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Developing Indicators for Sustainable Cities

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If our cities are going to become more sustainable -- more liveable, and built and maintained in harmony with natural systems and the hinterland -- we will have to revolutionize the way we think about them and manage them This process will require making five major changes

First, we will have to recognize the problems that accompany rapid growth in urban populations and in the creation of new, large cities, particularly in the developing world, while continuing to understand that cities can be great centers of economic and social opportunity

Second, we will need to identify the environmental problems that damage health, limit economic opportunities, and reduce the quality of life in our cities

Third, we will need to develop a conceptual approach that helps us understand and manage these environmental problems while taking into consideration the important objectives of economic production, social development and equity, and resource conservation

Fourth, we will need to initiate new strategies and mechanisms for bringing the city and its surrounding communities together to address these problems

Fifth, we will need to develop and use statistics and other information that help us identify critical issues, fashion goals, set targets, and measure progress In short, we need to develop indicators

Revolutionizing the way we think about cities and approach these problems is already underway In the process of developing Agenda 21 -- the blueprint for strategies and actions that resulted from the United Nations Conference on Environment and Development (UNCED) in Rio -- the International Council for Local Environmental Initiatives (ICLEI) and many other organizations proposed that cities and communities around the world initiate their own strategies and action plans Out of UNCED came a decision that all major cities would develop their own Local Agenda 21 Plans by 1996 During the recent five year review of Agenda 21, a worldwide survey found that Local Agenda 21 planning is underway in more than 1800 municipalities in 64 countries (ICLEI, 1997) In addition, the Asia-Pacific Economic Commission (APEC) at its recent meeting in Singapore agreed that all APEC countries would initiate national programs for Local Agenda 21 plans by the year 2000.

One of the important products to come out of the work of ICLEI and its many collaborators is the development of a Local Agenda 21 Planning Guide (ICLEI, 1996) The Guide provides information on a process for developing action plans to address the

complex social, economic, and environmental problems of cities The basic elements are

- a community vision, developed by the stakeholders, including a consensus position on current problems and opportunities,
- strategic goals for each problem area, based on the vision,
- specific targets to be achieved in meeting each goal,
- identified strategies and programs for achieving these goals,
- a description of key partnerships to be established for implementation, including linkages with existing planning processes, and
- a framework for periodic evaluation of progress

For a community to follow this framework, or any other strategic planning framework for sustainable development, information and indicators will be essential tools

In the rest of this paper I would like to build on the work of ICLEI and the Local Agenda 21 Planning Guide and suggest some tools and techniques that may help analysts identify and develop indicators that can be used to help establish goals and assess progress

Much of this discussion will focus directly on the environmental dimensions of sustainable development, but these are always linked to the social and economic systems that are so important and of such immediate concern to citizens and city leaders

Five techniques for developing and using indicators are described below a typology of urban environmental problems, which can be used by analysts to link environmental problems to social and economic goals, a list of the characteristics of good indicators, which can be used to test how well we are doing to achieve the best measurements possible, a framework for developing urban environmental indicators, a core list of environmental indicators, which can provide a starting point for urban planners in developing their own indicators, and ideas and suggestions for environmental reporting that makes use of indicators and is needed to assess the progress made toward sustainability

1. Typology of Urban Environmental Problems

Planning and the implementation of plans are often presented as a cycle and rightly so A plan is developed, goals and targets established, partnerships secured, projects and programs developed and implemented, results measured and reported, lessons learned, and new plans and strategies developed The cycle continues

A typology of urban environmental problems based on two characteristics can be used to bring analytical rigor to the process the spatial scale of environmental problems and the type of impact the problem causes (WRI, 1993)

Cities generate environmental problems over a wide range of spatial units As center of population, production, and transportation, as consumers of natural resources that are obtained from outside the city, and as generators of waste that is disposed both inside and outside the city, cities cause environmental problems at the level of the household or workplace, the community, the metropolitan area, the region, and the globe as a whole Table 1 provides examples of the kinds of problems caused by cities at different spatial scales The first column indicates the spatial scale of the problem The second column indicates the pressures that give rise to the specific problems The third column indicates the effect of a pressure on the condition of the environment

Environmental problems have different kinds of impacts on society Environmental problems may impair human health, cause economic and other welfare losses, or damage the ecosystems on which human life ultimately depends Most environmental problems entail all three kinds of impacts However, impacts can be direct or indirect For example, outdoor air pollution at the metropolitan level has a direct impact on human health, increasing the incidence of respiratory disease Its impact on the economy is mainly indirect since economic costs result largely from impacts on human health Column four of Table 1 indicates major direct impacts

The horizontal organization of the table is meant to suggest that cause-effect relationships cluster within spatial units For example, the domestic use of low-quality fuels probably has its most serious effects on air quality and on human health within the home However, it should be kept in mind that pressures arising at one level will have effects on environmental conditions at other levels For example, domestic fuel consumption also contributes to ambient air pollution

Spatial scale and the type of direct impact are linked in that health impacts tend to predominate at the household, community, and metropolitan levels, economic and ecological impacts are increasingly important at the regional, continental, and global levels

Note that this kind of matrix, in addition to providing a starting point for a city-wide

planning effort, can be used by communities and neighborhoods to identify critical issues and to better understand that many of these issues have impacts on a larger scale

This typology has important implications for the analysis to follow First, it shows that urban problems -- air and water pollution, exposure to toxics, solid waste dumping, and natural hazards -- are experienced as "people" problems with direct impacts on human health In contrast, regional or global problems tend to have greater direct impacts on the economy and on ecological systems

Table 1. Spatial Scale of Urban Environmental Problems

Scale	Pressure	Condition	Impact[1]
Household/ Workplace	Use of low quality fuels (heating, cooking, production), use of toxic substances, smoking, poor ventilation	Indoor air pollution	Hlth
	Lack of piped water connections	Poor personal and food hygiene	Hlth
	Poor hygiene practices	Food contamination	Hlth
	Crowding (persons per room)	Transmission of communicable diseases	Hlth
	Lack of sanitation (lack of pit latrines)	Accumulation of excreta in soils and water	Hlth
Community/ Neighborhood	Lack of sanitation (lack of communal latrines or water-born systems)	Accumulation of excreta in soils and water	Hlth
	Lack of piped water	Unsafe drinking water, unsanitary food preparation	Hlth
	Lack of trash collection/sanitary disposal	Solid waste accumulation	Hlth
	Industrial plants near residential zones	Toxic waste exposure	Hlth
	Construction on slopes, stripping of vegetation, poor drainage	Natural disasters (floods, landslides, etc)	Hlth, Ecn
	Crowding (persons per hectare)	Transmission of communicable diseases	Hlth

Scale	Pressure	Condition	Impact[1]
Metropolitan Area	Fossil fuel consumption (by households, transportation, industry), use of low quality fuels, poor transportation/land-use planning, over-reliance on private automobiles	Outdoor air pollution	Hlth
	Lack of sanitation (water-born systems)	Accumulation of excreta in soils and water	Hlth
	Lack of sewage treatment, industrial wastes, lack of sanitary solid waste disposal	Water pollution	Hlth
	Over-reliance on private motor vehicles, poor transportation/land-use planning	Traffic congestion, lack of open space	Ecn, Hlth
	Urban encroachment	Loss of natural areas (wetlands, coastal zones, forests, etc), loss of cropland	Ecl, Ecn
	Increasing demand for land and water	Increasing marginal cost of water, land, sanitation, and d waste disposal	Ecn
	Lack of land-use planning, crowding	Construction on marginal, hazard-prone lands	Hlth, Ecn
Region	Lack of sewage treatment, industrial wastes	Water pollution, coastal zone damage	Hlth, Ecn, Ecl
	Use of fossil fuels, Acid rain and ozone	Damage to forests and croplands	Ecl, Ecn
	Deforestation	Downstream flooding, siltation	Hlth, Ecn, Ecl
Continent/ Globe	Use of fossil fuels and CFCs	Global warming	Ecl
	Use of CFCs	Damage to ozone layer	Ecl

[1] Hlth = Health, Ecn = Economic, Ecl = Ecological

Second, the spatial analysis indicates that pressures within cities cause serious environmental problems whose impact is felt mostly within the cities themselves Pollution of water with domestic and industrial wastes, for example, can arise mostly from activities within the metropolitan area while most damages are felt locally, chiefly, through the health impacts of contaminated fresh water supplies and food This means that cities are both responsible for the state of their own environments and could reap considerable benefits from changing polluting behaviors

Third, in some cases, urban problems are caused by the same activities that cause regional or global problems Fossil fuel consumption causes air pollution that damages human health within the metropolitan areas But it also causes upstream damages in areas of exploration and mining and downstream damages in the form of acid rain and global warming This relationship suggests that planners can best address some major regional and global problems by better addressing local urban concerns It also suggests that, for some issues, a city's energies mobilized to solve its own problems can have benefits beyond the city

2. Characteristics of Good Indicators

Indicators can be defined as statistics that tell us whether we are making progress towards recognized goals and targets Unfortunately, goals are often stated in ways that are not measurable One of the challenges in the participatory planning process that cities are going through is to develop goals and objectives that reflect the values and concerns of the public at a given time and can be stated in such a way that quantitative measurements can be developed Setting goals and developing indicators is an iterative process that requires ongoing review and negotiation goals are stated, subgoals or measurable objectives are identified, databases are examined to see what statistics are available and their quality, indicators are chosen, measurable objectives may be slightly modified based on available indicators, and so forth The result is a balance between what measures are desired and what data are available or could be developed within the resources of the community

Listed below are seven tests that we have found essential for developing and selecting indicators once the overall goals are established

- Time Series Data should be available from ongoing monitoring programs or from repeatable studies to support comparisons over time

- Statistical Quality Data should be based on the best monitoring practices available and should be carefully documented and the documentation made publicly available

- Spatial Scale Data should cover the spatial units needed to properly analyze specific problems For urban indicators, the most appropriate spatial units are the household and the workplace, the neighborhood or community, the city proper, and the metropolitan area Because low-income neighborhoods tend to suffer disproportionate impacts, disaggregating data for marginal neighborhoods as a group from the city as a whole may help clarify analysis A geographic information system or GIS can be developed and used to analyze units at these scales The results can be displayed as mapped indicators

- Analytic Significance Data should help the user to understand causal relationships between different aspects of an environmental problem They should also help the user understand environmental problems in relation to performance goals or targets For example, targets, based on sound scientific and technical information, help citizens understand that their behaviors -- vehicle use, industrial production, etc -- influence the health and welfare of the community

- Frequency of Data Collection and Reporting The reporting of data should support the needs of policy makers and the assessment of plans and implementation Many statistics are compiled to meet the needs of more than one plan and purpose and this must be taken into consideration For example, local air quality indexes, aggregating different air quality parameters into one indicator or index, should be reported on a daily or hourly basis to achieve day-to-day air quality management goals or to modify behavior in appropriate ways, quarterly or annual summaries may be sufficient for long-term investment and planning decisions

- Feasibility Collection of environmental data and reporting of environmental indicators must be cost effective and technically feasible Monitoring and the reporting and analysis of data should be built into all sustainable development action plans

- Selectivity Indicators should be limited to the minimum number necessary to convey significant information about environmental problems and policy goals Limitation of the number of reported indicators will help the public and policymakers focus on the most serious environmental problems and help build support for environmental and development goals Indexes, or aggregations of indicators, may help reduce the number of reported environmental indicators An index of local air quality, for example, is often easier to communicate to the public than each individual air pollutant

3. Framework for Developing City Environmental Indicators

A conceptual framework for environmental problems can help guide the selection of indicators suitable for decisionmaking One such framework is the Pressure-State-Response framework, first developed in Canada by Tony Friend and David Rapport and later applied successfully by the Organization for Economic Cooperation and Development in its reports on the State of Environment and Environmental Indicators (OECD, 1995)

More recently, this framework has been expanded and enhanced by the U S Environmental Protection Agency to highlight the linkage between pressure, state, response, and impacts (USEPA, 1995)

The framework, outlined in Table 2, divides environmental problems into four general categories pressures on the environment, state of or condition of the environment, impacts or damages, and responses These categories are arrayed along the top of Table 2 The ordering of the categories suggests a flow of causation Along the left-hand border are components of the urban environment These components were selected to cover all major urban environmental problems They could be modified as needed to show more detail This framework will be used later to identify and classify a core set of urban environmental indicators

In using this framework, it should be kept in mind that causation between the different parts of an environmental problem follow complex pathways that are often poorly understood and difficult to quantify For example, one effect can have many causes, while one cause can contribute to many effects

Table 2. Framework for Developing Urban Environmental Indicators

	Indicator Categories			
	Pressures	State	Impacts	Response
Components of the Urban Environment				
Population and Health				
Atmosphere				
Water				
Land				
Economy				
Natural Disasters				

Environmental Pressures Environmental pressures include both social pressures and natural fluctuations that disturb the environment from baseline conditions Social pressures can be divided into underlying pressures (such as population growth and level or type of economic activity) and proximate pressures (such as raw sewage discharges or emissions of air pollutants)

Indicators of pressures are essential to help policymakers and the public understand and address environmental problems pressures are the basic causes of environmental problems, therefore, they are often the most economically efficient place to attack environmental problems that show up later as environmental impacts In developing countries with experience in the planning and analysis of economic development, information on pressures is often easier to obtain than other environmental information

To understand the problems of particular cities, it is important to note that different local environments are likely to experience different kinds of human pressures (for example, upland regions are likely to experience greater pressures from fuel consumption because of inefficient combustion than lowland regions) and that different ecosystems will respond in different ways to the same types of human pressures (for example, sunny regions will generate more ozone for a given level of nitrous oxide and hydrocarbon\emissions than cloudy regions)

Environmental States The environment consists of the natural environment more or less modified by society Ultimately, the natural environment is society's life support system It is commonly divided between natural resources and the three media air, water, and land State-of-the-environment indicators include depletion of natural resource and concentrations of wastes in water, air, and on land Because society may heavily modify the natural environment with roads and buildings, state of the environment indicators also include such measures as congestion or housing quality

Frequently, standards reflecting important social values are set for environmental indicators For example, the World Health Organization and other national and international bodies have set maximum concentration standards for many pollutants in the three media and in food Although state-of-the-environment indicators are important in themselves, they are most useful to policymakers and the public when supplemented with indicators of pressures and impacts that show the causes and effects of changes in the state

Environmental Impacts Environmental impacts on society can arise from exposure to pollutants, increased or new exposure to natural pathogens, disruptions in food supply or increased risk from other manmade or natural hazards Indicators would include incidence of environmentally related diseases or injury and death rates from hazards Environmental health impacts are often difficult to quantify because of insufficient knowledge of cause-effect (dose-response) relationships As a result, health impacts are described as risks With sufficient knowledge, they are expressed as a ratio between a change in the state of the environment and a change in morbidity or mortality

Direct economic losses from changes in environmental conditions can be estimated by estimating the costs from lost productivity due to health impacts, reduction in

agricultural productivity from pollution, depletion of natural resources, time lost to congestion, and other causes Economic losses are especially difficult to calculate when the underlying biological or physical impacts of changes in environmental quality cannot be accurately quantified

Other socioeconomic impacts, often highly subjective and difficult to quantify, include loss of aesthetic, recreational, or cultural amenities

Society may also suffer welfare losses through damage to ecological life-support systems Such welfare losses are especially difficult to quantify because they involve non-marketed goods and services that society takes for granted (for example, the environment's capacity to assimilate wastes) or because the effects of losing these goods and services would only be felt by future generations (for example, mining groundwater reserves)

Responses Society may respond to environmental impacts by reducing underlying or proximate pressures (for example, by installing sewer lines to remove human wastes from inhabited areas), by improving the state of the environment (for example, by cleaning up solid or hazardous waste sites), or by taking defensive action against impacts (for example, boiling water to kill microbes in drinking water) Response indicators, including measures of public opinion, environmental expenditures, environmental licensing and other regulatory actions, and protection and clean-up efforts, serve to measure levels of effort

Another category of indicator is performance, which is a measure of achievement It therefore can be used to measure to what extent a city or parts of the city are attaining the targets or goals they set for themselves These can be expressed in terms of percent attainment of a pressure, state, impact, or response indicator For example, a city wants to reduce the amount of solid waste generated by 50% The performance indicator would be the extent to which that target was met measured in percentage terms

This framework provides a means of organizing information on the environment in ways useful for decisionmakers and the public In particular, it provides a way to show cause-effect relationships that link pressures to the state of the environment, the state of the environment to impacts, impacts to responses, and responses to performance As such, the framework helps policymakers and the public to see environmental problems as interconnected wholes and to design and implement policies that address problems at the appropriate level The framework can also be used to identify areas in which new data and indicators need to be developed

4. Core Set of Urban Environmental Indicators

In this section we have compiled a core set of urban environmental indicators, identified with particular reference to the needs of developing world cities See Table 3 The core list focuses on impacts at the spatial scale of the community, the city proper, and the metropolitan area It is meant to cover the full range of possible ecozone types and income levels found in developing world cities It includes indicators of pressure, state, impact, and response

The list is meant to be the minimum length necessary to capture both likely significant problems in all developing world cities and basic cause-effect relationships More detailed information would be necessary for full-scale risk assessments and for investment decisions For some subjects, projections could be added

Local Agenda 21 teams may choose to compare their lists of goals and indicators with this core list to identify gaps and commonalities and differences

Table 3. Core Set of City Environmental Indicators

I Population and Health

A Demography
* Total Urban Population (P)[1]
* Annual Population Growth Rate (including natural growth and migration) (P)

B Population Density
* Total Population/Total Built-Up Area (P)

C Housing
* Persons/Dwelling Unit or Room (P)
* Total Number of Marginal Dwelling Units (characterized by lack of water and sanitation facilities and constructed with inadequate or dangerous building materials, marginal neighborhoods are those with a preponderance of such dwelling units) (P)
* Population Living in Marginal Dwelling Units (P)

D Health Impacts
* Life Expectancy at Birth (I)
* Infant and Child Mortality Rates (I)
* Mortality and Morbidity Rates for Environmentally-Related Diseases (I)

E Health State of the Environment
* Blood Lead levels (at risk populations) (S)
* Lead levels in Air, Food, and Water (at risk populations) (S)
* Other Toxic and Microbiological Contamination of Food (at risk population) (S)

II Atmosphere

A Outdoor Urban Air Quality
* Emissions of Air Pollutants Sulphur Dioxide, Nitrogen Oxides, Total Suspended Particulates, Carbon Monoxide, Volatile Organic Compounds, Lead, and Other Toxics (calculated for transportation, industrial, commercial, and domestic sectors by fuel type) (P)
* Concentrations of Air Pollutants Sulphur Dioxide, Nitrogen Oxides, Total Suspended Particulates, Carbon Monoxide, Volatile Organic Compounds, Lead, and Other Toxics (S)

III Water

A Water Resources and Use
* Water Supply and Demand (by volume of water withdrawal per day for domestic and industrial uses) (P)

B Domestic Water Supply and Sewerage
1 Water Supply Coverage
* Percentage of Dwelling Units, Households, or Population with Piped Water Connections, Communal Standpipe, and Other Water Sources (S)
* Percentage Water Loss from the Distribution System per Day (P)
* Quality of Water Consumed by City Residents (S)
2 Sanitation Coverage
* Percentage of Population with Sewer Connections, Communal Sanitation, and On-Site Sanitation (S)

C Wastewater Treatment
1 Domestic Treatment
* Percent of Population Served by Sewage Treatment (by kind of treatment, primary, secondary, tertiary, and no treatment) (R)
2 Industrial Treatment
* Percent of Total Industrial Discharges Treated (R)

D Downstream Water Quality Rivers, Streams, and Coastal Waters
* Pollutant Discharges Biochemical Oxygen Demand, Total Suspended Solids, Phosphorus, Organic Nitrogen, and Other Chemicals and Metals (P)
* Water Quality Total Suspended Solids, Biochemical Oxygen Demand, Dissolved Oxygen, Phosphates, Organic Nitrogen, Coliforms, Parasites, pH, Metals, Organic Micropollutants, and Pesticides (S)

IV Land

A Urbanization
* Land Area by Uses (agricultural, forest, vegetated, residential, commercial, industrial, vacant, transportation, and communications) (S)
* Area of Marginal Neighborhoods (S)

B Solid and Hazardous Wastes
1 Waste Generation
* Waste Generation (including municipal, commercial, and industrial solid and hazardous waste generated) (P)
2 Waste Collection
* Volume and Percentage of Municipal Waste Collected Daily (R)
* Percent Municipal Solid Waste Recovered (through recycling, scavenging, and conversion) (R)
* Total Commercial Solid Waste Collected (P)
* Total Industrial Solid Waste and Hazardous Waste Collected (P)
3 Waste Disposal
* Amount of Municipal Solid Wastes Disposed (by the following types open dumps, sanitary land fill, municipal dump site, and incineration) (S)

* Amount of Industrial Solid and Hazardous Waste Disposed (by the following types. sanitary land fill, municipal dump site, incineration, treatment, containment, and open dumps) (S)
* Population Scavenging at Dumpsites (S)

V Economy

A Level of Economic Activity
* Per Capita Income (P)

B Transportation
* Number of Motor Vehicles (by vehicle type cars, diesel buses and trucks, other buses and trucks, two and three-wheel vehicles, and bicycles) (P)
* Kilometers per Vehicle per Day (by vehicle type cars, diesel buses and trucks, other buses and trucks, two and three-wheel vehicles, and bicycles) (P)
* Average Commuting Time to Work (by private motor vehicle, by public transportation, and by other means) (I)

C Industry
* SIC Classification of Industries and Annual Production (provides the basis of a rapid pollution inventory assessment to identify the amountt of production from highly-polluting industries) (P)

D Energy
* Total Fuel Consumption (by type fuel oil, gasoline, diesel, kerosene, LPG, natural gas, coal gas, coal, soft coke, charcoal, firewood, and other) (P)
* Fuel Quality (by lead content of gasoline, sulphur content of coal, and sulphur content of diesel) (P)

VI Natural Disasters

A Built-Up Area and Population on Hazard-Prone Land (risk of volcanic activity, seismic activity, flooding, storms and typhoons, landslides and mudslides, and other) (S)

5. Indicators and Environmental Reporting Mechanisms

The purpose of developing urban environmental indicators is to help policymakers and the public understand and address environmental problems within a sustainable development context A key element in this process is the communication of indicators and their interpretation on a periodic, timely, and authoritative basis in reports that need to be useful to and useable by the public In addition, or in collaboration with the development of Local Agenda 21 report cards, there is a need for a reporting mechanism that meets the following objectives

- Help educate the public and decisionmakers about environmental issues, helping to identify major problems, cause-effect relationships, stakeholders, and necessary responses

- Help strengthen the capacity of local institutions for data collection and analysis and expose gaps in data availability and quality Publishing the reports on a periodic basis would lend continuity to data collection and analysis

- Raise public consciousness about urban environmental problems and increase the demand for environmental improvements It is surprising that in the United States, for example, environmental reporting is mandated by law at the national level, but relatively few state and local governments have developed state-of-environment reporting This may help explain the lack of progress in addressing local land-use problems in the country

- Create a more receptive audience for management strategies

- Raise the profile of urban environmental and sustainable development issues on the international development agenda and attract resources for urban environmental activities in cities that prepare them

A typical urban environmental report could consist of three sections, described here in reverse order of how they might actually appear First, the report would include tables of time-series indicators based on the core indicator list described above and including additional indicators that reflect other local priorities Second, the report would include an analysis of environmental conditions and trends based on the data tables Third, the report might include a special section on each issue that highlights specific local problems and successful management strategies The report would be reader-friendly, targeted at both the general public and at local decisionmakers Such a report would be widely distributed to local decisionmakers, the media, local and national NGOs, other cities in the country, and the public

Indicators are an essential tool for making cities more liveable and sustainable They are key statistics that can help us plan the future and continually assess progress toward agreed-upon goals Building better indictors and using them will help us make better decisions It is an investment worth making

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