SUSTAINABILITY ASSESSMENT

A RATING SYSTEM FRAMEWORK FOR BEST PRACTICES

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A Rating System Framework for Best Practices

With a theoretical application to the surface mining recovery process for the development and operation of oil sands projects

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INVESTOR IN PEOPLE

The force behind my inspiration and motivation, my family

A mis padres, mis éxitos son sus frutos; son el producto de una cosecha muy bien cuidada en tiempos de sequía, inundaciones, plagas, y días soleados

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PREFACE

Minimising the detrimental effects on the natural environment due to construction practices is an existing concern. Younger generations and society in general are becoming more aware of the different impacts intrinsically carried by organisations and projects in their operations, and the need for finding a more sustainable path; the increase in the levels of awareness helps explain the exponential increment in the development of sustainability assessment tools. Sustainability of current operations and possible future improvements to meet goals and objectives are the main target for the development of approaches, strategies, models, appraisals and methodologies for sustainability assessment; however, the development of efficient and reliable assessment methods and their respective tools is a challenge for both academia and the scientific community.

Sustainability is a multi-disciplinary area in permanent evolution; therefore, assessment tools evolve in parallel to meet new requirements and overcome existing and emerging limitations. Social, economic and environmental aspects require balanced and integrated approaches for implementation and measurement. While most current sustainability assessment tools focus on one aspect of sustainability, which often refers to the environmental pillar, very few present an integral approach that considers the interlinkages and dynamics of all three pillars of sustainability. In fact, the assessment of economic and social aspects has emerged to contribute to defining the progress towards sustainable development in developing countries; therefore, integrated assessment systems require not only the identification of dynamics among the social, economic and environmental parameters, but also the collection and analysis of much more detailed information.

Sustainability assessment tools gather information for decision-making; therefore, the systems can be designed to target a specific aspect or various aspects of sustainability. Sustainability assessment tools can be grouped in cumulative energy demand (CED) systems, which focus on energy consumption; life cycle analysis (LCA) systems, which focus on environmental aspects; and total quality assessment (TQA) systems, which evaluate ecological, economic and social aspects. The multi-criteria systems are the most common type of TQA systems, and aim to include the three pillars of sustainability. Multi-criteria systems compare the real performance of different parameters with predetermined baselines or thresholds. In environmental or sustainability rating systems, each criterion included in the multi-criteria system has a certain number of points, and the overall sustainability performance score of the organisation or project is calculated by summing the results of the assessed criteria. Although environmental or sustainability rating systems are widely used, the development and application of the tools have been concentrated in the building industry. In the 1990s, the building industry not only recognised the impact of its activities, but also the need for mitigating the environmental impact of the building sector driven by public policy and market demand for environmentally sound products and services. The different assessment tools for measuring sustainability in the building environment can be classified into assessment and rating tools. Assessment tools provide a qualitative understanding of the building performance, which is used for design purposes, while rating tools determine the building performance level with starts or points being awarded based on the criteria met within a specific certification process. Although each rating system and certification tool presents a specific structure, commonalities are found in categories of building design and life cycle performance: water, materials, energy, site and indoor environment.

The building research establishment environmental assessment method (BREEAM) was the first real attempt to develop a comprehensive building performance assessment method to meet the different needs of relevant interest groups. Currently, more than 600 sustainability assessment rating systems are available and used worldwide. If the success of environmental and sustainability rating systems (ESRS) is measured by the number of projects or square metres certified, then the number of square metres certified in the construction building industry ranges in the millions while the number of projects certified is in the thousands. While BREEAM has been recognised as the first rating system to assess sustainability in the construction building environment, Leadership in Energy & Environmental Design (LEED) is certainly competing to position / for positioning itself as the worldwide leader.

ESRS target different performance aspects of the building in different stages of the life cycle. The aim of the assessment tools is to promote sustainable practices in the building industry during design, construction, operation, maintenance, disassembly or deconstruction, and disposal while integrating social, economic and environmental needs and the concerns of the different stakeholders. Therefore, the purpose of sustainability assessment is to gather information to support decision-making during the project's life cycle. ESRS are easy to understand, and enable performance assessment of the building in several stages. Currently, rating systems strongly support the design process of a building, but there is a trend for covering the construction, operation and dismantling phases with a whole-life-perspective analysis; consequently, the evolution of any rating system must continue to cover the multi-dimensionality of sustainability while improving the triple bottom line of buildings.

The framework for developing ESRS, already implemented in the building construction industry, can be extended and applied in other industry contexts. The different benefits carried in the development and implementation of ESRS has been studied to propose a framework of a rating system that can be adopted to other organisational and project contexts. The development of the framework considers the stakeholders as the main tool in the decision-making process while the rating system itself can be used by companies, stakeholders and policy makers to measure, in a consistent manner, the implementation of sustainable development strategies and overall sustainability of the organisation or project.

The development and operations of the Canadian oil sands have been highlighted in this book with the aim of demonstrating the need for developing and implementing ESRS in industry contexts carrying great social, economic, environmental, health and other impacts throughout the project life cycle. Canadian oil sands developments are of interest to oil producers because of the size of the proven reserves; but the scale of development and the perceived enduring impacts are of concern to different stakeholders. Currently, the oil and gas industry — which includes oil sands operations — does not possess standardised environmental or sustainability rating systems to measure and benchmark performance. Oil and gas industry projects are typically large and of long duration. Different aspects are to be considered in the development and implementation of a rating system to break into a new industrial context with effective engagement, participation and stakeholder management as primary areas of consideration.

The development of the structure of the Wa-Pa-Su project sustainability rating system considers three main aspects: areas or categories of excellence, each with a set of criteria; areas or sub-divisions of an oil sands or heavy oil project and management integration. In this particular adaptation of the assessment framework (i.e. The Wa-Pa-Su project sustainability rating system), the structure of the rating tool considers the complexity and size of oil sands projects, dividing them into 10 different areas or sub-divisions: project integration, provisional housing/buildings, permanent housing/buildings, roads, oil transportation & storage, mining process, in situ process, upgrading & refining, shutdown & reclamation and CO_2, SO_x & other greenhouse gases (GHG) capture and storage. The development of the Wa-Pa-Su project sustainability rating system offers a proactive approach, which aligns with sustainability principles, for oil sands projects throughout their life cycle phases, the project management processes (e.g. initiation, planning, execution, monitoring and control, and close-out), and the life cycle of sub-projects and processes. The resources involved in project development, expectations of stakeholders and potential environmental impact define the 10 areas or categories of excellence: project & environmental management excellence (PEME); site & soil resource excellence (SSRE); water resource excellence (WRE); atmosphere & air resource excellence (AARE); natural & artificial lighting excellence (NALE); energy resource excellence (ERE); resources & materials excellence (RME); innovation in design & operations excellence (IDOE); infrastructure & buildings excellence (IBE); and education, research & community excellence (ERCE).

As the structure of the rating system is defined, the focus turns to identify the different parameters to address the 'what' and the 'how' in sustainability assessment. What should be measured or included in the assessment (i.e. SDIs (sustainable development indicators)) and how to measure those parameters (e.g. metrics). SDIs can be found within currently existing approaches, strategies, models, appraisals and methodologies for environmental and sustainability assessment. Conceptually, the design and implementation of SDIs brings together different stakeholders towards finding the balance among economic, social and environmental development; however, questions surround SDIs for the assessment of sustainability of projects (e.g. surface mining operations) or industries (e.g. oil and gas) for which the development of SDIs still is in its infancy: (1) Do the SDIs properly align theory with practice? (2) Do the SDIs meet their intent? and (3) Can the stakeholders and project proponents afford the implementation of SDIs? Individual efforts have been made to establish a set of SDIs by companies developing projects; and regulatory systems (in some way predecessors of SDIs) require certain levels of investment to meet a minimum level of performance, particularly on environmental grounds.

But large industrial projects (such as oil sands projects, which include surface mining operations) do not have a comprehensive set of SDIs to benchmark sustainable performance and/or measure the advances made towards the implementation of sustainable development strategies. Questions remain regarding the rate at which extractive industry companies align with more sustainable practices, whether it is the applicability of SDIs, their degree of usefulness, or the cost of development and implementation of SDIs, or other factors.

An assertive set of SDIs is not solely based on regulatory systems, as measuring sustainability cannot become a bureaucratic process, nor can any other SDI source single-handedly determine or mandate the final set of indicators, as the real objective is to assist decision makers (DMs) and effectively engage stakeholders. As the government and oil sands developers are turning towards increasing productivity with a more conscious sustainable development approach, a pre-selection of SDIs is required to assist further formal multi-criteria selection processes.

The structure design defines the organisation of the rating system while SDI selection and metrics design addresses the stakeholders' vision and needs, and the fundamentals, goals and objectives of sustainable development. Subsequently, the assessment methodology utilised in the rating system measures the relevance of the different criteria to present a numeric result of sustainability assessment or performance score. As a result, properly developed sustainability rating systems not only require the identification and design of metrics in the social, economic and environmental pillars of sustainability, but also weighting of the different criteria. The weighting process can be characterised by its subjectivity in certain areas of assessment; consequently, the stakeholder participation becomes critical from the credibility and validation standpoint. Current multi-criteria decision-making (MCDM) methods present valid alternatives for weighting the various criteria while allowing for the participation of different stakeholders. Among those, the analytic hierarchy process (AHP) structures the decision problem in a manner that is easy for the stakeholders to comprehend and analyse independent sub-problems by structuring the problem in a hierarchy and using pairwise comparisons. However, the relevance of criteria (e.g. weight) can be assessed through the application of other MCDM methods.

Measuring the weight is the initial step in the process of assigning a score to the different criteria; the criteria final score (CFS) may be impacted by other factors considered in the calculation of the overall performance of each criterion. The Wa-Pa-Su project sustainability rating system presents an integrated approach to sustainability assessment by incorporating three distinctive areas of knowledge: (1) sustainable development theory and fundamentals support the ultimate goal of the rating system of contributing to sustainability with the aim of finding a path to balance social, economic and environmental needs; (2) CPI becomes primordial due to the duration of the projects, thus it is critical to allow organisations or projects to improve performance over time and (3) multi-criteria decision analysis (MCDA) assists the assessment process through stakeholder engagement and participation, and the design and implementation of a criteria weighting system.

Previously, the discussion of sustainability and the application of ESRS led to: (1) concluding the need for the development of a rating system for industrial projects, with a particular application to oil sands projects; (2) defining the structure of the rating system; and (3) assisting in the pre-selection of SDIs for surface mining operations. Assessing the sustainability of projects at certain points in time required the application of a methodology selected by the interested groups and/or stakeholders; however, measuring the improvement of projects in sustainability performance over time (i.e. CPI) presents additional challenges.

Certain industries (i.e. oil & gas), projects (i.e. oil sands) or specific operations (i.e. surface mining) require a rating system with a particular level of flexibility, offering the opportunity for developers to improve the performance of operations and for stakeholders to understand the difficulties — and benefits — of implementing SDIs and reach the levels of sustainability performance expected by the various stakeholders.

Large-scale projects create a variety of social, economic, environmental and other impacts throughout their life cycles. Assessing sustainable development becomes a measurable factor, not only for the organisations directly involved in the development, construction and operation of projects, but also for a number of other stakeholders. In the oil sands operations, assessment turns into a periodic task, since the construction and operation phases of the projects can last for a considerable period of time.

The sustainability assessment tool must have the capability for the organisations and/or projects to evaluate and improve performance over time. To that end, the Wa-Pa-Su project sustainability rating system's design and characteristics meet the sustainability assessment needs of the oil sands operations; therefore, the development of its structure is based to support each area of operation (i.e. sub-divisions) and address the diverse impacts (i.e. areas of excellence) in each pillar of sustainability (i.e. social, economic and environmental). Though the different SDIs are incorporated with the aim of measuring the sustainability of the oil sands projects, the framework of assessment methodology can be implemented in a large range of projects and organisations due to its integrated approach, which allows the measurement of performance based on CPI with a high degree of stakeholder participation through the assessment process.

MOTIVATION AND ABOUT THE ORGANISATION OF THIS BOOK

As world energy demands increase, so will the exploration and exploitation of alternative energy resources. The present level of energy generation cannot meet the needs of future generations if the pace of population growth and energy consumption continues at the current rate. While some unconventional energy sources are still in the research and development phase, others have been effectively implemented.

The impacts of different energy operations are still being debated, with respect to environmental, social, economic and health, among other effects. The definition of sustainable development adopted by the United Nations (UN) uses the expression 'meets the needs of the present' to indicate the required development by a current generation to maintain its standard of living while minimising environmental, economic and social impacts. Large industrial developments will affect a range of stakeholders and may entail cultural and political change. The level of impacts and their implications depends on many characteristics of the development such as its size, production rate, duration of exploitation, processes used (including treatment of waste streams) and regulatory standards. While local communities, businesses and surrounding areas are first expected to be impacted, certain developments can attract global attention.

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 scientists and practitioners have developed an increasing variety of tools with the aim of demonstrating progress towards the different facets of sustainable development.

Measures for assessing the environmental, social and economic impacts and long-term overall sustainability will become an increasingly important requirement in industrial project management. The concept of sustainability influences all aspects of a project throughout its life cycle. Considerations and expectations of stakeholders are at the forefront in each phase of the project life cycle, from the earliest phases in which the business case is presented for consideration by investors, followed by the design and construction of facilities and infrastructure, and continue during the operation of the industrial facility. Project management researchers and practitioners are working together to find effective and efficient methods and techniques to minimise environmental, social, economic, health and other potential impacts that projects inherently carry along each phase of their life cycle.

The rationale behind sustainable development indicates the balance of social, economic and environmental needs. For stakeholders, the rationalisation process of sustainability consists of quantifying the different impacts found in the operations and developments of companies and projects throughout their life cycle; however, as some areas are subjective in nature, the quantification process of the different impacts and assessment of sustainable development performance becomes an arduous task of development, validation, and application of scientific and empirical methods with the intrinsic objective of finding an agreement among the involved parties (i.e. stakeholders). Several environmental and sustainability assessment tools, instruments, processes and methodologies have been developed; ESRS have gained attention and credibility, demonstrated by the vast number of certified projects around the world and the widely-known usefulness and advantages of their application.

ESRS are structured decision-making tools in support of measuring environmental, social and economic performance throughout the project life cycle, not only complying with government and non-government regulations, but also meeting internal and external standards, procedures, processes and requirements. The majority, if not all, of ESRS created to date focus on buildings and residential housing construction, which demonstrates the need for gaining ground in the implementation of similar sustainability assessment methodologies in other industrial contexts. To that end, the motivation behind this book and its true aim is to introduce a methodology with a framework that can easily be applied to any type of project or organisation, putting the stakeholders at the centre of the decision-making process while making them accountable not only throughout the process but also for the end results.

The content of the book is organised in 14 chapters grouped in four parts: (1) sustainability assessment, (2) a new sustainability system, (3) the Canadian oil sands and (4) a step-by-step application: the surface mining process.

Chapter 1 discusses a range of fundamental and generic approaches and frameworks, as well as specific and integrated strategies for sustainability assessment, as the foundation of a framework for the methodology developed in a new rating system applicable to contexts other than the construction building industry. Assessment methods identified by different schemes are also presented along with a classification of the assessment tools.

Chapter 2 focuses on ESRS with emphasis on some of the most popular tools: LEED, BREEAM, comprehensive assessment systems for built environment efficiency (CASBEE), Green Star and SBTool. A description of the criteria weighting tool (CWT) used by each ESRS is described.

Chapter 3 presents the potential benefits of developing and implementing ESRS. While the valid argument that the benefits have been already proven in the construction building industry can be made, those described in this chapter are considered potential benefits as ESRS have not been implemented in other industry contexts; hence one of the motivations behind this book.

Chapter 4 introduces the origins and fundamentals of the Wa-Pa-Su project sustainability rating system, which was originally conceived for measuring, in a consistent manner, sustainability performance of the Canadian oil sands projects. However, the methodology evolved into a generic framework that can be adapted to any other project or organisation type.

Chapter 5 presents the integrated approach to sustainability assessment implemented in the Wa-Pa-Su project sustainability rating system. This chapter also highlights the reasoning behind the integration of three distinctive areas of knowledge for sustainability assessment: sustainable development theory and fundamentals, CPI and MCDA. The principles of the assessment methodology and the intersection between the different areas of knowledge are also described.

Chapter 6 provides the brief background of the Canadian oil sands and describes their life cycle. Each phase of the life cycle is explained and the two recovery processes (i.e. surface mining, in situ) are analysed in detail. Factual information about the development of the Canadian oil sands is presented and different facets of the projects are discussed.

Chapter 7 presents a discussion and analysis of the economic, social, environmental, health and other impacts of current operations in the Canadian oil sands that are of concern to different stakeholders, including some uncertainties in levels and persistence of impacts. An overview is provided of efforts undertaken by government and developers to minimise impacts; and comments are offered on possible future strategies.

Chapter 8 provides factual statistics in the area of sustainability performance of 10 of the developers and operators of the Canadian oil sands. Sustainability performance in each of the four main areas (land, water, air, and tailing ponds) of concern are discussed along with social, economic and organisational sustainability. Shortcomings in sustainability reporting are identified and suggestions for improving sustainability assessment performance and reporting are provided.

Chapter 9 introduces the Wa-Pa-Su project sustainability rating system structure in a step-by-step application to surface mining, one of the two recovery processes used in the Canadian oil sands projects. For this particular application of the assessment methodology, the areas of excellence and sub-divisions are identified and described in detail. Additionally, management interaction between project management processes groups, sub-projects' life cycle and process life cycle are analysed.

Chapter 10 presents an analysis of six different sources for pre-selecting SDIs, accompanied by a methodology to then finalise with a set of SDIs for the surface mining operations in oil sands projects. Each SDI description is later provided in Appendix C.

Chapter 11 analyses the development and implementation of SDIs in surface mining operations for oil sands projects, highlights the benefits of using SDIs, proposes an alternative framework for SDIs in the Canadian oil sands industry and offers recommendations for the use of SDIs to measure the sustainability of surface mining operations.

Chapter 12 presents the application of the AHP to weight the different criteria to measure the sustainability of surface mining operations. Prior to the application of the AHP method, the various criteria were pre-selected using a preliminary selection method consisting of the identification of criteria from six different sources as described in Chapter 10. The results of the weighting process assist scientists and practitioners not only by identifying those criteria that stakeholders consider relevant in the sustainability assessment process, but also by expressing the degree to which the criteria should be addressed in order to accomplish the project's and/or organisation's sustainability goals.

Chapter 13 introduces the performance improvement factor (PIF), which can be determined using three different methodologies: relevance factor or subjective stakeholder valuation, comparative assessment methods (CAMs) and links to metrics. Additionally, CPI indicator measurement is suggested and discussed for a pre-selected set of SDIs for surface mining operations in oil sands projects. Finally, a brief preamble discusses the proposed integrated approach for sustainability assessment and the part it plays in CPI, offering a foreword to upcoming manuscripts that discuss the other complementary parts of the integrated approach.

Chapter 14 highlights the flexibility and applicability of the rating system by presenting a simulated case study of implementation and sustainability assessment using the integrated approach adopted in the Wa-Pa-Su project sustainability rating system. The simulated implementation demonstrates how the assessment methodology can be utilised by the users of the rating system to determine progress towards sustainable development by comparing criteria performance against previously established baselines and thresholds, and allocating criteria and overall sustainability assessment scores. Since the Wa-Pa-Su project sustainability rating system is the first of its kind focusing on industrial projects with an emphasis on the Canadian oil sands, it must be understood that a variety of SDIs have not yet been measured, and the data required for this purpose have not been collected; therefore, the objective of the simulated case study of implementation and sustainability assessment using the developed integrated approach is to highlight the flexibility and applicability of the rating system.

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PART I
SUSTAINABILITY ASSESSMENT

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CHAPTER 1

ASSESSMENT APPROACHES, FRAMEWORKS AND OTHER TOOLS

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, methodologies and frameworks 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. This chapter discusses a range of fundamental approaches, as well as specific and integrated strategies for sustainability assessment, as the foundation of a new rating system. Assessment methods identified by different schemes are also described. Thus, the present work is a review of the status of sustainability development and its different assessment tools: approaches, strategies, models, appraisals and methodologies.

1.1. 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). Others argue that the notion is not necessarily modern: Gibson, Hassan, Holtz, Tansey, and Whitelaw (2010) imply that the concept of sustainability, as an old wisdom, has been around since the dawn of time in most communities. Conversely, the discussion surrounding the origins of the terms (i.e. sustainable development, sustainability) presents contrasting — at times contradicting — information found in the diverse and wide range of literature resources.

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 organisation 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 these 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 those resulting from the Rio Summit (UNCED, 1992), Mitchell, May, and McDonald (1995) identify 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 many 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 towards 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 to questions remain to be found regarding what measures are important and how they can be quantified, especially for social and economic dimensions.

1.2. FUNDAMENTAL AND GENERIC APPROACHES AND FRAMEWORKS

Different approaches have been taken by practitioners and researchers to promote sustainability principles, particularly 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 artefacts. 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). Other frameworks have also emerged and gained momentum; among others, the steady-state economy and circular economy, which has been refined and developed by the following schools of thought: cradle to cradle (C2C), natural capitalism, performance economy, biomimicry, blue economy, regenerative design and industrial ecology. And, more frameworks and approaches will continue to be developed as the concept and area of knowledge of sustainability is a dynamic evolving matter rather than static.

1.2.1. Steady-State Economy

The concept of steady-state economy considers the economy as an open subsystem of a finite and non-growing ecosystem, the natural environment (Daly, 1980, 2007). An economy in a steady state imports resources from nature that are transformed and manufactured into goods while pollution and waste are the throughput of the process (Daly, 1992). Nature provides two sources of wealth: mineral resources and solar energy. In the steady-state economy, recycling of material resources is possible only by using some energy resources and additional material resources, but energy resources cannot be recycled at all (Daly, 1980). Moreover, while mineral resources can be extracted at any chosen rate, solar energy is at a rate beyond human control; as a result, it is the mineral stock that constitutes the scarcity factor (Daly, 1992). With the aim of stopping and preventing further growth, the proponent of the steady-state economy framework, Herman Daly, considers it necessary to establish three institutions in addition to the current market economy: stabilise the population, correct inequality and stabilise the level of capital (Daly, 1980). While addressing that growth is at the centre of the steady-state economy, consumption (rate and exhaustion) of mineral resources is not prevented, but only postponed, as Daly (1980) points out, 'a steady state economy cannot last forever, but neither can a growing economy or a declining economy'. Consequently, Kotler (2015) states that Herman Daly and his '"ecological economics" community have advocated that long-term sustainability requires the transition to a steady-state economy in which GDP remains more or less constant'.

1.2.2. Circular Economy and Other Schools of Thought

The concept of circular economy evolved upon and encompasses principles from various schools of thought: C2C, natural capitalism, performance economy, biomimicry, blue economy, regenerative design and industrial ecology (Ellen Macarthur Foundation, 2015a). Figure 1.1 is a graphic representation of the outline of circular economy. According to the Ellen Macarthur Foundation, 'the circular economy concept has deep-rooted origins and cannot be traced back to one single date or author'. A circular economy (or economy in loops) or 'self-replenishing economy' is 'restorative and regenerative by design' (Ellen Macarthur Foundation, 2015b; Stahel & Reday-Mulvey, 1982). The opposite of an open-ended economy that does not tend to recycle and treats the environment as a waste reservoir (Pearce & Turner, 1989), the circular economy considers that systems should work like organisms, processing biological or technical nutrients that can be fed back into a closed-loop or regenerative cycle (Stahel & Reday-Mulvey, 1982). The two, technical and biological, cycles aim to keep products, components and materials 'at their highest utility and value at all times' (Ellen Macarthur Foundation, 2015b). With the objective of addressing the challenges that industrial economies face, the circular economy applies three principles: preserve and enhance natural capital, optimise resource yields and foster system effectiveness.

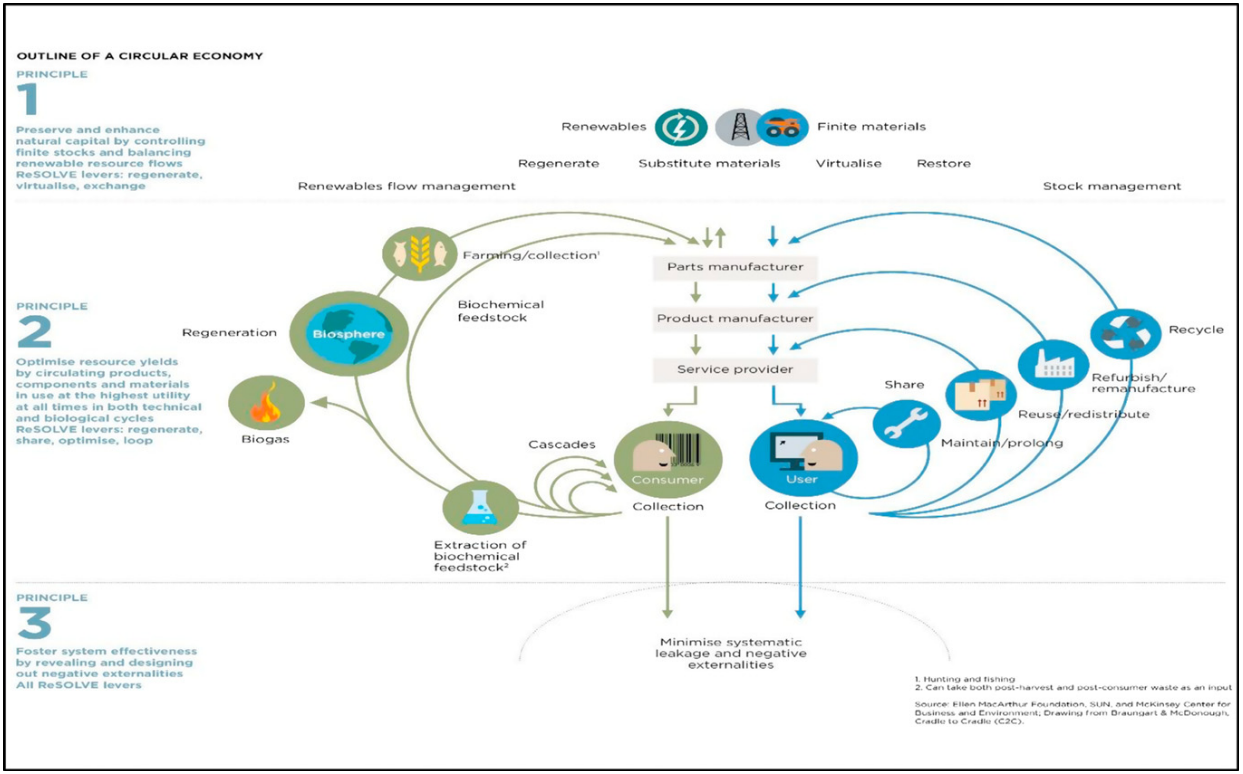

Figure 1.1: Outline of a Circular Economy. *Source*: Adapted from www.ellenmacarthurfoundation.org with authorisation of the Ellen Macarthur Foundation.

1.2.2.1. Cradle to Cradle (C2C)

With the philosophy of moving from simply being 'less bad' to becoming 'more good', the C2C framework uses a biomimetic approach to design products and systems (Braungart & McDonough, 2002). Oyevaar, Vazquez-Brust, and van Bommel (2016) refer to C2C as a methodology for eco-effectiveness and state it 'simply means that industry is geared to social values, safety and low cost, and aim to strengthen the position of natural sources instead of implementing a damage control approach'. Moreover, the framework is based on the following principles: waste equals food, use current solar income and celebrate diversity; whereas the C2C design certification process is based on five principles: material health, material reutilisation, renewable energy, water stewardship and social fairness (McDonough Braungart Design Chemistry, 2016). Not only the certification process, but also the framework has faced criticism, yet Kopnina (2015) cautions throwing the baby out with the bathwater, as the C2C framework has potential for starting a new industrial revolution with ecological benefits, if applied globally. Nevertheless, in addition to non-compliance with all conditions for a sustainable society, experts in the field of sustainability criticise the approach in the areas of energy, industrial ecology, social, consumption, material cycles, transport and developing countries (Oyevaar et al., 2016).

1.2.2.2. Natural Capitalism

The concept of natural capitalism was introduced by Paul Hawken, Amory Lovins and L. Hunter Lovins in the book entitled *Natural Capitalism: Creating the Next Industrial Revolution*. The concept describes a global economy depending on natural resources and ecosystem services provided by nature. Soil, air, water and all living things are the set of natural assets acting as the world's stocks. The concept of global economy described in the natural capitalism framework recognises the overlap between business and the environment. Moreover, by taking into consideration natural and human capital, natural capitalism takes a contrasting position with traditional capitalism, which primarily recognises as capital the value of money and goods. The four principles framing natural capitalism are: (1) radically increase the productivity of natural resources; (2) shift to biologically inspired production models and materials; (3) move to a 'service-and-flow' business model; and (4) reinvest in natural capital (Ellen Macarthur Foundation, 2016; Hawken, Lovins, & Lovins, 1999).

1.2.2.3. Performance Economy

In a research report, entitled 'The Potential for Substituting Manpower for Energy', Walter Stahel and Genevieve Reday envisioned an economy in loops or circular economy; the authors further the argument by discussing the impact of their approach on job creation, waste, resource savings and economic competitiveness. The four main goals of the performance economy concept are long-life goods, reconditioning activities, product-life extension and waste prevention. In addition to the fundamental principles of selling services rather than products (i.e. selling goods as services), performance economy is characterised by an economic and quality focus on (1) utilisation and performance in use, not manufacturing, (2) an optimisation of existing stocks and (3) an automatically higher competitiveness if or when waste, material, energy and/or carbon cost increase and/or if labour costs decrease.

1.2.2.4. Biomimicry

The book entitled *Biomimicry: Innovation Inspired by Nature*, authored by Janine Benyus, describes the concept of biomimicry as ‘a new discipline that studies nature’s best ideas and then imitates these designs and processes to solve human problems’. The three fundamental principles of the concept are (1) nature as model, which refers to solving human problems by studying nature’s models and emulating the forms, processes, systems and strategies found in it; (2) nature as measure, which indicates the use of ecological standards to assess the sustainability solutions and innovations and (3) nature as mentor, which sees the natural as a learning tool instead of just a deposit for the extraction of resources (Benyus, 1997).

1.2.2.5. Blue Economy

The blue economy philosophy states, ‘The Earth’s limited resources pose “carrying capacities” for populations of species — the number of individuals an environment can sustain. Yet through efficient use of resources and energy, and evolving clever mechanisms to adapt to and overcome environmental conditions and challenges, ecosystems have maximised the sustainable sizes of diverse populations. Nature constantly increases its efficiency and has proven to be the most economic actor of our planet’ (Blue Economy, Undated). There is conflicting reporting regarding the number of principles behind the blue economy approach; but, the Blue Economy team has merged the principles into six basic modules: local (use what you have), efficient (substitute something with nothing), systemic (mimic nature), profitable (optimise & generate multiple cash flows), abundant (satisfy all basic needs) and innovative (create change, seize opportunities).

1.2.2.6. Regenerative Design

John T. Lyle conceived the idea of applying the concept of regenerative design to other systems besides agriculture, for which the regeneration framework had already been conveyed previously. Kubba (2010) indicates that regenerative design is ‘a process-oriented system theory based approach to design; the term “regenerative” describe processes that restore, renew or revitalise their own sources of energy and materials, creating sustainable systems that integrate the needs of society with the integrity of nature'. A regenerative system does not create waste; the idea behind the approach is to have outputs either equal or greater than the inputs. Instead of disregarding the outputs to create waste, the system uses them as much as possible to create further outputs.

1.2.2.7. Industrial Ecology

Graedel and Allenby (2010) present the following two definitions of industrial ecology: (1) 'industrial ecology is the means by which humanity can deliberately approach and maintain sustainability, given continued economic, cultural and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a system view in which one seeks to optimise the total materials cycle from virgin material, to finished material, to component, to product, to obsolete products and to ultimate disposal' and (2) 'industrial ecology is the study of technological organisms, their use or resources, their potential environmental impacts and the ways in which their interactions with the natural world could be restructured to enable global sustainability'.

1.2.3. The Natural Step

The natural step, a framework created by Dr. Karl-Henrick Robert in the 1980s, considers that all the environmental problems facing society are wide and complex (yet unclear), and that basic science is the foundation of a consensus view (Robert, 2002). There are four basic scientific principles on which this concept is based: (1) matter and energy cannot be destroyed; (2) matter and energy tend to disperse; (3) material quality can be characterised by the concentration and structure of matter (energy is not consumed, only its exergy); and (4) 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, overharvesting 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) (Roberts, 2011)

The key word common to the first three conditions 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 60 local communities, more than 50 of Sweden's leading scientists and companies around the world, such as IKEA, OK Petroleum, Electrolux, Scandic, Gripen, Bilspedition, SJ (Swedish rail), The Interface Corporation, Home Depot, McDonalds, Placon, Mitsubushi Electric (USA), Collins Pine (Forest products) and Nike (Brandon & Lombardi, 2011).

1.2.4. Community Capital

Community capital is based on the concept of capital, which is well known in economics and refers to accumulated wealth. This concept can be applied to broader 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. Figure 1.2 represents the community capital triangle as envisioned by Maureen Hart.

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).

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, 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; however, techniques such as cost-benefit analysis are used to have some basis for comparison. All three levels of capital are managed by

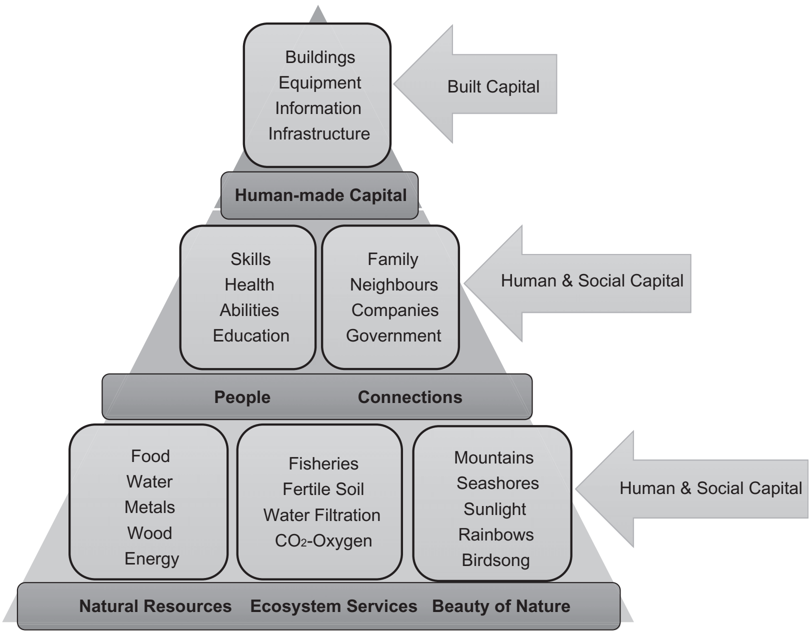

Figure 1.2: Community Capital Pyramid. *Source*: Adapted from Hart (1999).

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).

1.2.5. Ecological Footprint

The 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 8.60; in Canada, it is 11.18 and, in the United States, 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, organisation/operational costs, etc. At the end of the life cycle, the costs of demolition and disposal are included, as well as 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 criticised by some, who debate that the true carrying capacity of the biosphere cannot be calculated, measured or predicted with any accuracy (Haberl, Fischer-Kowalski, Krausmann, Weisz, & Winiwarter, 2004; Pearce, 2005; Van Kooten & Bulte, 2000). Others criticise 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 criticises 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'.

1.2.6. Monetary Approach

The monetary approach calculates the national wealth of different kinds of capital as function of their sum and 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 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 (UN, 2007).

1.2.7. The Driving Force-State-Response (DRS) Model

The driving force-state-response (DSR) model was originally based on the pressure-state-response model (OECD, 1994). Later, the DSR was expanded into the framework known as driver-pressure-state-impact-response (DPSIR). 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.

1.2.8. Issues or Theme-Based Frameworks

Issues or theme-based 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-based 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 easily adjust to upcoming priorities and policies targets over time; however, benchmarking is complicated because of the lack of homogeneity in the themes across nations (UN, 2007).

1.2.9. Accounting Frameworks

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, then they are aggregated and can be used in a consistent manner for classification and definition purposes. A widely known accounting framework is the system of integrated environmental and economic accounting (SEEA), which is a joint effort between the UN Statistical Commission, the International Monetary Fund, the World Bank, the European Commission, and the Organisation for Economic Co-operation and Development (UN, 2003). SEEA provides an internationally agreed-upon conceptual framework to measure the interactions between economics, the environment and the state of the environment (UN, 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.

1.2.10. Frameworks for Assessment Method Tool Kits

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 building environmental quality evaluation for sustainability through time (BEQUEST), construction and city related sustainability indicators (CRISP), large urban distressed areas (LUDA), Sustainability-Test and the Conseil International du Batiment (CIB) network provide the basis for planning, structuring and developing assessment method tool kits.

1.2.11. The Holistic and Integrated Framework

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, Curwell, and Lombardi (2001) recognise 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 recognises different levels of information and attempts to integrate key aspects to provide a continuum for harmony and decision-making based on 15 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 those that follow. The holistic approach claims to be flexible, consider different scenarios and planning and design issues, and include easy-to-check and relevant criteria for the decision makers.

1.3. STRATEGIC APPROACHES

Throughout the assessment process, decision makers encounter many choices. First and foremost, decision makers must decide 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.

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 organisations, recognising 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) 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 purposes, 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 considering a case review of integrated planning for sustainability for Greater Manchester (Ravetz, 2000);
(i) International Union for Conversation of Nature (IUCN) Monitoring and Evaluation Initiative offers a sustainability assessment method for evaluating human and environmental conditions that are progressing towards sustainability (Guijt, Moiseev, & Prescott-Allen, 2001);
(j) the Mining, Mineral and Sustainable Development (MMSD) project outlines the basic components of integrated impact assessment (MMSD, 2002);
(k) the North American working group of Mining, Minerals and Sustainable Development (MMSD-NA) 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, 2016);
(m) the Pembina Institute published the report entitled Sustainability Indicator Frameworks in Alberta which reviews and compares a series of indicator frameworks: Alberta Genuine Progress Indicator (GPI), Government of Alberta's Measuring Up Reports, The Canadian Index of Wellbeing and Sustainable Calgary's State of Our City Reports (Taylor, 2006).
(n) the Hong Kong Sustainable Development Unit (HKSDU) designs an assessment system for integrated consideration of proposals (HKSDU, 2002);
(o) Bradley, Daigger, Rubin, and Tchobanoglous (2002) use sustainability criteria to evaluate onsite wastewater treatment technologies;
(p) the Stockholm Environment Institute (SEI) uses sustainability assessment of World Trade organisation negotiations in the food crops sector (Maltais, Nilsson, & Persson, 2002);
(q) 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);

(r) Jenkins, Annandale, and Morrison-Sanunders (2003) propose a comprehensive sustainability assessment framework to the Western Australia State Sustainability Assessment Working Group;
(s) Nelson et al. (2004) develop a strategic environmental assessment for sustainability appraisal of Ghana's Poverty Reduction Strategy;
(t) the Forest Stewardship Council (FSC) creates a series of certification principles, criteria, standards and processes for forestry operations and wood products (FSC, 2004); and
(u) the Regional Municipality of Waterloo (RMW) develops the terms of reference for the assessment of a rapid transit initiative (RMW, 2005).

1.4. INTEGRATED APPROACHES

Sustainability is a complex and multi-dimensional area, which is under continual 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 (EU) — 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.

1.5. ASSESSMENT METHODS

Assessment methods are required to make progress towards 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.

Presently, there is no agreement among scholars under which framework to place the evaluation methods (Curwell, Deakin, & Symes, 2005; Deakin, Mitchell, Nijkamp, & Vreeker, 2007; Horner, 2004). In fact, there is a division between those who believe that environmental assessments contribute to sustainable development (Bergh, Button, Nijkam, & Pepping, 1997; Brandon, Lombardi, & Bentivegna, 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 many 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 Eco2 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 1.1, assessment frameworks, participatory tools, scenario analysis, multi-criteria analysis, cost-benefits analysis and cost-effectiveness analysis, modelling tools, accounting tools, physical analysis tools and indicator sets. The 'Sustainability A−Test' project was led by Institute for Environmental Studies (IVM) and carried out by four Dutch partners, 13 other

Table 1.1: 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
	Modelling, 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 organisation 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 behaviour

Table 1.1: (*Continued*)

Group	Sustainable Development Tool (Methodologies, Models, Approaches and Appraisals)
	Market methods
	Conjoint choice questions
	Cost-effectiveness analysis
Modelling 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

European partners, and one Canadian partner. It was commissioned by the EU FP6-STREP programme. Examples of the tools include 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 to achieve greater ecological and economic sustainability. The Eco^2

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. The World Bank (2011) states, 'urbanisation in developing countries is a defining feature of the 21st century. Some 90% 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 urbanisation in a lasting and powerful way. The decisions we make together today can lock-in systemic benefits for the present and for future generations'.

Suzuki, Dastur, Moffatt, Yabuki, and Maruyama (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 aid the cities to undertake leadership and collaboration; (2) methods for analysing 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, LCC, 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.

LUDA 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 16 project members and 12 reference cities.

In a survey, the BEQUEST project released a list of 61 assessment methods, tools and procedures. Table 1.2 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 building products, investors and building owners, consultants, residents, facilities managers, researchers, and authorities (Haapio & Viitaniemi, 2008;

Table 1.2: Sustainability Assessment Methods, Tools and Procedures.

1. Analysis of Interconnected Decision Areas (AIDA)[a]
2. Analytic Hierarchy Process (AHP)[a]
3. Assessing the Sustainability of Societal Initiatives and Proposed Agendas for Change (ASSIPAC)[a]
4. ATHENA[a]
5. BEAT 2002[b]
6. BeCost (previously known as LCA-house)[b]
7. Building Environmental Performance Assessment Criteria (BEPAC)[a]
8. BRE Environmental Assessment Method (BREEAM)[a]
9. BRE Environmental Management Toolkits[a]
10. Building Energy Environment (BEE 1.0)[a]
11. Building Environmental Assessment and Rating System (BEARS)[a]
12. Building for Economic and Environmental Sustainability (BEES 2:0)[a]
13. Comprehensive assessment system for built environment efficiency (CASBEE)[b]
14. Cluster Evaluation[a]
15. Community Impact Evaluation[a]
16. Concordance Analysis[a]
17. Contingency Valuation Method[a]
18. Cost-Benefit Analysis[a]
19. DGNB[b]
20. Eco-Effect[a]
21. Eco-Indicator 95[a]
22. Eco-Instal[a]
23. Economic Impact Assessment[a]
24. Ecological Footprint[a]
25. Eco-points[a]
26. Ecopro[a]
27. Eco-Profile[a]
28. EcoProP[a]
29. Eco-Quantum[a]
30. EIA—Environmental Impact Analysis[a]
31. ENVEST[a]
32. Environmental Profiles[a]
33. Environmental Status Model (Miljostatus)[b]
34. EQUER[a]
35. ESCALE[a]
36. Financial Evaluation of Sustainable Communities (FESC)[a]
37. Flag Model[a]
38. Green Building Challenge, changed in Sustainable Building (SB) Tool[a]
39. Green Globes[b]
40. Green Guide to Specification[a]
41. Green Star[b]
42. GRIHA[b]
43. Hedonic Analysis[a]
44. HKBEAM[b]
45. Hochbaukonstruktionen nach okologischen Gesichtspunkten (SIA D0123)[a]
46. INSURED[a]
47. Leadership in Energy and Environmental Design Green Building Rating System (LEEDTM)[a]
48. LEGEP (previously known as Legoe)
49. Life Cycle Analysis (LCA)[a]
50. Mass Intensity Per Service Unit (MIPS)[a]

Table 1.2: (*Continued*)

51. MASTER Framework[a]
52. Meta Regression Analysis[a]
53. Multi-Criteria Analysis[a]
54. NABERS[b]
55. Net Annual Return Model[a]
56. OGIP (Optimierung der Gesamtanforderungen ein Instrument fur die Integrale Planung)[a]
57. PAPOOSE[a]
58. PIMWAQ[a]
59. Project Impact Assessment[a]
60. Regime Analysis[a]
61. SBTool 2015/2016[b] (formerly known as GBTool)
62. Quantitative City Model[a]
63. Planning Balance Sheet Analysis[a]
64. Risk Assessment Method (s)[a]
65. SANDAT[a]
66. Semantic Differential[a]
67. Social Impact Assessment[a]
68. System for Planning and Research in Town and Cities for Urban Sustainability (SPARTACUS)[a]
69. Strategic Environmental Assessment (SEA)[a]
70. Sustainable Cities[a]
71. Sustainable Regions[a]
72. Transit-oriented Settlement[a]
73. Travel Cost Theory[a]

[a]Assessment methods, tools and procedures listed in the BEQUEST project, including some rating systems.
[b]Additional tools (e.g. rating systems) complementing the BEQUEST project list.

Poveda & Lipsett, 2011a, 2011b). 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 and SEA were also already established. The next section presents a brief description of the most commonly used tools: methodologies, models, approaches and appraisals.

1.5.1. 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).

1.5.2. Strategic Environmental Assessment

EIA presents a specific challenge because its application is limited to a specific project. The UN Economic Commission for Europe recommended the extension of EIA as an integrated assessment for policies, plans and programmes (PPP). As a result, SEA 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.

1.5.3. Cost-Benefit Analysis (CBA)

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 net present value (NPV) and internal rate of return (IRR) 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 the 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.

1.5.4. 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 resulting from the addition of, change in access costs for, elimination of, or 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.

1.5.5. 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.

1.5.6. 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 by questionnaires. Two critical aspects in the CVM are the hypothetical scenario characterisation 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.

1.5.7. 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.

1.5.8. Multi-Criteria Analysis

Multi-criteria analysis (MCA) presents an alternative valuation method to 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 deal with quantitative data for each criterion yielding a weighted summation. Qualitative methods process qualitative data, typically by applying a type of logic ladder. Mixed methods deal with data as they are measured.

1.5.9. Material Intensity per Service Unit (MIPS)

Material intensity per service unit (MIPS) 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).

1.5.10. 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 and 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).

1.5.11. 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 (building 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).

1.5.12. Environmental and Sustainability Rating Systems (ESRS)

Environmental and sustainability rating systems (ESRS) have been designed to measure performance — or as referred by some, the degree of 'greenest' — of a variety of projects in the construction industry. ESRS 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). An integrated approach assists the decision-making process and minimises 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, comprehensive assessment system for built environment efficiency (CASBEE) and Green Star are some of the existing sustainability/environmental rating systems, as shown in Table 1.2. LEED, for example, initially emphasises six categories, including 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, 2009). Other categories have been developed for specific rating systems, for example, LEED for neighbourhood development. Whereas LEED has been a success in North America and certified LEED projects are present in more than 150 countries, BREEAM (developed in the United Kingdom by BRE) has demonstrated its applicability in Europe. BRE has more than 100,000 certified buildings, and operates in dozens of countries. BREEAM uses nine categories: management, health and well-being, energy, transport, water, materials, waste, land use and ecology, and pollution. Dividing the criteria into categories facilitates practitioners to make effective and efficient decisions on the use and operation of the resources involved in the planning, execution and operation of projects.

1.6. CLASSIFICATION OF ASSESSMENT TOOLS

To assess the progress towards accomplishing the implementation of sustainable development strategies, the use of assessment tools becomes imperative; the goals of sustainability cannot be met unless advances and/or setbacks are periodically measured. The number of sustainability and environmental assessment tools range in the hundreds, with some focusing on specific areas of sustainability (e.g. social, economic, environmental) and others positioning themselves as integrative approaches. While some assessment tools are well positioned and accepted as indicators of performance, others continue to improve the assessment methodology used, and others will most likely emerge. The most challenging aspect of the development and classification of sustainability assessment tools refers to not only the different interpretations — at times manipulation — of the sustainability concept, but also its evolving nature as an area of knowledge. Scientists and developers of sustainability assessment tools face the need to consider several questions during the process: (1) What should we measure, how do we effectively measure it and who should we include in the decision-making process?; (2) Have the assessment tools captured the intensity of the impacts? If so, which impacts?; and (3) When do we know we have accomplished sustainability? Consequently, when it comes to sustainability and assessment tools, we face the chicken and egg dilemma; do we wait until we agree upon the definition before defining the tools needed to assess the progress made towards its (sustainability) goals? Or, do we design assessment tools hoping to 'encounter' a definition — we can agree upon — along the process of improving social, economic and environmental performance? The lack of a precise and agreed upon definition of sustainability and sustainable development poses clear difficulties for the development and subsequent classification of assessment tools, because two other questions come to mind: (1) Which assessment tool(s) should be used to assess meeting the goals and objectives of sustainability?; and (2) Which tool(s) meet the needs and expectations of the stakeholders?

But, the lack of common definition of sustainability has not stopped the development of tools to assess impacts (e.g. social, economic, environmental) or progress towards 'sustainability' or at least the vision of sustainability stakeholders have agreed upon. Assessment tools can be categorised based on numerous factors. This section highlights a framework proposed by Ness, Urbel-Piirsalu, Anderberg, and Olsson (2007) for the categorisation of sustainability assessment tools which considers three main factors: temporal characteristics, the focus and integration of nature-society systems.

Furthermore, the framework presents a classification that includes three general categorisation areas: indicators and indices, product-related assessment tools and integrated assessment.

As represented in Figure 1.3, the first category, indicators and indices, includes three sub-groups: non-integrated indicators, regional flow indicators and integrated indicators and indices. ESRS — which is the assessment methodology at the centre of this book — are included in this category. The second category, product-related assessment, considers the tools in the subgroups of LCA, LCC, product material flow analysis and product energy analysis. This second category focuses on the material and/or energy flows of a product or service from a life cycle standpoint. And, the third category, integrated assessment, refers to those tools focused on policy change or project implementation. There is another category indicated at the bottom of Figure 1.3, monetary valuation, which is used when non-market values are needed in the other three categories.

1.7. FINAL COMMENTARY

In sustainability, assessment and measurement are concepts that go hand in hand; but assessment and measurement each entail a different process. In the

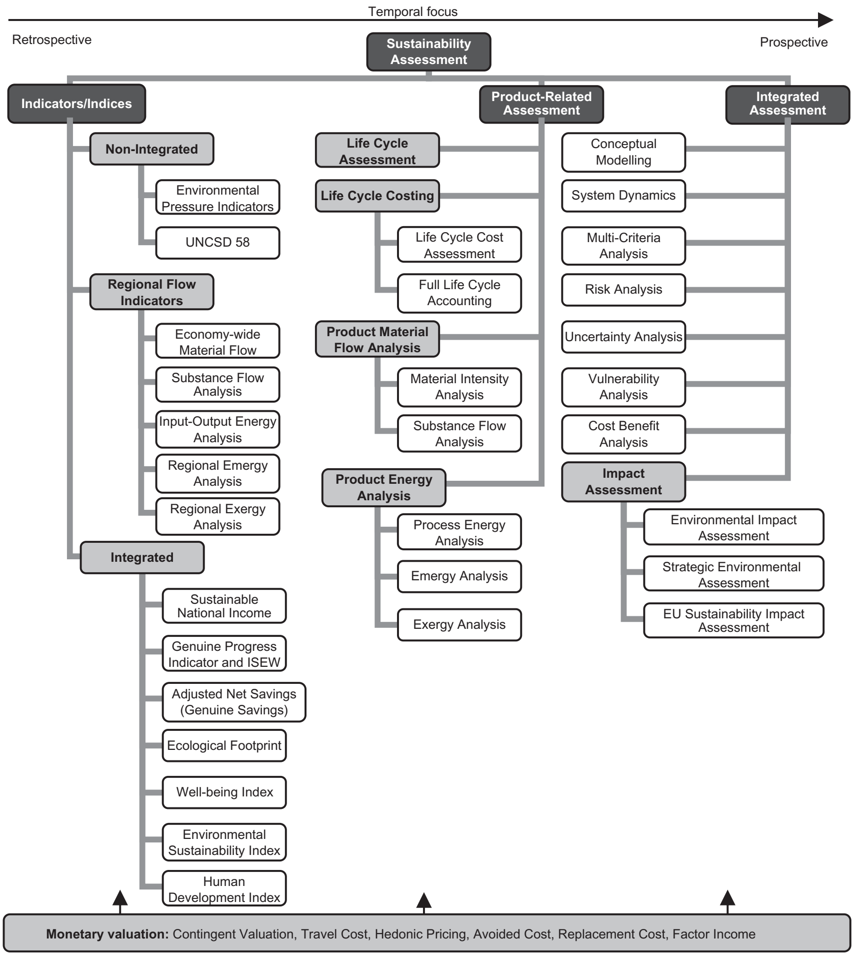

Figure 1.3: Framework for Sustainability Assessment Tools. *Notes*: The proposed assessment tool framework is based on the temporal focus of the tool along with the object of focus of the tool. The arrow across the top of the framework shows the temporal focus, which is either retrospective (indicators/indices), prospective (integrated assessment) or both (product-related assessment). The object of focus of the tools is either spatial, referring to a proposed change in policy (indicators/indices and integrated assessment), or at the product level (product-related assessment). The *monetary valuation* tools at the bottom are used when monetary valuations are needed in the above tools. *Source*: Adapted from Ness et al. (2007) with permission of Professor Barry Ness.

measurement process, variables related to sustainable development are identified and data are collected and analysed with technically appropriate methods. During the assessment process, the performance is compared against a standard for a criterion (or for several 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 12 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).

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 recognised 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. This chapter has laid out a classification of sustainability approaches and frameworks as generic, strategic and integrated, with description of the most-used assessment tools.

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