

## Sustainability: Measurement, Activities and Tools

Approach	Application	Example(s) of Implementation
Cooperative Farming	Balinese Rice <i>Subaks</i>	Shared water rights integrated with <i>Tri Hita Karna</i> , (religious tenet emphasizing harmony), practiced more than 1000 years
Governing for Future Generations	Seven Generations	'In every deliberation, we must consider the impact on the seventh generation...' – the Constitution of the Iroquois Nations (more than 500 years ago)
Sustainable Yield	Timber Harvest in Forestry	Royal Mining Office (Germany) and Hanns Carl von Carlowitz suggest <i>Nachhaltiger Ertrag</i> (sustained yield) for timber supply (1713)
Statistical Dispersion (Income Equality)	Gini Coefficient	Corrado Gini, <i>Variability and Mutability</i> , 1912, relative distribution (usually used to measure income inequality)
Cost-Benefit Analysis		<ul style="list-style-type: none"> <li>• Jules Dupuit in France analyzes merits of bridge and possible toll rates (for Pres Bonaparte) 1848</li> <li>• US Corp of Engineers mandated to use C-B analysis in 1936 Federal Navigation Act</li> </ul>
Measure of Economy	Gross Domestic Product	<ul style="list-style-type: none"> <li>• William Petty creates first estimate of national income, 1665 (for England – Improved 1696 by King George to measure domestic product by income, production and expenditure)</li> <li>• Simon Kuznet presents concept of GDP to US Congress (National Income, 1929-35)</li> <li>• Wassily Leontief develops economic input-output model, 1936 (same year John Maynard Keynes publishes "General Theory" and commissions Meade &amp; Stone to estimate national income and expenditure)</li> <li>• Upon coronation, King Wangchuck of Bhutan declares country's pursuit is 'Gross Domestic Happiness' (1972)</li> <li>• UN's Human Development Index (1990)</li> </ul>
Measure of Well-Being	Gross Domestic Well-Being	World Values Survey (started 1981, now available for more than 100 countries)
Product Labelling		<ul style="list-style-type: none"> <li>• Germany's Blue Angel Program (1978)</li> <li>• Environment Canada's EcoLogo certified products (1988)</li> </ul>

Environmental Agencies	Legislative Establishment	<ul style="list-style-type: none"> <li>• Canada Water Act (1970); Department of Environment (1971), advocated 'ecosystem management'</li> <li>• US EPA started December, 1970</li> </ul>
Probabilistic Risk Assessment	Risk Informed Decision Making	US National Research Council (1982); US Nuclear Regulatory Commission (1983) and NASA
Material Flows Assessment	Urban Metabolism	<ul style="list-style-type: none"> <li>• Wolman, Scientific America (1965); 'Industrial Ecology' (1989)</li> <li>• Urban GHG emissions inventories (approx. 1989)</li> </ul>
Equivalency Aggregation	Disability Adjusted Life Year (DALY)	Harvard University develops concept for the World Bank as means to measure overall disease burden (1990)
Strategic Decision Making	Game Theory	<ul style="list-style-type: none"> <li>• Mixed Strategy Equilibria, zero-sum games (Von Neuman's minimax theorem, 1928)</li> <li>• Tucker's 'Prisoner's dilemma' (1950)</li> </ul>
Life Cycle Assessment		<ul style="list-style-type: none"> <li>• Coca Cola retains Midwest Research Institute in 1969 to compare types of beverage containers</li> <li>• Proctor &amp; Gamble retains Franklin Associates to compare packaging and surfactants (1988)</li> </ul>
Systems Engineering		<ul style="list-style-type: none"> <li>• Schlager (1953) – 'Systems Engineering key to modern development' (key role in engineering)</li> <li>• Interdisciplinary (lifecycle) field of engineering</li> <li>• Schlager 1956 (Bell Telephone Laboratories)</li> <li>• National Council on Systems Engineering (NCOSE, 1990)</li> <li>• 'Limits to Growth', MIT, global ecosystems modelling.</li> <li>• 'Ecological engineering' (1962) coined by H.T. Odum – Systems Ecology and energy/material flows 1983</li> </ul>
Scenario Analysis and Integrated Assessment		<ul style="list-style-type: none"> <li>• Herman Kahn and Hudson Institute for scenario planning and public policy (1961)</li> <li>• Royal Dutch Shell scenario planning (1971)</li> </ul>
Contingent Valuation	Willingness to Pay	<ul style="list-style-type: none"> <li>• Surveys proposed by Ciriacy-Wantrup (1947)</li> <li>• NOAA convenes high-level advisory panel on survey methodology (1993)</li> </ul>
Social Entrepreneurship		<ul style="list-style-type: none"> <li>• Ashoka: Innovators for the Public, 1981</li> <li>• <i>Various</i> – usually individual metrics</li> <li>• Grameen Bank, 1983</li> </ul>

Philosophy		<ul style="list-style-type: none"> <li>• Jeremy Bentham (1748-1832): Greatest happiness principle.</li> <li>• John Stuart Mill (1806-1873): liberty, scientific method, and utilitarianism.</li> <li>• Gifford Pinchot (1865-1946): 'conservation ethic' and Wise Use, US Forestry Service</li> <li>• Aldo Leopold (1887-1948): land ethic (e.g. A Sand County Almanac)</li> </ul>
Earth Summit	UN Conference on Environment and Development in Rio de Janeiro, 1992	<ul style="list-style-type: none"> <li>• 109 heads of state</li> <li>• Agenda 21 (Local Agenda 21)</li> <li>• Outcomes: climate change convention, convention on biological diversity, UNFCCC, reform of GEF, statement of forest principles</li> <li>• 'Common but differentiated responsibilities'</li> </ul>
Use of Indicators	Simple indicators	Numerous examples, including Australia's Sustainable Forest Management Framework, e.g., Indicator 1.1.a – Area of forest by forest type and tenure
	Compound and complex indicators	World Economic Forum's sustainably-adjusted Global Competitiveness Index (GCI)
Assessments	Environmental Impact Assessment (EIA), Social Impact Assessment (SIA)	Standard practice in many countries for all new developments
	Life Cycle Assessment (LCA)	Roundtable on Sustainable Biofuels Fossil Fuel Baseline Calculation Methodology (RSB-STD-01-003-02)
Framework Assessments	European Research Projects	<ul style="list-style-type: none"> <li>• European Common Indicators (1999 – 2003)</li> <li>• LASALA – Local Authorities' Self-Assessment of Local Agenda 21 (1999 – 2002)</li> <li>• Indicators to Assess New Urban Services (2000 – 2003)</li> <li>• Urban-Nexus (2011 – 2014)</li> </ul>
Equivalence Measurement	Ecological Footprint	<ul style="list-style-type: none"> <li>• William Rees (1992)</li> <li>• Wackernagel and Rees (1996)</li> </ul>
Maintenance of Capital Stocks and Flows	Triple Bottom Line (TBL) Sustainability	The Global Reporting Initiative (GRI) founded in Boston (1997)

Schemes and Standards for Measuring, Assessing, Reporting and Certifying Sustainability		<ul style="list-style-type: none"> <li>• Montreal Process Criteria and Indicators of Sustainable Forest Management</li> <li>• Forest Stewardship Council – Certification</li> <li>• The Carbon Disclosure Project (2000)</li> <li>• The Standards Map: information on 120 voluntary standards operating in over 200 countries, and certifying products and services in more than 80 economic sectors</li> <li>• ISO 9000 Quality Standards</li> <li>• EcoChoice, Blue Dot, Fair Trade</li> <li>• ‘Dolphin Safe’</li> <li>• Jantzi Social Index</li> <li>• Energystar</li> <li>• Acumen (Capital) Fund, 2001</li> </ul>
(Driver-Impact) Pressure-State-Response (DIPSR)	Pressure-State-Response (PSR)	OECD: Environmental Indicators 2008; Guidelines for Multinational Enterprises (voluntary standards), 1976
Accounting System Approaches	System of Integrated Environmental and Economic Accounting (SEEA)	SEEA Central Framework, adopted in 2012 as an international standard by the United Nations Statistical Commission, supported by the European Commission, FAO, IMF, OECD, UN and World Bank
	Consumption-based Accounting (CBA)	United Kingdom 2011-2013 – Department for Energy and Climate Change (DECC) with the University of Leeds, developing a CBA Indicator for GHG emissions
	Supply Chain	Global Forest Watch
Indexes		<ul style="list-style-type: none"> <li>• Dow Jones Sustainability Index, 1999</li> <li>• Yale’s Environmental Sustainability Index, 2000</li> <li>• Transparency International started by Peter Eigen, 1993</li> <li>• World Bank’s ‘Ease of Doing Business’ Index launched Nov, 2001</li> </ul>
Risk Assessment Dealing with Uncertainty	Risk Assessment and Management	<ul style="list-style-type: none"> <li>• ISO 31000 – Risk Management</li> <li>• Risk Management – Principles and Guidelines</li> </ul>
Subjective Well-Being		Cognitive and affective evaluations; Ed Denier (2000) – proposes a US national Index of SWB

Rating of Buildings	Sustainable Buildings	<ul style="list-style-type: none"> <li>• BREEAM (Building Research Establishment Environmental Assessment Methodology, 1990)</li> <li>• US Green Building Council (1993), LEED (Leadership in Energy and Environment Design, 2000)</li> <li>• Canadian GBC (2002)</li> <li>• BOMA (founded 1907) provides advisory services and ratings for building owners</li> </ul>
Rating of Cities		<ul style="list-style-type: none"> <li>• GaWC – Globalization and World Cities, Beaverstock et al., 1998 – e.g., London and NYC ‘Alpha++’</li> <li>• Saskia Sassen, <i>The Global City</i> (1991), NYC, Tokyo and London. Now city ranking and indices common and widespread, e.g. Mercer Index of Livability, 2000</li> <li>• WHO ‘Healthy Cities Project’, 53 indicators from 47 cities (1992-94)</li> <li>• Mercer (2005), Economist (2005), Siemens Green City Index (started 2009), and others, ranking cities for ‘livability’, ‘quality of life’, etc.</li> </ul>
Management Approaches: Adherence to Prescribed Approaches	Best Management Practices (BMP), Codes of Practice; Environmental Management Systems (EMS) Six Sigma	<ul style="list-style-type: none"> <li>• Cotton Australia’s MYBMP, a best management practice tool for Australia’s cotton growers</li> <li>• BSI Group – first EMS (BS 7750)</li> <li>• ISO 14000 series (1996); ISO 14001 used by more than 250,000 organizations in 159 countries (ISO, 2010)</li> </ul> <p>Motorola introduces quality control scheme, 1988</p>
Cost Curves	Marginal Abatement Cost Curves	Rose in prominence post Kyoto Protocol, e.g., McKinsey Global GHG abatement cost curve to 2030
Adaptive Management		Canadian Environmental Assessment Agency – Operational Policy Statement: Adaptive Management Measures under the Canadian Environmental Assessment Act
Engineering Principles	Strategic Guidance	<ul style="list-style-type: none"> <li>• <i>Sustainable Development in the Consulting Engineering Industry</i>. FIDIC (2000) list of 18 objectives</li> <li>• Clift and Morris (2002), <i>Engineering with a human face</i>. Dealing with uncertainty; social acceptance</li> </ul>

Millennium Development Goals	UN consensus – various metrics, various attainment	<ul style="list-style-type: none"> <li>• Established September 2000. Eight goals over 15 years to 2015: (i) eradicate extreme poverty; (ii) primary education; (iii) gender equality; (iv) child mortality; (v) maternal health; (vi) combat disease; (vii) environmental sustainability; and (viii) partnership for development</li> </ul>
Rio +10	Johannesburg, 2002	<p>Johannesburg Declaration</p> <p>Included some 300 ‘partnership initiatives’ to help achieve MDGs</p>
Scenario Analysis and Integrated Assessment		<ul style="list-style-type: none"> <li>• Intergovernmental Panel on Climate Change (IPCC) – 5th Assessment Report (AR5)</li> <li>• Shell Oil scenario planning continues</li> </ul>
Environmental Performance Index		<ul style="list-style-type: none"> <li>• Fare et al (2004) apply environmental performance index to sample of OECD countries</li> <li>• Esty and Porter (2005) – National Environmental Performance (data-driven and analytical rigour)</li> </ul>
Millennium Ecosystem Assessment (MA) - Ecosystem Services Report		<ul style="list-style-type: none"> <li>• Millennium Ecosystem Assessment</li> <li>• UK National Ecosystem Assessment 2011</li> </ul>
Resilience Thinking, Thresholds and Planetary Boundaries		<ul style="list-style-type: none"> <li>• Resilience Practice: Engaging the Sources of our Sustainability, Brian Walker and David Salt (2012), exploring the application of resilience theory to real-world situations</li> <li>• Rockstrom et al., <i>A safe operating space for humanity</i>, (climate change, ocean acidification, ozone depletion, N and P cycles, freshwater use, biodiversity loss, land use – plus pollution and aerosols), 2009</li> </ul>
Measuring City Performance	City Indicators, GCIF (2007)	<ul style="list-style-type: none"> <li>• Federation of Canadian Municipalities, ‘Quality of Life in Canadian Communities’ (2001)</li> <li>• European Common Indicators, Towards a Local Sustainability Profile (2003)</li> <li>• The power and potential of well-being indicators. A pilot project by nef (the New Economics Foundation) and Nottingham City Council (2004)</li> <li>• World Bank discussion paper, <i>The Current Status of City Indicators</i>. “City Indicators: Now to Nanjing” presented at WUF3, Vancouver (2006)</li> </ul>

Urban Growth Modelling	City Scaling	West and Bettencourt propose city scaling – economy scales super-linearly while infrastructure scales sub-linearly
Emissions Inventory	GHG Protocol	GHG emissions inventory (national, regional and city) – Scopes 1, 2 and 3; ISO 14064 (2006) from WBCSD-WRI 1998
Adaptive Governance		<i>Adaptive governance and climate change</i> , Ronald D. Brunner and Amanda H. Lynch (2010), arguing for decentralized adaptive governance to provide diversity and innovation in addressing climate change
Corporate Social Responsibility		<ul style="list-style-type: none"> <li>• Various corporate forms, ISO 26000 (November 2010): e.g. Marks &amp; Spencer, Plan A; Body Shop; Patagonia</li> <li>• Sustainability Consortium (2009) – ASU, University of Arkansas and Walmart – product sustainability metrics (now more than 100 member companies)</li> </ul>
Engineering Principles	Strategic Guidance	<ul style="list-style-type: none"> <li>• Shanghai Declaration on Engineering and Sustainable Development. WFEO (2004) – commit to: ethics; interdisciplinarity; education and capacity building; gender issues; international cooperation</li> <li>• Abraham (2006) proposed nine principles</li> <li>• National directives: ICE, UK (2003); IPE, NZ (2004); Eng Aus., IIE, Spain (2005); CSCE and Engineers Canada (2006)</li> <li>• Meadows, <i>Thinking in Systems</i> (2008)</li> </ul>
Engineering Tools	Infrastructure Ratings	<ul style="list-style-type: none"> <li>• Arup’s ASPIRE (2008) with DFID and Engineers Against Poverty</li> <li>• Envision Infrastructure Rating System by ISI</li> <li>• Numerous other tools, e.g., BE2ST, GreenLITES, Greenroads, I-LAST and INVEST</li> </ul>
Rio +20	Rio de Janeiro, 2012	<ul style="list-style-type: none"> <li>• Billed as largest UN event ever organized</li> <li>• ~45,000 participants (130 heads of state)</li> <li>• Renewing Agenda 21</li> <li>• ‘Green economy roadmap’ with SDGs (“The Future we Want”)</li> <li>• Larger role for UNEP</li> </ul>

Defining Urban Boundaries and Borders	Consultative or Directive	Data, Boundaries, Competiveness: The Toronto Urban Region in Global Context. Global City Indicators Facility (2013)
Community Indicators	World Council on City Data	Sustainable development of communities: Indicators for City Services and Quality of Life. ISO 37120 (2014)
Sustainable Cities	Guidance Document	<ul style="list-style-type: none"> <li>• Indicators of the Emerging and Sustainable Cities Initiative, Inter-American Development Bank, 2013</li> <li>• Certu, European Commission</li> </ul>
	Resource Efficient Cities	UNEP – International Resource Panel – ‘Decoupling’
Inventories	Global or Regional Assessments	WWF Living Planet Report (2014) – ‘half of all global wildlife lost since 1970’
Assessment Tools	Higg Index	<ul style="list-style-type: none"> <li>• Apparel and footwear products – used by hundreds of organizations</li> <li>• Sustainability Consortium (100+ corporate members, 7 retail sectors)</li> </ul>
Modelling, Data Management, ‘Smart Cities’	Predictive Analytics	Predictive policing, e.g., Santa Cruz
	Algorithms in Policy Making	Traffic management, e.g., Lyon, Stockholm
	Data Mining and Systems Development	City management through data collection and predictive modelling, e.g., Rio de Janeiro, New York, Kunming
Indexes, continued	Sustainability	Yale’s Environmental Sustainability Index (ESI) modified to Environmental Performance Index (EPI), 2005 – national rankings published annually (with WEF)
	Adaptation	Notre Dame – Global Adaptation Index (GAIN) – transferred from Global Adaptation Institute, 2013 – national rankings published annually



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Sustainable Development Goals	UN consensus, 2015	<ul style="list-style-type: none"> <li>• Target implementation 2016 to 2030</li> <li>• As of August 2015, 169 targets and 304 indicators proposed</li> <li>• Comprised of 17 goals: (i) end poverty; (ii) end hunger, promote sustainable agriculture; (iii) promote well-being; (iv) quality education for all; (v) gender equality; (vi) sustainable water and sanitation for all; (vii) sustainable energy for all; (viii) economic growth and productive employment work for all; (ix) sustainable industrialization; (x) reduce inequality; (xi) sustainable cities; (xii) sustainable consumption and production; (xiii) combat climate change and its impacts; (xiv) conserve the oceans; (xv) manage lands and halt biodiversity loss; (xvi) inclusive societies and institutions; (xvii) revitalize global partnerships</li> </ul>
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NB: Ballantine (CitiesToday, Oct 2014) and Monnen & Clark (2013) list more than 150 benchmarking tools for sustainable cities metrics, e.g., Corporate Knights, Siemens Green City Index, AT Kearney’s Global Cities Index, Mercer, ICLEI, C40, Covenant of Mayors, GRI, Eurostat Urban Audit. Poveda and Lipsett (2014) outline more than 600 existing approaches to sustainability assessment (mainly for buildings and infrastructure projects). Adapted from World Economic Forum, *Designing for Action: Principles of Effective Sustainability Measurement* (2013). European research projects from Moreno Pires *et al* (2014). Engineering principles adapted from Gagnon *et al.* (2008).

From: Hoornweg, D., *A Cities Approach to Sustainability*, University of Toronto, 2015.