ENVIRONMENTAL INDICATORS FOR AUSTRALIAN CITIES


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State of the Environment Australia 1996 (SOEAC, 1996) represents the most comprehensive attempt, to date, of reporting on the condition of Australia’s natural and built environments. Human Settlements (Newman et al., 1996) was selected as the first substantive chapter in this 500 page report in part because human settlements constitute a significant ‘environment’ in their own right as well as impacting pervasively upon Australia’s natural environment (as represented by the atmosphere, land resources, biodiversity, inland waters, estuaries and marine). This dual characteristic of human settlements is reflected in the set of environmental indicators being developed as part of the present phase of the SOE Reporting process (Newton et al., 1998). In the 1996 Report, Australia’s urban, rural and remote settlements were each examined separately in the context of their own characteristic ‘environmental’ pressures, states and responses (P-S-R). In the present phase of SOE reporting, a set of key and core indicators of human settlements are being sought that represent P-S-R at a range of spatial scales in the urban hierarchy.

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\textbf{Note:} Material for this paper has been drawn from Newton \textit{et al.} (1988) and Newton (1998).

In this paper we explore the underpinning concepts, frameworks and models that are being employed in developing environmental indicators for human settlements in contemporary Australia. An over-arching concern is that indicators reflect a thorough understanding of the systems they are to monitor. In this regard, the extended metabolism model acts as a highly useful conceptual representation of human settlements, in that it is both descriptive—identifying the primary domain areas of urban systems such as energy, transport, housing, etc., which key indicators are developed—and normative—specifying desired directions for future urban development.

GUIDING MODEL

The extended metabolism model of human settlements developed by Newman et al. (1996) for State of the Environment Australia 1996 is a valuable conceptual model for guiding environmental indicator development (Figure 1).

![Extended metabolism model of human settlements](image)

**Figure 1:** Extended metabolism model of human settlements

*Source: Newman et al. (1996).*
Unlike traditional state of the environment (SoE) reporting (e.g. OECD, 1994) where social and economic conditions are discussed to the extent that they impact the biophysical environment, and quality of life (QOL) studies which seek to examine social, economic and environmental conditions and the linkages among them with little regard for inter-generational issues (Maclaren, 1996), the extended metabolism model of human settlements is closely aligned conceptually with the sustainable development paradigm. Here the primary emphasis is upon such issues as: future orientation, sustainability goals and targets and linkages among economic, social and environmental factors.

The extended metabolism model also has merit in highlighting the following key domains for indicator development: urban planning and design, population, transport, energy, water, waste, noise, indoor air quality, health, housing and urban access.

**Dynamics of settlement.** Cities represent the engines of 21st century economies, where 90% of GNP will be produced as a result of the utilisation of resource inputs (Brotchie *et al.*, 1995). In this context, the key transformative and mediating processes of cities, such as urban planning and design—viz: broadly speaking, how infrastructure, population and economic activity are distributed across a metropolitan area—assumes considerable significance in the context of recent studies which clearly link urban form with environmental performance (Newton, 1997). Where to locate such factors as population in an urban metabolism model are liable to be the source of some debate, however. In a society and an economy which is becoming increasingly information-based it is appropriate that population be located within the *dynamics of settlement*, given that the key human inputs to production are increasingly knowledge-based (machines having replaced human muscle in the course of the earlier transition to an industrial society).
Indeed, it is primarily through the implementation of scientific and technological knowledge that von Weizsacker et al. (1997) can claim that the prospect of halving resource use while doubling wealth is a realistic prospect for 21st century societies. Transport and accessibility represents another key domain area. It has been largely through the evolution of transport (and, more latterly, communication) technologies that human settlements have evolved from towns spatially delineated by horse-based travel to global megacities linked by high speed rail, road, air and telematic networks.

**Resource inputs.** The inputs to urban systems are many and varied. For the most part they are inanimate (land, water, food, energy) and are subject to the laws of nature as well as to human operation\(^1\). Energy and water represent key resource inputs to human settlement. Food, materials for building and industry, and especially land, are other major resource inputs to human settlements.

**Waste outputs.** The catalogue of waste outputs from human settlements are now relatively well studied and over time have been subject to a variety of attempts at minimisation if not removal, ranging from end-of-pipe technologies to systemic redesign. Indicators related to waste outputs represent fundamental vital signs for urban communities. Key domain areas for indicator development include: noise, water and waste.

**Livability.** As places which accommodate an increasing proportion of the world’s population, cities and their livability are increasingly important factors for resident quality

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\(^1\) Ann Hamblin (1998) makes this important distinction when discussing indicators of land resources, separating pressures into two principal classes, termed ‘geomorphic process’ and ‘human interventions’.
of life as well as key factors in global competition for investment capital and human capital. A wide array of indicators may be assembled to measure livability. In the report on which this paper is based, key domain areas for indicator development include: *environmental health, housing* and *indoor air quality*.

Debate exists as to which domain areas should be included in SoE reporting under Livability. A minimalist position would include only those with a clear or dominant link with a *physical built environment*, such as *housing* or *indoor air quality*. Housing, however, involves many issues in addition to the purely physical (e.g. condition) such as affordability, access and homelessness—which are social and economic issues. *Human health*, also, while generally being regarded as linked to the physical environment, also involves many socio-economic considerations.

Many other sustainability or SoE reporting frameworks have adopted a more comprehensive approach, and give (for example) quality of life concerns such as neighbourhood crime, social cohesion, citizen participation, and local government financial stability an equal weighting to the natural environment. Irrespective of whether one adopts a minimalist or comprehensive approach to indicator development, however, the extended metabolism model appears well suited to accommodating both at a conceptual level (although in the former case it would not be fully populated or specified).

**GUIDING FRAMEWORKS**

In a recent review of SoE reporting, Maclaren (1996) identified several general frameworks capable of being employed in environmental indicator development.
Sustainability Frameworks

Sustainability frameworks typically highlight the interconnected troika of economic, social and environmental systems as represented in Figure 2, where a variety of economic-environment paradigms exist, reflecting the dominant societal ethos of the day in relation to development. The spectrum is one which extends from a strongly anthropocentric frontier economics paradigm, through environmental protection, resource management and eco-development to deep ecology paradigms that are strongly bio-centric (Naess, 1992).

![Figure 2: Models of sustainable development: changing paradigms](image)


These frameworks consider separate spheres - ecology or the physical environment, society or the social environment, and economy or the economic and institutional environment, in different relationships to each other. The strength of this approach lies in its universal acceptance as defining the key dimensions of sustainability, which require joint attention, but lacks the specificity necessary for practical implementation. They can be used in conjunction with other more detailed sectoral frameworks, and this has been done in several places in this report.
Progress towards the development of sustainable development indicators (SDI) is under way in the United States where an Inter-agency Working Group on Sustainable Development Indicators (IWGSDI) have developed a framework to identify, organise and integrate national SDIs. The framework is proposed to cover all aspects of the earth system: society, economy and environment, and is based on the concept of endowments, outputs and the processes that act on both (see Figure 3). To date, IWGSDI have assembled a candidate list of some 450 indicators, drawn from a wide variety of sources, which are considered relevant to sustainable development issues. From this set, the SDI Group (IWGSDI) have selected 32 indicators considered necessary for measuring progress towards sustainable development. The indicators will collectively monitor the capacity of the United States to meet present and future needs.

**Figure 3: Sustainable development indicator framework**

*Source: http://venus.hq.nasa.gov/iwgdsi/sdi_ol_framework.html*

**Issue and Goal-Based Frameworks**

Issue and goal-based indicators emerge as a consequence of community concern in particular areas. Common examples of issue-based indicators include crime and safety, unemployment, urban sprawl, air quality, etc. Possibly the oldest approach to developing indicators is directly policy linked, and uses policy development concepts rather than system concepts. The early social indicators work of Bauer (1966) and other authors...
focussed on developing a comprehensive series of norms or objectives for social well being, and on finding indicators which would best measure progress towards meeting these objectives. These indicators were arranged following a sectoral approach, or sometimes an issue based approach.

This methodology was carried further in 1991-1996 by the United Nations Centre for Human Settlements/ World Bank Urban and Housing Indicators Programmes (Flood, 1997). The modified approach asks the question “What is a well-functioning city?”. It seeks to represent all the major concerns or “norms” in human settlements from the point of view of each major group of stakeholders or actors in the arena, and to develop indicators which will measure progress toward achieving each policy “norm”. This approach has the advantage of taking a community-based, holistic approach to indicators which explicitly recognise the distinct views of different actors. The methodology is also very explicit about including only indicators for which some policy action may be taken; the philosophy is “no policies without indicators, and no indicators without policies”. (UNCHS /World Bank, 1994-6).

The model is driven largely by the policy process, by the need to incorporate the often conflicting views of different players in the policy arena, and in utilising indicators during policy and strategy development, during monitoring of outcomes, and during strategy reformulation and redirection. The advantages of the model are the highlighting of possible alternative viewpoints, the association of particular indicators with particular strategies and outcomes, and the incorporation of indicators as part of general policy development.
The disadvantage of the model that it pays no attention to environmental causality except as already accepted within the policy process. While generally attractive to policy makers and other stakeholders in that each indicator is associated with explicit goals, issue-based approaches have been less appealing to modellers and physical scientists who prefer to use more explicit, objective and causal frameworks which may assist in establishing more complete and consistent indicator sets (Maclaren, 1996).

Urban metaphors have also emerged in recent years as a source of powerful city-oriented goals, and are frequently featured in city promotional literature. Their heritage is a well established one in the field of urban analysis, where well chosen metaphors represent important guides for thinking about the present and likely future working of cities. A representative sample of urban metaphors are featured in Figure 4.

![Figure 4: Desirable urban futures: use of urban metaphors in metropolitan goal setting](image)

Figure 4: Desirable urban futures: use of urban metaphors in metropolitan goal setting
Causal Frameworks

A majority of environmental indicator studies are characterised by a listing of diagnostic variables which are likely to be clustered or grouped in a particular manner to reflect the generative framework that has been used in directing the work (see, for example, Department of Home Affairs and Environment, 1983). A major shortcoming of such studies, as outlined in the sections above, has been the absence of an over-arching 'model' of the respective domain areas and the set of linkages that inter-connect the key elements (indicators).

The pressure-state-response (P-S-R) framework represents an advance in environmental indicators development in that it introduces the idea of cause and effect relationships. The framework was developed by the OECD (OECD, 1994) to differentiate indicators which respectively relate to human pressures on the environment, actual states of the environment, and the responses which may be undertaken to alleviate environmental damage. The emphasis of P-S-R is on causality within a systems diagram such as Figure 5, with flows between inputs, states, and outputs. It is particularly useful in focussing attention on responses to environmental problems, which are often a neglected area in indicator studies.

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2 The P-S-R model is also termed by some as the pressure-condition-response (P-C-R) or condition-stress-respond (C-S-R) model. In some studies (UN, 1996) the P-S-R framework has been modified to D-S-R (Driving forces-State-Response). Here the concept of pressure has been replaced by that of 'driving forces' in order to accommodate more accurately the additional social, economic and institutional indicators. In others, both 'Driving Force' and 'Pressure' have been jointly applied as affectors of State: Driving forces refer to socio-economic activities, while Pressures refer '...to the environmentally harmful products that may emerge from the socio-economic activities' (Kjellstrom and Corvalan, 1995, p.149).
**Figure 5:** The pressure–state–response model in environmental reporting

*Source:* Adapted from OECD (1994).

The categories of P-S-R are:

**Pressures** — refer to policies, programs or activities, generally human which affect the environment. In the case of urban transport, for example, pressures may include: changing patterns of travel demand by mode; urban density patterns; the siting of new housing or commercial development; tax deductibility for commercial vehicles regardless of size and efficiency; the fuel efficiency and pollution control requirements for vehicles; spending on roads and public transport; and local requirements for provision of parking spaces as a condition of new development.

**States** — are observable conditions of various aspects of the environment of a defined place. For transport these may include: the level of emissions of different pollutants including CO₂; the number of cases of asthma reported in urban areas; the number and size of vehicles on the road; the number of kilometres travelled by various types of vehicles; traffic noise; accidents; the amount of fossil fuel consumed, and the distance of housing from public transport.
**Responses** – are the actions taken to respond to impacts or impediments to sustainability. They may ameliorate or exacerbate the impacts. Where responses cause an increase in impact, they become further pressures. Responses to transport impacts could include: tighter air pollution requirements for new vehicles; reduction of the amount of lead in petrol; public transport pricing; traffic calming measures; construction of new roads and freeways to reduce congestion; encouragement of higher density housing development and locally based employment opportunities; increased sales tax on imported cars; tax deductibility and government employee reimbursement limited to levels for efficient vehicles; and programs to encourage companies to offer transport vouchers as alternatives to free parking.

**Limitations of P-S-R.** The model is a useful framework to apply to any environmental indicators set, with its focus on human causes and responses, but it has some acknowledged shortcomings. Firstly the implied cycle of cause and effect is simplistic; in particular the model only deals with human responses and not ecological (non-human) ones; so that feedback from other parts of the physical environment to the phenomena under question is not usually part of the model.

Secondly, the distinctions between pressures, states and responses are not always clear-cut, because the focus of the viewer may change depending on the underlying objective, so that an indicator which is a pressure in one perspective may be a state in another and a response in a third. For example, an indicator such as “Number of housing starts” can have different interpretations. If the perspective is the use of resources in housebuilding and the effect on land use, then the indicator is a Pressure. If the focus is on the activity of
the building industry, then it is a State. If the focus is on housing shortage and homelessness, then it is a Response. It is therefore necessary to specify the perspective or the policy objective before an accurate decomposition into P-S-R can be undertaken. Thirdly, it lacks the intergenerational dynamics inherent in sustainability approaches to future paths of development. These shortcomings notwithstanding, the Australian SoE Report in 1996 adopted P-S-R as its guiding framework, as have the subsequent Indicators studies.

There is a further element that needs to be built into a P-S-R model applied to human settlements that recognises the macro processes that exert pressures on urban centres in late 20th century society (Sassen, 1995). As such, we propose to add a set of Macro Pressures (i.e., influences exerting their presence beyond national borders) to those Endogenous Pressures which are more closely aligned to a particular built environment domain (see Figure 6). The key macro-level pressures associated with Australia’s human settlements are: international migration; economic growth; globalisation in the context of trade and economic dependency; and technological change in energy (renewable) and information processing and communication.
Figure 6: Macro-level context for human settlements indicator development

**Sectoral and Domain Frameworks**

Indicators developed on a sectoral basis respond primarily to the requirements of government departments at all levels (local, state, federal); for example: transport, housing, employment, social welfare, environment. As such they can be narrowly focused (i.e., restricted to those areas for which a Department is directly accountable) and may fail to capture the complexity inherent in major urban settlements (the strong linkages between housing, employment, transport and the environment are one example).

An alternative to using industry or societal sectors is to use *domains*, which are similar to sectors but reflect specific disciplinary areas or areas of expertise; viz. contents of 'boxes' in Figure 1. To some extent, it is necessary for any SoE report to make use of a domain framework for human settlements, simply because experts are necessary in each domain to develop credible indicators with a substantial scientific or disciplinary backing.
The approach used in this report has been to develop indicators separately for each domain and to revise these in collaboration with experts from other domains: urban design, population, housing, water, waste, transport, indoor air quality, health, access. Domain models are developed for each of these areas to assist in obtaining as comprehensive a picture of causality as possible. These make use of, inter alia, extended metabolism, sustainability, and pressure-state-response frameworks at each domain level, and are outlined briefly below.

**DOMAIN MODELS**

Indicators have to reflect a thorough understanding of the systems they are to monitor. In developing environmental indicators for human settlements, the extended metabolism model or its variants have much to offer. The extended metabolism model of human settlements (discussed earlier) identifies several domain areas in respect of resource input, settlement dynamics, livability and waste output that call for development of key indicators.

In the main report (Newton et al., 1998) domain models were established for each of the ten substantive areas of the extended metabolism model of human settlement, namely: energy, water, urban design, transport and accessibility, population, housing, indoor air quality, environmental health, noise and waste. Given space constraints in this paper we illustrate only for indoor air quality and refer readers to Newton et al. (1998) for the remaining set.
A domain model for indoor air quality is presented in Figure 7. This model acknowledges the following major factors that impact on indoor air quality and their relative priorities:

- the bulk of indoor air pollution arises from the materials, appliances and processes that occur in modern buildings; by comparison, the level of pollution indoors that arises from the ingress of outdoor pollutants with ventilation/infiltration air is small and probably restricted to a few specific pollutants with no indoor source (e.g. sulphur dioxide, automobile exhausts in some buildings); thus, there is no general relationship between indoor air pollutants and outdoor air pollutants and each must be considered independently with an emphasis on pollutant sources for the former;

- building ventilation and air infiltration rates will influence the degree to which pollutants of indoor origin accumulate to high concentrations in indoor air; similarly they will influence the degree to which outdoor air pollutants penetrate into buildings;

- temporal variations in pollutant emissions from sources and in building ventilation rates will result in both short-term and long-term variations in pollutant concentrations in any building;

- building type will influence how the building is constructed, operated and occupied, all of which will influence indoor air quality;

- human occupation of buildings will vary over time according to the type of building and the occupant (e.g. worker, student, other), although there is good evidence that most people spend over 90% of their time in an indoor environment (Newton, 1997);

- human susceptibility to illness from exposure to air pollutants will vary but will be especially critical for the very young or old, the asthmatic, and people with allergies and chemical hypersensitivity.
KEY INDICATORS

The key indicators identified by Newton et al. (1998) for SoE reporting are listed in Table 1 below.

Table 1: Key Environmental Indicators for Human Settlements

<table>
<thead>
<tr>
<th>Key Indicators</th>
<th>P-S-R</th>
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<tbody>
<tr>
<td><strong>Macro-Level</strong></td>
<td></td>
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<tr>
<td>International Migration to Australia</td>
<td>P</td>
</tr>
<tr>
<td>Gross Domestic Product (GDP)</td>
<td>S</td>
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<tr>
<td>Globalisation—Economic Dependency</td>
<td>P</td>
</tr>
<tr>
<td>Information Economy</td>
<td>S</td>
</tr>
<tr>
<td>Renewable Energy</td>
<td>R</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
<td></td>
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<tr>
<td>Total Energy Use</td>
<td>S</td>
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<tr>
<td>Energy Use in Industry</td>
<td>S</td>
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<tr>
<td>Energy Use in Transport</td>
<td>S</td>
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<tr>
<td>Domestic Energy Use</td>
<td>S</td>
</tr>
<tr>
<td>Commercial Energy Use</td>
<td>S</td>
</tr>
<tr>
<td>Expenditure on Energy Programs</td>
<td>R</td>
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<tr>
<td><strong>Water</strong></td>
<td></td>
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<tr>
<td>Proportion of Settlements Served by Treated Water</td>
<td>S/R</td>
</tr>
<tr>
<td>Category</td>
<td>Code</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Community Drinking Water Violations</td>
<td>P/S</td>
</tr>
<tr>
<td>Municipal Daily and Annual Household Water Consumption</td>
<td>P/S</td>
</tr>
<tr>
<td>Total Annual Water Usage by Water Body and Sector</td>
<td>P/S</td>
</tr>
<tr>
<td>Biochemical Oxygen Demand Discharged</td>
<td>P/S</td>
</tr>
<tr>
<td>Total Suspended Solids Discharged</td>
<td>P/S</td>
</tr>
<tr>
<td>Nutrient Loads in Water Bodies</td>
<td>P/S</td>
</tr>
<tr>
<td>Sewage Disposed to Water Bodies and Re-used</td>
<td>P/S</td>
</tr>
<tr>
<td>Wastewater Discharged</td>
<td>P/S</td>
</tr>
<tr>
<td>Population Serviced by Treated Wastewater</td>
<td>S/R</td>
</tr>
<tr>
<td>Stormwater Recycled</td>
<td>R</td>
</tr>
<tr>
<td>Wastewater Re-used by Type of Application</td>
<td>S/R</td>
</tr>
<tr>
<td>Residential Water Consumption Under Alternative Water Pricing</td>
<td>R</td>
</tr>
<tr>
<td>Investment in Wastewater and Stormwater Technology / Conservation</td>
<td>R</td>
</tr>
<tr>
<td>Urban Design</td>
<td></td>
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<tr>
<td>Stock of Heritage and Cultural Assets</td>
<td>S/R</td>
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<tr>
<td>Land Converted from Non-Urban to Urban Uses</td>
<td>P</td>
</tr>
<tr>
<td>Public Urban Green Space per Capita</td>
<td>S/R</td>
</tr>
<tr>
<td>Residential Density</td>
<td>P</td>
</tr>
<tr>
<td>Percentage of Medium and High Density Residential Construction</td>
<td>S/R</td>
</tr>
<tr>
<td>Index of Industrial Concentration</td>
<td>S</td>
</tr>
<tr>
<td>Mixed Land Use Ratio</td>
<td>S/R</td>
</tr>
<tr>
<td>Home-based Workers</td>
<td>S</td>
</tr>
<tr>
<td>Physical Assaults in Public Places</td>
<td>S/P</td>
</tr>
<tr>
<td>House Burglaries</td>
<td>S/P</td>
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<tr>
<td>Indices of Urban Socio-Economic Inequality</td>
<td>P</td>
</tr>
<tr>
<td>Indices of Socio-Spatial Segregation</td>
<td>P</td>
</tr>
<tr>
<td>Transport and Accessibility</td>
<td></td>
</tr>
<tr>
<td>Access to Public Transport Stops</td>
<td>S</td>
</tr>
<tr>
<td>Car Ownership</td>
<td>P</td>
</tr>
<tr>
<td>Perceived Residential Density</td>
<td>P/S</td>
</tr>
<tr>
<td>Driving Licence Holders by Age and Sex</td>
<td>P</td>
</tr>
<tr>
<td>CBD Parking Supply and Charges</td>
<td>P/R</td>
</tr>
<tr>
<td>Fuel Pricing and Taxing</td>
<td>P/R</td>
</tr>
<tr>
<td>Average Speed by Mode and Distance</td>
<td>S</td>
</tr>
<tr>
<td>Mode Choice by Trip Purpose by Area</td>
<td>S</td>
</tr>
<tr>
<td>Total Time and Distance Traveled</td>
<td>S</td>
</tr>
<tr>
<td>Perceived Daytime Density</td>
<td>P/S</td>
</tr>
<tr>
<td>Economic Costs of Road Accidents</td>
<td>S</td>
</tr>
<tr>
<td>Fuel Consumption per Transport Output</td>
<td>S</td>
</tr>
<tr>
<td>Costs of Congestion</td>
<td>P/S</td>
</tr>
<tr>
<td>Population</td>
<td></td>
</tr>
<tr>
<td>Population and Household Growth Rate</td>
<td>P</td>
</tr>
<tr>
<td>Households in Poverty</td>
<td>S</td>
</tr>
<tr>
<td>Unemployment Rates</td>
<td>S</td>
</tr>
<tr>
<td>Visitor Numbers</td>
<td>P</td>
</tr>
<tr>
<td>Housing</td>
<td></td>
</tr>
<tr>
<td>Floor Area per Person</td>
<td>S</td>
</tr>
</tbody>
</table>
House Price to Income Ratio .......................................................... S
New Dwellings Completed ............................................................. P/S
Dwellings Constructed on Greenfield Sites .................................... P/S
Ranges of Lot Size ........................................................................ P/S/R
Homelessness ............................................................................... S
Building Materials Used in Housing/Embodied Energy .................. P/S/R
Operating Energy Efficiency ......................................................... P/S/R

**Indoor Air Quality**
- Occupant Satisfaction with Commercial Indoor Air Quality .......... S
- Mechanical Ventilation Rate of Commercial Buildings .................. S
- Thermal Comfort in Commercial Buildings ................................... S
- Air Infiltration Rates of New Housing ......................................... S
- Proportion of Population Sensitive to Pollutants ......................... S
- Proportion of Adults Smokers with Children ............................... P
- Proportion of Commercial and Recreational Buildings with Smoking
  Prohibition ................................................................................. R
- Quantity of Asbestos Products Removed from Workplaces .......... P/R
- Number of Unflued Gas Heaters in Residences and Schools ........... S
- Number of People Housed in Mobile Buildings ......................... P
- Proportion of Residences with High House Dust Mite Allergen ....... P/S
- Incidence of Legionnaires’ Disease ............................................ S
- Production of Low-VOC Emission Building Products ................... R

**Human Health**
- Prevalence of Regular Smoking Among Adults ............................. P
- High Alcohol Consumption Rate ................................................. P
- Proportion of Low Birthweight Newborns .................................... S
- Incidence Rate for Melanoma of the Skin .................................... S
- Mortality Ratio for Male/Female Injuries ................................... S
- Relative Health Status of Indigenous vs Non-Indigenous Australians S
- Asthma Hospitalisation Among Young Children .......................... S/R
- G.P. Consultations ........................................................................ S/R
- Health Literacy ........................................................................... S/R
- Dental Health .............................................................................. S
- Mental Illness .............................................................................. S
- Hospitalisation Rate ..................................................................... S

**Noise**
- Exposure to Traffic Noise ......................................................... S
- Exposure to Aircraft Noise ............................................................ S
- Exposure to Industrial Noise ........................................................ S
- Industrial Noise Injuries .............................................................. S
- Cost of Noise Control ................................................................... R
- Road Traffic Density ................................................................... P
- Air Traffic Density ....................................................................... P

**Waste**
- Domestic Solid Waste Generated ............................................. P
- Domestic Solid Waste Disposed to Landfill ................................. P
- Waste Recovered—Recycled ......................................................... R
Commercial and Industrial Waste Generated .......................................................... P
Energy Recovered from Waste ................................................................................ R
Proportion of Sludge and Biosolids Re-used .......................................................... P/R
Hazardous Waste Generated .................................................................................. P
Domestic Hazardous Waste Collected .................................................................... R
Contaminated Land .................................................................................................. P

FUTURE DEVELOPMENT

In the context of the knowledge pyramid (Figure 8), the set of indicators as developed in this report represent a half-way house. Each step of the pyramid represents a value-added step, typically characterised by a higher-level conceptualisation of a particular domain area. With SoE reporting, a P-S-R framework (with additives such as sustainability goals and sectoral representation) has encouraged cause-effect thinking between sets of indicators, albeit in a relatively low level fashion.

Figure 8: The knowledge pyramid

Source: Adapted from World Resources Institute (1996).
Composite Indicators. One logical progression is towards composite indicators (e.g. SEIFA indices used in Newman et al., 1996). The former has attracted its share of supporters who appreciate the gestalt effect that surround measures such as the CPI, GDP, Genuine Progress Indicator (GPI), etc. There are, however, some detractors who find difficulty in identifying which variables in a composite index are specifically implicated in a positive or negative shift in the indice’s trajectory; that is, which particular 'levers' to pull to try to re-direct the path of development for a particular aspect of the environment, economy or society.

Internet-html-systems dynamics model ‘construction’. One of the criticisms that can be levelled at Indicator reports is their production of a seemingly unconnected set of indicators as ends in themselves rather than stepping stones to a more fundamental understanding of a particular domain area.

There are a bundle of technologies that now provide a platform for making a step-function improvement in this regard. Key among them are the Web-based technologies that provide a capability of linking documents. If we conceive of an indicator (viz. Occupant Satisfaction With Commercial Indoor Environments) as a single document where links to other indicators (documents) are also embedded—as in the report on which this paper is based—then it will be possible to establish html (hypertext macro language) connections to all cross-specified indicators. This will facilitate the creation of a model comprising all inter-linked indicators triggered from a 'hit' on any initiating indicator. The resultant model of linked indicators constitutes the precursor to possible systems dynamics modelling (Newton and Taylor, 1985) and scenario analysis.
**Integrated multi-factor modelling of the built environment.** SoE Reporting as it currently stands does not possess the capability of examining what if? types of questions or exploring probable futures or alternative scenarios (although goal-based indicators attempt to establish elements of a desirable future and possibly a target date for achieving particular outcomes).

To achieve outcomes in this area requires the development of integrated models which link key indicators located in different domain areas. Integrated landuse-transport-environment models (Hayashi and Roy, 1996) are illustrative of what is required. Such models give us the prospect of exploring how future settlements might be designed in order to minimise resource inputs and waste outputs while maximising livability. Perspectives are both analytical and prescriptive. The analytical focus is on the ways in which resource inputs of various kinds are ‘processed’ by human settlements to produce both livability outcomes for the inhabitants, and waste outputs. Selected indicators must be able to capture the processes of transformation at each critical stage. However, there is also a normative imperative driving the urban metabolism approach—viz. the aim to increase the productivity of resource use (and efficiency of transformations) to increase livability outcomes and reduce both resource use and waste flows.

To illustrate what is possible, reference can be made to research undertaken for the Inquiry into Urban Air Quality in Australia (Newton, 1997) which sought, among other things, to explore the nexus between energy use (‘Resource Input’), air quality (‘Waste Output’) and urban form (‘Settlement Dynamics’). Given that there are several archetypal urban forms—dispersed, compact, multi-nodal / edge, corridor—the key
question was whether one or more were demonstrably superior in terms of the criteria air pollutants such as NO$_x$, SO$_2$, CO, VOCs, ozone and particles, as well as other key dimensions of human settlement sustainability, such as energy consumption and greenhouse gas emission.

The modelling indicated that there was indeed significant scope to improve the environmental performance of cities and identified strategies that could be devised to re-shape cities for a more sustainable future.

REFERENCES


