

EVALUATING A PROJECT'S RELATIVE ENVIRONMENTAL IMPACT ACROSS REGIONS

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Abstract

Sustainability requires planners to consider the comparative environmental impact of projects across regions. The proposed objective tool can be used to evaluate the comparative impact of different projects and schemes across regions with a shared ecosystem, in light of their relative economic development. This would then allow planners to set priorities and allocate resources based on measurable environmental criteria, and thus maximize the overall development while minimizing negative impacts. This tool is based on the World Bank's indicator for development, the "Development Diamond", and on earlier work on an "Environmental Diamond". This modified "Environmental Diamond" could serve as a comparable framework for ecosystem risk for the different areas in the region considered for development. The approach followed in this paper was based on an approach developed to measure environment quality in Asia, which was adapted by the author to evaluate "environmental performance" in the Levant. The result is an integrative index that reveals a general picture without concealing specific aspects of environmental quality. Because of the use of objective indicators, this index could serve as the basis for analysis and systematic decision making. As it expands, the index would serve as a common tool for planners and policymakers, as they collaborate to mitigate the impact of continuing development on shared environments.

Keywords: Planning; Policy; Project Evaluation; Environmental Impact Assessment.

Introduction

Planners who evaluate projects and allocate resources increasingly have to reconcile development needs with sustainability. By doing so, they have to contend with the differences between project need and the necessities of sustainability. On one hand, project requirements are essentially "linear", defined by time-sensitive objectives and specific outputs achieved at a predetermined cost. On the other hand, development projects have to contend with the "circular" nature of sustainable environmental management that impose often open-ended necessities (Bell and Morse, 2004).

Reconciling those two needs has been ever more difficult as civilization progressed and its energy needs increased. Civilization has always been dependent on the optimal use of the sun's energy. As humans settled into population centres, they were harvesting more of the sun's energy from wood, food, water, and the ecosystem. With growing challenges came rising complexity; when confronted with decreased rainfall, early Sumerians developed irrigation networks. Faced with the need to expand them, they developed the administrative structures to manage them, and the tax system to fund it (Tainter, 1990). Managing such rising complexity was made possible by "importing" increased amounts of energy into the "system", and more ways were developed to transmit it, from work animals and water power, to coal and oil powering steam, and diesel engines (Bar Yam, 1997).

This environmental damage that resulted had increasingly diverse and interrelated aspects. In the context of today's more elaborate societal structures, the environment requires societies to reach a point of "environmental sustainability", where their current energy needs do not mortgage those of future generations, and where resource use is optimal. For this reason, projects need to factor in such complexity, and to take into account the requirements of sustainability. This is ever more critical today, as societies have evolved into complex knowledge-based, "inspiration" economies, where the quality of life in cities and towns is "one of the prime determinants of investment decisions and, hence, the attraction of knowledge workers" (NRTEE/TRNEE, 2003). As societies move towards ever greater complexity, they require a larger amount of resources for their sustenance, with the ever-present risk of diminishing returns (Tainter, 1990).

Today, as they select development projects, planners are faced with the need to optimize energy consumption and development and maximize returns from environmental resources without over-exploiting or damaging them. While they can rely on many methods to evaluate development needs and their environmental impact, they need a tool that can describe the complexity of the problem, particularly on large geographic scales.

For this reason, a tool is needed to help them visualize the extent of the problem, and how project-related decisions impact sustainability. The proposed tool offers an adaptation of the "Environmental Diamond", a graphical display that summarizes the environmental "position" of a region with respect to others (Rogers et al., 1997). As such, the impact of any given project can be easily reflected across regions in a shared ecosystem.

Indicators and indices

In order to reflect those dual needs, this adaptation of the "Development Diamond" is based on two main components. The first component is a standard measure of economic development, and the second is a set of environmental indicators.

Measuring economic development allows planners to compare different regions and to ascertain human well-being. Two types of statistics can be considered; either the Gross Domestic Product (GDP) for smaller regions such as municipalities or counties, or the Human Development Index (HDI) for larger societal groups.

The measures evaluating environmental state allow the determination of relative environmental performance across a region. For planning purposes, it may be advisable that the regions considered have a shared ecosystem, to better reflect the cross-regional impact of resource allocation. For this reason, data collection would need to reflect the "natural boundaries" of a shared ecosystem, rather than "human defined", administrative borders. Such a "natural boundary" is best defined by watersheds, which are the optimal framework for "delineating the spatial distribution and linkages between physical processes and biological communities in an appropriate physical context" (Montgomery et al., 1995). In addition, by considering watersheds as a single regional entity, one places complex problems in an apolitical context, in which the interaction between the environment and human development across various regions is objectively defined.

In evaluating the environment across a watershed, two types of parameters can be considered; "State" parameters that evaluate existing conditions, and "Pressure" parameters that measure the extent of human activity (Ott, 1978). Those parameters are shown in Table 1.

Table 1. Issues, Pressures, and Available State Parameters

Issue	Pressure	State
Climate Change	GHG Emissions	Commercial Energy Use
Ozone Depletion	Hydrocarbon Emissions	
Toxic Contamination	POC Heavy Metal Emission	
Waste	Industrial and Municipal Waste	
Eutrophication	Nitrates Potassium Water Soil Emissions	DO, BOD
Water Resources	Demand/Use Intensity	Renewable Water Availability
Acidification	Specific Pollutants	CO ₂ , NO _x , SO ₂
Urban Air Quality	Haze NO _x SO _x	Coefficient of Haze, NO _x , SO ₂
Biodiversity	Land Use Threatened species	Land Use, Threatened species
Soil Degradation	Land Use Changes	Topsoil Loss
Coastal Zones	Emissions Oil spills, Depositions	N/A
Forest Resources	Use Intensity	
Fish Resources	Fish Catches	
Source: Hammond et al., 1995; Rogers et al., 1997.		

Defining the indices

From the parameters described above, a “comparative” index can then be developed that shows the relative environmental performance of different regions. The relative environmental performance is determined from a series of indices that are based on consensus recommendations issued by the United Nations Development Program. The indices considered were the ones that were found not to be correlated, following a key study that determined the variables to be selection and defined the optimal method to compute the four basic indicators of “Land”, “Water”, “Air”, and “Ecosystem” (Rogers et al., 1997). The components defined account for 64% of the total variation among all the original environment indicators previously suggested (Rogers et al., 1997).

It is important to note, however, that when considering environmental data, one should bear in mind the time-dependent nature of that information. In some regions, the current state of affairs may actually reflect environmental damage that has accumulated over the years. For this reason, planners need to consider those parameters in function of the duration of the project, or their impact over time. For example, a planner involved in the exploitation of tar sands would need to factor in the long-term impact over forested areas by considering a time horizon that reflects not merely the project’s lifetime, but the time necessary for the forest to recover.

Research method

In determining environmental performance, three steps need to be carried out. The first step is to define the individual indicators. The second step would then be to define region boundaries, based on a watershed framework. Following such framework, a third step would then be to collect the data within the watershed.

The focus in the present study is on the first step; defining each of the five parameters used in the analysis; “Land”, “Water”, “Air”, “Ecosystem”, and “Development”. Using those parameters, each

region's environmental performance can be compared relative to the others. The result is a plot, an "Environmental Diamond", similar to the World Bank's "Development Diamond".

From indices to indicators

The "Environmental Diamond" is a five-axis "spider", or "radar" chart, with an axis for each of the five parameters considered. The method focuses on evaluating five indicators that correspond each to an "issue"; four "environment" indicators, and one "development" indicator (Table 2). The indicators for "Land", "Water", "Air", and "Ecosystem" were selected to provide an extensive description of the state of the environment; their components account for 64% of the total variation among all original environment indicators suggested by other methods (Rogers et al., 1997).

Table 2. Main Indicators and Selected State Parameters.

Indicator	Parameter	Needed for:
Issue: Air Quality		
Specific Pollutants	CO ₂ Emissions (Tonne / Person)	Power Production Manufacturing
Industrial Emissions	Commercial Energy Use (Kg Oil / Pers.)	Power Production
Issue: Water Quality		
Pollutants in Urban Areas	Dissolved Oxygen (mg/l)	
Ambient Water Quality	Biological Oxygen Demand (mg/l)	
Issue: Land Quality		
Forestry	Forested Area (% of Total)	Urban development Mining
Urban Areas	Persons Living in Slums (% of Total)	Urban development
Rural Areas	Barren and Eroded Land Area (% of Total)	Agriculture Water Resources
	Annual Fertilizer Use (Kg/Ha)	Agriculture Water Resources Coastal Development
Issue: Ecosystem		
Biodiversity	Threatened species (% of Total)	Land Development
Pesticides	Pesticide Use (Kg/Ha)	Agriculture
Issue: Development		
Human Development	HDI or GDP	Land Development

Each parameter (i) is then expressed as a percentage of the average of parameters across the regions considered;

$$i = 100 \times \frac{i_{Region}}{i_{AVG}} \quad (1)$$

Where " i_{Region} ", represent the index measured in a given region, and " i_{AVG} " represents their average across the regions considered. For example, consider an evaluation across four distinct regions in a shared watershed. The parameter for "threatened species" for "region 1" would be equal to the "number of threatened species" in that region, divided by the "average number of threatened species" across the four regions in that watershed.

Then, the indicator (I) for each "issue" are each computed as averages of the values of the parameter (i) that define them;

$$I = \frac{\sum i}{n_i} \quad (2)$$

Where “ n_i ” represents the number of parameters related to each environmental issue. For example, the indicator for “Ecosystem” would be equal to the average of the values for the parameters for “threatened species” and “pesticide use”. An indicator is computed for each of “Land”, “Water”, “Air”, “Ecosystem”, and “Development”.

The “Land” Indicator

The “Land” Indicator is computed as the average of four parameters defining; “Forest Area (% of Total)”, “Persons in Slums (%)”, “Barren and Eroded Land Area (% of Total)”, and “Annual Fertilizer Use (Kg/Ha)”. It should be noted that the parameter for “Persons in Slums (%)”, while adapted to developing countries, may have to be redefined for some developed countries.

In considering the data, it should be noted that all estimates of “Barren and Eroded Land Area” are not equal. This is because evaluation methods may overstate the actual extent of the problem in some areas, and do not always distinguish between reversible and irreversible damage. In modern days, it appears that only 0.5% of recent human-induced soil degradation is irreversible (Olderman, 1992).

However, in some regions, the data appears to reflect historic trends. This is critical in zones of ancient settlement, where the impact of current projects, through “Annual Fertilizer Use”, is adding to the effect of ancient activity. This is the case of the once “Fertile Crescent” in the Middle East, where the first farmers were frequently acting “as a parasite on soil” and exacerbated the region’s desertification by clear-cutting trees and reclaiming swamp areas (Hyams, 1952). The Fertile Crescent’s fragile soils could not resist those early trials and errors, and as large areas were irremediably damaged, the destructive effects of land degradation accumulated. Any projects carried out in such areas may need to take into account how the effect of ill-adapted agricultural practices were magnified by deforestation, as well as once useful innovations such as terracing and ploughing aggravated land degradation.

The “Water” Indicator

The “water” Indicator is computed as the average of three parameters defining; “Dissolved Oxygen / DO (mg/L)”, “Emissions of ‘Biologic Oxygen Demand’ (mg/l)”, and “Water Availability (m^3 /Person)”.

Earlier work also considered “Fecal Coliform Counts”, such as E. Coli, and referred to the “Proportion of Human Population with Access to Safe Water” rather than “Water Availability” (Rogers et al., 1997).

However, cases published data on “Fecal Coliform Counts” may not always be reliable, and it was decided to disregard this parameter rather than risk “skewing” the indicator. In addition, in regions of water scarcity, most of the urban population may only have nominal access to improved water sources; the pipes may be there, but not the freshwater. For this reason, measures of “Per Capita Freshwater Availability” can be far more reliable, even if they do not always reflect a region’s dependence on outside sources. The value will have to be normalised with respect to the “Water Stress Index” benchmark (Falkenmark and Widstrand, 1992). The normalisation was adjusted so that a value of “0” corresponded to the freshwater level of 1,700 m^3 /Person defined by the index, and “100” meant no freshwater.

The “Air” Indicator

The “Air” Indicator is computed as the average of two parameters defining; “CO₂ Emissions (Tonne/Person)”, and “Commercial Energy Use (Kg Oil /Person)”.

Much of the aspect of air quality can be inferred from “Commercial Energy Consumption”, since oil and coal power plants still account for most of the electricity produced, and thus for most of the pollutants (IPCC, 2001). This parameter was found to correlate with the emissions of nitrous oxides (NO_x) and sulphur dioxide (SO₂) (Rogers et al., 1997). Since data on emissions of carbon dioxide (CO₂) is not directly related to “Commercial Energy Consumption”. Since the statistic is expressed as a rate, in kg/person, lower rates do not necessarily mean a lower impact, since demographic growth can cause an increase in carbon dioxide emissions.

The “Ecosystem” Indicator

One way to document human impact on ecosystems is to consider “canaries in the coal mine”, or the proportion of species in each region that are threatened by extinction. An additional parameter that appears to reflect human pressure on ecosystems is the amount of pesticides that are used over a given area. There are indices that also rely on measure of radioactivity effects (Inhaber, 1976), but this may be an issue that is specific to some industrialized regions.

For this reason the “Ecosystem” Indicator is computed as the average of two parameters, “Pesticide Use (Kg/Ha)”, and the “Number of Threatened Species (per 1,000 Inhabitants)”.

By considering “threatened species” rather than “extinct species”, this index does not always reflect the historic impact of human activity. This may be an issue for projects with a longer term outlook in fragile environment, where planners would need to take into account species extinctions. The cumulative human impact may indeed be far more significant than recent data may suggest. As an example, when data on fish populations factors in the centuries of fishing, it shows that current fisheries are unsustainable (Pauli and Palomares, 2005). Current technology fixes appears to be merely postponing the inevitable by displacing exploitation to less sustainable species rather than solving the over-fishing problem (Morato et al., 2006). However, since reliable forensic data of past ecosystem impact remains hard to obtain, the historic of human impact will remain.

The Development Indicator

In order to provide a proper evaluation of the economy, there are two types of “Development” Indicators that reflect wealth, that can be considered. Such indicators reflect the ability to cope with environmental changes, since financial strength is can serve as “a rough indicator of the ability to cope”, even if poverty cannot be “considered synonymous with vulnerability”. The importance of wealth has been demonstrated in many cases where it allowed inhabitants to better manage environmental hazards (Smit et al., 2001).

For smaller regions such as municipalities or counties, it may be simpler to consider the Gross Domestic Product (GDP). For larger regions such as cities, provinces or countries, the Human Development Index (HDI) offers a more comprehensive representation of the status of the economy.

The HDI is a composite index measuring average achievement in three basic dimensions of human development; a long and healthy life, knowledge, and a decent standard of living (UNDP, 2003). It should be noted that, since the calculation of HDI is an evolving methodology, comparisons between countries can only be made within a given year; only then would the index be based on similar data sources.

The “Development Diamond”

Once the five indicators have been determined, the “Development Diamond” can then be traced on the “spider” or “radar” chart. Except for the HDI index, it is considered that the smaller the value, the better the score. For indicators in which a large value represents a positive environmental variable, the parameter considered was “reversed”; for example, the parameter for “Forested Area” was computed to represent “Deforested Area”.

For illustrative purposes, the figure below is developed based on four regions in a shared watershed. The combined plots show the “footprint” of each individual region, relative to the average within the watershed.

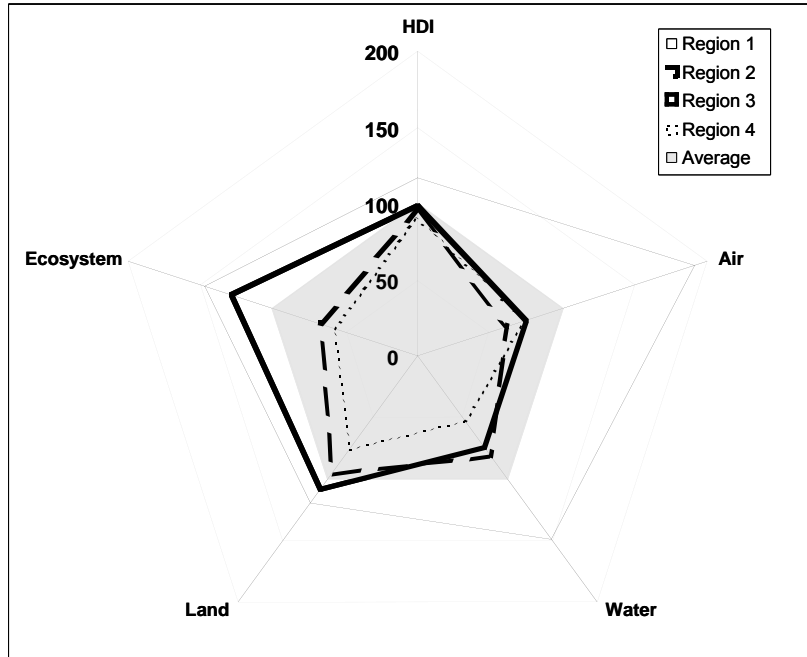


Fig. 1. Example of a Computed “Environmental Diamond”

From the “Environmental Diamond”, each region’s relative impact can be ascertained at a glance. Understanding the relative environmental impact of each region with respect to one another simply becomes a matter of comparing “footprints”. In addition, the relative environmental cost of economic development can be intuitively understood, thanks to the inclusion of an economic development parameter in the “Environmental Diamond”.

As shown in this example, the plot shows “Region 1” to be the local economic powerhouse, with others clustered behind it. The plot also shows how this region has the highest relative environmental impact, and will likely face clear limitations to its future development, as common resources become increasingly taxed by the expansion of neighbouring economies. The plot shows clearly that further development in that region requires taking into account issues of air pollution, water scarcity and quality, and ecosystem management. However, it also hints at better land management practices.

The example also shows that the other regions have a lesser impact, but appear no less limited. The future economic development of “Region 2” may be greatly helped by better land management, and any project considered in that region may need to take this into account. A similar issue faces “Region 4”, in addition to increased air pollution problems. In “Region 3”, economic growth appears to be overtaxing the ecosystem and the land, indicating that any development projects need to take into account the need for better conservation and land management.

Research Objectives:

- Review previously defined parameters,
- Identify any limitations of existing parameters,
- Define alternative parameters that can be used, and how they can be measured.

Discussion and conclusions

This implementation of the “Environmental Diamond” is a comparison tool that is easy to use and visualize, and that could prove to be a useful tool for planners when they address policy makers. The plot appears as an “environmental radar”, showing objective measures of development and environmental impact in an intuitive format. Because of its reliance on objectively-defined units, the method can serve to create a common and objectively-defined framework for discussion among actors who may often have various or even divergent interests or outlooks. Any divergence then becomes technical, focused on either parameter type or data availability. In addition, since it makes the impact of complex, interrelated effects readily “visible”, the “Environmental Diamond” can become a valuable tool to policy makers and planners.

For planners, the addition of economic parameters such as HDI or GDP illustrates cost-benefit considerations. This would allow planners to compare the relative merits of decisions and to set priorities that balance the need for optimal economic return with the necessity of sustainable management of a shared environment.

For policy makers, the graph generated shows clearly the *relative* impact of a project across regions in a shared ecosystem, and can help educate policy makers as to the impact for a given project, or the necessity for its execution in a given region.

Key Lessons Learned:

- Regions can best be defined by watersheds, since this would frame the discussion in an objectively defined context.
- Reliance on objectively defined parameters will then provide a common framework to various decision makers, and thus move discussions away from policy choices, towards parameter relevance or data availability.
- The choice of parameters considered could be adjusted to reflect what can be reliably measured.
- Since the benchmark index is the average of the measure indices, the method provides a measure of *relative* environmental performance across regions.

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Author's Biography



George J. Nasr researches sustainable development by focusing on a multidisciplinary approach where technical topics of hydrology, climatology, ecology, engineering, and economics intersect with political and social factors. Very often, societal, political, and historical considerations prove to be the determinant parameters in sustainable development issues, in which case a purely engineering approach would be ill-adapted. He applies this approach in his upcoming book, where the crisis in the Middle-East is approached from the perspective of Sustainable Development, beyond the ongoing struggle over water resources and oil.