Article

Tools for Measuring Progress towards Sustainable Neighborhood Environments

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Abstract: Various assessment tools are available to assist designers, developers and regulatory bodies to reduce the negative impacts of contemporary multi-housing subdivision projects in industrialized countries. These tools vary considerably in what and how they measure and how the measurement results are presented and interpreted. This paper is largely a desktop study of subdivision assessment tools developed in Australasia, Great Britain and the United States of America. The paper identified a variety of themes and sub-themes that support assessment tools at both the project design phase and the project operational phase. These themes and sub-themes revolve around one or more of the three pillars of sustainability—namely the environmental, economical and social pillars. The paper firstly compares the themes and sub-themes of the assessment tools and then relates those themes to a set of sustainability targets produced for a proposed inner suburban housing subdivision in Perth, Western Australia.

Keywords: measurement tools; urban sustainability; housing sustainability

1. Introduction

Global interest in the concept of sustainable development (SD) in industrialized countries and the increasing concern about global warming have created a need to assess whether building construction projects in urban areas that are promoted as sustainable are really significantly different to 'business as usual' building projects. It is more than 20 years since Brundtland, in 1987, at the United Nations World Commission on Environment and Development identified "sustainable development" as

> "Development that meets the needs of the current generation without compromising the ability of future generations to meet their own needs" [1].

This frequently quoted, broad and ambiguous definition encompasses a certain level of environmental and social responsibility although the economic imperative appears frequently to be foremost in construction development debates. As the definition provides little detail on "what to sustain, to what extent and on what time scale" [2] whilst seemingly embracing the concept of sustainability, it is not surprising that the term has become conveniently popular.

There is evidence that the living arrangements of growing urban populations are at the forefront of environmental damage, particularly through depletion of natural resources, pollution [3,4] and loss of biodiversity resulting from the rapid increase in areas covered by urban housing stock [5]. Urban populations exceeded 50% of the total population in 2008 [6] and exceeded 75% of Australia's total population in 2004 [7]. In spite of this understanding of environmental damage no definitive measures have evolved in Australia as to how to gauge whether the impact of new urban subdivision and development is more sustainable than urban development in the past. The only way of establishing whether housing developments are becoming less environmentally, socially and financially damaging is to measure their performance and thus provide a basis for comparative analysis.

An argument exists that there are major opportunities for innovative sustainable subdivision development in urban centers resulting from the concentration of population. Such a concentration provides enormous leverage in moving towards sustainable housing development due to economies of scale and thus lower costs per capita [8]. Without a comprehensive set of measures though, this argument cannot be confirmed. This review of assessment tools seeks to establish what types of measures have been created to assess housing subdivision projects to determine their sustainability.

A number of reviews [9-12] of sustainability assessment tools, measures and checklists that cover the broad aspects of multi-housing subdivision projects from site selection through construction to post building operation and management (referred to in this paper as assessment tools) show that assessment tools can vary significantly. Variability occurs in what is measured, how it is measured and how the results are presented and interpreted.

This paper seeks to identify current multi-housing subdivision assessment tools originating from Australasia, Great Britain and United States that purport to measure the broad performance of multi-housing development projects (but not individual houses/buildings). What is being measured and the units of measure are then compared and analyzed. A set of sustainability indicators and targets, prepared for a local authority in Perth, Western Australia and co-written by one of the authors of this paper, is then compared with the current suite of assessment tools.

2. Method

Broad, inclusive criteria were used in the literature search to identify assessment tools for sustainability of multi-housing subdivisions. Potential relevant electronic data bases available through Curtin University were accessed, as well as regulatory documents from Australasia, United States and Britain that were available on-line. A World Wide Web search using the 'Google' search engine was also carried out. The databases used were Australian Architecture Database, Avery Index to Architectural Periodicals, BUILD: Australian Building Construction and Engineering Database, Current Contents Connect, EVA: Environmental Abstracts, Google Scholar, ICONDA: International Construction Data Base, Sustainability Science Abstracts, and Web of Knowledge.

The sources of material came from key word searches. Specific terms were identified from the research question and from preliminary reading. These key words (including truncations) were sustainable development measures, sustainable tools, sustainable housing, sustainable subdivisions, sustainability in the construction industry, green development, sustainable development indicators, urban sustainability, and measures in sustainable developments.

One of the primary drivers for this paper was to assess the themes and sub-themes being included in multi-housing subdivision assessment tools that could be relevant to measuring sustainability in Perth, Western Australia. Thus assessment tools were limited to those originating from Australasia, Great Britain and United States. Only those assessment tools that included a measure within each of the three pillars of sustainability—the environmental, economical and social pillar—were included. Rating tools for the operational impact of energy and water use in individual buildings and specialized life cycle analysis tools that assessed materials, components and construction systems for individual buildings were excluded. The assessment matrix used to record the features of the assessment tools is shown in Table 1. For those tools that met the above mentioned inclusion criteria, the researchers proceeded to identify what was being measured in each tool and how the assessment tools were quantifying the measures and guiding interpretation. These measures could then be compared with sustainability indicators that were developed in 2004 for an inner suburban industrial site that was to become an example of practical, sustainable redevelopment in Perth, Western Australia.

Table 1. Matrix for coding assessment tools.

Reference	Nationality	Developing Body	Primary Objective	Assessments			Stage for using tool	Comments
				Environmental	Economical	Social		
Author, date	Country of origin	Private consultant, Local authority, State Government, National government, Special body	Commercial tool, Planning Approval, Voluntary guide	Yes/no	Yes/no	Yes/no	Design, Approval process, Post occupancy	

3. Results and Discussion of Assessment Tools

From the initial review it was clear that many assessment tools focused on measuring aspects within only one or two of the three pillars of sustainability. This initial review also revealed the wide variety of units of measure used in assessment tools and the plethora of results being presented and interpreted. Some assessment tools focused on measuring outcomes (also called state or pressure indicators) such as CO_2 levels generated from transport usage (an environmental sustainability measure). Other assessment tools focused on measuring inputs (also called response to problem measures) such as the percentage of solar water heaters in a housing development project (an environmental sustainability measure) whilst still other assessment tools considered local or national contexts that were outside the influence of any particular housing subdivision project such as education levels of the population being housed (a social sustainability measure reflective of government policies towards higher education).

3.1. Key Documents

Two reports prepared in conjunction with a consortium of Dundee, Glasgow Caledonian, Loughborough and St Andrews Universities funded under the UK Engineering and Physical Sciences Research Council's Sustainable Urban Environment Programme to develop Metrics Models and Toolkits for Whole Life Sustainable Urban Development (called the SUE-MoT project) provided an insight into the complexity of undertaking such a measuring task. One report [7] focused on analyzing a wide range of assessment tools used to describe, predict or evaluate environmental, social or economic sustainability of urban environments. That report established the types of tools available and the range of approaches taken to measurements. It also investigated suitable criteria against which to validate such tools.

Of the more than 600 tools identified by the Levett-Therivel report [9], 25 tools for assessment of the built environment, from countries such as Europe, USA, UK, Australia, Canada and Hong Kong were fully evaluated by McCreadie [10]. The report by McCreadie, prepared on behalf of the Building Research Establishment (BRE), identified and catalogued existing assessment tools for sustainable environmental aspects of individual buildings as well as a number of broad planning assessment tools for the urban environment. The report concluded that:

- the 25 assessment tools could be grouped into the following five categories - urban planning, design, building rating systems, life cycle analysis tools (LCA) and infrastructure tools
- urban planning and building rating systems were the most developed as sustainability assessment tools
- all the assessment tools contained environmental dimensions and most contained either social and/or economic dimensions, and
- none of the assessment tools were truly holistic with regard to coverage of the three dimensions of sustainability

From the McCreadie report three assessment tools (Leadership in Energy and Environmental Design for Neighborhood Development Rating System [13], the South East England Development

Agency checklist [14] and Sustainable Project Appraisal Routine [15]) met the prerequisites for review in this paper.

A report prepared by Hargreaves [12] for BRANZ (Building Research Authority New Zealand) identified assessment schemes that were either operating, in a pilot phase or under development in Australasia. Of the nine schemes identified, two schemes under development had the potential to meet the criteria for this paper. However it was found that neither of these schemes (TUSC-Tools for Urban Sustainability Code of Practice) and NZSLI (New Zealand Settlement Livability Index) mentioned by Hargreaves included a measure within each of the three pillars of sustainability.

Another resource from the literature review, a paper by Xing *et al.* [16], provided an insight into how holistic assessment tools for sustainability of the built environment could be categorized to more clearly identify critical areas. That paper described the Construction Sustainability Assessment Model (CSAM) which was a full cost accounting-based model for sustainable building assessment that evolved from two streams of sustainability assessment methods - Building Whole Life Performance Assessment and Sustainability Accounting. CSAM described general assessment tools under four categories of sustainability—environmental, social, economic, and natural resources depletion.

3.2. Identifying What Was Being Measured and How It Was Quantified

In order to identify *what* was being measured, the themes and sub-themes in each assessment tool were sub-divided into the four categories of sustainability—environmental, social, economic, and natural resources depletion—as identified in the CSAM model. Natural resources depletion was included as a separate category as it measures how a project can reduce what it takes from the environment. It is differentiated from the environmental category which measures the magnitude of a project's impacts on the environment via outputs created.

The other crucial area of interest was *how* assessment tools quantified or qualified the measures and how the results were presented or interpreted. Thus a tabulation of the types of units of measure being used was required.

3.3. Assessment Tools

Six assessment tools met the parameters established for this review. All six assessment tools:
- included some measures for the environmental, economical, and social pillars of sustainability
- were relevant in establishing the sustainable performance of urban housing subdivisions, and
- included some audit traceable scoring features.

Two assessment tools were developed in the USA—the Cascadia Scorecard [17] and the LEED (Leadership in Energy and Environmental Design) for Neighborhood Development Rating System [13]; three tools were developed in the UK—One Planet Living (OPL) [18], the South East England Development Agency (SEEDA) checklist [14] and SPeAR® (Sustainable Project Appraisal Routine) [15]; and one tool was developed in Australia by the Victorian Government Sustainable Development Agency—VicUrban Masterplanned Community Assessment tool [19].

The tools were instigated by a variety of organizations including government authorities (SEEDA and VicUrban), not-for-profit agencies (Cascadia and OPL), a joint venture between interest groups (LEED), and a private consultant (SPeAR®). Consequently, given the different background of each of

the instigators, the focus of each tool varied. Some could be universally applied while others were locally specific. A summary of the assessment tools and the themes included is shown in Table 2. The themes are compiled under the four categories of sustainability—environmental care (A), natural resources depletion (B), societal well-being (C) and economic well-being (D).

Table 2. Summary of assessment tools and themes.

Assessment Tool	Comment	Themes
Cascadia Scorecard [17]	A straightforward assessment tool that requires annual review to highlight trends in seven theme areas that relate to a specific geographic area. Although the assessment tool was developed to show trends in the US Pacific North West it could be utilized to capture long term livability of a housing project. One advantage of this tool is that it uses commonly available data.	A. energy use, urban sprawl, wildlife restoration, pollution level B. − C. health, population growth D. economic well-being.
LEED for Neighborhoods [13]	A voluntary rating system generally using performance measures in eight theme areas. The system is intended to strike a balance between established practices & emerging concepts. This rating system can be used as a design tool but full LEED certification occurs when construction is complete. Detailed information on units of measure is provided.	A. smart location, linkages, design innovation, green technology B. green construction C. neighborhood pattern & design, accessibility D. affordability.
OPL [18]	OPL provides an internationally useable template to address the multi-dimensions of sustainability. A combination of aggregate indices, goal oriented indicators & performance measures are used. <u>Ten</u> theme areas are identified. Targets for short, medium & long term time frames are provided. OPL enables the utilization of currently available metrics to address some broad categories of sustainability but it requires location specific data to be developed in other instances.	A. zero carbon emissions, sustainable transport, sustainable water use, natural habitat & wildlife support B. zero waste production, sustainable material use C. local sustainable food production, culture & heritage support, health & happiness support D. equity & local economy support.
SEEDA checklist. [14]	The checklist highlights best practice & regionally specific sustainability & planning issues. The checklist generally uses performance measures in eight theme areas. The checklist provides little guidance about initial choice of site as it is assumed that the choice of site has already been subjected to formal sustainability appraisal. This checklist is primarily to be used at design stage but could assist in post-occupancy evaluation.	A. climate change & energy, transport & movement, ecology, energy & water efficient building B. resources protection C. community support, sensitive place making D. support for business.
SPeAR® [15]	Goal is to review and optimize sustainable opportunities. SPeAR has the potential to address multiple dimensions of sustainability. Generally performance measures are used in 22 theme areas although these can be added to or subtracted from depending on relevance. The units of measure are very general & thus may give a distorted view of sustainable performance (e.g., 'excellent' is defined as 'targeted or innovative' or 'holistic' or 'gaining an award').	A. air quality, land use, water discharge, natural heritage, cultural heritage, building design, building operation, transport infrastructure & affordability B. materials use, water use, energy use, waste minimization C. health, well-being, public form & space, accessibility, amenity D. employment availability, impact of competition, financial viability.

Table 2. *Cont.*

VicUrban Masterplanned Community Assessment tool. [19]	This assessment tool provides a basic framework to assist in planning & delivery of sustainable communities in new developments of mixed use having at least 500 dwellings. It generally uses performance measures in 11 theme areas.	A. energy minimization, water minimization, transport integration, biodiversity protection, atmosphere protection, B. sustainable materials choice, waste minimization, C. community well-being, urban design excellence, D. housing affordability, commercial success.

As there were numerous uniquely titled themes and sub-themes in the different assessment tools, the tabulation did not permit fully consistent cataloguing of all the themes. For example public transport was generally listed under the broad category of environmental care with a theme title of 'urban sprawl' in the Cascadia Scorecard or 'transport and movement' in SEEDA or 'linkages' in LEED. Also, some sub-themes could fit into more than one theme. For example, in LEED, 'transit facilities' are included as a sub-theme of the theme 'neighborhood pattern and design' which could fit into the broad category of societal well-being as well as into the broad category of environmental care. In cases where the sub-themes straddled more than one of the broad categories of sustainability it was decided to include them in the category with the most closely related theme.

3.4. Themes of Assessment Tools

Each assessment tool elaborates on the themes noted in Table 2 by describing a set of sub-themes. Using the four broad categories of sustainability, Tables 3 to 6 provide the details of these wide ranging sub-themes.

Table 3. Environmental care.

Tool	Themes and sub-themes
Cascadia Scorecard [17]	**Energy Use**: per capita consumption of motor fuels, *per capita use of energy in buildings* **Sprawl:** percentage of residents living in neighbourhoods compact enough to support public transport & walking as *alternatives to private car use* **Wildlife:** five representative species of *native wild life are to be restored* to one-third or one-half their historical abundance, as proxies for ecological well being, **Pollution:** level of PCBs (polychlorinated biphenyls) & PBDEs (polybrominated diphenylethers) in breast milk
LEED [13]	**Smart location:** proximity to water/ waste water infrastructure, endangered species protection, wetland conservation, agricultural land conservation, floodplain avoidance, brown field redevelopment, *topography protection/ restoration* **Green technology:** on-site energy generation & *renewable energy sources,* district heating/cooling, infrastructure, energy efficiency & recycled content, waste management for water & construction materials & operation, light pollution reduction **Innovation:** in design **Linkages:** *reduced car dependence*, bicycle network, housing/job proximity, school proximity,

Table 3. *Cont.*

OPL [18]	**Zero carbon:** energy efficiency, *onsite renewable energy generation* supplemented by off site renewable energy **Sustainable transport:** *reduce travel need*, prioritise sustainable transport modes, future flexibility **Sustainable water:** water conservation, water efficiency & recycling, surface water management **Natural habitat & wildlife:** *net positive contribution to local native biodiversity* & natural habitats, financed management plan, comprehensive planting schedule, demonstrate & publicize biodiversity & regeneration activity
SEEDA checklist [14]	**Climate change & energy:** flood control, heat island effect reduced, water efficiency, *sustainable energy*, site energy management **Transport & movement:** *available/accessible public transport*, reduce car parking facilities, traffic management, promote cycling **Ecology** - *conserve native habitats*, enhance ecological value, plant ecologically supportive vegetation **Building** - comply with EcoHomes/BREEAM or Code for Sustainable Homes
SPeAR® [15]	**Air Quality**—*reduce direct/indirect emissions from non-renewables*, reduce base line environment, dust & particulate matter, refrigeration & ozone depleters **Land use** -site location, planning intent, context, diversity/mixed use, flood plain, open space, contaminated land **Water discharge** - drainage system, risk management of water pollution, sewage treatment **Natural & cultural heritage**—*habitat conservation*, uptake of designated & protected areas, biodiversity, cultural heritage resources, archaeological resources, soil **Design & operation:** assessment methods, appropriate technology, EMS accredited to ISO 14001, in-use management, management regime, microclimate, flexibility, refurbishment, LCA impact **Transport:** *public transport infrastructure*, choice of transport, pedestrian/bicycle facilities, *green transportation*
VicUrban Masterplanned Community Assessment tool [19]	**Energy** - energy efficiency, *energy use reduction, renewable energy encouraged*, carbon offsetting of infrastructure **Water** - conserve potable water, manage storm water **Transport** - *integrated with community plan to reduce private car travel* **Biodiversity:** prevent light spill on to adjacent sites, *achieve net gain of native site vegetation* **Atmosphere:** zero ozone depleting refrigerants, noise reduction strategies

All six assessment tools provided the highest number of themes in the Environmental Care category. It can be seen from Table 3 that the themes generally revolved around minimizing air, water and ground pollution and supporting natural habitats. There were three sub-themes that appeared in all six assessment tools in this category of sustainability. These sub-themes, shown in italics in Table 3, were restoration of native vegetation, reduction in private car use and reduction in non-renewable energy use in buildings.

Five of the six assessment tools included sub-themes that clearly recognized the need to measure the rate of natural resource depletion. As can be seen in Table 4 OPL provided the strongest direction in this category by including a theme of zero waste. As shown in italics in Table 4, the Natural Resource Depletion sub-themes that were common to each of five assessment tools were waste minimization and water efficiency.

Table 4. Natural resource depletion.

Tool	Themes and sub-themes
Cascadia Scorecard [17]	**None**
LEED [13]	**Green construction:** *construction pollution/waste prevention*, certified green buildings, energy efficiency, *reduced water use*, building reuse, minimize site disturbance, contaminant reduction in remediation, stormwater management, heat island reduction, solar orientation.
OPL [18]	**Zero waste:** *solid & liquid waste prevention*, re-use, re-cycling **Sustainable materials:** measure embodied CO_2 of project materials & use for decision making, reduce embodied GHG impacts from consumer goods
SEEDA checklist [14]	**Resources:** protect heritage, minimize embodied energy of materials, maximise local materials, *minimise water use*, protect water supplies, encourage composting, reduce noise pollution, *minimise construction waste* & landfill
SPeAR® [15]	**Materials:** reduction of materials use, renewable resources, materials re-use, local materials, material specification & supply during **Water use:** *water efficiency*, water reuse, water monitoring, on-site water sourcing **Energy:** energy efficiency, renewable energy, energy monitoring, daylight use **Waste hierarchy:** *waste avoidance during design/construction*, waste reduction, re-use, recycling, hazardous waste management
VicUrban Masterplanned Community Assessment tool [19]	**Materials:** verified environmentally preferred materials **Waste:** *recycled & reused during construction, water efficiency*

The second highest number of themes in the assessment tools occurred in the category of Societal Well-being. McCreadie [10] noted in his review of sustainability assessment tools that social sustainability measures were particularly difficult to establish as they frequently revolved around subjective measures of human wellbeing. The greatest variety of sub-themes occurred in this category with sub-themes varying from the ability to grow food locally to optimization of local employment. As can be seen in Table 5 common themes revolved around public transport and safe accessibility to facilities, where facilities referred to homes, places for relaxation, employment or provision of services.

Table 5. Societal well-being.

Tool	Themes and sub-themes
Cascadia Scorecard [17]	**Health:** life expectancy **Population:** fertility rate
LEED [13]	**Neighbourhood pattern & design:** open community, compact development, diversity of use, diversity of housing types, reduced parking footprint, walkable streets, porous street network, transit facilities, public transport management **Access to**—surrounding vicinity, public spaces, universal design, community outreach programmes, local food production

Table 5. *Cont.*

OPL[18]	**Local & sustainable food:** encourage healthy diets high in local, seasonal, organic produce, integrate food growing on site, encourage food waste minimisation, transparent food purchasing systems
	Culture & heritage: site specific community-involved action plan to maintain/ enhance/ revive aspects of local culture & heritage, 2 showcase projects carried out
	Health & happiness: assist to create thriving community from development phase to long term occupation -
SEEDA checklist [14]	**Community:** promoting networks & interaction, involving in decision making, supporting public services/social economy & community structure, management assistance
	Place making: efficient land use, location-specific design process, safe/pedestrian friendly form of development, open space, adaptable design, inclusive/ diverse communities, control light spill
SPeAR® [15]	**Health & well being;** lifestyle support facilities, health & fitness recreation facilities
	Stakeholder comfort/satisfaction and inclusion/ social responsibility
	Form & space: internal & external security, pedestrian scale, high quality circulation patterns, right to natural daylight
	Access: public transport, pedestrian/cyclist facilities, key service facilities, access for physically impaired, local education & training, range of housing types, telecommunication networks
	Amenity: landscape, leisure facilities, green space, noise & vibration
VicUrban Masterplanned Community Assessment tool [19]	**Community well-being:** respond to community needs, optimise local employment, integrate & build community capacity
	Urban design excellence: interpret place & context, quality of public realm, diversity of lots whilst maintaining good solar access to public & private spaces, impart a unique sense of place, legible & permeable movement patterns, safe, healthy active life style encouraged, mixture of uses
	Housing affordability: widen housing choice, deliver accessible & adaptable design, deliver affordable rental housing, deliver affordable lots, partner to deliver affordable house/land package, minimise ongoing maintenance/ operating costs , reduce transport costs

As can be seen in Table 6, economic viability themes and sub-themes varied widely between the six assessment tools. This may be partly explained by taking account of the instigator of the assessment tool. For example a not-for-profit agency such as OPL included macro issues whilst government authorities involved in issuing planning approval appeared to be more restrained in making demands on developers. The wide variety of sub-themes probably also reflect the lack of a clear vision for combined economic and sustainable viability in any industrialized country. As argued by Bartelmus [20] this is a significant problem as accounting for economic performance in terms of environmental impacts is an essential first step towards moving towards sustainability.

Table 6. Economic viability.

Tool	Themes and sub-themes
Cascadia Scorecard [17]	**Economy:** median income, poverty rate, share of children living below poverty line, unemployment rate
LEED [13]	**Affordable:** rental and for sale housing
OPL [18]	**Equity, fair trade, local economy:** employment, inclusiveness, participation & democracy, ownership & affordability
SEEDA checklist [14]	**Business:** complement/promote local business space, improve connectivity between different businesses, create additional jobs

Table 6. *Cont.*

SPeAR® [15]	**Transport:** reduce demand for transport infrastructure, accessible & affordable public transport,
	Employment/skills: job creation, investment in skills, equal opportunities, diversity
	Competition effects: ethical competition, vitality & regeneration, diversification & choice, local supply chain
	Financial viability: secure benefits to stakeholders, risk management, minimise displacement effects
VicUrban Masterplanned Community Assessment tool [19]	**Commercial success:** sound financial management, benefits optimisation, risk assessment & management

3.5. Units of Measure

As discussed by Xing *et al.* [16] audit traceability of every unit of measure of an assessment tool was vital even if the unit of measure did not capture all the information required. Thus the fertility measure as stipulated in the Cascadia Scorecard is valuable although it may provide an incomplete view of societal well-being. A similar position was taken by Olewiler [21] who discussed the lack of meaningful data particularly in relation to natural capital indicators in considering environmental sustainability of urban areas. She concluded that even if available data did not provide the ideal measures and thus the indicators were imperfect, they were useful in showing directions of change, raising awareness and stimulating responses.

In the six assessment tools considered sub-themes were generally the elements that were to be measured except for part of the Cascadia Scorecard where there were no sub-themes. Some of the units of measure used in the six assessment tools were commonly collected national or local data such as statistics for the number of properties for sale and rent (an economic viability sub-theme in LEED) whilst other units of measure such as growth of local supply chains (an economic viability sub-theme in SPeAR) were far less precise.

Pinter *et al.* [11] refer to the following four types of units of measure currently evolving in relation to sustainability:

- Aggregate indices such as the ecological footprint,
- Headline or core indicators that are few in number and generally relate to high-level policy priorities and decision-making structures,
- Goal-oriented indicators such as the Millennium Development Goal Indicators,
- Performance measure indicators that provide either a comparison between actual and expected results or a method of ranking actual results.

As can be seen in Table 7 the units of measure most frequently used in the assessment tools were based on performance measures. However the most user friendly tool, Cascadia Scorecard, also used headline indicators such as life expectancy and fertility rate to measure societal well-being. Such headline indicators are based on readily accessible data. A performance measure of environmental care used in the Cascadia Scorecard was to measure the pollution level via the levels of polychlorinated biphenyls and polybrominated diphenyl ethers in breast milk. The goal was to achieve a level of pollution equivalent to the best international urban example having the lowest pollution levels. The score in any particular year was expressed as the number of years it was expected for each geographic zone within Cascadia to reach that goal. These units of measure adopted by the Cascadia Scorecard

may provide a useful model for assessment tools in a transition phase as the industrialized world tries to move towards greater sustainability.

Table 7. Units of measure.

Tool	Units of measure
Cascadia Scorecard [17]	Headline indicators provide a long term measuring system using generally available metrics. The score is goal-oriented and expressed as the number of years it might take to achieve a target. The target has been established using an international model of best practice.
LEED [13]	Points are allocated to each sub-theme to determine the overall LEED certification level. Certification occurs in 10-point steps with a minimum of 40 points required for basic LEED certification, through silver & gold certification to platinum LEED certification between 80 -106 points. 106 points indicates that all the sub-themes have achieved the maximum number of points available. Sub-themes shown in *italics* are prerequisites & not included in the point score.
OPL [18]	Overarching targets are to reduce GHG emissions to 0.8 tonnes of CO_2/person by 2050, reduce ecological footprint to maximum of 1.5 global hectares/person by 2020 & 1.25 gha/person by 2050, avoid air, water, land pollution in line with international best practice. Specific targets are set for all sub-themes in 1, 5, 10 & 20 year time frames. Targets exceed legal requirements & achieve national best practice in year 1. Targets are either quantifiable goals (e.g., at least 70% of waste by weight generated by residents and commercial operations to be reclaimed, composted or recycled) by 2020 or expressed as exemplar projects to be undertaken (e.g., to score Culture & heritage at least 2 completed case studies should be showcased to demonstrate commitment to global leadership in the field).
SEEDA checklist [14]	SEEDA provides generally performance based targets which are colour coded in four categories—Best, Good, Minimum, Minimum not met. Some scores are in quantifiable 'end states' (e.g., 20% of sanitary fixtures connected to grey water for reuse) allowing measuring of 'distance from target' (i.e., 100% connected to grey water). Others are less specific and provide a 'direction to target'.
SPeAR® [15]	The units of measure are not linked to transparent, broadly agreed objective measures but depend on the Arup assessor team. Each theme is rated on a 7-tier color coded pie chart with tiers ranging from -3 (worst case performance) to +3 (leadership performance) with 0 representing business as usual. Detailed worksheets for sub-themes determine the final score with both quantitative and qualitative values. Weighting given to sub-themes can vary in response to context.
VicUrban Masterplanned Community Assessment tool [19]	Maximum scores are allocated to meet 5 core objectives—commercial success, housing affordability, urban design excellence, community well-being & environment care. Scores are based on quantitative and qualitative criteria for each sub-theme of the core objective. Bonus points are available for each core objective if the initiative is in advance of best practice.

The only tool that included an aggregate index was OPL. As an overarching target, OPL's objective for new neighborhood developments was to not exceed a specified maximum ecological footprint per person within a set timeframe. The OPL tool also used goal-oriented indicators and performance measures which were tied to specific targets to be achieved in one, five, ten and twenty years time frames.

All the assessment tools depended on being able to quantify the current status of a sub-theme. Sustainable performance could then be judged as a change in that current status although change was expressed in a variety of ways. Most assessment tools generally relied on performance measure indicators. For example SPeAR® categorized performance of each sub-theme as it related to business-

as-usual. Best practice for a sub-theme earned one point, excellence earned two points and leadership status earned three points. In the same vein, worst case performance earned minus three points. The sub-themes in the VicUrban rating system comprised of elements that were each allocated a maximum numerical score. The intent was to highlight those sub-themes that were low scoring and thus were inadequately addressing one or more of the four categories of sustainable development. As the VicUrban assessment tool is practical in terms of its aim for the immediate development of urban land, rather than leading edge as is OPL, each theme in VicUrban includes bonus points for what is called 'industry advancement initiatives'.

The two assessment tools largely developed by planning authorities (SEEDA and VicUrban) highlighted the fact that decision-makers tend to select units of measure that are, or could readily be, linked to the policy process. Assessment tools that required ongoing review, such as the Cascadia Scorecard or OPL, carried drawbacks for project developers in that they would be responsible for checking that changes in performance were moving in the right direction and they could become clearly accountable and financially responsible over the longer term. Thus assessment tools that required ongoing review were not likely to be adopted by planning authorities.

4. Applying Sustainability Assessments in Perth, Western Australia

The City of Subiaco, an inner city local authority in Perth, Western Australia made a decision in 2004 to reinforce its position as a place of choice to live, work and invest by negotiating with a developer to apply practical sustainability solutions to the redevelopment of a former industrial site. A mixed use housing subdivision was proposed to be constructed on the site. A report was commissioned by the local authority to guide the future developers of the site. The stated aim of the City was "… to achieve a responsible, integrated and commercially viable approach to sustainable management including high levels of water quality and increasingly sustainable design and building performance and reductions in potable water and fossil fuel consumption" [22].

That report, entitled the Sustainability Indicators and Targets Report, proposed that seven themes form the measurable sustainability targets. These themes are tabulated in Table 8 using the same pillars of sustainability used elsewhere in this paper. The existing measures for each theme (referred to as 'status quo') were determined either based on the average available data for Perth or as established for the particular site. The intent was that the new subdivision should perform better than the status quo by a predetermined agreed percentage. That measurable required improvement for each theme, described as a percentage improvement on the status quo, is shown in Table 8.

In comparison to the breadth of coverage of sustainability themes in the six assessment tools discussed previously, the proposed move towards sustainability by the Council seems very modest. Nevertheless in the Council report the themes of restoring natural vegetation, reducing energy use in buildings, liquid and solid waste minimization and reduction in mains water use are very similar to the most common themes appearing in the six assessment tools. However even implementation of such modest improvements has not occurred in relation to this particular site as no agreement has yet been reached for development of the industrial site. This lack of development on this site has occurred over a period when the housing needs of the growing population of Perth have been met largely through

green field subdivisions on the periphery of an already sprawling city and without measurable sustainability targets.

Table 8. City of Subiaco, Perth, Western Australia—Measurable Sustainability Targets.

Pillars of sustainability	Themes	Status quo	% improvement		
			25	50	100
Environmental Care	Reduce waste water	All water to main sewer 130 kL/household/a	x		
	Improve soil quality/ natural habitat	Remediation required/poor quality public open space/ poor ecosystem		x	
	Reduce energy use	4745 units electricity/household/a		x	
Natural Resource Depletion	Reduce mains water consumption	280 kL/household/a		x	
	Construction waste	80 Kg/new dwelling	x		
	Operational waste	470 Kg/household/a		x	
Societal Well-being	Local food production	Zero food production	x		

5. Conclusions and Recommendations

Cities by their very nature and the processes which occur within them create pressure on natural resources and existing physical infrastructure. Conventional approaches to residential land development, whether on peripheral, undeveloped sites around urban centers or on previously developed urban sites, put additional pressures on resources and infrastructure. In the interests of sustainability these pressures need to be mitigated and conventional development techniques changed to alleviate the impacts and damage.

This paper has highlighted a number of assessment tools that can be used to measure the level of environmental impact, natural resource depletion, societal well-being and economic viability of land development in urban areas in Australasia, Great Britain and United States. There are common themes emerging in these assessment tools such as the need to restore native vegetation, reduce private car use, reduce the use of non-renewable energy in buildings, minimize waste, improve water efficiency, provide high quality public transport and safe access to a broad range of social facilities. Perhaps in industrialized countries, irrespective of differences in geography, governance and building construction techniques, these are the areas in which first steps towards sustainability will be taken. However there is no consistency in how to measure progress and set benchmarks for achievement. As can be seen in the example from Perth, there are no absolute targets. Perhaps absolute target figures such as those provided on OPL are necessary as even a significant improvement based on an unsustainable status quo will still be unsustainable.

The main differences between the various initiatives are the emphases placed on one or other of the broad categories of sustainability—environmental care, natural resource depletion, societal well-being and economic viability—and the particular themes and sub-themes being measured. As would be expected this reflects the different levels of importance placed on the categories of sustainability by different stakeholders and the most obvious environmental issues in a particular locality. As noted by

Meadows [23] themes and sub-themes evolve as a result of their compatibility with government processes, directives or funding support which varies from one jurisdiction to another. They also reflect the national statistical data collection systems.

It is suggested that if assessment tools for urban development are to become firmly anchored in mainstream statistical data collection systems three factors must be addressed. Firstly it is vital to identify what are the most important measures in a particular locality. Secondly a decision needs to be made regarding what units of measure are to be used. Ideally an international standard should be created that establishes the data input requirements, the reliability and updating facility of the data, and the form of output data in much the same way that financial data protocols are set. Thirdly responsibility needs to be allocated for making substantive responses to the direction of change indicated by the measures.

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