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Risk Characterization and Quantification: An Operational Perspective on Risk Mitigation for the Developing World[1]

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Abstract – Objective, comparative risk assessment is an essential requirement in strategic policy formulation that seeks to address cost-effective risk reduction and mitigation strategies. This paper offers a conceptual framework and risk assessment approach to integrate the bio-physical and socio-economic considerations and complexities from a spatial and temporal perspective, with emphasis on the developing world. It is suggested that this framework is not only useful in the identification of relative risk scenarios given principal public policy and quality-of-life concerns such as food security and safety, or environmental impacts and associated health risks, but also can be used to communicate long-term risk factors, and identify effective risk prevention and mitigation strategies. As such, major relative needs and intervention opportunities are identified associated with principal risk themes. With emphasis on the developing world, they include: food security and health impacts exacerbated by global warming; the need for generating local energy and the potential use of biomass as a supplemental and safer energy source in food preparation using clean combustion; the need to reduce environmental impacts and associated health risks in resource extraction; and the need to preserve biodiversity and environmental capital to promote eco-tourism and sustainable economic development, and preserve both genetic diversity and medicinal potential.

Keywords – *risk assessment, environmental quality, public health, community sustainability*

1. Introduction

Risk assessment is scientific process that seeks to objectively evaluate adverse impacts on the human condition. These impacts may be caused by exposure to a toxic substance - such as environmental contaminants, naturally occurring phenomena – such as environmental hazards, human activity – such as land use, life style, or other external conditions affecting quality of life – e.g. food security, nutrition and safety. The purpose of risk assessment is to quantify the various environmental and health effects on the human ecosystem and by doing so, inform public policies designed to improve quality of life (Cohrssen and Covello, 1989). In addition, risk assessment seeks to identify the cost-effectiveness of different control or mitigation strategies to stabilize or reduce risks. This process should be designed to identify best practices by location and over time. As such, it involves the dynamics of spatial and temporal interactions within the modified risk function (Schultink, 2000):

$$R_n = \sum_{i=1}^{n} r_n x p_n v_n - t_n \tag{1}$$

where r - is the expected value of the magnitude or degree of risk (expressed as social cost), p - the exposure probability (expressed as frequency or probability of occurrence (%)), this factor may be weighted for larger impact areas where spatial decay is expected or adjusted over time to reflect temporal dynamics, v – the vulnerability of the affected population (e.g. reflecting composition and age, weight and other socio-cultural factors), and t – the potential risk reduction factor (e.g. effects of risk prevention or mitigation policies), and n - the number of risk variable identified.

Rather than viewing risk solely as a physical health factor, it is suggested that risk in policy formulation reflects the broader view of human well-being or quality of life. More recently, the issue of social equity in involuntary risk exposure has received increased attention. Elements that may be included into this assessment are invol-

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LIKELIHOOD and RELATIVE RISK					
5 – Certain to High	Low	Moderate	High	Extreme	Extreme
4 – Likely to Medium High	Low	Moderate	High	High	Extreme
3 – Possible to Medium	Low	Moderate	Moderate	High	High
2 – Unlikely to Medium-Low	Low	Low	Moderate	Moderate	Moderate
1 – Rare to Low	Low	Low	Low	Low	Low
RISK SIGNIFICANCE	1-Insignificant	2-Minor	3-Significant	4-Major	5 Catastrophic

Figure 1: Relative Risk Prioritization as a first step in Risk Quantification for High Risk Scenarios

untary exposure to water and air pollution, environmental disease vectors and their controls, occupational health or safety in the work place, such as exemplified by recent disasters in Bangladesh or mining conditions on the African continent, or various food safety issues.

Risk assessment must be viewed as a distinctly different in public policy studies as risk management. The former is a scientific assessment of potential health risk that may result from development impacts on the environment, while the latter addresses concerted public policy efforts to reduce risk through education, regulation and mitigation. Risk management uses the scientific results of risk assessment as expressed in comparative indices, while assessing the implications using economic, social and legal considerations to formulate policy decisions and regulatory interventions.

2. A comparative risk assessment framework for the formulation of global and national intervention policies

Quantitative risk assessment is an essential prerequisite for the formulation of sound and cost-effective public policies that seek to manage risk on the basis of objective, scientific criteria. In practice, this means balancing the cost of risk reduction strategies with the benefits, being human lives saved, improving quality of life or associated economic benefits. As a first step, this requires the generalization of risk scenarios and an assessment of the relative risk based on *likelihood* and *significance*. For instance the seismic risk associated with certain construction zones – i.e. structural damage to certain public housing types that may result in loss of life based on the proximity to active fault lines, geologic stability, prevailing site conditions for a 100-year period (Figure 1).

Such assessment may be conducted for small areas under impact consideration or for large areas such as macro-watersheds or political administrative jurisdictions encompassing a multitude of variables. For all impact considerations, objective and science-based factors should be considered that may affect relative risk or quality of life considerations. Based on this first phase assessment initial interventions may be enacted and more detailed quantitative assessment conducted for high(er) risk areas.

Below, a comparative and hierarchical risk assessment framework is introduced that permits the relative quantification of risk at the local, regional and national levels on the basic of social cost (e.g. fatalities, loss of life time earnings potential, comparative risks and aggregate multiplier effects) born by a specific society, and the potential effects of specific policies and mitigation strategies to reduce risk, by location and over time (Fig. 2). Such systematic approach across locations and regions provides the analytical framework to inform public policy formulation based on cost-effectiveness considerations and to conduct the relevant monitoring and evaluation using the appropriate treatment and control sites.

Cost-effectiveness analysis (CEA) is distinct from cost-benefits analysis, which assigns monetary value outcomes to measure effect (Bleichrodt and Quiggin, 1999). Cost-effectiveness analysis is often used in the field of health services, where it may be inappropriate to value health effect as an economic benefit. Typically the CEA is expressed in terms of a ratio where the denominator is a gain in health from a measure (e.g. extending human life, reducing infant mortality) and the numerator is the cost associated with the impact. The most commonly used outcome measure is quality-of-adjusted life (QAL). This index expresses the *utility of investments* and values both impact quantity and quality. For instance, how life expectancy may be increased but negatively affected by serious side health effects resulting from contaminant exposure reducing the *quality-of-life* experienced or for instance, how the lack of protein in a child's early years' diet may affect brain development and its compounded effects during its life cycle [2]. As such, CEA overcomes the comparative difficulties of cost-benefits analysis that poses the challenge to *value human life* and the complexity of assessing comparable life earnings in various societies and monetary systems.

3. Emerging policy perspective, risk mitigation strategies and analytical needs

Environmental impacts, risk assessment and mitigation are receiving increased attention. In the western industrialized world important policy initiatives principally address risks associated with deteriorating air and water quality, and the preservation and restoration of ecosys-

[2]QAL assumes that a year of life lived in perfect health is worth 1 QAL (1 Year of Life x 1 Utility value = 1 QAL) and that a year of life lived in a state of less than this perfect health is worth less than 1 (the utility value). To determine the exact QAL value, one multiplies the utility value of a state of health by the years lived in that state. QAL means "years lived in perfect health", therefore half a year lived in perfect health is equivalent to 0.5 QALs (0.5 years x 1 Utility), the same as 1 year of life lived in a situation with utility of 0.5 (able to work 50% of the standard workload (1 year x 0.5 Utility)

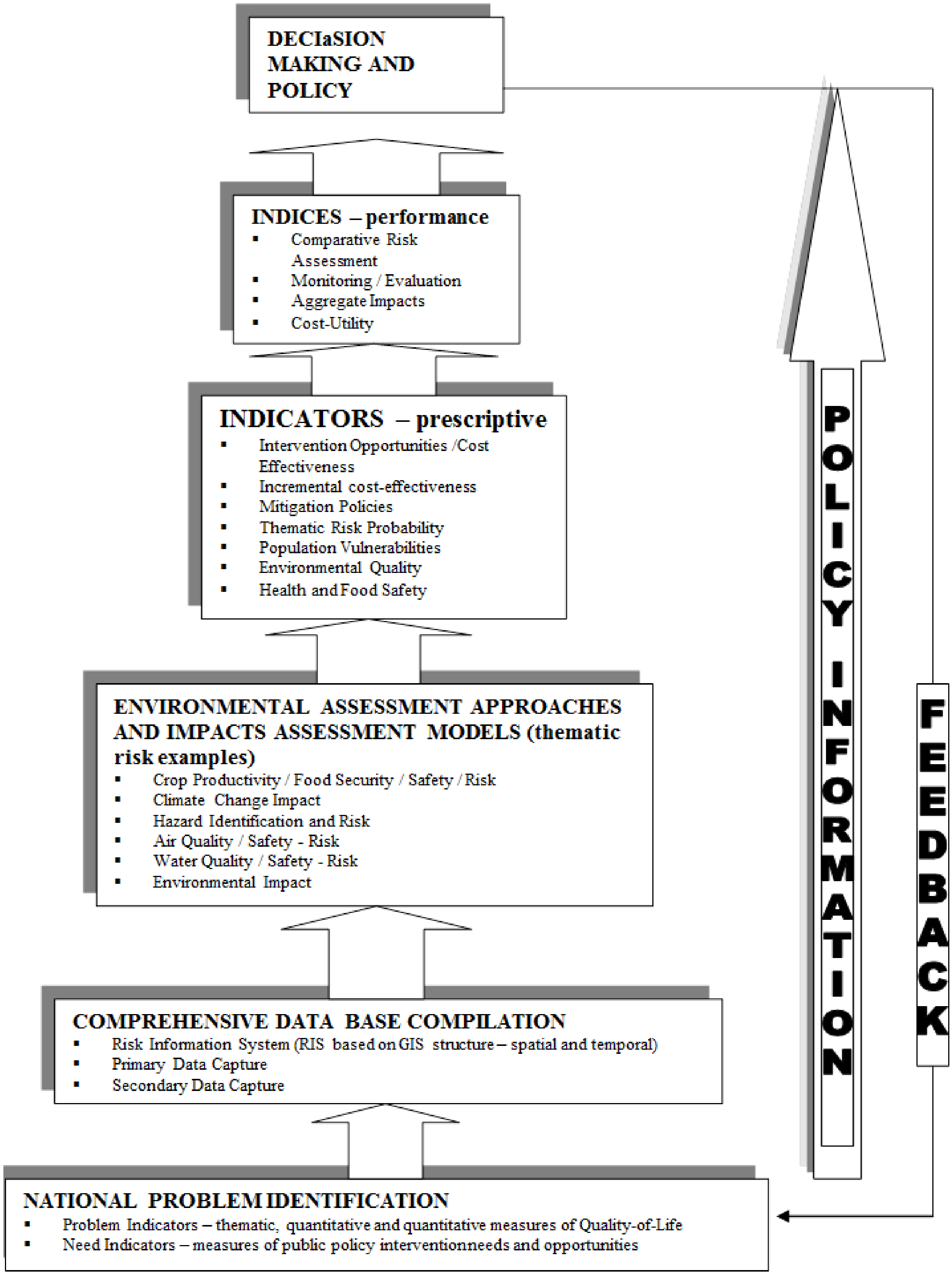

Figure 2: Hierarchical information flow and use of basic data, indicators and indices in development planning and public policy formulation (connecting arrow size signifies relative information content)

tems functions and biodiversity. G*eneral Environmental Impact* may be quantified by *P x R x I*, where P is the number of people in a given country or region, R a profile of the type and number of resource units used per capita (e.g. an average profile of energy intensity and type of use mix for a specific location), and I the environmental impact of type and mix of inputs and resulting outputs (e.g. toxicity of heavy metals or arsenic used in extraction of gold concentrate, or air quality emissions by mode of energy generation).

The themes identified more globally, include: food security and health impacts associated with global warming, the need for generating local energy and the potential use of biomass as a supplemental and safer energy source in food preparation using clean combustion, the need to reduce environmental impacts in resource utilization and extraction, the need to preserve biodiversity and environmental capital to promote eco-tourism and the preservation of genetic diversity and medicinal potential

The prioritization of risk reduction strategies and management intervention policies should ideally be based on the cost-utility function identified, above. This approach permits the identification of the most promising policy interventions within their domestic and world-regional settings. In this paper various promising risk reduction strategies and intervention policies are identified that should be considered and their overall cost-utility quantified to guide comprehensive risk reduction and management.

The paper advocates the development of proactive, *comprehensive policies and regulations of land use and their impacts on environmental quality and public health* based on the development of a decision support system that is effective and transparent in making informed public policy choices. Such a policy analysis system consists of three major functional components, comprising *diagnostic (problem identification), prescriptive (policy formulation), and performance (dynamic monitoring) indicators* and their derived resulting indices at various aggregate levels (Fig. 3).

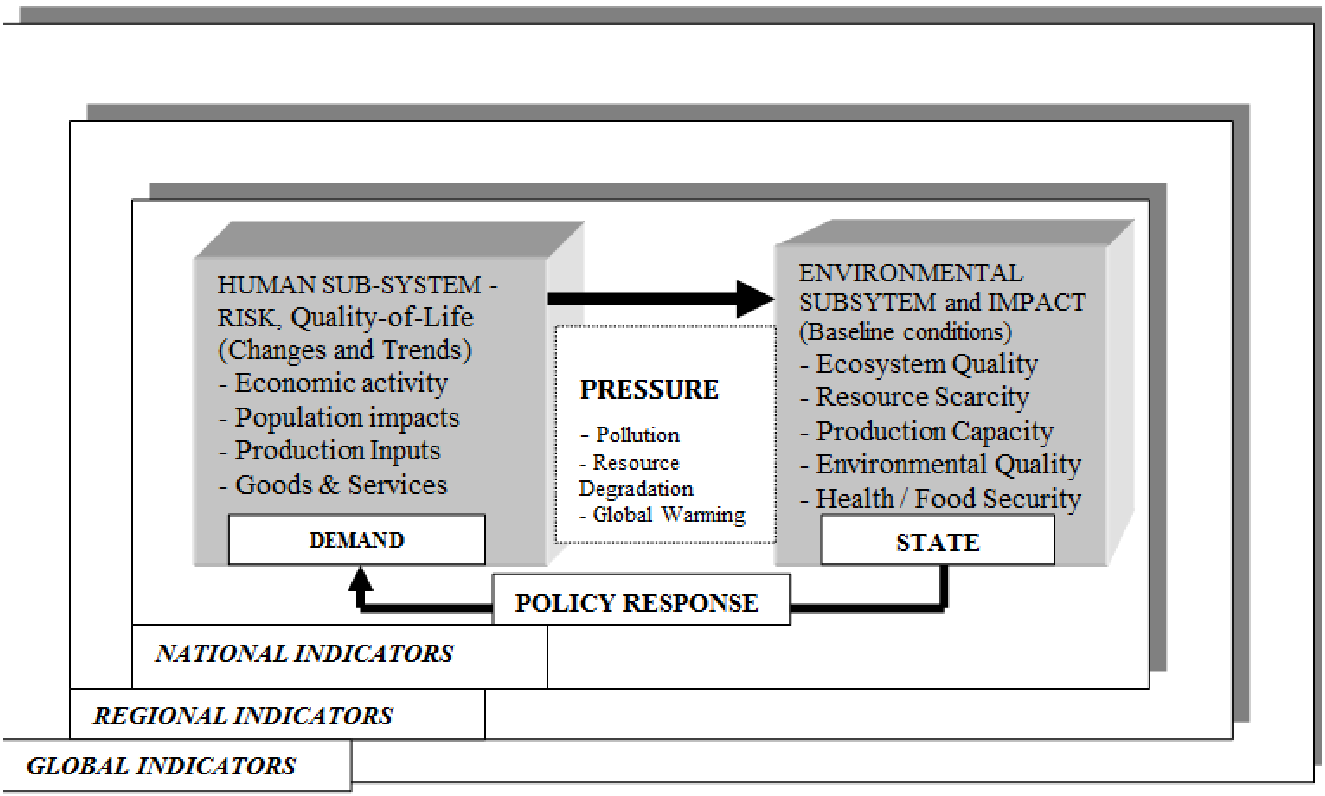

Figure 3: Comparative Pressure-State-Response Framework for Global Risk Policy Formulation and Evaluation. *Diagnostic Indicators* are used to define the STATE of the environmental system (relative magnitude of associated human risks), *Pressure Indicators* may be used to predict and quantify the relative risk impacts associated with evolving DEMAND and impacts on the resource base (e.g. environmental pollution or land degradation), while *Cost-effectiveness Indicators* (i.e. QAL, see above) may be used to identify the best intervention policies to reduce or manage risk.

The conceptual framework is not unlike the one advanced by the OECD to address Pressure-State-Response interactions (OECD, undated and Levrel, H. et al, 2009). It could be used as an international comparative framework to assess (a) issue-based i*ndicators of change or stress posing environmental risks* ("biophysical system state", e.g. food security and safety, natural resource production capacity, air quality emissions, natural hazards), (b) related impacts of human activities (measured by *pressure indicators*, e.g. land degradation, resource scarcity, concentrations of air and water pollutants), and (c) resulting policy responses (e.g. prevention and mitigation strategies, development of energy and transportation alternatives, market controls such as fuel taxes, or specific incentive in the form of subsidies). It is important to note here that targeted prevention policies are generally much more cost-effective than mitigation policies.

This approach provides a nested analytical hierarchy of policy concerns and response. Systemic indicators are primarily designed as diagnostic tools – that is, to derive a composite measure of a system's status and express its degree of vitality or stress. This hierarchical indicator approach offers the most promising tool in policy analysis and decision support. It can be used to quantify needs, trends and spatial/temporal impacts of public policies, while reducing the subjective element in public policy formulation by identification of objective diagnostic standards and measurable goals and objectives.

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