Environmental Risk: Management Strategies in the Developing World

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ABSTRACT / This paper describes a heuristic model which helps to relate a developing nation's environmental risk to the level of sophistication appropriate in adjusting management strategy to dealing with environmental hazards. The model takes into account three factors: the degree of risk, the stage of economic growth, and the sophistication of adjustment. The interrelationship of these factors is examined, and the role of international cooperation in establishing strategies is outlined.

Introduction

The problem of adjusting adequately to environmental risk is particularly acute in the developing world. The monetary losses and human suffering caused by natural disasters in "third-world" nations are enormous. In February 1970, for example, a Peruvian earthquake triggered a landslide which carried away the city of Yungay and its 25,000 inhabitants. In the same year an Indian Ocean cyclone and associated storm surge killed some 500,000 citizens of Bangladesh. In southeast Asia floods destroy more than 10 million acres of crops each year and property losses from the same cause exceed $1000 million annually (United Nations 1963, 1973).

To date management strategies have been incapable of reducing the toll from natural hazards. Dworkin (1974), for example, recently documented that between 1947 and 1973 at least 828,800 people have died as a result of natural disasters. Economic losses continue to escalate. Dacy and Kunreuther (1969) have estimated that earthquakes, hurricanes, floods and tornadoes have been responsible for an annual average damage total of $600 million in the United States alone. This figure would have been greatly expanded if the destruction caused by tsunamis (tidal wave), forest fires, seiches (oscillation of lake surface) or droughts had been included; nor does this estimate take into account secondary impacts on production. Economic losses can also be expected to mount in the developing world ("Third World"). An *ad hoc* group of experts predicted, for example, that the flood loss potential, in the U.N. Economic Commission for Asia and the Far East region in 1980, will be three times the level of damage experienced in 1961–1970 (United Nations 1973). This is because increased industrialization and urbanization have led to the progressive movement of population and economic activity onto flood plains. The process is exemplified by Bangladesh, most of which is in the Ganges-Brahmaputra delta. As a result, the majority of that country's population is subject to the direct and indirect effects of floods.

KEY WORDS: environmental hazards degree of risk economic growth adjustment international cooperation management strategies third world

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It is perhaps inevitable that economic growth will be accompanied by the more intensive use of high-risk areas such as deltas, lacustrine sediments, talus cones and flood plains, since these may offer numerous advantages (such as flat land for building, water for industrial use, and easy access) and, therefore, provide the opportunity for economies of agglomeration. It does not follow, however, that natural hazard loss potentials must grow correspondingly. The challenge is to find a set of management strategies which permit the more intensive use of higher-risk locations but minimize the associated losses.

To meet this challenge, policy makers in developing countries will need to examine the full range of alternative adjustments to hazards and select from it a combination that is best suited to quite specific needs. It should be obvious that strategies appropriate to one set of physical or cultural circumstances may not work for others. Thus, massive and costly tsunami control works such as those along the Sanriku coast of Japan (Noh 1966) will not be a practical strategy in countries which have little capital. Similarly, large-scale evacuation after the issuing of hurricane warnings may be impossible where transportation and communication facilities are limited. A further essential is the formulation of policies and the establishment of institutions that are sufficiently flexible to accommodate the changing nature of the hazard problem, the shifting social values, and the emergence of new ways of dealing with risk.

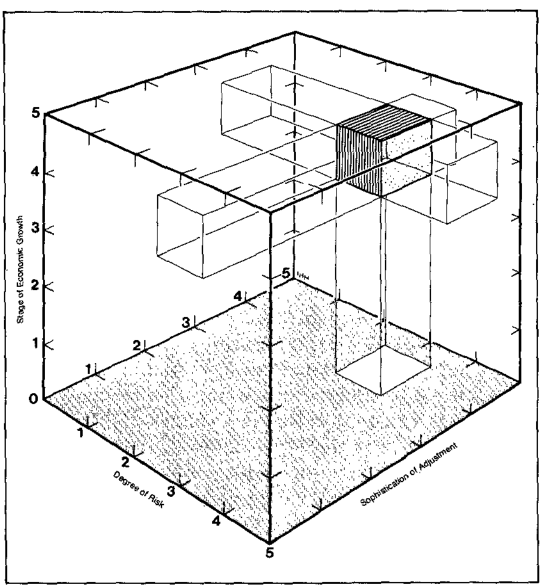
A major drawback in many countries is institutional inertia. Policies and agency structures tend to be retained long after the nature of the problem which led to their establishment has altered, or more effective ideas for dealing with it have appeared (Sewell 1975). Strategies are sometimes pursued which are appropriate to rural problems when the hazard has now become chiefly urban, or single-purpose agencies dealing with only one source of risk are retained when mutliple-purpose bodies are required for more effective coordination of policies.

This paper offers an approach to solving such problems. It describes a heuristic model which helps to relate a country's environmental risk to the level of sophistication appropriate in adjusting to it. Suggestions are also made concerning strategies that countries with specific degrees of risk and levels of economic development might adopt in attempting to deal with natural hazards.

A Risk-Growth-Sophistication Matrix

The efficacy of adjustment to natural hazards, in any country, is conditioned by three broad factors: (1) the degree of risk, (2) the stage of economic growth, and (3) the sophistication of adjustment. There are, of course, numerous individual variables which affect the efficacy of adjustment. The three dimensions noted above subsume many of these and appear to be especially critical in determining both the type of disasters experienced and the response invoked (Fig. 1).

Figure 1. A risk-growth-sophistication matrix.



The Degree of Risk

The magnitude of the natural hazard problem and the urgency for associated action can be characterized as the Degree of Risk. This factor describes the potential losses likely to occur from the operation of geophysical, biological and hydrological processes. The Degree of Risk is conditioned on the one hand by various physical elements such as geology, climate, terrain, and vegetation, and on the other by many human factors, including the nature of the society, its economy and infrastructure. Some countries, for example, are traversed by major rivers bordered by wide, flat flood plains terminating in large fertile deltas, which frequently overflow their banks. India, Bangladesh, Holland, Egypt, Burma and Vietnam are countries with a high Degree of Risk associated with such drainage networks. Others lie in the path of repeated tropical storms and suffer devastation from wind, flood rains, and, most lethal of all, the storm surge. Central America, India, Bangladesh and Japan have a high Degree of Risk associated with such storms. Geophysical instability, probably the result of continental drifting and plate tectonics, accompanied by volcanic eruptions, earthquakes and tsunamis is a further cause of risk in many countries including Japan, China, Indonesia, New Zealand, Chile and Guatemala. Unstable bedrock or surficial sediments such as clays or loess may lead to disasters induced by landslide, just as high slopes and extensive snowfall are conducive to avalanching. A high Degree of Risk caused by such mass-movement phenomena occurs in the St. Lawrence Lowlands of eastern Canada and in Hong Kong. Many countries are subject not merely to one natural hazard but to a wide range of both interrelated and unrelated threatening phenomena.

Risk is not simply due to the operation of physical processes, however, but is modified by the human use made of such risk locations and by various social adjustments that are taken because of the associated hazards. The probability of losses increases as more intensive use is made of flood plains, the sea coast, unstable slopes and seismically prone locations, particularly if urban development and industrial activities occur. Risk can be reduced by actions which limit the magnitude and frequency of destructive biological or geophysical events or which lower the potential for damage from them. The

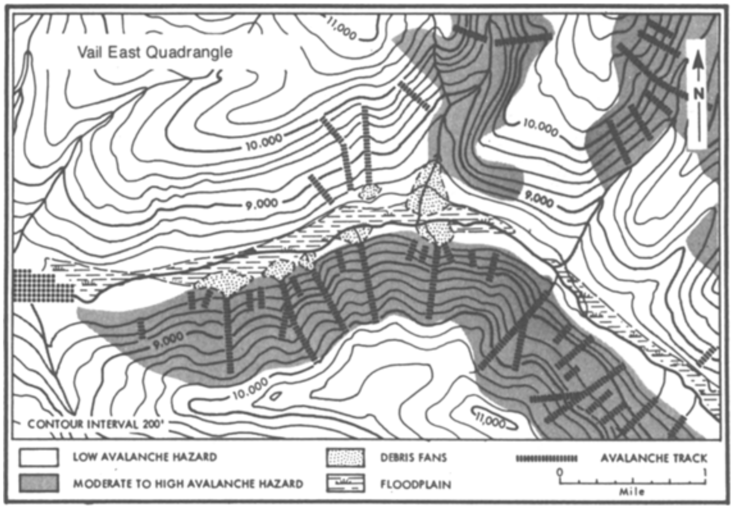


Figure 2. Avalanche microzonation in Colorado (after Madole).

latter steps include measures such as building houses on stilts or surrounded by thick stone walls or moving population and belongings out of the area of risk during the flood, hurricane or avalanche season.

At present, there is no broadly accepted estimate of the natural hazard loss potential for the world as a whole. However, important progress has been made in recent years in developing methods for assessing the Degree of Risk. These have involved both measuring geophysical, geological, biological and hydrological parameters and assessing potential losses of human life, crops, income, and property implied by these factors.

Of particular importance have been the development of methods for synthesizing the mapping of spatial variations in risk from natural hazards and associated loss potentials. It is often impossible to undertake a complete survey of potential losses because of cost or time constraints. Estimates of such loss potential can be derived, however, from synthetic functions which have been developed from the experience gained in similar situations (White 1964). Considerable improvements in techniques for defining areas subject to extreme geophysical, geological and hydrological processes have also been made. The flood mapping programs of the Japanese Geographic Survey Institute, the U.S. Corps of Engineers, and the Canadian Federal Government, for example, have built upon these improvements, using both advanced ground survey methods and new techniques of aereal photograph interpretation (remote sensing). Similarly, volcanic risk maps have been produced by the Volcanology Division of the Geological Survey of Indonesia. Progress has also been made in the production of microzonation maps showing spatial variations in risk from earthquakes, for example. Such documents are available for Sofia in Bulgaria, Bucharest, Galati and Arges in Romania and for several Turkish, Yugoslavian and Soviet cities (Karnik 1972). As shown in Figures 2 and 3 microzonation maps showing differing risk potentials have also been made for coastal erosion, storm surge, tsunami, avalanche and landslide hazards (Foster 1975).

Even in countries which have not yet been able to adopt these improved methods, there is a growing appreciation of the nature and magnitude of the natural hazard problem. Despite the limited data, it should now be possible to indicate at least approximately, where any nation lies on the Degree of Risk Scale. Countries which experience only slowly operating and infrequent geophysical, geological or hydrological process, or have only minor urban or industrial development in hazard-prone locations, or have developed highly effective adjustments, occupy the lower end of the scale. In contrast, countries which have very large, frequent damaging natural events, or which have considerable economic activity in high risk areas and have not adopted effective hazard adjustments are at its higher end.

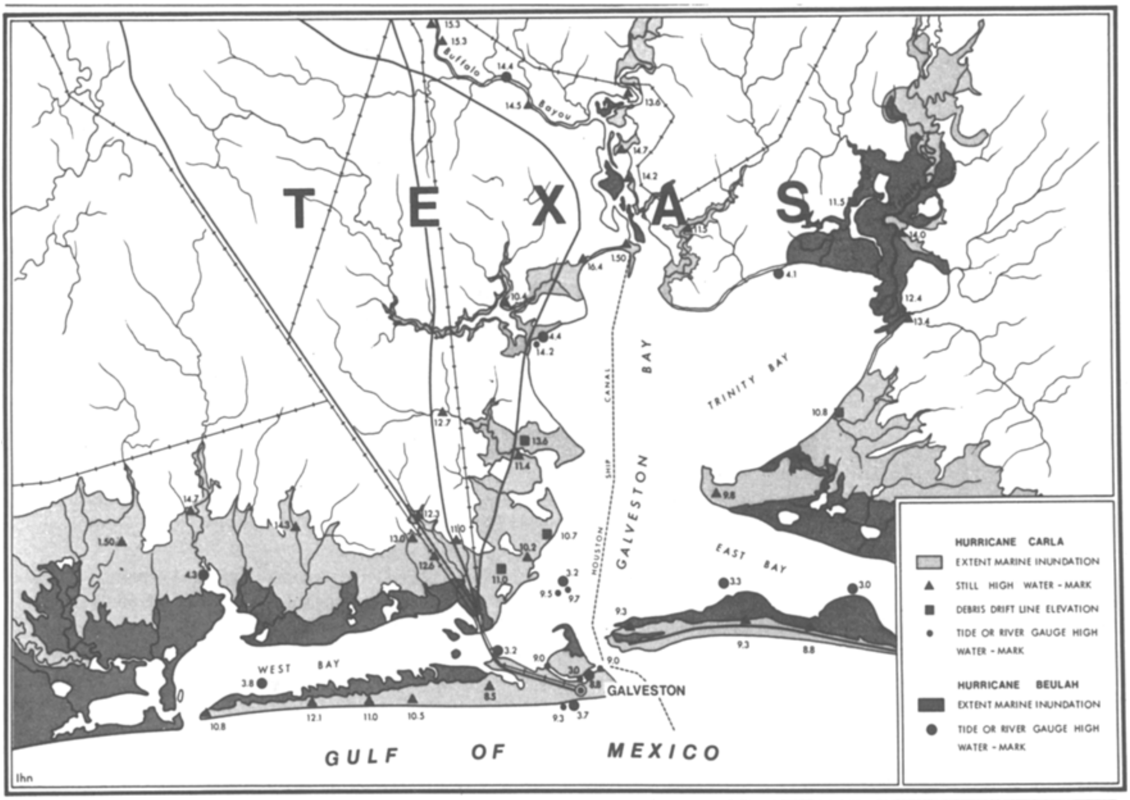


Figure 3. Storm surge microzonation of the Galveston, Texas area (after the Bureau of Economic Geology, University of Texas at Austin).

Stage of Economic Growth

The nature and magnitude of losses from natural hazards is profoundly affected by economic growth. A number of economists have described this process of growth as consisting of several steps or stages, beginning with a subsistence economy and gradually moving to successively higher degrees of industrialization and urbanization (Rostow 1960). Important shifts in social structure, as well as economic activities, accompany this process. Although the assumptions underlying this theory have been criticized, there is general agreement that a spectrum of economic development exists, and that countries on the lower end of the scale generally aspire to reach successively higher stages. Economies exemplified by those of some of the small Pacific islands occupy the spectrum's lower end while the United States, Japan, Sweden, Switzerland, and West Germany are located at its opposite end.

As economic growth proceeds, it tends to accelerate the pace of high-risk location. Transportation routes are built on the low-lying lands that characterize such areas, while certain kinds of industries move there to take advantage of the easy access to marine or river transport facilities or supplies of cooling water. Various economies of agglomeration encourage further concentration of settlement and industry in such locations. As a result economic growth, particularly during the 'take-off' phase, tends to increase the risk of serious natural hazard losses. At this stage, although newly-constructed infrastructure is clearly at risk, there is generally insufficient capital available to develop large-scale protection works. Major earthquakes, tsunamis, landslides and floods commonly occur, seriously damaging the economy and reducing the country's capacity to generate the capital to build a hazard protection infrastructure. This vicious circle obviously must be broken.

Level of Sophistication of Adjustment

A large number of possible adjustments to natural hazards are appropriate to various types of geophysical, geological and hydrological circumstances, varying cultural characteristics, and differing stages of economic development. Such adjustments can be classified in numerous ways; the following categorizations, however, seem most appropriate for present purposes: (1) bearing the loss, (2) modifying the loss burden, (3) modifying the physical process, and (4) modifying damage susceptibility. Examples of the various types of adjustment that are noted above are provided for floods in Table 1. Table 2 sets out some of the implications of their adoption.

Once more, a scale may be visualized, varying in this case from inaction to highly integrated comprehensive responses to natural hazard threat. At the lowest level of sophistication there are doubtless situations where a consistent policy of bearing the loss is pursued. This is particularly the case where either no alternative is perceived, or none appears possible. In some parts of

Table 1. *Potential Adjustments to Floods*

Modify the Flood	Modify the Damage Susceptibility	Modify the Loss Burden	Bearing the Loss
Flood Protection	*Flood Plain Management*	*Emergency Measures*	Bear the loss
Dykes	Land-use regulation	Flood warning	
Floodwalls	Statutes	Flood fighting	
Channel improvements	Zoning ordinances	Evacuation	
Floodways	Building codes		
River diversions	Urban renewal	*Redistribute Losses*	
Reservoirs	Subdivision regulations	Disaster relief	
	Government purchase of land or property	Financial aids	
Watershed Management	Subsidized relocation	Tax write-offs	
Terracing		Flood insurance	
Gully control			
Bank stabilization	*Structural Change*		
Forest fire control	Use of impervious material for basements and walls		
Revegetation	Land elevation		
Weather Modification	Construction of high floor houses		
Seeding of major storms			
	Flood Proofing		
	Permanent closure of low level windows & other openings		
	Waterproofing interiors		
	Store counters on wheels		
	Underpinning buildings		
	Installation of removable covers		
	Closing of sewer valves		
	Anchoring machinery		
	Plastic sheets covering machines		
	Seepage control		
	Sewer adjustment		

Table 2. *Potential adjustments to floods, appropriate applications, special features, and implications for policy-making*

Adjustment	Appropriate Applications	Special Features	Implications for Policy-Making
Flood protection	Especially appropriate where the potential losses are large, and particularly where the flood plain is highly urbanized and industrialized.	Flood protection works can often be provided as part of a multiple purpose project, such as a storage reservoir.	Tends to encourage persistent human occupance and may create a false sense of security among flood plain dwellers. Tends to shift responsibility from flood plain dwellers to the public at large. Needs to be supplemented by other measures.
Watershed management	Enough runoff remains in the low water period after the programs have been undertaken.	Can accomplish multiple objectives by involving forestry and/or agriculture. Is a useful complement to other measures	Most of the benefits are derived close to the area where watershed management is undertaken.
Weather modification	Where external or side-effects are minimum and those adversely affected can be compensated.	Still in a largely experimental stage with overall effects still somewhat uncertain.	Needs governmental control to ensure that the public at large is protected and that losers are compensated by gainers.
Flood proofing	To scattered buildings that are frequently flooded, and especially where the depth of flooding is less than 3 feet, and more than 3 hours warning is possible.	Structural measures which can be combined with other measures, such as emergency action or land use regulation.	Requires a well-organized flood forecasting system, aided by a flood hazard information program. Depends largely on individual action and tends to lag in intervals between floods.
Flood plain management	Where uses other than agricultural and recreational uses are competing for flood plain land, and especially where such uses involve urban and industrial uses.	Combinations of structural methods and nonstructural methods.	Tends to encourage efficient use of flood plain land. Responsibility is shared between the flood plain dweller and the regulatory authorities. Requires a rational basis for selecting land uses, and strong leadership and public support to ensure adoption.
Emergency measures	Everywhere, but especially where the flood-to-peak interval is greater than one day, the flood duration is short, flood frequency is high.	A non-structural measure which can be used independently or in combination with other measures.	Requires a well-organized flood forecasting system, with clearly defined and announced responsibilities for these functions. Tends to encourage persistent human occupance. Interest tends to lag when flood frequency is low.

southeast Asia, for example, the development of flood control works is too costly, and opportunities for the relocation of activities are very limited. As a result, much of that region anticipates and accepts loss from hazard's as the price of occupying any flood plain. Countries that have reached higher levels of economic development, such as Britain, France, Canada or the United States, have access to advanced technology and also tend to adopt more sophisticated approaches to institution building and to planning. As a consequence, the range of adjustments taken in the face of the natural hazard threat is broadened. Not only does it become possible to find better ways of controlling such hazards as floods and storm surges by dam and sea wall building, but it is also feasible to modify the susceptibility of property and people to losses from such events. Adjustments like protection works, watershed management, natural hazard microzonation, high risk area management, and insurance begin to enter the spectrum of practical options. Such economically advanced countries also have the greatest ability to finance loss management programs. Similarly, highly sophisticated electronic communications and monitoring devices provide the basis for the rapid and timely evacuation of threatened areas. Such nations can also engage in comprehensive hazard planning and can link this to policy-making concerned with the country's overall economic and social welfare.

Interrelationships Between Degree of Risk, Economic Growth, and Sophistication of Adjustment

The three dimensions risk, growth and adjustment, are closely interrelated. A change in any one is likely to be accompanied by responsive movement in the others. For example, if a country reaches a higher level of economic growth as the result of expansion onto coastal and flood plains or rich volcanically derived soils, it may also experience an increase in its Degree of Risk. Depending on the extent to which such economic development is accompanied by a broadening of the approach to natural hazard management, growth may also result in an improvement in the sophistication of adjustment and so may temper the growth of risk, or even reduce it.

Figure 1 (above) indicates the interrelationships between these three dimensions, risk, growth and adjustment. It shows, for example, how the degree of risk relates to sta ,es of economic growth. In the case illustrated in the diagram, the country in question has reached a stage of economic growth in the range 3–4 on the Rostow economic growth scale and experiences a degree of risk also between 3 and 4; its sophistication of adjustment to hazards is also at this level. The diagram shows the relationship of sophistication of adjustment to economic development and of the degree of risk to the sophistication of adjustment. The intersection between the projections from these three planes indicates the position of a given country in the action space relating to its adjustment to natural hazards.

Application of the Matrix

The model described above is a simple heuristic device. But it does aid in the description of a country's position with respect to natural hazards problems, and offers some indication of the policy directions in which it should move if there is a change along any one of the axes. Theoretically, it is possible to locate any country within this action space. To do so, however, one needs to make assumptions about its position with respect to each of the axes. To stimulate discussion, rather than to take a definitive position, the authors suggest in Table 3 that the eight selected countries are presently located at particular positions in the action space. The Degree of Risk in this Table is based upon an historical review of major disasters following natural hazard events.

Given a level of economic development, and a particular level of risk, there is an optimum level of sophistication that a country can attain in adjusting to natural hazards. Such an optimum would be defined in terms of the magnitude of the problem to be faced and the resources and technology that a particular country could devote to hazard necessitated adjustments. This optimum may vary with each individual country and even

Table 3.

Country	Degree of risk	Stage of economic growth	Sophistication of adjustment
Japan	4.0	4.5	4.5
U.S.A.	3.5	5.0	4.0
Chile	4.5	3.0	3.0
Bangladesh	4.5	2.5	2.0
Indonesia	4.5	3.0	3.5
Holland	4.0	4.5	4.5
Britain	2.5	4.0	4.0
Malaysia	4.0	3.5	3.5

Growth \ Risk	1	2	3	4	5
1					
2					
3					
4					
5					

Figure 4. An Economic growth-risk matrix.

regionally within it. For example, some countries, such as Japan, have very high Degrees of Risk and also considerable available resources to deal with hazards, while others such as Bangladesh have high risks but only minimal resources. Similarly, some regions within an individual country are better equipped to deal with natural hazard problems than others, either because they have superior financial resources or because they have greater technical expertise or better integrated institutions. Thus British Columbia is probably better able to deal with its flood problems than are the Maritime Provinces in Canada.

Examining a matrix composed of stages of economic growth and differing degrees of risk, it is possible to suggest the types of adjustment that would be appropriate to countries or regions located in each of the cells (see Fig. 4). Two cells in this matrix are now described for illustrative purposes only.

(1) G5R5

This cell represents the greatest level of economic growth yet achieved, together with the highest level of risk from natural hazards. A country or region in such a location could effectively adjust by taking a highly sophisticated approach to the loss problem. This would be characterized by (a) comprehensive planning, linking hazard loss management to resources management as a whole, and the latter to overall economic and social planning, and (b) the adoption of control measures accompanied by land use regulations and insurance, together with the development of sophisticated monitoring systems and high-speed communication devices.

No country seems to be in this matrix position, but the United States appears to be moving towards it. The United States experiences high risk from frequent major storms which affect its coasts and continental interior, seismic areas such as Alaska and California, and the progressive invasion of highly vulnerable locations by agriculture, industry and urban settlements. In consequence the United States has suffered numerous major disasters resulting in billions of dollars of property damage and in the deaths of thousands. Despite the high physical risk, for many years the approach to natural hazard loss management was highly conservative, with major focus upon the relief and rehabilitation of victims and the construction of protection facilities. The recognition that these policies had by necessity failed to arrest the growth of natural hazard loss potential led to a serious policy reappraisal. The new policies of the early 1960's took advantage of innovations on the technological front and encouraged the adoption of a wide variety of social measures, notable among these insurance, the provision of microzoning maps and other hazard information, the drafting of land-use regulations, and the incorporation of hazard-proofing measures in urban construction or reconstruction. As yet, however, present policies and institutional arrangements fall short of a fully integrated approach to hazard and resources management.

(2) G3R5

A country located in this cell of the matrix is in a transitional stage of economic growth. The application of technology and capital from external sources and the reorganization of local economic activities are accelerating the pace of economic development. Yet the risk of natural hazard-induced losses is high, partially because of physical conditions but also as a result of the rapidly increasing urban and industrial invasion of the high-risk locations which is unaccompanied by a corresponding increased level of physical control or damage mitigating measures. This situation is characteristic of many of the countries in the typhoon region of Southeast Asia (Typhoon Committee 1973). Countries affected include Hong Kong, Korea, the Philippines, Thailand, and Vietnam. (Japan, also affected, is atypical of the typhoon region.) Severe flood and landslide losses are typically sustained almost every year, and in some cases thousands of lives are lost. Damages may frequently exceed $100 million annually. Capital for protecting the growing economy against these losses is scarce and must be denied to other desirable activities that might promote economic growth if it is used to mitigate the problem. This is a typical dilemma for developing countries: how to stimulate economic development yet provide the means to minimize losses from environmental hazards with extremely limited capital resources. Expenditures for control, therefore, tend to be small in proportion to natural hazard losses in such countries. For example, as indicated in Figure 5 countries such as Korea, the Philippines and India invest an equivalent of little more than 10 percent of average annual flood losses for this purpose. This contrasts with the 200 percent spent by New Zealand. Fortunately, several relatively inexpensive strategies for mitigating this and many other hazards can be adopted. At a minimum, improved monitoring and warning systems can be established. Bearing the loss may remain the dominant strategy, but moves toward the organization of more effective evacuation programs and land use regulation should also be possible. A few control works may also be installed.

Such an approach is being adopted in Malaysia, where annual flooding follows in the wake of the monsoons. Usually these are small and localized, but occasionally major inundations of a regional character occur. One such flood took place in 1971. The city of Kuala Lampur was damaged and considerable losses were sustained by agriculture, trade and industry. There were several fatalities. The major adjustments adopted in this region have been bearing the loss, together with a limited amount of flood protection from levees and channel enlargement. The recent disastrous floods have led to a more aggressive approach. A National Flood Commission has been established with broad powers to prepare and execute plans and programs. It is presently examining not only a series of flood control measures but also warning and monitoring systems and land-use regulations. Possibilities of changing agricultural practices to minimize flood losses are also being considered.

This economic growth-risk matrix (Fig. 4) has a number of implications for natural hazard loss man-

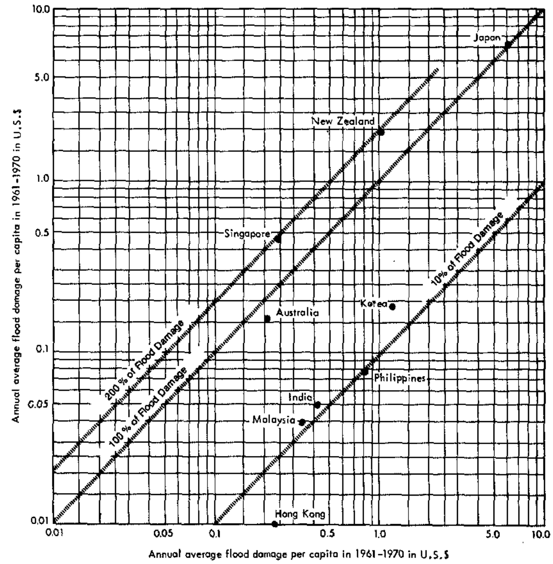


Figure 5. Expenditure for Flood Control and Average Annual Flood Damage, 1961–70.

agement policies in developing countries. The first of these is that there is an optimum set of adjustments appropriate to each level of risk and each level of economic development. Such adjustments tend to reach greater levels of sophistication but not necessarily cost as higher levels of economic growth are attained. A second implication is that countries with high levels of risk but low levels of growth must concentrate on those adjustments that can be accomplished with low capital investment but which are highly effective in saving lives and minimizing property losses. Priorities, therefore, would seem to be in the installation of monitoring and warning systems, the development of evacuation procedures, hazard proofing measures, and land use control. A third point is that there may be a large gap between what a country could technically attain by effective loss management with the resources already available to it and what is actually accomplished. Such a discrepancy is generally the result of institutional inertia. Tradition, a lack of communication, and other weaknesses may lead to concentration on measures that were appropriate at a lower level of economic development but are no longer optimum. Innovation in administrative structures, changes in types of personnel involved and variation in functions performed by responsible agencies might be one of the most effective ways of improving the efficiency of loss management and, therefore, in reducing the loss of life and property from hazards.

The Role of International Cooperation

The general tendency in most parts of the world is for countries to adopt independent strategies for dealing with hazard-related problems. Experience has shown, however, that there may be a considerable advantage to be obtained through international cooperation. A wide variety of opportunities exist. These include bilateral or multilateral arrangements, whereby countries sharing a common zone of risk such as a fault zone, sea coast, mountain range or river basin agree to cooperate in some phase of the planning, policy making or implementation process. As a minimum they might cooperate in the collection of data about geophysical, geological, biological and hydrological conditions. Such an arrangement, for example, has been worked out between Egypt and the Sudan, which share the Nile as a common resource and hazard. This might be extended to the development of warning systems, as has been the case with floods in the Danube Basin and with tsunamis in the Pacific Basin. A higher level of commitment is involved in joint planning ventures, such as those in the Lower Mekong where Laos, Cambodia, Thailand and Vietnam have been cooperating for almost three decades. There may also be opportunities for the construction of flood control facilities in one country to be used mainly for the protection of flood plain lands in another. An illustration is the construction of the dams on the Columbia River, in Canada, in part to protect communities in the United States' portion of this river basin.

A second type of cooperation is that extended through the various international agencies, notably those relating to the UN organization. Several of these have assisted materially in increasing knowledge about the nature and magnitude of hurricane, volcanic, seismic and flood problems in numerous countries and in the provision of personnel or finances. Examples include the World Meteorological Organization, the UN Disaster Relief Organization, and the UN Development Program.

Conclusion

An optimum level of sophistication in the management of natural hazards might be attained. Many countries fail to attain this level, largely because of problems associated with institutional inertia. In addition, in the developing world, there is often a lack of capital, technical expertise, and applied social science research. Remedy of these deficiencies could considerably increase the opportunity for Third World countries to improve the degree of sophistication of this adjustment to natural hazards. This would have the effect of temporarily moving them forward along the economic growth axis (Fig. 1) and, thereby, would make feasible a more sophisticated approach to the natural hazard problems. As a result, less damage would be suffered and economic growth could be accelerated. In this way the assisted country might permanently reach a higher level of material well-being. It would then be capable of funding a more sophisticated approach to the disaster problem from its own resources or, if international aid continued, of adopting management strategies appropriate to countries with even higher levels of economic growth.

REFERENCES

Bangladesh, Ministry of Relief and Rehabilitation, 1973, Cyclone Disaster and Cyclone Preparedness Programme in Bangladesh: Dacca, 17 pp.

Dacy, D. C., and Kunreuther, H., 1969, The Economics of Natural Disasters: New York, Free Press, 270 pp.

Dworkin, J., 1974, Global Trends in Natural Disasters 1947–1973: University of Toronto Natural Hazard Research Series, 16 pp.

Foster, H. D., 1975, Disaster Mitigation: A Geomorphological Contribution: Emergency Planning Digest Vol. 2 No. 5 pp. 2–9.

Karnik, V., 1972, Microzoning Programme Within the UNDP-UNESCO Survey of the Seismicity of the Balkan Region, in Proceedings of the International Conference on Microzonation for Safer Construction Research and Application: Seattle: N.S.F., UNESCO, University of Washington, A.S.E. and Academy of Mechanics, pp. 213–216.

Noh, T., 1966, Sanriku Coast Prepared for Tsunamis, The Science Reports of the Tôhoku University, Seventh Series (Geography), 15 pp. 1–24.

Rostow, W. W., 1960, The Stages of Economic Growth: Cambridge, Cambridge University Press, 179 pp.

Madole, R. F., 1974, Quaternary Research Methodologies Applied to Delimiting Natural Hazards in Mountainous Colorado, in Quaternary Environments Proceedings of a Symposium, York University-Atkinson College Geographical Monographs No. 5, pp. 79–98. This article was the source of Figure 3.

Sewell, W. R. D., 1965, Water Management and Floods in the Fraser River Basin. Chicago: University of Chicago, Department of Geography Research Series No. 100, 163 pp.

Sewell, W. R. D., 1975, Administrative Responses to the Changing Role of Water Resources Planning, in Proceedings of the Inter-Regional Seminar on Water Resources Administration, held in New Delhi, 22 January-2 February, 1973, pp. 48–55.

United Nations, Economic Commission for Asia and the Far East, 1963. Proceedings of the Fifth Regional Conference on Water Resources Development in Asia and the Far East, Water Resources Series No. 23, 229 pp.

United Nations, Economic Commission for Asia and the Far East, 1973, Ad Hoc Group of Experts on Flood Damage Prevention: Structural and Non-Structural Measures for Mitigation of Flood Damage in the ECAFE Region. Bangkok. 51 pp.

United States Office of Emergency Preparedness Disaster Study Group, 1972, Disaster Preparedness, Washington, U. S. Government Printing Office, 364 pp.

United States Task Force on Federal Flood Control Policy, 1966, A Unified National Program for Managing Flood Loss, Washington, D. C.: U. S. Government Printing Office, 47 pp.

White, G. F., 1964, Choice of Adjustment to Floods. Chicago: University of Chicago, Department of Geography Research Series No. 93, 149 pp.