Abstract: *This study describes a framework for developing urban environmental indicators. Several existing indicator frameworks are discussed and evaluated. Criteria are identified in order to guide the development of indicators that reflect real trends in underlying conditions, are analytically sound, and are directly related to the spatial and temporal scales, as well as the audience or policy purposes for which they are to be used. Several city indicators and "sustainable city" projects are compared in order to identify key issues in applying indicators to a city environment. Drawing on this extensive body of indicator and urban environment work, three model indicators were defined and applied to Providence.*

The indicators applied to Providence place less emphasis on addressing one audience or program area, and more emphasis on capturing a subset of measures of the physical landscape, human health, and the distribution of potentially dangerous commercial activities in an urban area. Impervious surface was measured as "percent of land area" and "acres per capita as functions of the distance from downtown Providence over the last ten years". It was found that Providence has indeed "sprawled" during that period, as the natural landscape away from the city has been converted to impervious surface at a high rate. The summertime effects of ozone on human health were measured by the average number of cases of respiratory or cardiovascular distress admitted to hospitals in Providence. A short period of available data limits the ability to draw conclusions about trends, but suggests that the rates have been declining in recent years, and the indicator should continue to be followed. The relationship between socio-economic variables and the distribution of potential sources of air toxics were used as a measure of environmental justice within the city. It was found that the number of sites per square mile was significantly higher in areas of the city below the median income and in areas where the number of non-english speaking people is above the citywide median.

INTRODUCTION

This study focuses on the development and application of environmental indicators to an urban setting in Providence, Rhode Island. Urban areas are particularly in need of environmental monitoring and indicators. The interactions of dense populations of people, extensively built landscapes, and high volumes of resource movement, create intense pressures on a city's natural resources and on its inhabitants. The complex relationship between the human, built and natural elements of a city make the identification of environmental attributes and the assessment of environmental quality a difficult task.

Perhaps the most difficult and essential step in working towards a conceptual framework from which to form a set of urban environmental indicators, is describing the *composition* of the urban environment. Cities have been described metaphorically as "organisms", comprised of fundamental *anatomy* (physical structure) that serves as support and conduit for the *physiology* (circulation and flow) of the city (Douglas 1983). A third element, the *human community* that occupies this physical setting and interacts with both the anatomy and the physiology of the city (White 1994;Dentler 1977), completes a popular conception of the fundamentals of the urban dynamic. These three primary elements- anatomy, physiology and the human community- are crucial to looking at urban environmental quality because each exhibits distinctive characteristics when applied to the analysis of an urban area. These three elements form the basis for the indicators applied here to Providence, Rhode Island.

The anatomy or physical landscape of the urban area is distinctive in relation to other areas due to its highly engineered character. The high degree of built form that has come to define the urban area severely limits the extent of natural elements that are abundant in other areas. While certain natural areas exist in the city, urban "ecology" has traditionally been dominated by the inert landscape of constructed nature (Hough 1995). While in many instances, urban nature has the potential to provide diverse benefits ranging from the purely aesthetic to purely "ecological", the parks, gardens, open spaces and street trees that have become valuable symbols of nature in the metropolis (Dwyer 1994) exist in distinct separation from the physical system of the city, predominated by pavement and built structure. Thus, while these resources have been considered with respect to the numerous aesthetic and "quality of life" benefits they provide to human residents, the task of considering natural elements and natural cycles such as buffering heat, noise and run-off within an urban area has been a difficult one historically (Dentler 1977; Hawley 1950).

Two major defining characteristics of a city, an extensively built landscape, and high volumes of resource consumption and waste generation (i.e. industry), have a significant impact on a third defining element, large populations of people. As mentioned previously, the infrastructure of a city supports activities which in turn, produce physical and chemical stresses on the individuals who inhabit densely populated communities sharing the urban space. The effects of these stresses have changed over time, especially since industrialization at which point urban areas are said to have begun evolving in an "energy-profligate land-use pattern" (White 1994). It is the effects on people in relation to the city's *physiology* that has been the prevailing focus of urban environmental study (Haughton 1994). Thus concerns of certain nuisances and health risks such as noise and air pollution have received greater recognition than concerns of the biological diversity of city ecosystems for example. Even without grossly generalizing the relative emphases or the relative values of the human and the "bio-physical" elements, it is apparent that a tension exists between the two when it comes to assessing the quality of the urban environment.

Focusing on cities in an international context as it approached the second Conference on Human Settlements, the United Nations acknowledged this tension and sought to bring together the definitions of "habitat" as both a human settlement and as an ecosystem. In contrasting the work of the first UN Conference on Human Settlements (held in Vancouver,1976) and that of the UN Conference on Environment and Development (held in Rio de Janeiro, 1992), it has been argued by participants and various commentators that "Vancouver focused on settlements without nature and that Rio examined nature without people" (Cohen 1996).

In anticipation of the June 1996 United Nations Conference on Human Settlements, the World Resources Institute (WRI) identified three priority areas for action on the urban environment: water supply and water resource management, solid waste management, and air pollution (WRI 1996). Although their report is intended to represent the issues most urgent in the urban areas of *developing* nations, it includes cities from developed nations in the framework and suggests that the concerns of these areas derive from similar dynamics. The WRI approach illustrates the merger of bio-ecological perspectives and human ecological concerns, as it considers "urban environmental conditions...important to the health and quality of life of a cities inhabitants" but also identifies urban impacts on surrounding natural resources to be "an issue of growing concern" (WRI 1996). The WRI report further clarifies this distinction by devoting individual chapters to "Urban Environment and Human Health" and to "Urban Impacts on Natural Resources".

As the critiques of the Vancouver and Rio conferences suggest, there is a significant tension between emphases on populations, or human health, and on ecology, or the physical landscape. This tension is often pronounced in the development of urban environmental indicators, as in the case of the original OECD indicators, which emphasize immediate impacts on the human population over the effects on ecosystems (OECD 1978). Spanning such disparate concerns is perhaps the greatest challenge to developing urban environmental indicators. It has been argued that applying ecological notions of sustainability to the urban setting is an oxymoron (Greenbie 1990), and that urbanization by definition has traditionally been viewed as destroying natural phenomena and processes (Platt 1994).

However, the fact that urbanization impacts large numbers in the present population, as well as the limited ecological resources within a city and the more extensive resources at the urban fringe, makes "sustainability" a useful framework for developing indicators.

Drawing on the most common definition of sustainability

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987) concerns for the amenities and health of the present population can be placed alongside those for the integrity of the physical landscape and the "natural capital" that will be required by future generations.

Sustainable urbanism, or the concept of sustainable urban environments helps focus environmental priorities in the context of *intra*-generational and *inter*-generational equity (Haughton 1994). Sustainability demands that the conditions of natural resources be understood and considered both in the present and in the long-term, and that we consider how the urban environment interacts with human society over long periods. This involves the spatial and temporal assessment of the organic qualities of a city as a system (Loucks 1994), as well as the assessment of the human condition as it is impacted by urban stresses.

The development of indicators for Providence was not based around a goal of sustainability *per se*, but rather around the consideration of three primary elements of the urban environment: physical landscape, economic activities, and human population, which collectively form the fundamental components of sustainability. These elements were applied in addition to other criteria in forming a framework from which to develop the indicators, as will be explained in the next sections.

The Urban Environment:	
Physical landscape	infrastructure, impervious surface, vegetative cover, related biota (i.e. biodiversity)
Economic activity	industry, including production, consumption, waste generation
Human population	health, recreation, aesthetics and amenities

USING ENVIRONMENTAL INDICATORS

The claim has been made that in the nations of the West environmental indicators are showing almost universally positive trends (Easterbrook 1995; Simon 1994). This however contrasts with the claim that cities in particular continue to suffer from "severe environmental pressure" related to water quality, traffic congestion, air pollution and waste disposal (EPA 1996a; Kovitz 1995). Why this potential discrepancy? Perhaps urban environments have been neglected in the analysis of environmental trends. Maybe the urban environment is such an anomaly that it defies being characterized by the same metrics applied to non-urban areas. Or we might conclude that one or both of these claims is simply based upon faulty data. While answering or even addressing these questions is by no means a simple task, it is apparent that urban environments are demanding attention and that a careful approach is required to assess the quality of our cities. This study poses a framework for, and an assessment of, environmental quality in Providence, Rhode Island by drawing on two dramatically progressing fields of environmental management: urban environments and environmental indicators.[1]

Monitoring trends in environmental quality is by no means a new concept. Indeed, an enormous quantity of data has been acquired on various parameters over a significant period of time. So much data is available that new methodologies are required to extract the most important and managerially useful information from it. Environmental indicators are intended for this purpose. Their ability to provide new information or to provide more useful information about existing concerns however, is a function of: the relationship between the measure and the actual environmental condition being indicated, the quality and appropriateness of the data used, the comprehensibility of the indicator to its end user or audience, and the values that are incorporated in defining the indicators.

Indicators are developed in this study in order to characterize the quality of the urban environment. The indicators applied here measure changes over time, as well as spatial trends and distributions. Several urban environmental projects have begun around the country, many of them using indicators to track progress and to identify concerns and priorities. These projects encompass a broad range of issues and measures, as well as a broad range of audiences to whom the indicators are potentially useful. In the study of Providence presented here, a general framework defines three key elements of the city environment: the physical landscape, the environmental stresses related to the economic activities indigenous to cities, and the health of the large urban human population. Based upon these key elements, three indicators were developed to describe Providence in terms of impervious surface, and citywide and local (community) air quality.

The indicators applied to Providence are:

1) Impervious surface as both a percentage of land area and per capita, both as functions of distance outward from downtown Providence, over time.

[1] In Rhode Island, two related efforts highlight the focus on both urban environments and on environmental indicators: The Rhode Island Department of Environmental Management (RIDEM) has entered into a partnership agreement with the US EPA to establish environmental objectives and an emphasis on “environmental indicators that measure the impact of [the] programs on the environment” (RIDEM 1997a). The RIDEM has subsequently developed a strategic assessment that is intended to “serve as a baseline for core DEM programs” and includes an emphasis on the Urban Environment among its main goals (RIDEM 1997b).

2) Total number of hospital admissions in Providence related to summertime air quality over time.
3) The distribution of potential sources of local air hazards in Providence, and the relationship between the density of sources and demographic data such as minority and low income populations.

Data was collected and analyzed for the three indicators, and conclusions were drawn where possible regarding the individual trends and present conditions. The three indicators are not however proposed as the sole measures required in assessing the Providence environment. Such a limited set of indicators cannot answer the question "is the environment in Providence getting better or worse?". Indeed characterizing environmental quality entails a balance between measuring too much and knowing too little. Thus it is the intention here to provide a framework for considering urban environmental indicators, and to assess a few recognized concerns of an urban environment.

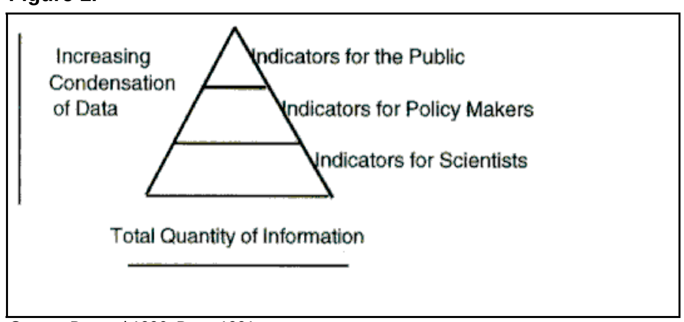
What are Indicators?

Indicators are actual measurements used to simplify the understanding of more complex phenomena that singularly or in combination describe underlying conditions, processes or activities (EPA 1996b; Deutsch 1980). As a society we utilize a wide variety of indictors in our everyday lives. These indicators range from the precise and complete quantification of actual conditions to broad estimations of complex activities. In some respect, any empirical measurement is an indicator, whether it be a direct measure of a condition such as the speed of a vehicle expressed in miles per hour, or an indirect representation of multiple trends such as the Dow Jones Industrial Average which generalizes the condition of the stock market based upon selected "proxies" (i.e. businesses whose stock prices reflect or predict general trends in the market and prices of other stocks). The most useful function of an indicator is to simplify our understanding of more complex or difficult to quantify concerns.

Indicators are especially important in assessing the quality of the environment. While as a society we have expressed a great desire to protect and conserve natural resources and maintain ecosystems for the benefits of human health and posterity. However, these are very general goals for such complex systems and the goals are often vague about the specific environmental attributes requiring protection (EPA 1995a). As we have increased our understanding of natural systems, the number of variables that we use to describe them has increased accordingly. Thus we are at a point where particular aspects and processes of natural resources such as the land, air and water have been well documented, but we are still struggling to be able to capture an image of the environment that will help characterize progress, and identify needs in the present and concerns for the future. This sentiment is often reflected in a common critique that those responsible for environmental protection and management find themselves “data rich but information poor” (EPA 1995a).

The potential uses of indicators range widely including communicating environmental conditions to various audiences, prioritizing among current problems or areas, providing early warning of potential environmental problems, and measuring responses and progress over time (Bernard 1996). Creating indicators that achieve any of these functions requires a process that identifies the environmental attributes of concern, the audience to whom the attributes are relevant (i.e. values or has jurisdiction over the attributes), and considers the data that can be used to communicate the condition of the attributes to the respective audience. The importance of this relationship between indicator and audience has been stressed in terms of the appropriateness of indicators to different types of audiences. For example, what may be lost be increasingly simplifying or condensing information, may be gained in the comprehensibility of an indicator to a less technical audience (see Figure 1).

Figure 1.

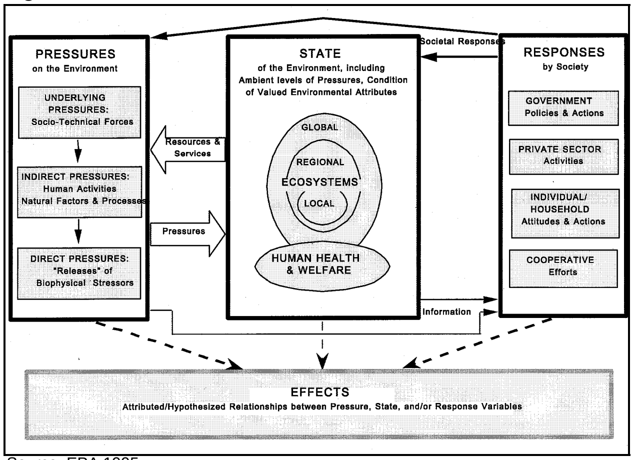


Source: Bernard 1996; Braat 1991

An Indicator Framework

In 1978, the Organization for Economic Cooperation and Development (OECD), an intergovernmental organization promoting coordination of domestic policies, adopted a framework for evaluating urban quality in its 29 member nations in North America, Europe and Asia. The OECD framework describes a relationship among *pressures*, the *state* of the environment, and *responses* by government or society (OECD 1978) (Figure 2) . *Pressures* can be both indirect (e.g. agricultural activity) and direct (e.g. pollutant emissions). These pressures affect the *state* of the environment, such as ambient concentrations of pollutants, diversity of species, or condition of human health.

Figure 2. PSR/E Framework



Source: EPA 1995

The EPA adapted the OECD's model into a national framework for indicator development (EPA 1995a). The national framework added one additional category that is intended to describe the relationships between two or more of the PSR categories. In calling this category "*effects*", the EPA framework highlights the importance of the causal relationship among environmental variables.

Box 1.

Effects: Relationships among Pressures (P), States (S) and/or Responses (R)

Effects indicators concern attributed relationships between two or more variables within any of the P, S and R categories. They are based upon models and analyses that provide plausible evidence of a linkage between a problem, potential causes, and/or solutions. In principle, indicators of this type should provide a relatively greater degree of certainty than just P, S, or R indicators about what is happening, why, and/or what societal responses might be most appropriate.

Figure 3.

asasas

Figure 3.

Source: EPA 1995a

Figure 3 illustrates distinct types of environmental indicators. Indicators located at the far right of the diagram comprise the most direct measures of environmental quality, the effects on human or ecosystem health. Relating this hierarchy to the OECD's PSR and the EPA's PSR/E frameworks, indicators under the heading "Administrative" measures at the far left of the diagram describe *responses* (here listed as government/regulatory responses, but could also include other societal responses such as individual or group actions). Moving from left to right

Administrative		Environmental			
Actions by federal or state regulatory agency	Responses of the regulatory community of emission quantities	Changes in discharge or emission quantities	Changes in ambient conditions	Changes in uptake and/or assimilation	Changes in health, ecology, or other effects

Source : Florida Center for Public Management for State Environmental Goals and Indicators Project

along the hierarchy, measures of "changes in discharge or emission quantities" describe indicators of changes in the *pressures* on the environment. And "Changes in ambient conditions" are measured by indicators of the *state* of the environment under the PSR frameworks. Looking at the far right box on the diagram, it is these measures of actual changes in "health, ecology, or other effects" that distinguishes EPA's framework from the OECD's. Each of these varied types of indicators have the potential to provide useful information. While it may be desirable to a specific audience to measure changes at the far left of the hierarchy, such as administrative responsiveness to a problem, it is suggested that the most needed indicators are those that are most direct measures of environmental quality, such as the "effects" described in Box 1. We are often constrained, however, to relying upon less direct measures depending upon the complexity or ambiguity of environmental concerns. The degree to which we can do so and still produce useful information is a function of the understanding of the relationship between cause and effect.

THE INDICATOR PROCESS

The process of developing indicators for Providence began by looking at the concerns of urban environments in the context of the physical landscape, the activities native to cities, and the human population. Designing an exhaustive suite of indicators with which to measure every facet of Providence's environmental condition was not feasible, nor was it desired. Instead, this study attempts to a) propose a framework for developing indicators and b) use a small set of indicators to measure the quality of several elements of the urban environment as both a physical and a human ecosystem.

The intended audiences and the values incorporated into the definitions of indicators can influence the choice of indicators and can vary dramatically. It should also be evident that the functions indicators serve are as varied, but all have in some way the ultimate purpose of providing managerially significant information (EPA 1995a). If the significant task of developing indicators as well as monitoring them at regular intervals into the future is to be justified, the question is raised as to what they will contribute to a body of knowledge above and beyond that of the vast quantities of empirical environmental data that already exist. An indicator provides useful information if it:

1) uses existing data to describe a condition that has not previously been articulated

2) describes a condition in a new way that is more accurate, or more closely describes the relationship between cause and effect,

or

3) describes a condition in a way that provides manageable information for a particular audience(s).

In satisfying any, or preferably all, of these general conditions, a good set of indicators will produce information that is able to communicate trends, extend that information across groups and agencies, and establish a standard for consistent evaluation of progress.

In developing indicators for Providence, several key criteria were considered with respect to the definition of indicators and the use of data. These criteria were drawn primarily from the work of the New England Goals and Indicators Project (NEGIP). In evaluating a set of indicators to be used at the state level, the NEGIP Steering Committee utilized five principle criteria. These criteria relate to 1) the *relevance* of the indicator to a specific audience or policy endpoint, 2) the *communication* of the indicator to its intended audience and its comprehensibility, 3) the *analytical soundness* of the relationship between the indicator and the conditions or trends it is intended to measure, 4) the quality of the *data* used in terms of availability and methodology, and 5) the *aggregation* of indicators. This later criteria evaluates whether the number of indicators used and the specificity of information they represent is appropriate to the needs of the audience (NEGIP 1996). The study presented here however, does not begin by identifying a particular audience for whom a set of indicators is developed. In fact the three indicators presented address a range from the planning and technical audience to the lay public. Thus, the criteria of *aggregation*, which considers a set of indicators as a whole or package intended for a particular audience, was not applied here. One additional criteria was used to evaluate the *geographic and spatial units* in which the indicators are analyzed.

Relevance and Communication

The relevance of an indicator to its intended audience or “assessment endpoints” is essential to the development of indicators. Both audience and endpoint will guide the choice of indicators. The endpoint for an indicator will be the ultimate purpose or end-use. Called "assessment endpoints" in EPA's indicator framework, these can include the prioritization and allocation of resources (i.e. fiscal and programmatic), the evaluation of progress, and the communication of environmental conditions. The audience for an indicator might include decision-makers at all levels of government, the regulatory and the planning community, and the public. By incorporating both endpoints and audiences into the indicator process, attributes of complex systems can be prioritized and necessary data inputs and outputs can be identified (EPA 1995a).

Complex environmental systems exhibit a range of attributes, the prioritization of which is subject to often disparate values (Reiquam 1972). One way to reduce the incorporation of value judgments in indicators is to isolate the values most pertinent to the identified audience and endpoint. For example, a given resource may exhibit both aesthetic and "functional" attributes (e.g. scenic vista and hydrologic maintenance). Given the difficulty in using such distinct values for measuring the same resource, how then to prioritize among possible measures? A clear articulation of the attributes that are valued and are to be measured by the indicator will help to clarify what the indicator is portraying. Thus, for example, it will be clear that an indicator measuring the number of people within a certain distance of a park is intended for a community or local audience; and the indicator will not be misrepresented to a technical audience as a measure of the benefits of that park to wildlife habitat.

The audience and endpoint can help determine which measures are most useful if certain attributes are either within or beyond the jurisdiction, scope or interest of the desired audience for the indicator. Aesthetic attributes may not fall under the jurisdiction of certain agencies using indicators to prioritize regulatory efforts, while they may be of most value to the public or special interest groups. This simplistic comparison is not intended to prioritize specific values here, but rather to stress the importance of identifying endpoints and audiences as a means to direct the difficult value choices necessary to indicator development. These decisions may even suggest that for resources with dramatically contrasting attributes, multiple or "parallel" indicators may need to be used to characterize the same system or medium.

Analytical soundness

The most important characteristic of an indicator is that it is analytically sound. In other words, that it is causally related to the condition it is intended to represent (NEGIP 1996; EPA 1995a). Indeed causality is not a dichotomous quality, but rather a matter of degree. Indicators should strive for the highest degree of causality possible. This is essential to the linkages between "pressure", "state" and "effect" indicators and the ability to rely on one to predict another. For example, the degree to which a technical audience agrees that changes in impervious surface coverage reflect a real trend in environmental (water) quality, will help determine whether or not impervious surface is a useful indicator.

Data Quality

Indicators should also be subject to data criteria. Both "input" and "output" data must be considered in the development and selection process. Input data is the information derived from monitoring or other collection means that are the basis for indicator measurements. Input data must:

1) be reliable, i.e. measured with an acceptable level of uncertainty for the desired outcome,

and

2) be consistent in methodology and definition.

"Output" data is information that is generated by the indicator from the input data in order to communicate the trends that the indicator represents. This information, subject to the all other criteria including causality, spatial scale, and appropriateness to endpoints and audiences, must have the ability to describe real changes in trends or conditions at appropriate magnitudes (EPA 1995a). In other words, an indicator must adequately reflect temporal and spatial changes with appropriate resolution.

Geographic and Spatial Units

While the boundaries used to define human-environment interactions have become increasingly porous, the definition of units for environmental assessment and monitoring have a direct impact on indicator outcomes and management actions (EPA 1995a). There is an emphasis in the literature encouraging a shift away from environmental assessment based upon political lines, to measures referenced to natural units (i.e. watersheds and "ecoregions"). At the same time, information referenced to jurisdictional and administrative units can often be useful, depending upon the audience and endpoint. Regardless, the spatial scale (i.e. neighborhood, city, state) and the geographic unit (i.e. watershed, region,etc.) should relate to both the system being measured and the information outcome desired.

City Indicator Projects

Examples of Key Issues

In recent years, many cities and metropolitan regions have begun the task of taking a formal look at their environmental condition. It is not the intention here to catalogue and evaluate these vast and diverse efforts. Instead, several efforts that have relied upon indicators in assessing urban environmental quality are discussed in order to highlight some of the issues that arise and affect the shape of an indicator project. Three city projects: San Francisco and Santa Monica California, and Seattle Washington, were chosen. Each of these city projects includes environmental quality as part of a "sustainability" assessment or plan, and each has developed a set of indicators with which to measure sustainability. One earlier project, conducted by the OECD as a framework for urban quality indicators to be applied to cities in OECD member countries, was used for comparison as well.

The earliest of these works was the OECD report, published by in 1978. The report proposed a framework and a set of indicators for application to cities in OECD countries. The indicators measured urban quality under several general topics including housing, economy, and "ambient environment and nuisances", with a stated emphasis on "the quality of man's urban environment" (OECD 1978). Indicators under the heading "ambient environment and nuisances" addressed air quality, water quality and noise. The report's indicators strongly reflect the explicit emphasis on the human experience in the urban environment. The indicators of air, water and noise are defined primarily in terms of ambient concentrations of pollutants and the extent of human exposure to levels above established health standards. For example, the percent of population exposed to concentrations of SO2 in the air above health standards was used as a measure of air quality. Other indicators used in the project addressed water quality and potability (the percent of population exposed to water containing pollutants above stated levels or with "objectionable taste or colour") and the percent of waters sufficient for recreation. Agriculture

While each of the three "sustainable city" projects cited above drew on the concept of sustainability originally conceived by the World Commission on Environment and Development in 1987, they are each unique in how they have identified goals and have developed indicators. The goals of the San Francisco project closely relate a) a set of indicators, and b) an urban environmental strategy, in seeking sustainability. The project itself was formed with representatives from the Commission on San Francisco's Environment, the City Planning Department, and a nonprofit organization called Sustainable City, but incorporated extensive involvement of the public and community representatives in particular. This group drafted strategies for San Francisco's sustainability within a broad range of topic areas (Box 2).

Box 2. Topics addressed in Sustainable San Francisco Plan

Air Quality
Economy and Economic Development
Energy, Climate Change and Ozone Depletion
Environmental Justice
Hazardous Materials
Human Health
Municipal Expenditures
Open Space and Biodiversity
Open Space: Parks, Public Spaces and Urban Forestry
Public Information and Education
Risk Management (activities of high environmental risk)
Solid Waste
Transportation
Water and Wastewater

Source: Sustainable San Francisco 1996

The goal of sustainability was intentionally limited by the group to the topics of environmental condition in order to keep the project manageable. The group notes that for that reason they chose "to omit such important social aspects as homelessness, crime, and spirituality" and focused on the physical systems of the planet that normally get short shrift from planners, and the social systems that have a direct impact on these"(Sustainable San Francisco 1996).

The indicators the group drafted to measure progress are intended to a) be obvious in what is being measured, b) utilize existing data, c) clearly indicate a trend toward or against sustainability, and d) be understandable to the general public and the media. The sustainability plan proposes too extensive a suite of indicators to include here in its entirety, but some examples are listed below.

Air Quality

- Citywide and local levels of ozone, CO, particulates, NOx, and SO2
- Public transit ridership
- Vehicle miles traveled, per capita

Environmental Justice

- Incidence of disease "clusters" disproportionately located in low-income neighborhoods
- Number of transit lines and frequency of service per unit of population in low-income neighborhoods compared to the city at large

Human Health

- Number of deaths from cancer

Like the Sustainable San Francisco project, Sustainable Seattle sought to incorporate an extensive amount of public involvement in defining measures of sustainability. The project began with by involving approximately 250 community members in various forums on the question of how to measure sustainability. The group originally identified almost 100 indicators, of which 20 were selected for further research to begin a dialogue on what constitutes a sustainable community (Sustainable Seattle 1993). Also similar to the San Francisco effort, is the Seattle project's attention towards action directed by the indicators. The group involved and identified a broad audience, including the media, decision makers, the business community and the general public. The indicators are intended to influence these groups in the development of a "Sustainability Assessment Framework" which will identify strategies for addressing the needs that the indicators may point to, and to influence specific planning policies. Unlike San Francisco however, Seattle includes within its sustainability framework indicators of "population and resources", "economy and culture", and "society".

These indicators were selected based upon several criteria similar to those employed by San Francisco and other efforts such as the New England Goals and Indicators Project with respect to data requirement and the expectations that the indicators inform about real trends in underlying conditions. The Seattle group however also used several unique criteria:

1) **The indicators should relate to the individual**

Indicators are measured per capita where possible. "Big numbers are brought down to earth".

2) **The indicators should relate to sustainability**

Each indicator is expressed as moving towards or away from "sustainability".

3) **The indicators should relate to each other**

Indicators are presented together as a holistic picture of the status of sustainability

Some examples of the indicators proposed by the Sustainable Seattle group are given below:

Air Quality

- The maximum daily levels of CO, particulates, SO2, and ozone
- The number of "good" air days per year, using the Pollution Standard Index

Vehicle miles travelled

- Number of vehicle miles travelled

Children living in poverty

- The number of children living in famillies with income below $14,350 for a familly of four

Source: Sustainable Seattle 1993

The third city project mentioned, the Santa Monica Sustainable City Program, utilized indicators to measure many topics similar to those in the Seattle project. The Santa Monica project however, is quite different from the others in its intended audience and relationship to policy goals. This project began with City officials primarily from the Department of Environmental and Public Works Management, a City Council appointed "Task Force on the Environment", and profesionals in planning and resource management (Zachary 1995). The first goal of the project was to identify and implement policies to promote a more sustainable way of life in the city. Indicators were employed to identify priorities and measure progress.

Rather than undergo a community input or "visioning" process, the City staff and City council adopted a set of guiding principles for sustainability and drafted 16 initial indicators that would measure the progress towards targets within, specific, existing City programs. Sustainability goals were broken down into four general categories: resource conservation, transportation, pollution prevention/public health protection, and community and economic development. Examples from the Santa Monica indicators are shown below.

- Water Use in gallons per day
- Number of trees in public spaces
- Dry weather stormdrain discharges to ocean in gallons per day
- Number of community gardens
- Public open space in acres
- Number of known underground storage tank sites requiring cleanup
- Ridership on bus lines in million of people

Source: Zachary 1995

Not surprisingly, among the most distinguishing features of these city indicator projects is the emphasis on the process of determining what is to be measured and how it should be measured. What groups and representatives are invited to the table at this fundamental stage will likely be determined by the initial intentions of the project and will further shape the indicators and thus the policies that are developed. In the projects discussed above, it is clear that choices have been made as to who should shape the selection of indicators, particularly with respect to the general public and community representatives. Both Sustainable Seattle and Sustainable San Francisco entrusted members of the community with the laborious task of determining what attributes to measure and how to measure them. In each of these projects, the public was identified as a primary audience. San Francisco incorporated "communication" to the public and the media into their indicator criteria; Seattle actually made the relation of indicators to the individual a main goal of their project, such as the use of per capita measures where possible.

The Santa Monica project on the other hand, began with an interest in measuring programmatic response, and thus utilized a group of professionals and city regulators to develop their indicators. The identification of the intended endpoints and audiences in each of these projects ensures that the indicators are ultimately relevant to their purpose. The tailoring of these indicators to a group or goal does however inevitably limit the scope of topics addressed and indicators used. It would, for example, be difficult for the Seattle organizers to introduce an indicator that was technically unpalatable to its lay constituency, even if such an indicator reflected real concerns to the public health. Conversely, while the Santa Monica group, by their own definition are not constrained by the need to present indicators to the public, they are constrained by their focus on measures of issues within the scope of existing programs. That is to say, the Sustainable City group is unlikely to include indicators of issues that lie beyond their jurisdiction (i.e. state regulated), even if such issues lie within the physical boundaries of the city and affect the urban population.

INDICATORS: PROVIDENCE, RHODE ISLAND

It is important to note that even with distinct goals and audiences, these projects each address a wide range of topics from ecosystem health to human health. In the case of the indicators applied here to Providence, the indicators are not proposed as a coherent "package", tailored to a common audience as the Seattle project implies is *necessary when measuring progress towards a goal such as sustainability*. Instead the three indicators here are proposed perhaps as models for the development of a comprehensive suite of measures in the future. As such, each indicator itself addresses a distinct goal or purpose, and an audience.

Impervious surface was used as an indicator of urban impacts (i.e. "sprawl"), on regional resources, and was measured as a function of distance from Downtown Providence. While the effects of sprawl are fundamentally related to individual behaviors, this is a relatively technical indicator, and is directed primarily at a planning audience. Air quality was measured in terms of the number of hospital admissions due to respiratory distress related to summertime air problems including ozone and particulate matter. This indicator relies upon a measure of health effects rather than ambient pollutant concentrations or emission rates in order to a) provide more comprehensible information to the public who are directly affected by these pollutants, and b) to utilize a measure that describes trends more closely related to the ultimate concern of air pollution. Finally, the location of potential sources of local air hazards were used to indicate relative risks to residents of the different communities within Providence, and are presented both statistically and graphically to provide information to a diverse audience.

Urban Anatomy

Impervious Surface: An Indicator of Urban Sprawl

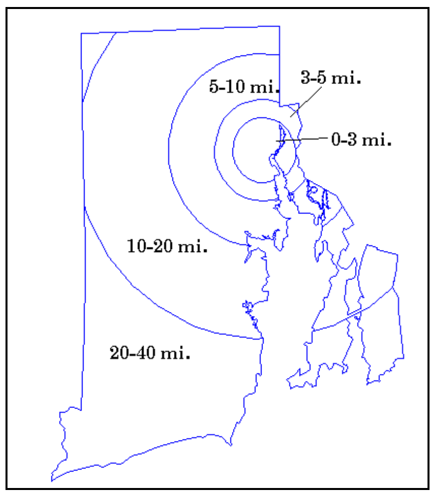
Urban areas have come to be characterized by asphalt and concrete and a landscape that is predominantly impermeable to the infiltration of precipitation and storm flows (Arnold 1996; Hough 1995). Impervious surface imposes a combination of serious environmental stresses. Primarily, run-off has been identified as a major source of water quality impairment in urban areas (Arnold 1996). In Providence, urban run-off has been identified as a leading cause of impaired river quality (RIDEM 1994c). But ecological impacts of urbanization are also felt beyond the "urban fringe" (Platt 1994). Because the sustainability of an urban environment is a product of both the integrity of the processes within the urban community itself, and the impact of cities upon the larger biosphere from which it draws sustenance (Platt 1994), monitoring the extent of urbanization is important in understanding the future of urban quality. The impervious surfaces that characterize urbanization (e.g. road surfaces, paved lots and buildings) are also major contributors to a chain of environmental impacts that follow such "urban sprawl". As an indicator, impervious surface has the potential to direct our attention to several important trends with respect to the urban system itself , such as the hydrology of urban rivers, as well as the impacts of urbanization on the city's less developed peripheral environment (i.e. "urban sprawl").

Impervious surfaces, including asphalt and concrete were used as an indicator of the extent of urbanization as a function of distance from Downtown Providence. Two indicators were used to describe this "sprawl" effect. The first calculated impervious surface as a percentage of total land cover. The second calculated the actual area covered by classified impervious surfaces and, using population estimates, produced a per capita measure of impervious surface in square feet. This later measure is intended to demonstrate trends in the population's demands for infrastructure such as roads. In other words, it compares the conversion of 'natural' ecosystems as a function of population density of the dense populations living within the urban core with that of lower density outlying areas. Both indicators rely on measurements within five concentric bands extending outward from the downtown Providence area (Figure 4). Varying intervals were used:

Band Distance from Downtown	
0 - 3 miles	From Dowtown outward three miles, encompassing the municipal bounday of the city
3 - 5 miles	A narrow band extending from three to five miles from Downtown, at the immediate urban polit
5 - 10 miles	Five to ten miles capturing the "suburban" and beginning rural areas
10 - 20 miles	Ten to twenty miles encompassing mostly rural areas
20 - 40 miles	Twenty to forty miles, reaching the southern coastal areas and the far corners of the state

Landsat satellite images were used to determine land cover. The cost and availability of images limited the trend analysis to three dates, 7 September 1984, 27 September 1991, and 6 September 1995. The images were selected based upon the longest time span available and to control for seasonal variations. The analysis utilized bands three of the seven band thematic mapper. Using one band introduces a certain and not insignificant amount of "noise" (i.e. false positives for impervious surface from sand and other materials of similar reflectance), and perhaps more rigorous future analysis should utilize a ratio of multiple bands (i.e. three, four, and five). However, noise was reduced as much as possible by multiplying the pixel values for each image by a factor of 1.5 and adjusting the contrast to maximize the presentation of impervious surfaces.

Figure 4. Concentric bands around downtown Providence

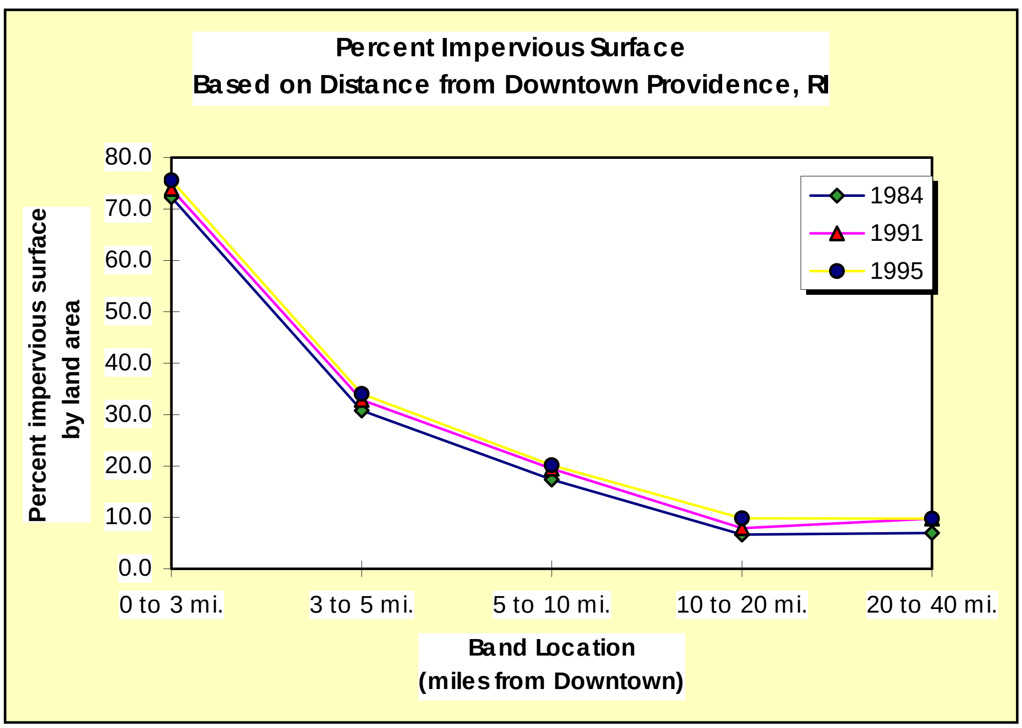


A readily available software package (NIH image™) was used to perform the analysis and calculate impervious surface as a percent of land cover. Sample fields of known and likely impervious surfaces, such as roads, parking lots and airstrips were used to identify a range of pixel intensity values (the impervious surface reflectance "signature") to characterize those surfaces[2]. The software then counted the pixels of data falling with these ranges. For the analyses, the five concentric bands in Figure 4 were overlaid on the large images, and the images were digitally cropped along the bands and the land classification done individually for each band.

The results of the land cover analyses are listed in Table 1. Data from all three image dates show relatively high percentages of impervious cover in the first band extending three miles from Downtown, as the percent by area decreases rapidly moving outward from the city. The indicator draws attention to the trends in land cover at the furthest distances from the city; little change in cover is detected within the first two bands between 1984 and 1995, while the largest proportional increases occur in the ten to twenty mile band during the three years, and in the furthest (twenty to forty mile) band between 1984 and 1991.

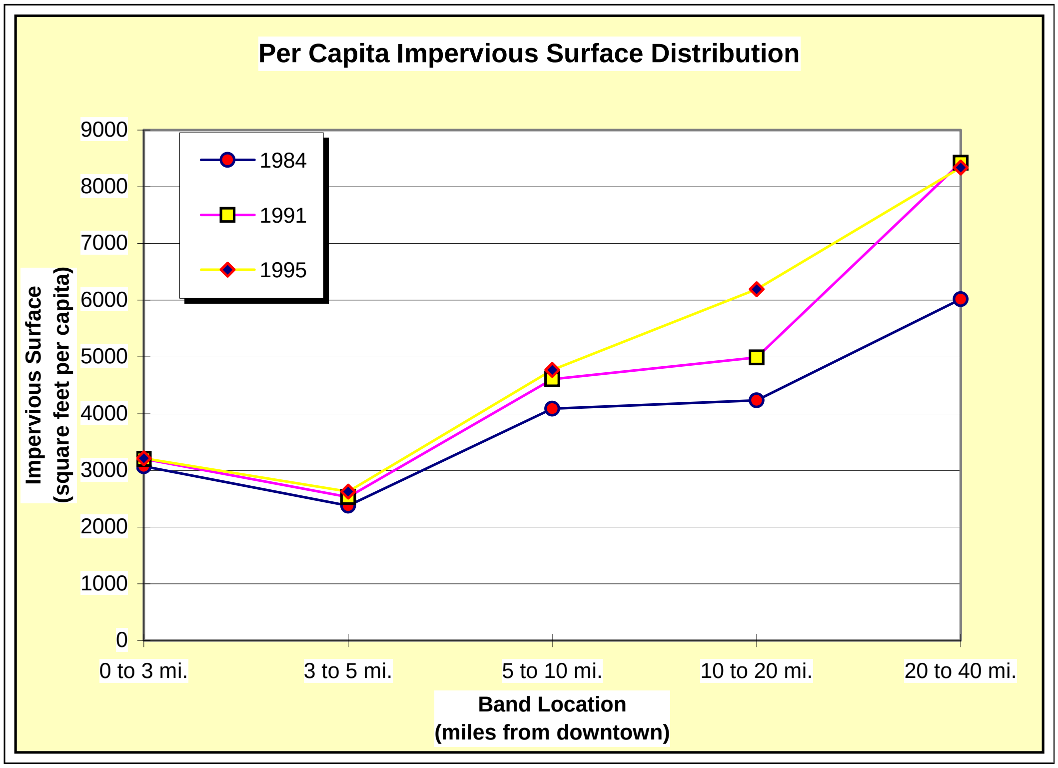
Table 1. Percent impervious surface cover

Band	Area (sq. mi.)	1984	1991	1995	Percent Change (1984-1995)
0 to 3 mi.	34.8	72.3	73.9	75.6	4.6%
3 to 5 mi.	45.5	30.8	32.8	34	10.4%
5 to 10 mi.	157.5	17.3	19.5	20.2	16.8%
10 to 20 mi.	463.9	6.7	7.9	9.8	46.3%
20 to 40 mi.	389.0	7	9.8	9.7	38.6%



[2] Pixel values for Band 3 within the ranges of 39-42 and 77-139 were classified as impervious surface. Minor adjustments were made to pixel factors between years to normalize variations in atmospheric conditions.

In the “per capita impervious surface” calculations, the two furthest areas again stand out in each of the three years. The ten to twenty mile band shows a steady increase in per capita allocation of impervious surface in the 1984-1991 and the 1991-1995 intervals; the far, rural, twenty to forty mile band exhibits a dramatic increase between 1984 and 1991, but almost no increase in the four year interval between 1991 and 1995.



What is especially intriguing about this measure in all three years is the magnitude of difference as a function of distance from Downtown. As of 1995, the less densely populated areas in the state (Appendix A-1) located beyond twenty miles from downtown, provided 2.6 times the amount of impervious surface per capita than the area within the urban three mile core.

Here, the indicator has the potential to serve a quite different function than the others. It is in fact an “anti-urban” indicator in the sense that it tells us about the condition of the areas that we consider non-urban, or sub-urban. It tells us how the characteristics of a built landscape that we are familiar with in the city core, are becoming characteristics of the landscape beyond the city. Measured as impervious surface per capita, it also conveys a measure of individual efficiency. Although the indicator is intended for a technical audience in the practice of land use planning, zoning, permitting, and other activities that are intended to preempt the behaviors and negative impacts of individuals, it does offer a comparison of the relative ecological impacts of residents of the urban and the suburban areas in the State. Much like the Sustainable Seattle indicators are intended to relate to individual behaviors where possible, this indicator may in fact prove useful as a way to relate large scale regional impacts to the individual. Urban sprawl is not a new concept, however, the ways in which we measure it, have not yet been fully explored, and could play a powerful role in both motivating action, determining at what level that action will occur, and how we will know if it is working.

The Urban Human Ecosystem

Effects of Ozone and Particulate Matter: An Indicator of Air Quality

On a national scale, significant reductions have been made in both the emissions and ambient concentrations of air pollutants, specifically the six criteria pollutants: CO, SO2, lead, NOx, particulate matter, and ozone (EPA 1995b). While extensive monitoring of air quality has been implemented, a significant number of people are still exposed to levels above national standards for several pollutants. In 1995, 127 million people in the United States lived in areas that did not meet national ambient air quality standards for one or more of the six criteria pollutants under the Clean Air Act[3]; 70 million people lived in areas that exceeded the national ambient standard for ozone in particular (EPA 1995c). Ozone and particulate matter are significant concerns for human health in urban environments. Vehicle and industrial emissions of ozone precursors such as NOx and VOC's, higher temperatures, and climatic inversions continue to produce high concentrations of the chemical. Vehicles and industry are also direct sources of particulate matter (EPA 1995b).

Ozone and particulates have a number of serious effects on human health, primarily respiratory and cardiovascular illnesses (Friebele 1996). Both pollutants cause respiratory problems ranging from milder irritation to more acute distress in asthmatics and sensitive populations (Friebele 1996). Reduced lung function is also associated with exacerbated cardiovascular stress, and particulate matter has been shown to aggravate existing respiratory and cardiovascular disease (Bascom 1996).

While a tremendous quantity of raw data is collected regularly on the concentrations of pollutants in the air, significantly less has been documented on trends in the ultimate human health effects related to air pollution. It could be said that these existing measures, primarily the recording of hourly ambient concentrations of several pollutants from a network of national monitoring stations, fall into the categories of environmental "*pressure*" and "*state*" indicators. While the understanding of pollutants such as ozone are far from complete, there is significant epidemiological evidence that ozone and particulates are related to increased hospital admissions for respiratory problems (Bascom 1996). Relying on this relationship, the Sustainable San Francisco project for example, defined an indicator of air quality based upon human health effects by the "total number of admissions to clinics for respiratory problems" (Sustainable San Francisco 1996).

Such an indicator is useful in providing more detailed information about the ultimate "effects" of an already well documented urban environmental concern, and is not related to standards for ambient concentrations which have the potential to change over time. Using hospital or clinic admissions as an indicator however is not without its shortcomings. The potential for confounders such as smoking rates and allergenic responses to fluctuating pollen levels, or for changes in reporting and diagnostic trends to affect the measure are significant concerns. These potential sources of uncertainty can be minimized where possible. Weighing the remaining uncertainty against the potential benefits of the indicator over more conventional (i.e. ambient pollutant concentrations) measures, requires the consideration of the audience to whom the indicator should be relevant. In the case of the Sustainable San Francisco project, the indicator using clinic admissions was likely chosen despite its potential uncertainty because of the project's focus on community involvement and communication with the public about progress towards "sustainability" (Sustainable San Francisco 1996); This assumes that trends in the number of people admitted to hospitals for air related ailments are more comprehensible or more meaningful to the general public than are trends in the ambient concentrations of air pollutants.

The number of admissions for respiratory or cardiovascular distress to hospitals within Providence was used as an indicator of the combined effects of air quality related to ozone and particulate matter. Several concerns arise when using health data, primarily with respect to potential confounders. In order to limit the influence of other factors on the measure, the indicator used admissions for the summer months when elevated levels of these air pollutants are most likely to be present. The admissions were further limited to those classified as

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[3] Carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide

"emergency" or "urgent", to reduce the influence of annual trends in referrals and general hospital admissions on the indicators.

Public files of hospital admissions, coded for the primary and secondary diagnoses of respiratory or cardiovascular ailments (Appendix B-1), were obtained from the Rhode Island Department of Health for the years 1991 through 1995. Maximum daily temperature values for Providence (NOAA 1997) were used to identify likely "bad" air quality days. The number of admissions were then summed for all days from June through August on which the maximum temperature equaled or exceeded 85°F. This number was then divided by the total days for that summer exceeding 85°F, and an average number of admissions per day was generated for each summer (Table 2).

Table 2. Hospital admission rates

Year	Number of days maximum temperature exceeded 85F June-August	Total number of hospital admissions on days exceeding 85F	Total hospital admissions during summer	Mean number of admissions per day exceeding 85F
1991	36	212	519	5.89
1992	13	86	584	6.62
1993	33	200	569	6.06
1994	31	176	533	5.68
1995	37	192	486	5.19

While the short period of available data (five years) limits our ability to identify long term trends, it does appear that the most significant change during that period was a drop in admissions between 1994 and 1995. A steady decline is indicated between 1992 and 1995. In this interval, the average number of Providence residents admitted to hospitals per day for respiratory and cardiovascular distress during the summer months, decreased by a total of 21.6%. Some concern is raised however, regarding general trends in hospital admissions affecting this measure. During the same period from 1992 to 1995, however, the total number of all cardiovascular and all respiratory admissions reported for all months declined by only 0.49%, suggesting that the decline in the particular admissions during the summer months is significantly greater than what can be explained by these admissions trends or by population changes.

Community Risks

Environmental Justice in the Distribution of Potential Air Hazards

Providence, like most cities, embraces diversity among its residents and in the character of its communities (Cianci 1997). The preservation of differences between neighborhoods and the smaller communities that comprise the city may be a desired attribute, however, an uneven distribution of risk is not. On a large scale, the disproportionate health impacts that are suffered by poor and minority populations from environmental hazards have been recognized (Pugliese 1995). This recognition has prompted the federal government to begin addressing environmental justice issues as a matter of policy, and to demand that information on the distribution of environmental impacts be used in setting strategies (Executive Order 12,898; 59 Fed. Reg. 6381, 1994). In the context of an urban environment, the high concentration of human population combined with the high volume of economic activities encouraged by the city infrastructure, creates a dynamic in which the distribution of localized threats to human health is a crucial concern.

Local Air Hazards

Local air hazards in Providence were used as an indicator of the distribution of risk from direct human health stressors such as volatile organic compounds (VOC's), isocyanates and industrial solvents. Threats to health from local air hazards are often the result of small point sources (EPA Office of Air and Radiation1991) and are important to measure on a community or sub-city level. The most convenient unit readily available is the census tract. Though not uniform in size, the number of census tracts (36) within the city provides better resolution than would be available by using neighborhoods (25) as principal units. In addition, extensive demographic data is available at the census level and is collected at regular intervals[4].

Five general sources of air toxics were considered: Auto body shops, dry cleaners, jewelry and metal plating businesses, gas stations, and facilities reporting air releases to the Toxic Release Inventory (TRI). Because of the aggregate nature of the indicator, using the number of potential hazards as a measure of human health risk, it was desirable to focus the range of effects as much as possible. These categories were selected based upon their likely emissions of toxics such as VOC's, benzene and solvents (Table 3) which pose nervous system and carcinogenic effects (Haughton 1994). In an effort

Table 3. Potential air hazard sources and emissions

Sources (n)	Typical Air Emissions
Auto Body Shops (129)	VOC's, degreasing solvents, paint thinners, isocyantes
Dry Cleaners (43)	Perchloroethylene
Jewelry and Metal Plating (55)	Solvents
Gas Stations (41)	Benzene
TRI Facilities (11)	Reported releases of VOC's

[4] At the time of this study, the latest census is not yet available. Therefore, the air hazard indicator relies on data from the 1990 census. Though an analysis of recent population trends is required to determine whether or not this data is obsolete, the census tract was considered the best available unit for the indicator.

to keep this particular indicator as simple as possible, a readily available electronic version of the yellow pages (American Yellow Pages 1997) was used to extract street addresses of businesses listed under the general headings, excluding the TRI releases which were extracted separately from the TRI on-line for the reporting year 1994 (EPA 1997). The yellow page listings returned 268 sites while the TRI, queried by business and limited to Providence businesses reporting actual releases of VOC's and solvents in 1994, returned 11 sites (Table 3). It should be noted that the while the yellow pages adds to the simplicity of this indicator and puts it within the technical reach of community and advocacy groups, it is expected that some number of businesses not listed or operating illegally will be overlooked in such a query. The significance of this (i.e. if non-listing/reporting is evenly distributed or occurs more in certain areas) should be the subject of further inquiry.

The sites were mapped using a desktop geographic information system (figure 5). These sites were then merged with the Providence census tracts and the number of sites were counted per tract (Append C-1), and calculated as a density of sites per land area (Figure 6).

Figure 5. Distribution of potential air toxics sources hazards

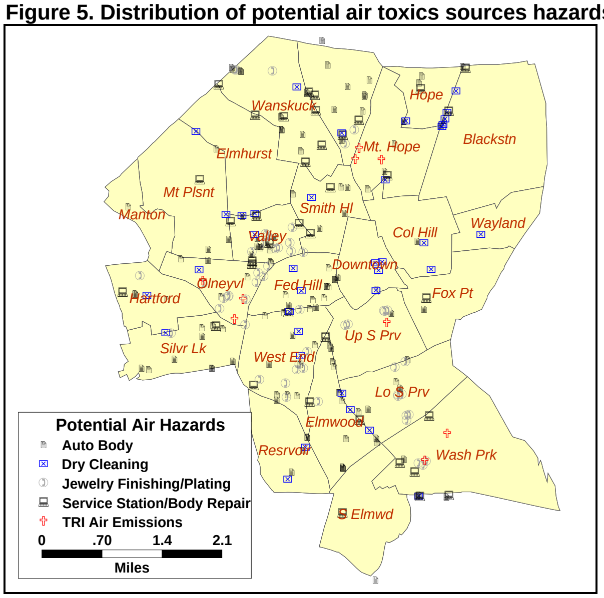
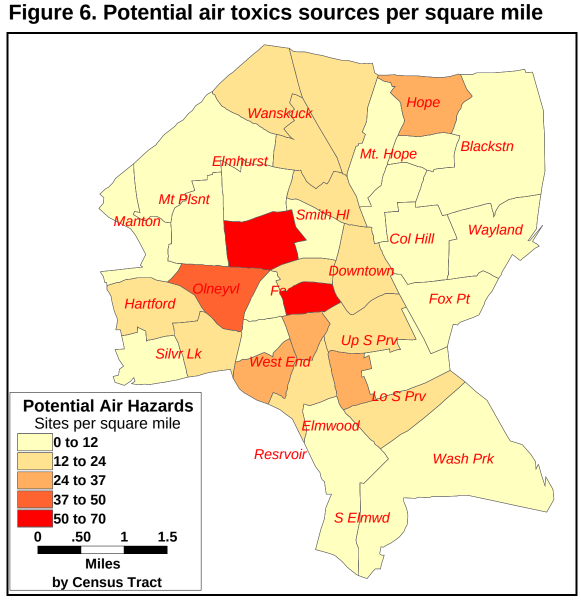


Figure 6. Potential air toxics sources per square mile



The specific emissions from these sites are likely to vary by type of activity and over time. Since no reasonably simple or objective scheme exists for the relative weighting of these types of sources of air hazards, each site was counted equally. It is apparent from each of these analyses, both visually and statistically, that the distribution of sites within the City is quite varied (Appendix C-2), and that several areas have particularly high total numbers and densities of sites (per square mile). Clustering sites that pose health risks is not necessarily an undesirable scenario in terms of the management of potential risks to the general population. However, there are environmental justice concerns related to the disproportionate clustering of these sites in areas of higher concentrations of minority and poor residents. The distribution of these sites was analyzed in relation to the distribution of income (Appendix C-3) and of minority populations (Append C-4) in Providence.

Given the limited number of samples (using census tracts as the units of analysis) and the high variance (in the number and density of potential sources of air toxics), it was not possible to determine the *degree* of the relationship between these demographic variables and the density of hazardous sites using regression analyses. Instead, for each variable, the citywide median among census tracts was identified, and the census tracts were seperated into two sample groups based upon whether they fell above or below the median. Thus, two sample groups each with 18 of the 36 Providence census tracts were formed for each of three key variables: median household income, percent of population non-white, and percent of population with a first language other than English. The mean density of hazardous sites (average of the total number of sites per square mile for all census tracts in sample group) were compared as a difference of means between the two sample groups.

	Mean sites/sq.mi.	Standard deviation	Difference of means	Result (α=.05)
Above median household income	11.50	13.65		
Below median household income	19.03	12.70	+7.53	Significantly greater
Above median % non-white	15.96	9.95	+1.38	Not significant
Below median % non-white	14.58	16.66		
Above median % not English speaking	20.77	16.28	+11.01	Significantly greater
Below median % not English speaking	9.76	6.95		

There are significantly more potential air hazards per square mile in the census tracts falling below the citywide median household income and in the census tracts with a greater percentage (above the citywide median) of population whose first language is other than English. There is not a significant difference between the mean hazard densities for those census tract groups above and below the Citywide median percentage of non-white population.

Environmental justice is indeed a concern in Providence. This relative risk measure however, stands out among the others in that it is in fact somewhat non-indicator like. It is a valuable example of the difficulties in simplifying complex data as indicators are intended to do. While we may acknowledge a need for measuring progress in the distribution of risk, this indicator seems to defy a singular metric. The location of potential air hazards in an urban community is a valuable indicator of environmental justice. To confine the quantification and assessment of the indicator to a single number however, would overly simplify the issue. A balance is required between simplicity and detail in the presentation of the indicator

In the case of air hazards, the difference of means tests tell us if particular populations, and which ones, are subjected to a significantly greater risk in their communities. Because the indicator is the geographical distribution of risk, presentation of the data, such as simply observed changes on the map of sites is as valuable as the other measures to both planners and the residents who comprise the principal audience for the indicator, and is certainly within the criteria of appropriate simplicity. The map in combination with the statistical tests should be used as information tools among these policy making and community audiences.

CONCLUSION

Continuing Urban Environmental Indicators

This study has presented several issues and concerns that collectively describe the framework in which three model indicators were defined and applied to Providence. The framework is intended to promote the incorporation of both the physical and the human ecosystems of an urban environment into the development of indicators. The *EPA pressure-state-response-effects* model (EPA 1995a) and the criteria discussed previously (NEGIP 1996; Sustainable Seattle 1993; Sustainable San Francisco 1996; Zachary 1995), suggest that a broad range in types of indicators can be applied to a city. Some complex and emerging issues such as local air hazards require somewhat indirect “pressure” indicators such as the number of potential sources of air toxics (in contrast to the quantity of emissions or number of resulting illnesses) However, other more traditional and extensively monitored problems such as citywide air pollution, have the potential to be measured by indicators that describe human health “effects” more directly (e.g. respiratory illnesses as opposed to ambient pollutant concentrations), if the audience (e.g. the public) or policy endpoint requires it.

It is difficult to assess the overall quality of the Providence environment by aggregating the three indicators. On the other hand, they are individually descriptive of the extent of urbanization beyond the city core, the health effects of air quality on city residents as a whole, and the relative risks to communities within the city. The impervious surface analysis shows that there has been an increase in urban “sprawl” during the period from 1984 to 1995. The per capita allocation of the infrastructure that is most often associated with these surfaces is disproportionately distributed throughout the State. While the area within three miles of the downtown area continues to have the highest degree of impervious surfaces, it is also most efficiently allocated here. The dense population living within the city is utilizing significantly less infrastructure per capita than those communities beyond the city, as measured by impervious surface, while the outlying areas of Rhode Island have experienced significant growth between 1984 and 1995. This should be an issue of concern for both planners and regulators responsible for the environmental impacts associated with "sprawl".

As host to approximately 150,000 people (US Census 1994), Providence should also be concerned for the health of its residents throughout the City and in specific communities. From the health indicator based upon hospital admission rates, it appears that we may be beginning to see positive gains in improving air quality and reducing the summertime ailments associated with ozone and particulate matter, though a longer period of data is necessary. The data is available at annual intervals and should be monitored accordingly, however it is perhaps most useful to observe trends over several years to ensure appropriate interpretation.

In terms of the exposure of residents to air hazards within their communities, both the residents and those involved in planning (i.e. zoning, siting, and permitting) should be concerned. It was not reasonably feasible to recreate a history of local hazards, and so no trend data is available. At present however, Providence experiences an uneven distribution of the risks associated with emissions from these sources. Those communities with higher percentages of population for whom English is not a first language, and those in which the median household income is below the Citywide median, contain a significantly greater density of potentially hazardous sites. The density of sites is intended to inform planners and community groups about likely or potential risks. The incorporation of changes in actual emissions (i.e. from pollution prevention measures) into the indicator in the future will yield even more information on trends in progress towards reducing these risks. Monitoring both the statistical relationship between hazards and demographics and simply mapping their distribution will provide valuable information. Presented in this fashion, the indicator has the ability to address both expert and lay (community groups and residents) audiences.

These indicators cannot tell us everything about Providence's environment. Developing a more comprehensive, but not overly complex suite of standardized indicators based upon concerns for the physical and human urban environment within this framework will provide valuable information on the quality and sustainability of Providence. The indicators must be appropriate to Providence's concerns and somewhat flexible. At the same time, some indicators such as air related illnesses will be comparable across cities. The next steps in this process should include the development of a more comprehensive "suite" of indicators for Providence, the presentation of the analysis of these indicators and trends to their intended and diverse audiences, and the incorporation of the feedback from these audiences into the development of goals and benchmarks.

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