A Review of Sustainability Assessment and Sustainability/Environmental Rating Systems and Credit Weighting Tools

Cesar A. Poveda
Department of Mechanical Engineering, University of Alberta
4 - 9 Mechanical Engineering Building, University of Alberta
Edmonton, Alberta T6G 2G8, Canada
Tel: 1-780-619-1872 E-mail: poveda@ualberta.ca

Michael G. Lipsett (Corresponding Author)
Department of Mechanical Engineering, University of Alberta
5 - 8J Mechanical Engineering Building, University of Alberta, Edmonton, Alberta T6G 2G8, Canada
Tel: 1-780-492-9494 E-mail: mlipsett@ualberta.ca

Received: October 8, 2011 Accepted: October 28, 2011 Published: December 1, 2011
doi:10.5539/jsd.v4n6p36 URL: http://dx.doi.org/10.5539/jsd.v4n6p36

Abstract

Developing a new assessment tool in the area of sustainable development requires a strategic methodology for a cohesive and logical framework incorporating relevant theory and practical experience, building on a critical analysis of the state of the art. The assessment process implies the existence of tools, instruments, processes, and methodologies to measure performance in a consistent manner with respect to pre-established standards, guidelines, factors, or other criteria. Sustainability assessment practitioners have developed an increasing variety of tools. The present paper discusses a range of fundamental approaches, as well as specific and integrated strategies for sustainability assessment, as the foundation of a new rating system being developed for large industrial projects. Assessment methods identified by different schemes are also described. The focus then shifts onto environmental and sustainable rating systems, emphasizing the more popular tools. The present work is thus a review of the status of sustainability development and its different assessment tools: approaches, strategies, models, appraisals, and methodologies. This work also presents a description of the credit weighting tool used by the most popular sustainability and environmental rating systems.

Keywords: Sustainable development, Environmental issues, Ratings, Energy efficiency, Energy consumption Sustainability assessment methods

1. Introduction

The term sustainability appeared in the early 1970s as the rapid growth of the human race and the environmental degradation associated with increased consumption of resources raised concerns. Finding a way for consent between environment, advancement, and well-being of the world's poor was discussed in the United Nation's 1972 Stockholm Conference. 'Sustainable development' was presented by Ward and Dubos (1972). The concept is not necessarily modern: Gibson et al. (2010) imply that the concept of sustainability, as an old wisdom, has been around since the dawn of time in most communities.

The definition of sustainability given by the Brundtland Commission, formally known as the World Commission on Environment and Development (WCED), was a turning point for government policy makers, scientists, politicians, sociologists, and economists. "The development that meet the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987) is a definition for sustainability that challenged the traditional ways of doing business, changed the interpretation of the word development, and helped scientists and practitioners to understand not only the environmental impacts but also the social and economic effects of projects as the human race interacts with its surroundings. The report also contains two key concepts: the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

Society, economy and the environment, as the three pillars of sustainability, pose three characteristics: independency, inter-relation/inter-connection, and equality. Based on those characteristics, an alternative definition for sustainable development is stated as the path to balance social, economic, and environmental needs. From a series of reports, including that resulting from the Rio Summit (UNCED, 1992), Mitchell et al. (1995) identified four principles underlining that developing in a sustainable manner goes beyond environmental aspects. These principles are: equity, futurity, environment, and public participation. Collin and Collin (2010) state: "The protection of the environment is at the forefront of sustainable development, and this can be accomplished only through collaborative decisions, increased regulations, and each individual becoming a steward of the environment on a personal and global level," which implies that a sustainable future is in the hands of all of us, and the responsibility is shared, not left to politicians and policy decision makers.

Since that time, the importance of sustainable development has continued to grow, transforming and adapting according to the social, environmental, economic, and geopolitical conditions in different jurisdictions. Sustainability has become a primary and essential area of concern for a number of politicians, academics, and members of communities. A community of practice has also developed, as shown by bibliometric indicators such as annual conference proceedings, journal publications per year on sustainability, and university and college degrees and certificates offered around the world related to sustainability. In the past few decades, significant international conferences have taken place with a variety of objectives, such as finding sustainability assessment guidelines, forging agreements amongst governments, setting targets for sustainability, and so on.

The growth of sustainable development will depend on advancing three elements of the assessment framework: unification of criteria; common definitions for guidelines, processes, and methodologies; and adequate implementation of concepts to develop best practices. As sustainable development evolves, sustainable assessment will likely move toward more pro-active approaches, such as involving decision makers in the very early stages of projects that have sustainability targets.

Progress has been made in sustainability assessment. The number of tools, methodologies and processes for assessing sustainability is in the hundreds. Finding the appropriate assessment instrument is critical to match theory with practice, and to have successful outcomes in improving sustainability. Although the existing mechanisms for assessment offer useful alternatives for academics and practitioners, clear answers for questions remain to be found regarding what measures are important and how they can be quantified, especially for social and economic dimensions.

2. Measuring Sustainability

In sustainability, assessment and measurement are concepts that go hand in hand; but assessment and measurement each entail a different process. In the measurement process, variables related to sustainable development are identified and data are collected and analyzed with technically appropriate methods. During the assessment process, the performance is compared against a standard for a criterion (or for a number of criteria). Assessments are practical undertakings in evaluation and decision making with expected participation by stakeholders. These exercises must be meaningful for all the parties involved.

Francescato (1991) points out that achieving a meaningful assessment requires that the value system underlying performance and criteria must be shared by members of the public and by experts. Brandon and Lombardi (2011) highlight a series of principles that should underlie all assessments in sustainability to obtain the maximum benefits. Assessments should be: holistic, harmonious, habit-forming, helpful, hassle-free, hopeful, and humane. Gibson et al. (2010) highlight a series of sustainability requirements as decision criteria: social-ecological system integrity, livelihood sufficiency and opportunity, intragenerational equity, intergenerational equity, resource maintenance and efficiency, socio-ecological civility and democratic governance, precaution and adaptation, illustrative implications, and considerations. Gibson also explains the twelve main components of the so-called 'sustainability assessment law.

The inclusion of the public and experts throughout the process does not guarantee the application of sustainable development practices. In an industrial project, management plays the key role of bringing stakeholders together with the goal of reaching harmony amongst them (to move the project forward with acceptable metrics for project completion). Furthermore, the decision-making environment must consider all the factors with a structured approach, in which every aspect is included and all parties are aware of the process and the critical milestones along the way (Brandon & Lombardi, 2011).

2.1 Fundamental and Generic Approaches

Different approaches have been taken by practitioners and researchers to promote sustainability principles, in particular with respect to environmental issues, including energy consumption, pollution of different resources (terrestrial, aquatic, and atmospheric), conservation of flora and fauna, and conservation of historical artifacts. Each of these approaches contributes to preservation of the environmental status quo; however, they only address one part of the problem. Peter S. Brandon and Patricia Lombardi (2011) identify a series of fundamental and generic approaches aimed at assisting sustainable development: the natural step, the concept of community capital, the ecological footprint, monetary (capital) approach, the driving force-state-response model, issues or theme-based frameworks, accounting frameworks, and frameworks of assessment methods tool kits. Additionally, the authors propose a new holistic and integrated framework based on the Dooyeweerd's Theory of the 'Cosmonomic Idea of Reality' (Dooyeweerd, 1968; 1979).

[a] **The Natural Step**, created by Dr. Karl-Henrick Robert in the 1980s, considered that all the environmental problems facing society are wide and complex (yet unclear), and so basic science is the foundation of a consensus view, calling this framework The Natural Step (Robert, 2002). There are four basic scientific principles on which this concept is based: a) matter and energy cannot be destroyed; b) matter and energy tend to disperse; c) material quality can be characterised by the concentration and structure of matter (energy is not consumed, only its exergy); and d) net increases in material quality on earth can be produced by sun-driven processes. Disorder increases in all closed systems; therefore, an exergy flow from outside the system is needed to increase order. The concept of quality in this case refers to value in which higher value equals more useful material. The energy generated by the sun has driven the creation of better materials through natural processes, and this constant cyclical process produces quality by reprocessing and concentrating waste into more valuable resources. According to Robert, this cycle can take place by providing a framework for assessing and monitoring, which consists of four basic sustainable conditions that are meant to be met in order to become a sustainable society:

"a) eliminate our contribution to the progressive buildup of substances extracted from the Earth's crust (for example, heavy metals and fossil fuels), b) eliminate our contribution to the progressive buildup of chemicals and compounds produced by society (for example, dioxins, PCBs, and DDT), c) eliminate our contribution to the progressive physical degradation and destruction of nature and natural processes (for example, over harvesting forests and paving over critical wildlife habitat); and d) eliminate our contribution to conditions that undermine people's capacity to meet their basic human needs (for example, unsafe working conditions and not enough pay to live on)" (Robert, 2011a).

The key word in the first three parts is progressive, meaning that some activities may occur, but the overall effect should not increase over a reasonable period of time. The natural step has been endorsed by more than sixty local communities, more than fifty of Sweden's leading scientists, and companies around the world, such as: IKEA, OK Petroleum, Electrolux, Scandic, Gripen, Bilspedition, SJ (Swedish rial), The Interface Corporation, Home Depot, McDonalds, Placon, Mitsubushi Electric (USA), Collins Pine (Forest products), and Nike (Brandon & Lombardi, 2011).

[b] **Community Capital** is based on the concept of capital is well known in economics and refers to accumulated wealth. This concept can be applied to more broad categories, such as human capital, intellectual capital, and social capital. The concept of community capital described by Maureen Hart (1999) includes three main contributors: built and financial capital, human and social capital, and natural capital. These three contributors are represented as a pyramid, in which natural capital is the base, human and social capital is added, and built capital is at the apex.

The first layer, natural capital, refers to the Natural Step concept; however, this layer includes other aspects that the community finds attractive and beautiful. Natural capital includes natural resources (e.g. food, water, metals, wood, energy), eco-system services (e.g. fisheries, fertile soil, water filtration, CO_2-oxygen), and beauty of nature (e.g. mountains, seashores, sunlight, rainbows, bird song, etc.).

The second layer, human and social capital, contains people (e.g. skills, health, abilities, education) and connections (e.g. family, neighbours, community, companies, and government).

The third layer, built capital, is the support for human and social capital, referring to physical infrastructure and supplies (e.g. buildings, equipment, information, and infrastructure). Monetary resources are not included, because money is considered to be only a medium used to exchange goods and services, and not capital itself; but financial and market systems could be included as the infrastructure for commerce to take place.

Each form of capital is measured differently, which makes them difficult to compare and contrast; however, techniques such as cost-benefit analysis are used to have some basis for comparison. All three levels of capital are managed by communities that need to be nurtured and improved (Hart, 1999). The concept of investment strategy is to use capital (without consuming or degrading it) to generate income, rather than spending the capital itself. Applying this analogy to natural capital implies that using non-renewable resources reduces natural capital over time. The community capital concept takes this idea one step further, by considering that quality of life not only depends on food, shelter, and access to natural resources, but also depends on how people care for themselves, interact, create, assimilate, and celebrate. These wants have an impact on our natural capital: if they are balanced, then the consumption of natural capital cannot exceed the rate at which it is replaced (Hart, 1999).

[c] **Ecological Footprint** was conceived in 1990 by Mathis Wackernagel and William Rees at the University of British Columbia (Global Footprint Network, 2011). It is based on "the impact that an individual or an individual development has on the environment and/or the community in which they live or are developed" (Brandon & Lombardi, 2011). The footprint is directly linked with the amount of resources that an individual consumes. Particular lifestyles add to the size of the footprint. The world average is 4.68 acres per person. In India, the average ecological footprint in acres per person is 1.04; in the Netherlands, it is 8.6; in Canada, it is 11.18; and, in the USA, the footprint is 13.26 acres per person (Wackernagel & Rees, 1995). The ecological footprint includes embodied energy, which refers to the impact of the extraction and processing of materials used by an individual. In any given construction project, the footprint must be calculated starting with the extraction of material, transportation of material, goods and labour, the construction process itself (e.g. infrastructure), building materials, water and energy supply, etc. During the operational stage, the project developers must consider the heating, cooling, organization/operational costs, etc. At the end of the life cycle, the costs of demolition and disposal are included, as well the waste management costs throughout the project lifetime. For cities and buildings to accomplish sustainability goals, their ecological footprint must be equal to or smaller than their physical footprint. The ecological footprint approach has been criticized by some, who debate that the true carrying capacity of the biosphere cannot be calculated, measured or predicted with any accuracy (Haberl et al., 2004; Van Kooten & Bulte, 2000; Pearce, 2005). Others criticize aggregated indicators, suggesting that they do not reflect the real issues in some areas (Bossel, 1998) and the idea of aggregating impacts in a simple index is reminiscent of the problems found in economic indicators such as gross domestic product (Doughty & Hammond, 2004). Bossel (1998) also criticizes aggregate and checklist types of indicators, arguing that they do not reflect the systematic and dynamic nature of urban processes. Furthermore, Fiala's (2008) criticism states, "the arbitrariness of assuming both zero greenhouse gas emissions and national boundaries, that the footprint is in fact a measure of inequality, historical evidence that intensive, rather than extensive, investment is the main driving force of production growth, though the footprint is an entirely static measure and so cannot capture this technological change, and the lack of correlation between land degradation and the ecological footprint, which obscures the effects of larger sustainability problems."

[d] **Monetary approach** calculates the national wealth of different kinds of capital as their sum or the interaction amongst them. The kinds of capital included in this model are financial capital, produced capital goods, social capital, human capital, natural capital, and institutional capital. For comparative assessment, these types of capital should be expressed in a common unit of measurement, which is usually monetary. Frameworks designed using the monetary capital approach try to define development in order to then find the most appropriate way to accomplish the development in a sustainable manner. The main challenge presented by the monetary approach relates to finding all the forms of capital expressed in monetary terms; however, data availability and the substitution and integration of intra-generational equity within and across countries present additional challenges (United Nations, 2007).

[e] **The Driving Force-State-Response Model** (DSR) was based on the pressure-state-response model (OECD, 1994). Later, the DSR was expanded into the framework known as DPSIR (driver-pressure-state-impact-response). The drivers, such as human activities and external forces, induce changes/impacts on different environments (e.g. biophysical and socio-economic) and the state of human settlements. The drivers produce certain amounts of positive or negative pressures (also termed forces), which change the quality and quantity of the natural resources base of air, water, soil, flora and fauna, and non-renewable resources. Based on the impacts generated by this pressure, society must react by developing policies and programmes to prevent, reduce, or mitigate not only the impact (outputs) but also the pressure generated (inputs). As expected, changes in policies and programmes generate incentives to use certain

technologies and abandon others. As in any other cyclical process, these responses produce new pressures that must then be addressed. Linking the three main components (pressure/force, state, and response) are information linkages between pressure/forces and responses, between the state and the pressures/forces, and from the state to the response. These interactions allow better understandings of the consequences of policy and technological intervention.

[f] **Issues or Theme-Base Frameworks** are widely known and commonly used in official national indicator sets. The indicators are grouped into a variety of issues that relate to sustainable development. The policy relevance determines the issues. The issues or theme-base frameworks are successful because of their ability to link indicators to policy processes and targets. This linkage provides clarity to decision makers, thus easing the challenge of communication and monitoring processes and increasing public awareness. These frameworks are flexible, because they easy adjust to upcoming priorities and policies targets over time; however, benchmarking is complicated because of the lack of homogeneity in the themes across nations (United Nations, 2007).

[g] **Accounting Frameworks** do not take into consideration all aspects of sustainable development; but some integrated efforts are working towards expanding the applicability of accounting to include sustainability. These frameworks obtain the indicators from a database that compiles all indicators, and then they are aggregated and can be used in a consistent manner for classification and definition purposes. A widely-known accounting framework is the SEEA (System of Integrated Environmental and Economic Accounting), which is a joint effort between the United Nations Statistical Commission, the International Monetary Fund, the World Bank, the European Commission, and the Organization for Economic Co-operation and Development (United Nations, 2003). SEEA provides an internationally agreed-upon conceptual framework to measure the interactions between economics, the environment, and the state of the environment (United Nations, 2011). SEEA contains three main parts: [1] a Central Framework, which includes internationally agreed-upon standard concepts, definitions, classifications, tables, and accounts; [2] Experimental Ecosystem Accounts; and [3] Extensions and Applications. Presently, SEEA is under revision and will build upon its predecessors: SEEA-2003 and SEEA-1993.

[h] **Frameworks for Assessment Method Tool Kits** comprise a comprehensive classification system of assessment methods, with their main objective being to provide decision makers with support in following the process, as well as to provide timely and structured information. These frameworks provide a set of assessment methods, indicators, models, appraisals, and procedures to decision makers. Frameworks such as BEQUEST (Building Environmental Quality Evaluation for Sustainability through Time), CRISP (Construction and City Related Sustainability Indicators), LUDA (Large Urban Distressed Areas), and Sustainability-Test and the CIB (Conseil International du Batiment) network provide the basis for planning, structuring, and developing assessment method tool kits.

[i] **The Holistic and Integrated Framework** proposed by Brandon and Lombardy (2011) was based on a simplified version of the philosophical theory of the Cosmonomic Idea of Reality. Deakin et al. (2001) recognize the need for new approaches to decision making for sustainable development —namely the holistic approach— to integrate the different dimensions of urban systems and different points of view. It recognizes different levels of information and attempts to integrate key aspects to provide a continuum for harmony and decision making, based on fifteen modalities (or aspects of reality): numerical, spatial, kinematic, physical, biological, sensitive, analytical, historical, communicative, social, economic, aesthetic, juridical, ethical, and creedal. The modalities are placed in logical order; earlier modalities serve as bases for the next. The holistic approach claims to be flexible, take into account different scenarios and planning and design issues, and include easy-to-check and relevant criteria for the decision-makers.

2.2 Strategic Approaches

Throughout the assessment process, decision makers encounter a large number of choices. First and foremost, decision-makers must decide on which sustainability assessment approach meets the needs of a specific project, and how sustainable development goals are to be met. In assessments, the decision-makers are faced with critical decisions that affect the project in some way. A sustainable choice could affect the budget, risk assessment, schedule, and other factors in a project; and project factors can influence a sustainability choice. The uniqueness of particular projects makes decision making more challenging. Furthermore, sustainability assessments should be more flexible in the sense of being more sustainability-focused decision making, based on suitable sustainability principles. At times advocates for sustainability have taken matters into their own hands by drafting, testing, and listing a set of core criteria related to the decision, with sustainability as the ultimate goal.

In Appendix 2 of Sustainability Assessment – Criteria and Processes, Gibson et al. (2010) present a series of strategic approaches (e.g. fundamental objectives, key challenges, essential strategy components, foundation principles, or design imperatives), without implying that the set of approaches is complete. In this series of selected sustainability assessment approaches, criteria and processes were developed and/or adopted by specific individuals and/or organizations, recognizing that local differences can be important and additions and elaborations are needed in each specific case/project. The list presented below represents a brief sample of the multiple strategic sustainable assessment approaches designed and used around the world:

[a] The International Council for Local Environmental Initiatives (ICLEI, 1996; 2004) and International Council for Local Environmental Initiatives-Europe (ICLEI, 1997), Local Agenda 21 (LA21) proposes a participatory planning process for communities, which has been applied to over 6000 cities; [b] the Government of British Columbia presents a growth management strategies law and a process for the pursuit of sustainability through the preparation of planning strategies by municipalities in expanding urban regions (Government of British Columbia, 1997); [c] B. Sadler approaches sustainability assessment as the next generation of environmental assessment (Sadler, 1996); [d] B. Becker reviews sustainability values, concepts, and methodological approaches (Becker, 1997); [e] D. Lawrence takes on a basic approach to the integration of sustainability into assessment requirements (Lawrence, 1997); [f] D. Devuyst describes the 'assessing the sustainability of societal initiatives and proposing agendas for change' (ASSIPAC) method for sustainability assessment, noting it was designed chiefly for urban planning uses, but is broadly used (Devuyst, 1999); [g] the Government of United Kingdom puts forward a strategy for sustainable development (Government of United Kingdom, 1999); [h] J. Ravetz describes the 'integrated sustainable cities assessment method' (ISCAM), which was proposed in light of a case review of integrated planning for sustainability for Greater Manchester (Ravetz, 2000); [j] IUCN (World Conservation Union) Monitoring and Evaluation Initiative offers a sustainability assessment method for evaluating human and environmental conditions that are progressing towards sustainability (Guijt et al., 2001); [10] the Mining, Mineral and Sustainable Development project outlines the basic components of integrated impact assessment (MMSD, 2002); [k] the North American working group of Mining, Minerals and Sustainable Development project develops a sustainability assessment framework for mining projects (MMSD-NA, 2002); [l] the Global Ecovillage Network Community Sustainability Assessment compiles a comprehensive checklist for evaluating the sustainability of individual communities (Global Ecovillage Network, undated); [m] the Hong Kong Sustainable Development Unit designs an assessment system for integrated consideration of proposals (HKSDU, 2002); [n] Bradley et al. (2002) use sustainability criteria to evaluate onsite wastewater treatment technologies; [o] the Stockholm Environment Institute uses sustainability assessment of World Trade organization negotiations in the food crops sector (Maltias et al., 2002); [p] Equator Principles are used for decision making on major project financing, prepared and adopted by a voluntary association of major financial institutions for the assessment of environmental and social risk of proposed projects expected to cost over US$50 million (Equator Principles, 2003); [q] Jenkins et al. (2003) propose a comprehensive sustainability assessment framework to the Western Australia State Sustainability Assessment Working Group; [r] Nelson et al. (2004) develop a strategic environmental assessment for sustainability appraisal of Ghana’s Poverty Reduction Strategy; [s] the Forest Stewardship Council creates a series of certification principles, criteria, standards, and processes for forestry operations and wood products (FSC, 2004); and [t] the Regional Municipality of Waterloo develops the terms of reference for the assessment of a rapid transit initiative (RMW, 2005).

2.3 Integrated Approaches

Sustainability is a complex and multi-dimensional area, which is under continuing development. Though the existing assessments contribute to the sustainability agenda, established tools are not yet working effectively (Gibson 2001), leading to a call for holistic approaches (Brandon & Lombardi, 2011) or holistic impact assessments (Kwiatkowski & Ooi, 2003). Rotmans (2006) addresses the point that—even though new tools such as Sustainability Impact Assessment (SIA) have been adopted by the European Union—there is a need for more strategic approaches, such as Integrated Sustainability Assessments (ISA). Sustainability targets and criteria are used by ISA to comprehensively assess international and national policy programs. The MATISSE (Methods and Tools for Integrated Sustainability Assessment) project was launched as a response to the challenge of unsustainability, and under its context a two track-strategy is proposed (Rotmans, 2006). The aim of MATISSE is to propose procedures, methods, and tools for effectively and efficiently integrated sustainability into policy development process and institutions. Furthermore, MATISSE defines ISA as “a cyclical, participatory process of scoping, envisioning, experimenting, and learning through which a shared interpretation of sustainability for a specific context is developed and applied in an integrated manner in order to explore solutions to persistent problems of unsustainable development” (SERI, 2011). Varey (2004), founder of EMRGNC, considers that any integrated approach with sustainability as its goal may include the processes and expertise of any, or all, of the disciplines of environmental impact assessment (EIA), strategic environmental assessment (SEA), environmental and social impact assessment (ESIA), political and policy assessment (PPA), privacy impact assessment (PIA), economic and fiscal impact assessment (EFIA), technology impact assessment (TIA), demographic impact assessment (DIA), health impact assessment (HIA), social impact assessment (SIA), urban impact assessment (UIA), biodiversity impact assessment (BIA), cumulative effects assessment (CEA), triple bottom line assessment (TBL), integrated impact assessment (IIA), and sustainability appraisal and sustainability assessment (SA). Furthermore, an integrated approach does not imply the integration of different approaches, but the principles of sustainability must be the base for an integral assessment that is an integral component of policies, programmes, and decision making processes. The new generation of ISA tools and instruments are meant to use the so-called Triple I approach: Innovative, Integrated, and Interactive, as required by the demands of sustainable development (Rotmans, 2006). More flexible and participatory focused methodologies are emerging as sustainable development evolves. Different tools (methodologies, approaches, models, and appraisals) are re-visited to look for ways of adjusting and improving them to meet the different needs of stakeholders, projects, and ultimately, the needs of a balanced development.

3. Assessment Methods

Assessment methods are required to make progress toward a purpose. They are designed to present the status of the environmental capacity, measure whether progress has been made, and support decision makers on present and future decisions (Brandon & Lombardi, 2011). Not only has the evaluation process become relevant, but also the monitoring of the progress has a definitive role in accomplishing sustainable development goals.

The sustainability needs of the oil sands and heavy oil projects and the expected benefits by the implementation of the WA-PA-SU project sustainability rating system (Poveda & Lipsett, 2011a) and its unique structure (Poveda & Lipsett, 2011b) determine which existing assessment tool characteristics can be adopted into its sustainability assessment methodology. Presently, there is no agreement among scholars under which framework to place the evaluation methods (Horner, 2004; Curwell et al., 2005; Deakin et al., 2007). In fact, there is a division between those who believe that environmental assessments contribute to sustainable development (Bergh et al., 1997; Brandon et al., 1997; Nijkamp & Pepping, 1998) and those who consider that the present methods are unable to evaluate non-market goods and services and therefore present methods make limited contributions to sustainable development (Guy & Marvin, 1997).

There are a large number of assessment methods available, and classifying them can be a challenge. Different projects and studies present inventories of the available tools: the 'Sustainability A – Test' EU project, the ECO^2 Cities study, the LUDA project, and the BEQUEST project, among others.

The Sustainability A – Test EU project applies a consistent and comprehensive evaluation framework to validate a series of sustainable development tools (i.e. methodologies, models, approaches, and appraisals). The project includes, as shown in Table 1, assessment frameworks, participatory tools, scenario analysis, multi-criteria analysis, cost-benefits analysis and cost-effectiveness analysis, modeling tools, accounting tools, physical analysis tools, and indicator sets. The Sustainability A – Test project was led by IVM and carried out by four Dutch partners, thirteen other European partners, and one Canadian partner. It was commissioned by the EU FP6-STREP programme. Examples of the tools included environmental impact assessment, scenario tools, multi-criteria analysis, cost-benefit analysis and accounting tools (IVM 2011).

The World Bank launched an initiative to help cities in developing countries achieving greater ecological and economic sustainability. The Eco² Cities: Ecological Cities as Economic Cities program provides practical, scalable, analytical, and operational support to cities. The program develops an analytical operational framework to be used by cities around the world towards accomplishing their sustainability goals:

"Urbanization in developing countries is a defining feature of the 21st century. Some 90 percent of global urban growth now takes place in developing countries – and between the years 2000 and 2030, developing countries are projected to triple their entire built-up urban areas. This unprecedented urban expansion poses cities, nations and the international development community with a historic challenge and opportunity. We have a once in a lifetime opportunity to plan, develop, build and manage cities that are simultaneously more ecologically and economically sustainable. We have a short time horizon within which to impact the trajectory of urbanization in a lasting and powerful way. The decisions we make together today can lock-in systemic benefits for the present and for future generations" (World Bank, 2011).

Suziki et al. (2010) in their Eco2 Cities: Ecological Cities as Economic Cities present a different classification of assessment methods. The Eco2 Cities study suggests three categories: [1] methods for collaborative design and decision making—these help the cities to undertake leadership and collaboration; [2] methods for analyzing flows and forms—these analytical methods and combinations provide a transdisciplinary platform to identify the relationships between the spatial attributes of cities (forms) and the physical resource consumption and emissions of cities (flows); and [3] methods for investment planning assessment, which include accounting methods, life-cycle costing, proactive risk mitigation, and adaptation. These methods provide to the cities a decision support system for the implementation of more strategic and long term management and decision making.

The LUDA (Large Urban Distressed Areas) is a research project of Key Action 4—"City of Tomorrow & Cultural heritage"—of the programme "Energy, Environment and Sustainable Development" within the Fifth Framework Programme of the European Commission. LUDA provides tools and methods for a more strategic approach towards urban rehabilitation, and towards bringing support to cities in initiating and managing the chosen approach in its early stages. The project was conceived in response to the high level of political pressure to assist cities experiencing distress caused by environmental, economic, and social impacts, to make rapid improvements to the quality of life (LUDA Project, 2011). LUDA ran from February 2004 to January 2006. It included sixteen project members and twelve reference cities.

In a survey, the BEQUEST (Building Environmental Quality Evaluation for Sustainability) project released a list of 61 assessment methods, tools, and procedures. Table 2 presents the results of the BEQUEST survey complemented with other tools (e.g. rating systems) commonly used by different parties in the construction industry: architects, engineers, constructors, producers of buildings products, investors and building owners, consultants, residents, facilities managers, researchers, and authorities (Haapio & Viitaniemi, 2008; Poveda & Lipsett, 2011). The BEQUEST project surveyed tools currently used in assisting the sustainable urban development process in the planning, design, construction, and operation stages. BEQUEST integrates four dimensions of urban development: development activity, environmental and social issues, spatial levels, and timescale.

After the Brundtland Commission presented its report, "Our Common Future," an explosion of new assessment tools (e.g. methodologies, models, approaches, and appraisals) became available; however, there were instruments already in place before 1987, such as cost-benefit analysis, contingent valuation, hedonic pricing method, travel-cost method, and multi-criteria analysis. Other evaluation procedures considered to be statutory instruments such as EIA (Environmental Impact Analysis) and SEA (Strategic Environmental Analysis) were also already established. The next section presents a brief description of the most commonly used tools: methodologies, models, approaches, and appraisals.

3.1 Environmental, Social and Economic Impact Analysis

Environmental impact analysis was developed in 1969 under the National Environmental Policy Act (NEPA) in the United States. The procedure assesses the physical and social impact of projects, and its main objective is to take into consideration—and inform stakeholders and decision makers of—environmental implications before decisions are made. Social and economic impact analyses function similarly with their respective issues, and these two components (social and economic) are usually included in an environmental impact analysis. While the tool allows users to take into consideration the different impacts during the decision making process, there are some limitations in the areas of prediction of impact, definition and measurement, monitoring, use of specific methods, and consultation and participation (Brandon & Lombardi, 2011).

3.2 Strategic Environmental Assessments

Environmental Impact Assessment (EIA) presents a specific challenge because its application is limited to a specific project. The United Nations Economic Commission for Europe recommended the extension of EIA as an integrated assessment for policies, plans, and programmes (PPP). As a result, SEA (Strategic Environmental Assessments) supports the decision makers in early stages of the process, guaranteeing that proper, prompt, and adequate decisions are made. A difference from the EIA, which is mainly focused at the project level, is that the SEA objective is to develop PPP at a higher level of the decision making process. While SEA allows more participation and facilitates the engagement of the public in the decision making process, the main weakness of the process is that it relies on time and resources. Other issues that can arise relate to data, the mechanism for public participation, and uncertainties; furthermore, social and economic aspects are usually left out.

3.3 Cost-Benefit Analysis

A cost-benefit analysis (CBA) examines costs and benefits of a project. In an economic decision making approach, it is often called benefit-costs analysis (BCA). This particular approach is meant to be applied in early stages to determine the viability of a project, measuring and comparing the expected costs and benefits of a set of projects that are competing for resources. This approach allows decision makers to search for the alternative providing the best return on capital. The NPV (net present value) and IRR (internal rate of return) are the most common capital budgeting tools. Internal rate of return must exceed a threshold return on investment criterion for a project to be acceptable.

There are two types of cost-benefit analyses: social and economic. The costs relate to all expenditures carried out by developer, and are expressed in monetary terms and adjusted for the time value of money, whereas the benefits refer to revenues received from the project. A CBA provides a systematic tool with a basis for comparison among projects by using a common basis in terms of present value. Similar techniques have been developed to address the weaknesses encountered in CBA, enhancing its strengths and/or offering alternative applications, including: community impact analysis (CIA), cost-effectiveness analysis, cost-utility analysis, economic impact analysis, social return on investment (SROI) analysis, and fiscal impact analysis.

3.4 Travel Cost Theory

Travel cost theory estimates economic use values related to sites or ecosystems used for recreation. For a recreation site, travel cost includes economic benefits or costs as result of: addition of, change in access costs for, elimination of, changes in environmental quality at a recreation site. Time and travel cost expenses count for the price of access to the recreation site. Using the market idea of willingness to pay for a determined good based on the quantity demanded at different prices, the travel cost theory measures people's willingness to pay to visit the site, based on the number of trips that they make at different travel costs.

3.5 Community Impact Evaluation

Initially known as the planning balance sheet (PBS), community impact evaluation (CIE) was developed by Lichfield in 1956. It presents an adaptation of cost-benefit analysis for urban and regional planning. In addition to providing the total costs and benefits of projects, CIE also evaluates the impact on other sectors of the community, illustrating the implications on social justice and equity of decisions made (Lichfield & Prat, 1998). While the strength of the CIE relies on stakeholder participation and the role of the community, the weakness arises in the data selection processes used for evaluation and classification of societal impacts.

3.6 Contingent Valuation Method

The contingent valuation method (CVM) considers two different criteria. For environmental improvements, CVM considers willingness to pay. For reduction in environmental quality, it assesses willingness to accept. CVM uses Hicksian measures of utility by generating estimates that are obtained through the use of questionnaires. Two critical aspects in the CVM are the hypothetical scenario characterization and the questionnaires development. It is suggested that the participants should be familiar with the hypothetical scenario; in fact, certain scenarios or cases require expert knowledge. While the strengths of CVM are its flexibility and capacity to measure non-use values, its main weakness is its limited appropriateness to value entire ecosystems.

3.7 Hedonic Pricing Method

Based mostly on Lancaster's (1966) consumer theory, the Hedonic Pricing Method was developed by Rosen (1974). Hedonic pricing is used for ecosystems and environmental services to estimate economic values that directly affect the market. The objective of the method is to determine the relationship between the attributes and price of a specific good. If a particular product possesses a certain number of characteristics, each with a specific price, then the price of a certain property can be calculated as the sum of its characteristics.

3.8 Multi-Criteria Analysis

Multi-Criteria Analysis (MCA) presents an alternative valuation method to cost-benefit analysis (CBA). Since impacts are difficult to assess in monetary terms, the MCA technique weights and ranks impacts in non-monetary terms. The strength of the MCA relies on three factors: [1] information present in the selected criteria, [2] weights given to each criterion, and [3] agreement amongst stakeholders on the weights given to each criterion. Sensitivity analyses are usually used to measure the degree of strength and adjust the weights of criteria. MCA methods can be classified according to the decision rule used or the type of data handled. Based on the decision rule used, there are three different types of methods: compensatory, partial-compensatory, and non-compensatory. In a compensatory method, bad or low performances on a certain criterion can be compensated by good or high performances of other criteria; and so a compensatory method allows the compensability factor to be fully applied. A partial-compensatory method allows some compensation based on a predetermined limit. Non-compensatory methods do not allow any compensation. Methods can deals with quantitative data for each criterion yielding a weighted summation. Qualitative methods process qualitative data, typically by applying some kind of logic ladder. Mixed methods deal with data as they are measured.

3.9 Material Intensity Per Service Unit (MIPS)

Material Intensity Per Service Unit (MIPS) and was developed at the Wuppertal Institute in the 1990s. To make a product or provide a service, a certain amount of material (or mass) must be moved or extracted. MIPS adds up the overall material to calculate the total material intensity of a product or service by dividing the total material input (MI) by the number of service units (S).

3.10 Analytic Network Process

Multi-criteria analysis offers some alternatives. The analytic hierarchy process (AHP) offers its most advanced approach through the Analytic Network Process (ANP). The structure of the ANP is a network, while the AHP structure consists of a hierarchy with a goal, decision criteria, and alternatives. The main components of the ANP are clusters, elements, interrelationships between clusters, and interrelationships between elements. Brandon & Lombardi (2011) describe the three main stages of the process: [1] structuring the decision making model, [2] developing pairwise comparison of both elements and clusters to establish relationships within the structure, and [3] achieving the final set of priorities. Both processes—ANP and AHP—use pairwise comparison to determine the weights of the elements in the structure, and then rank the different alternatives. "The ANP allows interaction and feedbacks within and between clusters and provides a process to derive ration scales priorities from the elements" (Brandon & Lombardi, 2011).

3.11 Life Cycle Assessment

Life Cycle Assessment (LCA) examines a product or service throughout its life cycle to assess environmental impacts. It is also known as life cycle analysis, eco-balance, and cradle-to-grave analysis. The LCA methodology is based on ISO 14040 and BS EN ISO 14041-43. In the case of buildings, software tools—including BRE (Buildings Research Establishment) and BEES (Building for Environmental and Economic Sustainability)—are available to evaluate their impacts. The main interlinked components of LCA are: goal definition and scoping, life cycle inventory, life cycle impact assessment, and improvement analysis (interpretation).

3.12 Sustainability/Environmental Rating Systems

Sustainability/environmental rating systems have been designed to measure environmental performance of a variety of projects in the construction industry. Sustainability/environmental rating systems support the decision making process throughout the project life cycle, or for certain phases of a project. In common practice, the designer does not have much interaction with the builder; however, accomplishing the sustainability goals requires an integrated effort between the parties involved, independent of the project delivery method used (e.g. design-bid-build, design-build, integrated project delivery, etc.). An integrated approach assists the decision making process and minimizes design and building errors, among other benefits. The building industry has a wide variety of sustainability/environmental ratings systems to choose from: ATHENA, BEAT 2002, BREEAM, LEED, Green Globes, CASBEE, and Green Start are some of the existing sustainability/environmental rating systems, as shown in Table 2. LEED, for example, initially emphasizes six categories: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation in design, adding the regional priority category in its most recent version (USGBC, 2009a). Other categories have been developed for specific rating systems, for example, LEED for neighborhood development. Whereas LEED has been a success in North America and certified LEED projects are present in more than 100 countries, BREEAM (developed in the United Kingdom by the Building Research Establishment (BRE)) has demonstrated its applicability in Europe. BRE has more than 100,000 buildings certified, and operates in dozens of countries. BREEAM uses nine categories: management, health and wellbeing, energy, transport, water, materials, waste, land use and ecology, and pollution. Dividing the criteria in categories facilitates practitioners to make effective and efficient decisions in the use and operation of the resources involved in the planning, execution, and operation of projects.

4. Sustainability/Environmental Rating Systems and the Credit Weighting Tools

This section focuses on describing, analyzing, and comparing the different credit weighting tools adopted by the most popular ratings systems around the world. The aim of this section is not to compare the efficacy of the existing sustainability/environmental rating systems on the reduction, mitigation, or elimination of the different impacts (e.g. social, economic and environmental) carried out by certain types of development. A brief description of the structure and components of each rating system is given to then focus on the application of each particular credit weighting tool. One of the critical issues in developing a rating system is the distribution of points and weights across the different areas and criteria of the rating system (Trusty, 2008).

As stated earlier, in the assessment process the performance is compared against a criterion or a number of criteria. A quantitative multi-criteria analysis (MCA) allocates weight to each criterion to then obtain a weighted summation. Since each criterion has a determined weight, the total performance score in a rating system will be given by the addition of every criterion's weight if the project or task has met a pre-established requirement. By definition, a credit weighting tool (CWT) is the methodology adopted to allocate certain weight to a criteria. The CWT refers neither to the systematic way to rate projects, nor to the rating scale used by different sustainable rating systems. A rating scale determines the number of points or parameters for a project to be categorized, certified, or acknowledged as sustainable.

4.1 Leadership in Energy & Environmental Design (LEED)

The current version of LEED (e.g. LEED 2009) uses a basic weighting equation to determine the value of the credits (see Box 1). Currently, the new version of LEED is under development (LEED 2012). LEED 2012 will use a set of categories developed by USGBC that more closely align with the mission and vision for ongoing LEED development (USGBC 2011). Since specifics of LEED 2012 have not been released, the credit weighting tool description in Box 1 is based on LEED 2009 (current version).

The objective of the equation is to combine information on buildings impacts, buildings functions (a.k.a. building "activity groups"), and performance of individual credits. (USGBC, 2009b).

Impact categories are defined and weighted directly by the National Institute of Standards and Technology (NIST) using impact categories defined by US Environmental Protection Agency's TRACI (tool for the reduction and assessment of chemical and other environmental impacts) project (Bare et al., 2002). The categories and their weights are described as follows:

Greenhouse gas emissions (29%) Water use (8%) Eutrophication (6%)

Fossil fuel depletion (10%) Ecotoxicity (7%) Smog formation (4%)

Particulates (9%) Land use (6%) Acidification (3%)

Human health-cancer (8%) Indoor air quality (3%) Ozone formation (2%)

Human health-non-cancer (5%)

To determine the weights of the categories, NIST used an analytical hierarchy process (AHP). The weights of the categories add to 100%.

Activity Groups reflect the core building functions. All LEED credits fall under one of these activity groups. Activity groups can be associated with specific building impacts in each category. These categories are described as follows:

Building systems (specifically fuel and electricity consumption)

Transportation (commuting and services)

Water consumption (domestic and landscaping-related)

Materials (core, shell, and finishing)

Indoor Environmental Quality

A certain number of credits are represented by each activity group. The percentages of total building-related impacts to each activity group are assigned by using a combination of empirical calculations and LCA (life cycle assessments). Each credit is given a binary association with each impact category: 0 = no association, 1 = association. Finally, the weight of each activity group is allocated proportionally to each credit associated with each impact category.

4.2 Comprehensive Assessment System for Built Environment Efficacy (CASBEE)

The Comprehensive Assessment System for Built Environment Efficacy (CASBEE) assesses buildings using environmental efficiency and impact on the environment. The assessment tool uses two factors: Q and L. Quality (Q) is defined as Building Environmental Quality and Performance, which evaluating improvement in living amenity for the building users within the hypothetical enclosed space (private property). Loadings (L) relates to Building Environmental Loadings, evaluating negative aspects of environmental impact that go beyond the hypothetical enclosed space and outside to public property (CASBEE, 2006). Using Q and L, CASBEE calculates BEE (building environmental efficiency), as the ratio of Q to L:

$$BEE = Q / L \quad (1)$$

Environmental Quality Q contains the indoor environment (including acoustics, lighting, thermal comfort, and air quality), service quality (includes adaptability, flexibility, and durability), and outdoor environment. Environmental Load (L) contains energy, materials, and the off-site environment.

Assessment categories. Q (building environment quality & performance) is broken down into three categories: Q-1 (indoor environment), Q-2 (quality of service) and Q-3 (outdoor environment on site). LR (reduction of building environmental loadings) is sub-grouped into LR-1 (energy), LR 2-2 (resources and material) and LR-3 (off-site environment).

Scoring. Each assessment item has a scoring criterion to meet. The level of technical and social standards at the time of the assessment gives the criteria to be applied to each assessment.

Weighting. Items such as Q-1, Q-2, and Q-3 or LR-1, LR-2, and LR-3 are weighted and the sum of Q adds up to 1.0. The score of each assessment is multiplied by the weighting coefficient, and then the set of coefficients is aggregated to obtain SQ and LR as total scores for Q and LR respectively.

4.3 Building Research Establishment Environmental Assessment Method (BREEAM)

In the Building Research Establishment Environmental Assessment Method (BREEAM), different environmental issues are grouped in three main areas: [1] global issues, which includes CO_2 emissions, acid rain, ozone depletion, natural resources and recyclable materials, storage of recyclable materials, and designing for longevity; [2] local issues, which include transport and cycling facilities, noise, local wind effects, water economy, overshadowing or other buildings and land, reuse of derelict/contaminated land, and the ecological value of the site; and [3] indoor issues, involving hazardous materials, natural and artificial lighting, thermal comfort, and overheating and ventilation.

Each individual issue gets a discrete credit. A credit is given if the design meets the requirements concerning that particular issue; however, there is no intention at weighting the issues (Brandon & Lombardi, 2011). The sum of the credits gives the overall performance expressed in a semantic scale based on a certain minimum level of credits obtained in each of the three main areas (e.g. global issues, local issues, and indoor issues).

BREEAM contains nine different categories, each with a pre-determined environmental weighting:

Management (12%)	Health & Wellbeing (15%)	Energy (19%)
Transport (8%)	Water (6%)	Materials (12.5%)
Waste (7.5%)	Land Use & Ecology (10%)	Pollution (10%)

A certain number of achieved available credits in each category determines the percentage obtained in the assessment. The overall score is the percentage sum of all categories.

4.4 GBTool

GBTool uses similar approaches to LEED and BREEAM**,** and includes an assessment scale and best practices. GBTool is based on a life cycle assessment methodology, and allows customized weighting of criteria. The scores are assigned in a range of -2 to +5, described as follows:

-2 and -1: the level of performance is below acceptance levels in the specific region

0: the minimum level of acceptable performance in the specific region

3: best practice

5: best technically achievable, without consideration of cost

Scores are provided for phases of building activity, including pre-design, design, construction, and operations. The four levels of parameters included in the system include issues, categories, criteria, and sub-criteria. The issues and category parameters are voted on by team members, and criteria and sub-criteria are assigned automatically. The scores are multiplied by the weights and the weighted scores (PETUS, 2011).

4.5 Green Star

Green Star contains nine categories: management, indoor environment quality, energy, transport, water, materials, land use & ecology, emissions, and innovation. These categories assess the environmental impact that is directly linked to project site selection, design, construction, and maintenance. A number of credits follow under each category to address initiatives for improvement or to show the potential for improving environmental performance. Similar to LEED and BREEAM, each category has a certain weight. In the case of Green Star, the category weightings are developed by taking into consideration scientific and stakeholder input, which includes: [1] the OECD Sustainable Building Project Report, [2] the Australian Greenhouse Office, [3] Environmental

Australia, [4] CSIRO, [5] the Cooperative Research Center for Construction, [6] the Commonwealth Department of Environment and Heritage, and [7] a national survey conducted by the Green Building Council.

The weightings vary by geographical location. The weighted category score is calculated by using the following formula:

$$\text{Weighted Category Score} = \text{Category Score (\%)} \times \text{Weighting Factor (\%)} / 100 \tag{2}$$

A certain number of credits are available in each category. The category score is based on the percentage of achieved available points.

As noted above, the most popular environmental/sustainable rating systems use similar approaches in their credit weighting tools, with the exception of CASBEE. The systems weight the different categories and a number of criteria fall under each category; however, there is no intention of directly weighting each credit. Most rating systems are based on the Life-Cycle Analysis methodology and have similarities to Environmental Management Systems (EMS) (Papadopoulos & Giama, 2009). The main objective of EMS is continual environmental improvement. When evaluating and selecting rating systems, a series of criteria must be taken into consideration. Fowler and Rauch (2006) conducted a survey to identify such criteria: measurability, applicability, availability, development, usability, system maturity, technical content, communicability, and cost.

5. Discussion and Conclusions

As the understanding of sustainable development grows, its applicability and usefulness are more accepted. The number of methodologies, models, approaches, and appraisals for assessing sustainability has dramatically increased since the concept of sustainable development was recognized as separate from balancing economic wealth creation and environmental degradation in the 1960s and early 1970s. The number of tools for assessing sustainability is expected to increase as this approach to assessing broad impacts of technology gains popularity. There are already several hundred types of assessment tools. As the number of tools increases, some classification becomes necessary. The present work has laid out a classification of assessment tools as generic, strategic, and integrated, with description of the most-used assessment tools and sustainability and environmental rating systems and their respective credit weighting tools. The classification of the existing tools for assessing sustainability varies with the criteria used. The framework presented in this manuscript serves as support for the development of the WA-PA-SU project sustainability rating system by indicating where it stands in the world of decision making tools for sustainability assessment.

References

Bare, J. C., Norris, G. A., Pennington, D. W. & McKone, T. (2002). TRACI: The tool for the reduction and assessment of chemical and other environmental impacts. *Journal of Industrial Ecology.* 6 (3/4), 49-78. http://dx.doi.org/10.1162/108819802766269539

Becker, B. (1997). Sustainability Assessment: A review of values, concepts and methodological approaches, issues in agriculture 10. Washington, DC: Consultative Group on International Agricultural Research/World Bank.

Bergh, J., Button, K., Nijkam, P. & Pepping, G. (1997). *Meta-analysis of environmental policies*. Dordrecht: Kluwer.

Bossel, H. (1998). *Earth at a Crossroads*. Cambridge: Cambridge University Press.

Bradley, B., Daigger, G. T., Rubin, R. & Tchobanoglous, G. (2002). Evaluation of onsite wastewater treatment technologies using sustainable development criteria. *Clean Technologies and Environmental Policy.* 4 (2), 87-99. http://dx.doi.org/10.1007/s10098-001-0130-y

Brandon, P. S., Lombardi, P. & Bentivegna, V. (eds). (1997). *Evaluation of the Built Environment for Sustianability*. London: Chapman & Hall.

Brandon, P. S. & Lombardi, P. (2011). *Evaluating Sustainable Development in the Built Environment* (2nd Ed.). Hoboken, NJ: Wiley-Blackwell.

Brundtland, G. (eds). (1987). *Our Common Future: The World Commission on Environment and Development*. Oxford: Oxford University Press.

CASBEE. (2006). Assessment tool of CASBEE. [Online] Available: http://www.ibec.or.jp/CASBEE/english/method2E.htm (Jun 14, 2011).

Collin, R. M. & Collin, R. W. (2010). *Encyclopedia of Sustainability*. Santa Barbara, California: ABC-CLIO, LLC.

Curwell, S., Deakin, M. & Symes, M. (eds). (2005). *Sustainable urban development: The framework, protocols and environmental assessment methods: Vol. 1*. Oxford: Routledge

Deakin, M., Curwell, S. & Lombardi, P. (2001). BEQUEST: Sustainability assessment, the framework and directory of methods. *International Journal of Life Cycle Assessment.* 6 (6), 373-390. http://dx.doi.org/10.1007/BF02978869

Deakin, M., Mitchell, G., Nijkamp, P. & Vreeker, R. (eds). (2007). *Sustainable urban development the environmental assessment methods: Vol. 2*. Oxon: Routledge

Devuyst, D. (1999). Sustainability assessment: The application of a methodological framework. *Journal of Environmental Assessment Policy and Management.* 1 (4), 459-487. http://dx.doi.org/10.1142/S1464333299000351

Dooyeweerd, H. (1968). *In the twilight of Western thought*. Nutley, NJ: Craig Press.

Dooyerweerd, H. (1979). *Roots of Western culture: Pagan, secular and Christian Options*. Toronto: Wedge Publishing Company.

Doughty, M. R. C. & Hammond, G. P. (2004). Sustainability and the built environment at and beyond the city scale. *Building and Environment.* 39, 1223-1233. http://dx.doi.org/10.1016/j.buildenv.2004.03.008

Equator Principles. (2003). The Equator Principles: An industry approach for financial institutions in determining, assessing and managing environmental & social risk in project financing. [Online] Available: http://www.equator-principles.coml (October 3, 2011).

Fiala, N. (2008). Measuring sustainability: Why the ecological footprint is bad economics and bad environmental science. *Ecological Economics.* 67 (4), 519-525. http://dx.doi.org/10.1016/j.ecolecon.2008.07.023

Fishburn, P. C. (1970). *Utility theory for decision making*. New York, NY: Wiley.

Fowler, K. M. & Rauch, E. M., (2006). Sustainable building rating systems - summary. Richland, WA: Pacific Northwest National Laboratory, Department of Energy.

Francescato, G. (1991). *Housing quality: Technical and non-technical aspects. In: Management, Quality and Economics in Buildings (eds A. Bezelga & P. Brandon).* London: E & FN Spon.

FSC (Forest Stewardship Council). (2004). About FSC. [Online] Available: http://www.fsc.org/fsc/about (July 29, 2011)

Gibson, R. (2001). Specification of sustainability-based environmental assessment decision criteria and implications for determining "significance" in environmental assessment. [Online] Available: http://www.sustreport.org/downloads/Sustainability,EA.doc (August 3, 2011).

Gibson, R. B., Hassan, S., Holtz, S., Tansey, J. & Whitelaw, G. (2010). *Sustainability Assessment: Criteria and Processes*. London, UK: Earthscan.

Global Ecovillage Network (undated). Community sustainability assessment (CSA). [Online] Available: http://gen.ecovillage.org/activities/csa/English (October 3, 2011).

Global Footprint Network. (2011). Footprint basics – overview. [Online] Available: http://www.footprintnetwork.org/en/index.php/GFN/page/footprint_basics_overview/ (August 1, 2011).

Government of British Columbia. (1996). Revised Statutes of British Columbia, Chapter 323 Municipal Act, Part 25 – Regional Growth Strategies. Victoria, BC: Government of British Columbia.

Government of United Kingdom. (1999). A better quality of life: A strategy for sustainable development for the United Kingdom. [Online] Available: www.sustainable-development.gov.uk/uk_strategy/index.htm (Oct 3, 2011).

Guijt, I., Moiseev, A. & Prescott-Allen, R. (2001). IUCN Resource kit for sustainability assessment. Geneva: IUCN Monitoring and Evaluation Initiative.

Guy, S. & Marvin, S. (1997). Splintering networks: Cities and technical networks in 1990s Britain. *Urban Studies.* 34 (2), 191-216. http://dx.doi.org/10.1080/0042098976140

Haapio, A. & Viitaniemi, P. (2008). A critical review of building environmental assessment tools. *Environmental Impact Assessment Review*. 28, 469-482. http://dx.doi.org/10.1016/j.eiar.2008.01.002

Haberl, H., Fischer_Kowalski, M., Krausmann, F., Weisz, H. & Winiwarter, V. (2004). Process towards sustainability? What the conceptual framework of material and energy flow accounting (MEFA) can offer. *Land Use Policy*. 21, 199-213. http://dx.doi.org/10.1016/j.landusepol.2003.10.013

Hart, M. (1999). *Guide to Sustainable Community Indicators (2nd Ed.).* North Andover, MA: Hart Environmental Data.

HKSDU (Hong Kong Sustainable Development Unit). (2002). Sustainability assessment. [Online] Available: www.susdev.gov.hk/text/en/su/sus.htm (October 3, 2011).

Horner, R. M. W. (2004). Assessment of sustainability tools (Report No. 15961). Glasgow: Building Research Establishment.

ICLEI (International Council for Local Environmental Initiatives). (1996). Local Agenda 21 Planning Guide: An introduction to sustainable development planning. Ottawa, ON: International Development Research Council.

ICLEI-Europe (International Council for Local Environmental Initiatives, Europe). (1997). Briefing sheets on local Agency 21 - Performance criteria. [Online] Available: www.iclei.org/europe/la21/support/perfcrt.htm (October 3, 2011).

IVM (Institute for Environmental Studies). (2011). Sustainability A – Test. [Online] Available: http://www.sustainabilitya-test.net/ (July 29, 2011).

Jenkins, B., Annandale, D. & Morrison-Sanunders, A. (2003). The evolution of a sustainability assessment strategy for Western Australia. *Environmental and Planning Law Journal*. 20 (1), 56-65.

Kwiatkowski, R. E. & Ooi, M. (2003). Integrated environmental impact assessment: a Canadian example. *Bulletin of the World Health Organization*. 81 (6), 434-438. PMid:12894328, PMCid: 2572469

Lancaster, K J. (1966). A new approach to consumer theory. *Journal of Political Economy*. 84, 132-157. http://dx.doi.org/10.1086/259131

Lawrence, D. (1997). Integrating sustainability and environmental impact assessment. *Environmental Management*. 21 (1), 23-42. http://dx.doi.org/10.1007/s002679900003

Lichfield, N. & Prat, A. (1998). *Linking ex-ante and ex-post evaluation in British town planning. In: Evaluation in planning: pacing the challenge of complexity (eds. N. Lichfield, A. Barbanente, D. Borri, A. Kakee & A. Prat).* Dordrecht: Kluwer Academic Publishers.

LUDA Project. (2011). LUDA Project: Description of the project. [Online] Available: http://www.luda-project.net/proj02.html (July 29, 2011).

Maltais, A., Nilsson, M. & Persson, A. (2002). Sustainability impact assessment of WTO negotiations in the major food crops sector. Stockholm: Stockholm Environment Institute.

Mitchell, G., May, A. & McDonald, A. (1995). PICABUE: a methodological framework for the development of indicators of sustainable development. *International Journal of Sustainable Development and World Ecology*. 2, 104-123. http://dx.doi.org/10.1080/13504509509469893

MMSD (Mining, Minerals and Sustainable Development Project). (2002). Breaking New Ground: The Report of the MMSD Project. [Online] Available: www.iied.org/mmsd/finalreport (Oct 3, 2011).

MMSD-NA (Mining, Minerals and Sustainable Development Project North America) Task 2 Work Group. (2002). Seven questions to sustainability: How to assess the contribution of mining and minerals activities. Winnipeg: IISD.

Nelson, P., Azare, C., Sampong, E., Yeboah, B., Fosu, A., Tagu, P., Dare, O. & DarkoMensah, E. (2004). SEA and the Ghana poverty reduction strategy. Vancouver, Canada: International Association for Impact Assessment 2004 Conference, 28 April.

Nijkamp, P. & Pepping, G. (1998). A Meta-analytic evaluation of sustainable city initiatives. *Urban Studies*. 35 (9), 1481-1500. http://dx.doi.org/10.1080/0042098984240

OECD. (1994). Report on environmental indicators. Paris: Organization for Economic Cooperation and Development.

Papadopoulos, A. M. & Giama, E. (2009). Rating systems for counting building' environmental performance. *International Journal of Sustainable Energy*. 28 (1-3). 29-43. http://dx.doi.org/10.1080/14786450802452423

PCSD (President`s Council on Sustainable Development). (1996). Sustainable America – A new consensus for prosperity, opportunity and a healthy environment for the future. [Online] Available: http://clinton2.nara.gov/PCSD/Publications/TF_Reports/amer-top.html (October 3, 2011).

Pearce, D. (2005). Do we understand sustainable development?. *Building Research & Information*. 33 (5), 481-483. http://dx.doi.org/10.1080/09613210500219154

PETUS (Practical Evaluation Tool for Urban Sustainability). (2011). Tool summary. [Online] Available: http://www.petus.eu.com/left.php?sct=6&sbsct=2&pageid=155&pagesect=0&pagelang=en (June 15, 2011).

Poveda, C. A. & Lipsett, M. G. (2011a). A rating system for sustainability of industrial projects with application in oil sands and heavy oil projects: Origins and fundamentals. *Journal of Sustainable Development*. 4 (3), 59-71. http://dx.doi.org/10.5539/jsd.v4n3p59

Poveda, C. A. & Lipsett, M. G. (2011b). A rating system for sustainability of industrial projects with application in oil sands and heavy oil projects: Areas of excellence, sub-divisions and management interactions. *Journal of Sustainable Development*. 4 (4), 3-13. http://dx.doi.org/10.5539/jsd.v4n4p3

Ravetz, J. (2000). Integrated assessment for sustainability appraisal in cities and regions. *Environmental Impact Assessment Review*. 20, 31-64. http://dx.doi.org/10.1016/S0195-9255(99)00037-2

RMW (Regional Municipality of Waterloo). (2005). Individual environmental assessment terms of reference: Rapid transit initiative. Kitchener: Regional Municipality of Waterloo.

Robert, K.-H. (2002). *The natural step story: Seeding a quiet revolution*. Gabriola Island, Canada: New Society Publishers.

Rosen, S. (1974). Hedonic prices and implicit market: Product differentiation in pure competition. *Journal of Political Economy*. 82, 34-55. http://dx.doi.org/10.1086/260169

Rotmans, J. (2006). Tools for integrated sustainability assessment: A two-track approach. *The Integrated Assessment Journal*. 6 (4). 35-57.

Sadler, B. (1996). Environmental assessment in a changing world: Evaluating practice to improve performance, international study on the effectiveness of environmental assessment. Ottawa, ON: Canadian Environmental Assessment Agency and the International Association for Impact Assessment.

SERI. (2011). Methods and tools for integrated sustainability assessment (MATISSE). [Online] Available: http://seri.at/projects/completed-projects/matisse/ (August 3, 2011).

Suzuki, H., Dastur, A., Moffatt, S., Yabuki, N. & Maruyama, H. (2010). *Eco2 cities: Ecological cities as economic cities*. Herndon, VA: World Bank Publications.

The Natural Step. (2011a). The Natural Step: The four system conditions. [Online] Available: http://www.thenaturalstep.org/en/canada/the-system-conditions (July 29, 2011).

The Natural Step. (2011b). The Natural Step: Our story. [Online] Available: http://www.naturalstep.org/en/our-story (July 29, 2011).

Trusty, W. (2008). Standards versus recommended practice: Separeting process and prescriptive measures from building performance. *Journal of ASTM International*. 5 (2). http://dx.doi.org/10.1520/JAI101169

UNCED (United Nations Conference on Environment and development). (1992). *Earth summit 92 (Agenda 21).* London: Regency Press.

UNCSD (United Nations Conference on Sustainable Development). (1996). CSD Working list of indicators. Paris, France: United Nations Division for Sustainable Development.

United Nations. (2003). Handbook of National Accounting: Integrated Environmental and Economic Accounting. [Online] Available: http://unstats.un.org/unsd/envAccounting/seea2003.pdf (August 2, 2011).

United Nations. (2007). Indicators of Sustainable Development: Guidelines and Methodologies. [Online] Available: http://www.un.org/esa/sustdev/natlinfo/indicators/guidelines.pdf (August 2 2011).

United Nations. (2011). About the Revision of the SEEA. [Online] Available: http://unstats.un.org/unsd/envaccounting/seearev/ (August 2, 2011).

USGBC (United States Green Building Council). (2009a). *LEED – Leadership in energy and environmental design: green building rating systems, Version 1.0*. Washington D.C.:US Green Building Council.

USGBC (United States Green Building Council). (2009b). Introduction to the LEED 2009 credit weighting tool. [Online] Available: http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1971 (June 14, 2011).

USGBC (United States Green Building Council). (2011). LEED rating system development. [Online] Available: http://www.usgbc.org/ShowFile.aspx?DocumentID=9828 (August 11, 2011).

Van Kooten, C. & Bulte, E. (2000). *The economics of nature*. Oxford: Blackwell.

Varey, W. (2004). Integrated approaches to sustainability assessment: An alignment of ends and means. [Online] Available: http://www.emrgnc.com.au/sustainability.htm (August 3, 2011).

Wackernagel, M. & Rees, W. (1995). *Our ecological footprint*. Philadelphia, PA: New Society Publishers.

Ward, B. & Dubos, R. (1972). Only one earth: The care and maintenance of a small planet. London: Deutsch.

World Bank. (2011). Eco² Cities: Ecological cities as economic cities: [Online] Available: http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTURBANDEVELOPMENT/0,,contentMDK:22643153~pagePK:148956~piPK:216618~theSitePK:337178,00.html (July 29, 2011).

Table 1. Tools included in the 'Sustainability A – Test' EU project

Group	Sustainable Development Tool (Methodologies, models, approaches and appraisals)
Assessment Frameworks	EU impact assessment system Environmental impact assessment Strategic environmental assessment Integrated Sustainability Assessment / Transition Management
Participatory Tools	Electronic focus groups Tools to inform debates, dialogues & deliberations Consensus conference Repertory grid technique Interactive backcasting Focus group Delphi Survey In-depth interviews Citizen`s Jury
Scenario Analysis	Trends Cross Impact Relevance trees and morphologic analysis Modeling, simulating, training Interactive brainstorming Scenario workshops Integrated foresight management model Ranking method
Multi-criteria Analysis	Multi-attribute value theory Weighted Summation Analytic hierarchy process Preference ranking organization method for enrichment evaluations Novel approach to imprecise assessment and decision environments REGIME Dominance method Software for MCA
Cost-benefit Analysis and Cost-effectiveness Analysis	Cost-benefit analysis Travel costs Hedonic pricing Cost of illness Contingent valuation Averting expenditures Contingent behavior Market methods Conjoint choice questions Cost-effectiveness analysis
Modeling Tools	Family of socio-economic models General economy models Demographic models Public health models Partial economic models Family of bio-physical models Climate models Biogeochemistry models Hydrology models Family of integrated models Land use models Integrated assessment models Qualitative system analysis models Scenario building and planning tools
Accounting Tools, Physical Analysis Tools and Indicator Sets	Measure of economic welfare Sustainable national income Genuine savings National accounting matrix including environmental accounts Index of sustainable economic welfare Ecological footprint Global land use accounting Economy-wide MFA Lifecycle assessment Indicator sets for assessments Vulnerability Assessment: Livelihood sensitivity approach

Table 2. Sustainability assessment methods, tools, and procedures

1.	Analysis of Interconnected Decision Areas (AIDA) [1]
2.	Analytic Hierarchy Process (AHP) [1]
3.	ASSIPAC (Assessing the Sustainability of Societal Initiatives and Proposed Agendas for Change) [1]
4.	ATHENA[1]
5.	BEAT 2002[2]
6.	BeCost (previously known as LCA-house) [2]
7.	BEPAC (Building Environmental Performance Assessment Criteria) [1]
8.	BRE Environmental Assessment Method (BREEAM) [1]
9.	BRE Environmental Management Toolkits[1]
10.	Building Energy Environment (BEE 1.0) [1]
11.	Building Environmental Assessment and Rating System (BEARS) [1]
12.	Building for Economic and Environmental Sustainability (BEES 2:0) [1]
13.	CASBEE[2]
14.	Cluster Evaluation[1]
15.	Community Impact Evaluation[1]
16.	Concordance Analysis[1]
17.	Contingency Valuation Method[1]
18.	Cost Benefit Analysis[1]
19.	DGNB[2]
20.	Eco-Effect[1]
21.	Eco-Indicator 95[1]
22.	Eco-Instal[1]
23.	Economic Impact Assessment[1]
24.	Ecological Footprint[1]
25.	Eco-points [1]
26.	Ecopro[1]
27.	Eco-Profile[1]
28.	EcoProP[1]
29.	Eco-Quantum[1]
30.	EIA – Environmental Impact Analysis[1]
31.	ENVEST[1]
32.	Environmental Profiles[1]
33.	Environmental Status Model (Miljostatus) [2]
34.	EQUER[1]
35.	ESCALE[1]
36.	Financial Evaluation of Sustainable Communities (FESC)[1]
37.	Flag Model[1]
38.	Green Building Challenge, changed in Sustainable Building (SB) Tool[1]
39.	Green Globes[2]
40.	Green Guide to Specification[1]
41.	Green Start[2]
42.	GRIHA[2]
43.	Hedonic Analysis[1]
44.	HKBEAM[2]
45.	Hochbaukonstruktionen nach okologischen Gesichtspunkten (SIA D0123) [1]
46.	INSURED[1]
47.	LEEDTM (Leadership in Energy and Environmental Design Green Building Rating System) [1]
48.	LEGEP (previously known as Legoe)
49.	Life Cycle Analysis (LCA) [1]
50.	Mass Intensity Per Service Unit (MIPS) [1]
51.	MASTER Framework[1]
52.	Meta Regression Analysis[1]
53.	Multi-Criteria Analysis[1]
54.	NABERS[2]
55.	Net Annual Return Model[1]
56.	OGIP (Optimierung der Gesamtanforderungen ein Instrument fur die Integrale Planung) [1]
57.	PAPOOSE[1]
58.	PIMWAQ[1]
59.	Project Impact Assessment[1]
60.	Regime Analysis[1]
61.	SBTool 2005[2] (formerly known as GBTool)
62.	Quantitative City Model[1]
63.	Planning Balance Sheet Analysis[1]
64.	Risk Assessment Method (s) [1]
65.	SANDAT[1]
66.	Semantic Differential[1]
67.	Social Impact Assessment[1]
68.	SPARTACUS (System for Planning and Research in Town and Cities for Urban Sustainability) [1]
69.	SEA (Strategic Environmental Assessment) [1]
70.	Sustainable Cities[1]
71.	Sustainable Regions[1]
72.	Transit-oriented Settlement[1]
73.	Travel Cost Theory[1]

[1] Assessment methods, tool and procedures listed in the BEQUEST project including some rating system

[2] Additional tools (e.g. rating systems) complementing the BEQUEST project list

Basic weighting equation

Relative importance of each **impact category**

$\times$

Relative contribution of a building **activity group** to building impacts

$\times$

Association between individual credits and activity groups

$=$

Credit Weight

Where,

•**Impact Category**: impacts of building on environment and occupants (e.g. TRACI categories)

•**Activity Group**: a building-related function associated with a group of LEED credits (e.g., consumption of energy by building systems, transportation, water use)

•**Association with activity group**: a binary (yes/no) relationship indicating whether or not a credit contributes to reducing impact.

Box 1. The LEED credit weighting system equation