility level, more sophisticated consideration of natural hazards can be made. For example, a 100 year flood plain map could be developed. Probabilities of different hazards can be estimated and used to adjust cost and benefit figures. If a formal benefit-cost analysis is conducted, procedures discussed later in the chapter can be used to incorporate the natural hazard information directly into the analysis.

Finally, at the feasibility stage, the effects of natural hazards on benefits and costs can be more carefully evaluated. More detailed information on the likelihood and consequences of natural hazards can be collected and used to revise the benefit-cost analysis.

Natural hazard and other risk information needs to be considered explicitly in the form of probabilities and consequences of different outcomes. Otherwise, it will enter into the analysis implicitly. If an agronomist is asked to provide a single valued yield estimate he may account for risk by giving a pessimistic value, although if asked he could give pessimistic, optimistic, and most likely values, as well as assign probabilities to each value. An engineer will also take risk into consideration by selecting structural design criteria for a 20 year storm for example. Risk can be accounted for in a more systematic fashion by drawing these risk considerations out into the open.

V. Principles of Benefit-Cost Analysis

A. Introduction

Economic analysis is seldom the only criteria upon which project decisions are based. The choices made by decision makers also reflect the social and political aspects involved in project selection. One approach taken when considering several criteria for making decisions is a Multicriteria Analysis, which is an assessment of acceptable levels of each criteria. Although natural hazard risk information can be incorporated directly into an economic analysis, the probability of natural hazards could be considered as a separate decision making criteria. A Multicriteria Analysis would evaluate how much this criteria could be lowered before affecting other project criteria, and lead to a decision on acceptable risk. It is important to realize that project selection decisions, as well as alternative selections within a project, are made based on several criteria, including economic analysis.

Benefit-cost analysis is a method economists have developed to evaluate the efficiency of public sector activities. Although benefit-cost analysis is designed for evaluating nonmarket activities, economic information to conduct the analyses is frequently obtained from market activities. It is a practical technique for comparing the merits of different government projects over time. There are numerous variations of each economic analysis technique within a benefit-cost analysis, so project economists should seek to find the best method for each individual case. This section provides a very brief overview of benefit-cost analysis, which can be used as a general guideline, but readers are encouraged to review other literature.[11]

The point of view taken in benefit-cost analysis is that of society as a whole. This is what is referred to as accounting stance. When a private individual considers whether or not to make an investment, he or she considers only the benefits and costs that have a direct personal impact. When the societal perspective is taken, the accounting stance shifts to consider all benefits and costs affecting society.

Another important aspect of benefit-cost analysis is the with-and-without criteria. The analysis should assess the state of affairs with versus without the project in place. The with-and-without criteria is important in sorting out what should be counted as benefits and costs of a project. Suppose an irrigation project is being considered for an area where crop yields are showing an upward trend. The irrigation project will cause the yields to increase even more. When assessing potential project benefits, it would be erroneous to attribute to the project all of the growth in yields from before the project, to after it is constructed, since some of the growth would have occurred anyway.[12] In areas that are rapidly developing, it is particularly important to make sure that project benefits and costs are

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[11] For a more complete treatment see Gittinger, Economic Analysis of Agricultural Projects, and E. J. Mishan, Cost-Benefit Analysis: An Informal Introduction, 3rd ed., Boston: George Allen and Unwin, 1982.

[12] Charles W. Howe, Benefit-Cost Analysis for Water System Planning, American Geophysical Union, Water Resources Monograph 2, Washington, D.C., 1971.

properly accounted for and do not include changes that would have taken place without the project.

A benefit-cost analysis can be organized in three main steps:[13]

1. enumeration of all benefits and costs of a proposed project;
2. evaluation of all benefits and costs in dollar terms; and
3. discounting of future net benefits to put them into current dollar terms.

While these steps may appear simple, a thorough analysis requires considerable effort. The economist or planner carrying out the analysis should work with other specialists such as agronomists, engineers, and hydrologists to ensure that all relevant factors are taken into account and that technical production relationships are properly reflected. This integrated, interdisciplinary approach to planning has been advocated by OAS.[14]

Costs must be defined so as to weigh foregone alternative benefits if the project is selected. Benefits can include both direct and indirect effects resulting from the project. In comparing the benefit stream to the cost stream over time, all present and future values must be put into a common frame of reference known as "present value". This requires the choice of an appropriate discount rate.

B. Costs

In measuring the costs of a project, care must be taken to accurately reflect foregone alternatives. These are referred to as opportunity costs. In addition to foregone alternatives, a project may entail direct as well as indirect costs. Direct costs can include expenses incurred in material and administration, as well as the use of natural resources. Costs of natural hazard mitigation, such as canal systems, dams and windbreaks should be included. Non-structural mitigation measures, such as crop diversification and agricultural zoning, can also be considered. In addition, indirect costs must be taken into account. If a new project will draw water resources from nearby agricultural land, the resulting decline in agricultural production should be counted as project cost.

The analyst must also be aware that due to market distortions, prices of inputs may not reflect their true valuation by society. In these cases prices should be adjusted to correct for distortions. Prices so adjusted are referred to as shadow prices. As an example of adjusting market prices, consider the case of a government subsidy on fertilizer. The subsidy lowers the cost of the fertilizer used in the project. For a benefit-cost analysis, the market price must be increased by the amount of the subsidy to reflect its true cost to society.

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[13] David N. Hyman, The Economics of Governmental Activity, New York: Holt, Rhinehart, and Winston, 1973.

[14] Organization of American States. Integrated Regional Development Planning.

C. Benefits

The benefits in an agricultural project may result from either increased value of farm output or from reduced production costs. Benefits from natural hazard mitigation could be measured in terms of avoided agricultural income losses. In addition to direct benefits, projects generate indirect benefits. For example, an irrigation project might have the "spill-over" benefit of increasing the productivity of land adjacent to the land actually irrigated by the project.

An evaluation of the benefits of a project should only include real increases in output. A flood control project may lead to a higher value of farmland in the protected area. Because this higher value merely reflects the increased output potential of the land, counting the value increase as a project benefit would lead to a double counting of project benefits.

D. Discounting

After enumerating and evaluating all benefits and costs, the third step in project analysis is to discount future benefits and costs. This is accomplished through the use of a discount rate to convert future values into present values. The need to discount arises from the fact that money received today is worth more than an equivalent amount of money received in the future. This is because money received today can earn interest in the interim. An investment of $100 at an annual interest rate of 10 percent will be worth $121 at the end of two years. Future benefits and costs must be discounted in order to express them in a common denominator -- today's dollars or present value.

The project analyst must choose the discount rate, and often more than one rate is used in a project. Gittinger suggests three possible alternatives: opportunity cost of capital, borrowing rate for the capital used to finance the project, and social time preference rate. The opportunity cost of capital is the rate that will result in utilization of all capital in the economy if all possible investments are undertaken that yield as much or more in return. The opportunity cost of capital cannot be known with certainty, but in most developing countries, is considered to be between 8 and 15 percent in real terms.[15]

E. Evaluation

The discounted or net present value (NPV) of a project is represented mathematically as

$$\Sigma B_t/(1 + r)^t - \Sigma C_t /(1 + r)^t \qquad t = 1, 2, \ldots n \qquad (1)$$

where B = benefits, C = costs, r = discount rate, t = time period, n = life of the project in years, and Σ is the summation operator. After benefits and costs are evaluated and enumerated and a discount rate is selected, equation (1) will indicate the net present value (NPV) of the project under consideration. The economic decision criteria about the worth of a project is usually (a) the NPV is positive, and (b) the NPV is higher than that of alternative, competing projects. Another

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[15] Gittinger, Economic Analysis of Agricultural Projects.

way to consider the benefits and costs is to set equation (1) equal to zero and solve for the value of r. This is referred to as the internal rate of return (IRR).

To facilitate comparison of projects, expression (1) is often rearranged as a benefit-cost ratio:

$$\frac{\Sigma B_t/(1 + r)^t}{\Sigma C_t/(1 + r)^t} \qquad t = 1, 2, \ldots n$$

The higher the net present value of the project, the higher the ratio. A benefit-cost ratio greater than 1 indicates that the discounted benefits exceed the discounted costs.

VI. Incorporating Risk into Benefit-Cost Analysis

A. Introduction

Should risk be considered in benefit-cost analysis? Arrow and Lind have argued that even though individuals are risk averse, governments should take a risk neutral stance when evaluating projects.[16] They argue that since project benefits and costs are spread over a large number of individuals in the society, the element of risk facing each individual is negligible. Since project risks are widely shared, this would imply that a government should be indifferent between a high risk and low risk project which both have the same expected net present value. While there are a number of important qualifications to these well known theoretical results, for this discussion the most important point is that their argument only applies to risks which are actually borne by the government. Natural hazard risks are to a large extent borne by individuals and thus investments in projects which affect natural hazard risks should account for risk. Furthermore, in view of government debt problems, income distribution concerns, and other social and political concerns, governments are more likely to exhibit risk averse behavior than Arrow and Lind's abstract model would suggest.

Consider the example of how a single project with highly variable outcomes could have a significant impact on a particular region or group of people.[17] Suppose there are two projects under consideration in a coastal area of a country. Project A has a NPV of $2 million and project B has a NPV of $1.5 million. Now consider the variability in returns to both projects. Because project A has the highest NPV, it would be selected if risk was ignored. Project A is vulnerable to floods and thus could have an actual NPV of between $0.5 million and $2.5 million depending on the frequency and severity of future floods in the area. Project B is less susceptible to flood damages and therefore has a NPV range of $1.3 million to

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[16] K. J. Arrow and R. C. Lind, "Uncertainty and the Evaluation of Public Investment Decisions," American Economic Review, Vol. 60, 1970

[17] Warren C. Baum, "Risk and Sensitivity Analysis in the Economic Analysis of Projects," World Bank Central Projects Note 2.02, July 1980.

$1.7 million. Because the returns to project B are more stable, the residents of the coastal area might prefer the project with the lower NPV. They would probably be unimpressed by arguments about the merits of societal risk sharing, since the risks (variation in NPV) their cummunity bears from these projects are rather large.

In some cases, lending agencies may also take a risk averse stance. This is because they must take into account the probability of timely repayment of the project loan. However, they are more likely to be concerned about how macroeconomic risks will affect a government's overall repayment ability rather than how natural hazards will affect the return to a particular project.

Several methods for including risk considerations in benefit-cost analysis are available to analysts. The first category of methods can be applied when there is little risk or natural hazard information available. The second group of methods is appropriate when information on probability distributions can be obtained. All of these can be used in comparing different projects as well as comparing alternatives within a project.

B. Decision Criteria with Limited Information

1. Cut-off Period

The crudest procedure for incorporating risk into benefit-cost analysis is the use of a cut-off period.[18] This approach is primarily utilized by private investment agencies, whose main interest is in capital return rather than long-term development. Economic feasibility under the cutoff period requires that in a relatively few years, sufficient benefits must be accrue to more than cover project costs. For very risky projects, the cut-off period might be set as low as 2 or 3 years, whereas for low risk projects it would be much longer, say 30 years.[19] The underlying logic of a cut-off period rule is that benefits and costs are so highly uncertain beyond the cut-off date that they should be ignored in determining project feasibility. A cutoff period should be determined by the pre-feasibility stage of project development, at the latest.

Some information is necessary to determine the relative riskiness of the project. The most useful data would be a list of natural disaster events, or episodic information, as well as meteorological records, land use maps, agricultural cropping maps, and previous damage assessments, which could give the economist a rough idea of inherent risk. In addition, satellite photography of natural hazard impacts could be useful in making a decision concerning a cutoff period. In many cases, it would not be too difficult to obtain this information for the minimum required 2-5 year period.

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[18] Mishan, Cost-Benefit Analysis, p. 399.

[19] Even when benefits are expected to go on beyond 30 years, these benefits are hardly worth considering in a benefit-cost analysis because their present value is so low. For example, using a 10 percent discount rate, each dollar received in 30 years is worth only about 6 cents in present value.

A cutoff period should only be considered when few records are available, and the nature and magnitude of possible hazards could have great potential for agricultural damage, such as would be the case in severe storms and floods. It would be more difficult to dictate a cutoff period in the case of slow onset hazards, such as drought or desertification.

As an example of the cutoff period, this method could be applied to a vegetable and livestock farming systems project being planned for a developing country. The objectives of the project would be to increase cropping intensities and agricultural income. This project may be viewed as risky if the area is subject to frequent flooding. The flooding would damage crops and destroy livestock and thus reduce the project benefits. Therefore, one might choose a 2 or 3 year cutoff period for costs and benefits.

While this approach attempts to consider risk effects, it is rather unsatisfactory. Short cut-offs can ignore economic information associated with much of the life of projects. Rather than deal with risk directly, this method discards all information beyond the cut-off period. If benefits and costs are highly variable beyond the cut-off date, there are other methods which can be used to consider these benefits and costs while recognizing their inherent riskiness.

2. Discount Rate Adjustments

Another *ad hoc* way to reflect uncertainty in project analysis is to add a risk premium to the discount rate. The effect of increasing the discount rate is to give less weight to the increasingly uncertain costs and benefits in future time periods.[20] This is consistent with what has been observed in the private sector; when business investments are made, managers generally require higher internal rates of return for riskier investments.

In using this technique of economic analysis, the economist is faced with the subjective decision of determining an arbitrary risk premium to add to the discount rate. The same type of information that is useful for a cutoff period can be utilized to determine the discount rate. This information should be available by the pre-feasibility stage of project planning.

A subjective decision on the discount rate could include available information on the possibility of a slow onset hazard, such as desertification, as well as short-term, high immediate impact hazards such as severe storms and flash floods. Once again, this method should be employed as a last resort, when little or no information on natural hazards is available.

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[20] Some writers suggest raising the discount rate for uncertain benefits and lowering it for uncertain future costs. See, for example, Lee G. Anderson, and Russell F. Settle, *Benefit-Cost Analysis: A Practical Guide*, Lexington Mass.: D. C. Heath, 1977. However, in some types of projects, costs will be less subject to uncertainty than benefits.

In reviewing the example farming systems project presented in the previous section, it can be seen that any indication of flooding would be viewed as making the project risky. If normal practice is to use a discount rate of 10% for the benefits, the discount rate for this particular project might be increased to 12% or 15%.

This approach is preferable to the cut-off period method because it does not ignore information about future benefits and costs. Yet, the amount of risk adjustment of the discount rate is arbitrary and the approach does not recognize risk differences across project components. More rigorous and defensible approaches which are capable of quantitatively assessing the uncertainty in benefits and costs over time are discussed below.

3. Game Theory Approaches

When there is no reliable information on probability distributions of hazards, two strategies from game theory have been suggested, the maximin-gain strategy and the minimax-regret strategy. Both can be applied at the earliest stages of project formulation, as the necessary information becomes available. The types of information required for each are records of historical events, climatological and meteorological data, and previous natural hazard damage records for the sector in question; for example, crop damage data in the agricultural sector. Using this information, it is possible to estimate the benefits resulting equivalent project alternatives under varying degrees of severity of the natural hazard. The game theory approaches are better suited for short term, high immediate impact hazards, which can easily be divided into least/most damage scenarios.

To illustrate the maximin-gain approach, which derives its name from maximizing the minimum gain, an example will be given. Suppose that a decision has been made to augment the earlier discussed farming systems project with a structural, natural hazard mitigation measure. Three alternative flood control projects, (A, B, and C) with equal cost are under consideration.[21] For convenience it is assumed that there are two possible states of nature; heavy rainfall and normal rainfall. If heavy rainfall occurs, the net present value of benefits from the three projects are \$100 million, \$120 million, and \$150 million respectively. If there is normal rainfall, the projects will provide irrigation and other discounted benefits of \$30 million, \$60 million, and \$120 million respectively. Project benefits will be greater in the case of heavy rainfall, since the primary benefit of the flood control projects is prevented flood damage. The various outcomes are summarized below:

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[21] This example is similar to one in Anderson and Settle, Benefit-Cost Analysis, pp. 103-104.

Benefit Matrix for Three Hypothetical Flood Control Projects

	Heavy Rainfall	Normal Rainfall
Project A	\$100 million	\$30 million
Project B	\$120 million	\$60 million
Project C	\$150 million	\$20 million

Applying the maximin-gain strategy would result in choice of project B since its minimum benefit is \$60 million as compared to \$30 million for project A and \$20 million for project C.

The maximin-gain strategy has the drawback of basing project selection completely on security and is very conservative. Even if project benefits for A and C were 10 times larger than for project B under heavy rainfall, B would still be selected. Thus, it can lead to selection of projects which most people would agree are inferior. Therefore an alternative approach has been proposed: minimax-regret.

The minimax-regret strategy is to minimize the maximum regret or loss that could be realized. This strategy can be illustrated with the three project example above. If heavy rainfall does occur, project C would have resulted in the greatest benefit, \$150 million. If project A had been selected the regret or foregone benefits for not selecting C would have been \$50 million (\$150 million - \$100 million) and if project B had been selected the foregone benefits would have been \$30 million (\$150 million - \$120 million). If instead of heavy rainfall, there was normal rainfall, project B would have produced the most benefits, \$60 million. In that case the foregone benefits would have been \$40 million for project C and \$30 million for project A. Now considering both possible weather events, heavy and normal rainfall, it can be seen that the maximum regret (foregone benefits) would have been \$50 million, \$30 million, and \$50 million respectively for projects A, B, and C. Therefore, a minimax-regret strategy would lead to a choice of B since it has the smallest maximum regret.

4. Sensitivity Analysis

Another method to allow for risk consideration in benefit-cost analysis is sensitivity analysis. Analysts change key parameter values subject to risk to determine their effects on the NPV of a project. Usually, the values are changed one at a time, but sometimes they are changed in combination with one another. This can be useful if there is information that can indicate how much each parameter should be changed, for example, plus or minus one standard deviation.[22] More typically the values are varied by an arbitrary

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[22] George Irwin, Modern Cost-Benefit Methods, London: MacMillan Press, 1978, p. 52.

percentage, say 10 percent. This will not be informative about the degree of dispersion in NPV and does not take into account the amount of uncertainty in the key parameters, e.g. crop yields.

Sensitivity analysis can help identify project elements worthy of more indepth consideration, and thus could be used at the project profile stage to precede more sophisticated risk analysis. In addition, sensitivity analysis can be used to identify areas where hazard mitigation measures can be applied. A sensitivity analysis is suited to all types of hazards, even when minimal information is available. The types of information that are useful for this analysis are event histories, climatological and meteorological data, and previous damage reports. Such data would assist an economist in estimating percentage variations in parameters from previous hazard information. If probabilistic information such as episodic data is readily available and reliable, a more complete risk analysis can determine frequency of hazards for assessing their efforts on economic variables used in NPV calculations. This type of analysis will be discussed later.

The example farming systems project presented earlier can be utilized to demonstrate the application of sensitivity analysis methods. With the aid of a personal computer or even a hand calculator, a sensitivity analysis can be performed on each cost and benefit to determine their effects on the rest of the project. For example, a sensitivity analysis performed on crop yields may demonstrate that if production falls by 40% in the first year as the result of an intermediate-level flood, the overall project benefits may be greatly decreased, or that it would take much longer to recover the costs.

The best way to report the results of sensitivity analysis is by means of "switching values.[23] These are the values of the key variables at which the NPV of the project becomes zero (or the benefit-cost ratio falls below one). Switching values can be presented as follows:

<u>Switching Values of Key Variables</u>

Variable	Switching Value
Price of Corn	-60%
Yield of Corn	-20%
Construction Costs	+50%

In this example, the information on switching values tells us that corn yields would only have to decline by 20 percent from their expected value to make the project NPV zero.

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[23] Baum, "Risk and Sensitivity Analysis," pp. 5-6.

C. Decision Criteria With Probabilistic Information

If probability distributions for key natural hazard and other variables are available, a more rigorous consideration of risk can be carried out. The probability distributions may be based on the subjective assessments of experts or on historical information such as episodic, climatological, meteorological, agronomic, and geological data. For example, if adequate data are available, the probability distribution for crop yields can be estimated from historical farm or experiment station records. In many cases, such data are not available. An alternative approach would be to elicit subjective probabilities from farmers, extension agents, or agronomists. One relatively simple way to obtain subjective probabilites is the triangular distribution method. An individual is asked the most likely yield and the best possible and worst possible yields. Formulas can then be used to estimate the mean and variance of the probability distribution.[24] Experts could be asked to provide subjective distributions of yields with and without natural hazard mitigation measures in place.

Because natural hazards can affect the benefits of a project (for example, by destroying crops) as well as the costs (for example, by damaging irrigation systems), in some cases it may be desirable to obtain probability distributions of natural hazard events. The availability of probabilistic information on natural hazards will depend on the quantity and quality of natural hazard information collected. More accurate records will lead to better probability distributions, and thus a better overview of the hazard situation. Probabilistic information can be obtained from any type of natural hazard with measurable magnitude and frequency.

In estimating the probability distribution of the NPV (or other economic feasibility measure), typically, only a select number of variables are considered random, or subject to fluctuations. Others are considered fixed for purposes of the analysis. The variables allowed to vary may be those identified from sensitivity analysis as important or those known from observation to fluctuate widely. The various probability distributions can be combined to form a probability distribution of NPV either mathematically or with computer simulation methods. The latter is generally the easier approach.[25]

Available computer routines will repeatedly sample values of the random variables (taking into account interrelations among them). These random draws can then be used to calculate NPV. The resultant large number of NPV values will then approximate the probability distribution of the NPV. The distribution conveniently conveys information about the riskiness of projects.

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[24] For additional details, see Jock R. Anderson, John L. Dillon, and J. Brian Hardaker, Agricultural Decision Analysis, Ames: Iowa State University Press, 1977.

[25] For details on procedures, see Shlomo Reutlinger, Techniques for Project Appraisal Under Uncertainty, (World Bank Staff Occasional Paper, No. 10), Baltimore: Johns Hopkins University Press, 1970. If more than one random variable is used, covariances between random variables (e.g. prices and yields) should be specified. Otherwise, results can be misleading.

After the probability distributions have been calculated, one could compare the mean or average values of each distribution to select between projects, or between alternatives within a project. This is essentially the commonly used procedure of utilizing most likely values of the key economic variables. This would be a risk-neutral approach; that is, even though risk information was used to estimate the NPV probability distribution, the final decision would ignore the relative riskiness of the project. It was argued earlier, though, that there are a number of reasons why governments or lending agencies should take risk into account in comparing projects. Therefore, only considering the average NPV is inadequate and it also discards useful information contained in the probability distribution. Two methods of summarizing the risk information in a probability distribution -- mean-variance analysis and safety-first analysis -- will be discussed below.

1. Mean-Variance Analysis

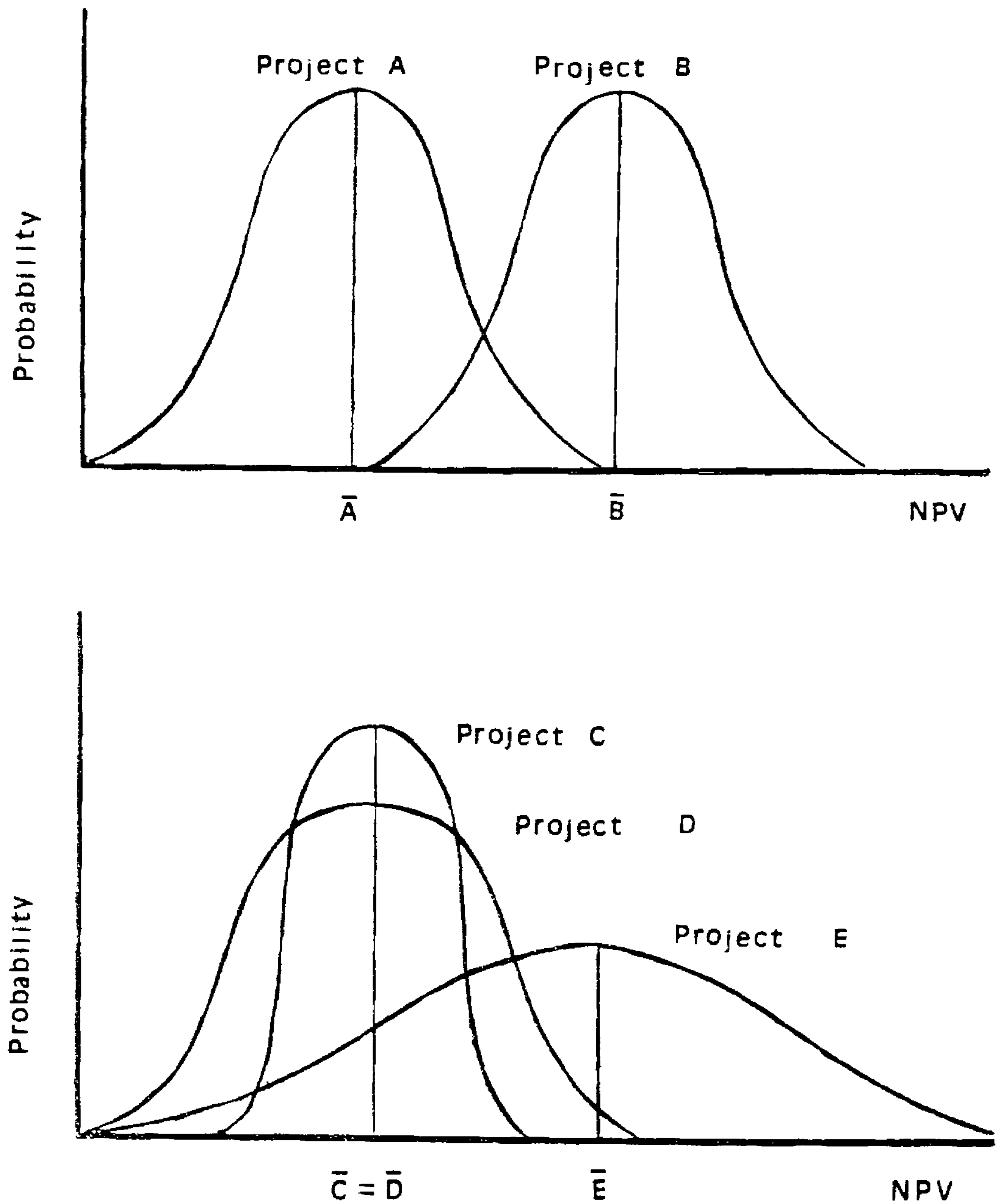
Mean variance analysis can be applied in the pre-feasibility stage in project development. Comparison of projects can proceed by graphing the NPV probability functions. In Figure 1, several probability functions are displayed for different projects. In the top part of the figure, project A and project B have similar probability distributions, but the one for project B is further to the right, indicating that the average or mean NPV is greater; $\bar{B} > \bar{A}$. Both projects have the same risk, because the variance or dispersion around the mean is the same. Project B would be preferred over A because the expected NPV of B is greater and the risk is the same.

Several other project comparison cases are depicted in the lower half of Figure 1. Projects C and D have the same mean, but project D is riskier because it has a greater dispersion around the mean. If only the mean values of the project's NPV were considered, society would be indifferent between projects C and D. However, if society (or the lending agency) is risk averse, then project C would be preferred because there is less chance of the NPV falling below the mean.

The comparison of project C to project E is less clear cut. Project E has a much higher mean than project C, but its variance is also greater. There is clearly a tradeoff between a higher expected NPV and accepting greater risk. The decision maker (not the analyst) will have to decide what weights to apply to higher mean NPV versus greater risk.

A mean-variance analysis can be easily applied to the example flood control project presented earlier. The information needed to proceed with the analysis is historical data on past heavy rainfall or floods--magnitudes as well as frequency of occurrence. Statistical means and variances can be calculated from this information. Sufficient data would then be available for a determination of the probability of the hazard, in this case a flood. A project planner can view this information when making a decision. In addition, this information can be used to calculate the probability distribution of the NPV of alternative flood control projects. The probability distribution can then be used to calculate the means and variances of the projects' NPV. The project planner can view the variance, or the risk, of the NPV resulting from flood events.

FIGURE 1. Probability Distributions of NPV for Different Projects



2. Safety-First Analysis

The variance of a distribution reflects dispersion around the mean, both positive and negative, yet risk management is primarily concerned with reducing losses and thus is more focused on the left hand side of a distribution. If the probability distribution is symmetric, like a normal distribution, then decisions based on the variance will be suitable for risk management because negative and positive fluctuations around the mean are equally likely. However, some probability distributions, such as the beta, are not symmetric. Some real world phenomenon of interest to risk analysts appear to follow distributions that are skewed in one direction or the other. For example, if corn yields average 100 bushels per acre, a drought that occurs every 5 years could cause yields to fall as low as zero. Yet one would probably never observe yields fluctuate equally far above the mean to 200 bushels. Thus, analysts may want to choose a decision criteria that focuses on the lower tail of a distribution. An additional advantage of such an approach is that it lends itself more easily to discussions of minimizing losses. This can be useful when considering hazard mitigation measures for minimizing agricultural losses. Safety first criteria could be applied to relatively frequent natural hazards, such as floods and severe storms, but may not be as useful for low frequency catastrophic events such as volcanic eruptions and tsunamis.

A popular risk analysis method which focuses on the lower tail of probability distributions is known as safety-first analysis. This can be readily applied to benefit-cost analysis. A safety-first approach could be stated as:

$$\text{Maximize } \overline{NPV}$$

$$\text{subject to } P(NPV < C) \leq a$$

where $\overline{NPV}$ = mean net present value, P = probability, C = a critical threshold value, and a = a small probability value. The decision criteria is to maximize expected NPV subject to a constraint that says the probability is small that NPV will fall below a critical value. For example, the decision maker might choose the project with the highest expected NPV as long as the probability of it falling below zero was less than 5 percent.[26]

In Figure 2, the cumulative probability of the NPV for two projects is depicted. Suppose the safety-first criteria is established as: maximize $\overline{NPV}$ subject to a no more than 20 percent chance of NPV falling below $20,000. As the graph indicates, the probability of falling below the critical value is 40 percent for project A and 15 percent for project B. The safety-first criteria would eliminate A from further consideration. If there were other projects with a less than 20 percent chance of having a NPV smaller than $20,000,

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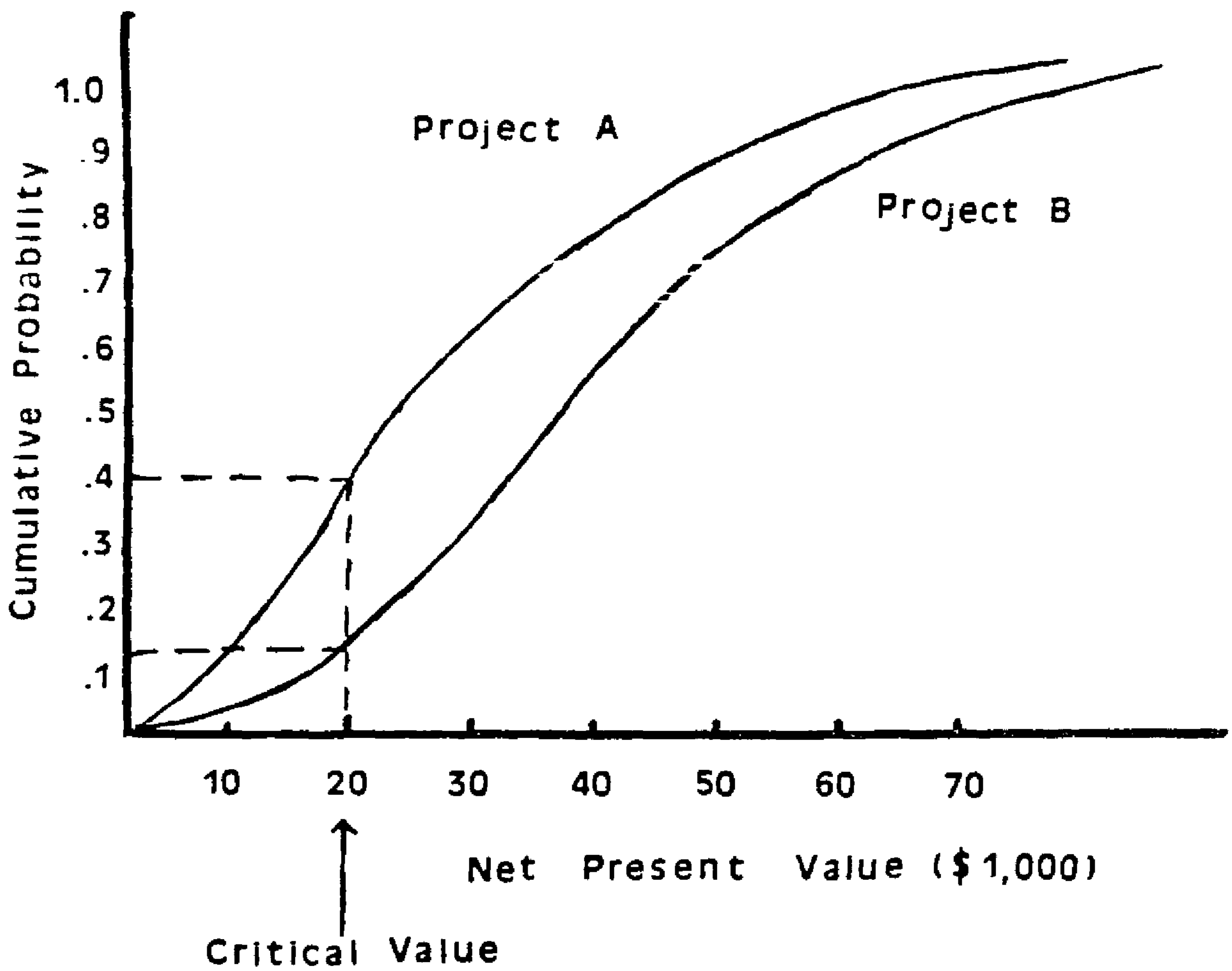
[26] For an illustration of applying this approach to the appraisal of an irrigation project, see Sushil Pandey, "Incorporating Risk in Project Appraisal: A Case Study of a Nepalese Irrigation Project," A/D/C - APROSC, Research Paper Series No. 18, Kathmandu, March 1983.

FIGURE 2. Cumulative Probabilities of Project NPVs



then the one with the highest expected NPV would be recommended for implementation.

A safety-first approach can be applied to the flood control example presented earlier. At this stage, the project planner can decide what level of NPV is the absolute minimum for the project to continue. If the minimum acceptable NPV is $1 million and the probability of NPV falling below $1 million, is 40%, 20%, and 70% respectively for the different flood control projects, the one with the smallest probability might be preferred.

VII. Conclusions

Natural hazards can have considerable economic impacts on agricultural sectors in developing countries. The effects can be direct in terms of crop and livestock losses and indirect such as employment and spending declines. Natural hazards and other forms of risk can make the outcomes of development projects uncertain. Some of this uncertainty can be reduced by hazard mitigation measures. Traditional methods of project analysis produce single values of evaluative criteria, the most widely used being net present value, benefit-cost ratio, and internal rate of review. These values are inadequate for judging projects whose benefits and costs fluctuate widely. A variety of methods are available to analysts to incorporate natural hazard and other risk information into project analysis. Presenting probability distributions to decision makers, allows them to better able assess the effects of risk on project outcomes. When risk information is limited, cut-off periods, discount rate adjustments, and sensitivity analysis can be used to crudely assess risk. However, these approaches have several drawbacks. When better probability information is available, probability distributions of net present value as well as other feasibility criteria can be generated by computer simulations and other methods. These probability distributions can then be used to compare projects based on mean-variance and safety-first analysis.

THE ORGANIZATION OF AMERICAN STATES

The purposes of the Organization of American States (OAS) are to strengthen the peace and security of the Hemisphere; to prevent possible causes of difficulties and to ensure the pacific settlement of disputes that may arise among the member states; to provide for common action on the part of those states in the event of aggression; to seek the solution of political, juridical, and economic problems that may arise among them, and to promote, by cooperative action, their economic, social, and cultural development.

To achieve these objectives, the OAS acts through the General Assembly; the Meeting of Consultation of Ministers of Foreign Affairs; the three Councils (the Permanent Council, the Inter-American Economic and Social Council, and the Inter-American Council for Education, Science, and Culture); the Inter-American Juridical Committee; the Inter-American Commission on Human Rights; the General Secretariat, the Specialized Conferences; and the Specialized Organizations.

The General Assembly holds regular sessions once a year and special sessions when circumstances warrant The Meeting of Consultation is convened to consider urgent matters of common interest and to serve as Organ of Consultation in the application of the Inter-American Treaty of Reciprocal Assistance (known as the Rio Treaty), which is the main instrument for joint action in the event of aggression. The Permanent Council takes cognizance of matters referred to it by the General Assembly or the Meeting of Consultation and carries out the decisions of both when their implementation has not been assigned to any other body; monitors the maintenance of friendly relations among the member states and the observance of the standards governing General Secretariat operations, and, in certain instances specified in the Charter of the Organization, acts provisionally as Organ of Consultation under the Rio Treaty The other two Councils, each of which has a Permanent Executive Committee, organize inter-American action in their areas and hold regular meetings once a year. The General Secretariat is the central, permanent organ of the OAS. The headquarters of both the Permanent Council and the General Secretariat is in Washington, D.C.

The Organization of American States is the oldest regional society of nations in the world, dating back to the First International Conference of American States, held in Washington, D.C., which on April 14, 1890, established the International Union of American Republics When the United Nations was established, the OAS joined it as a regional organization. The Charter governing the OAS was signed in Bogotá in 1948 and amended by the Protocol of Buenos Aires, which entered into force in February 1970. Today the OAS is made up of thirty-two member states

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