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A Review of Sustainability Assessment Methods in Engineering

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Abstract: Sustainability Assessment (SA) debate had undergone a dramatic transformation in response to global policy changes, i.e. Kyoto Protocol, trade liberalization, Doha negotiations. The purpose of this paper was to review the body of literature relevant to Sustainability Assessment functional methods in engineering. To shed light on the current standing of sustainability assessment (SA) this paper reviewed and compared up to fifty five (SA) tools. These include descriptive, quantitative and qualitative measures, or indices. In order to achieve a unified approach integrating the needs of society and the natural system, the application and spatial implication of these tools in engineering were considered within the bounds of systems theory. It was found that whilst progress has been made in the development of assessment tools, definitional ambiguities remains evident (i.e. indicators and criteria). Furthermore (SA) exhibited a skewed alignment towards the triple bottom line theory i.e. economic, social, environmental objectives with baseline conditions. Therefore, there is a pressing need for further research into engineering (SA) sustainability assessment frameworks and their ultimate objectives, direction and magnitude, particularly whether the engineering professional can afford to endorse scores of tools.

Keywords: Sustainability Assessment (SA), Technology, Social, Economic

Introduction

THIS PAPER IS part of an extended study of sustainability philosophy in engineering context; the premise of this research is centered on sustainability assessment methods drawing on standard features and limitations; it is intended to present a perspective that recognizes definitional ambiguities of indicators and criteria. WHY IS SUSTAINABILITY ASSESSMENT IMPORTANT? Sustainability has become a key political and policy issue, permeating many areas of public and commercial activity, (Selman, 2000), Spangenberg (2004), Devkota (2005), Keirstead and Leach (2007), Linnenluecke et al (2007). Although it grew out of environmental concerns, the Rio Earth Summit affirmed the equal status of socio-economic matters, and subsequent developments have framed these within a 'quality of life' or 'liveability' discourse (Selman, 2000). There is no single rubric at the engineering level. For Agenda 21 and its associated compacts (for biodiversity, forestry and climate change), and variants have ranged from a formal action planning to vision statements with little policy content. Whilst Agenda 21, adopted by over 178 nations at the 1992 Earth Summit in Rio de Janeiro, calls for actions to address disparities in social and economic development among and within nations, especially in terms of poverty, hunger, adequate housing, and public health, as well as education and institutional capacity. In addition, it recognizes the need for social and economic development to be accompanied by the conservation and management of natural resources in terms of protecting the atmo-

sphere, forests, fragile ecosystems, oceans, and freshwater resources, managing land use and releases of wastes and toxic chemicals, and conserving biodiversity (Tanzil and Beloff 2006).

In order to appreciate sustainability assessment tools it is vital to recognize

1. What it is we are assessing?
2. Why are we assessing it?
3. What indicators are used to measure progress towards Sustainability assessment?
4. How are they assessed? and
5. How do we use them?

In essence sustainability is imperative due to the uncertainty its very absence presents, as a society we want certainty, as it is perceived we need assurances, to predict are we going to survive, our children, loved ones, specie etc. According to Yencken (2000) we rely on our national governments to recognize major global trends affecting all societies, to evaluate their national impacts and to put in place long term strategies and short term actions to respond effectively to them. At a glance sustainability drive of the 21st century is an investment proposition for a flourishing planet in the long term, because it is one of the effective ways of counter-acting the over production. The engineering industry uses vast quantities of natural resources; energy, water, materials, land, and produces products and services. Sustainability policy and assessment is an important first step to make a move towards being more environmentally responsible proactive steering. The 1997 U.N. conference in Kyoto, Japan, was ratified on



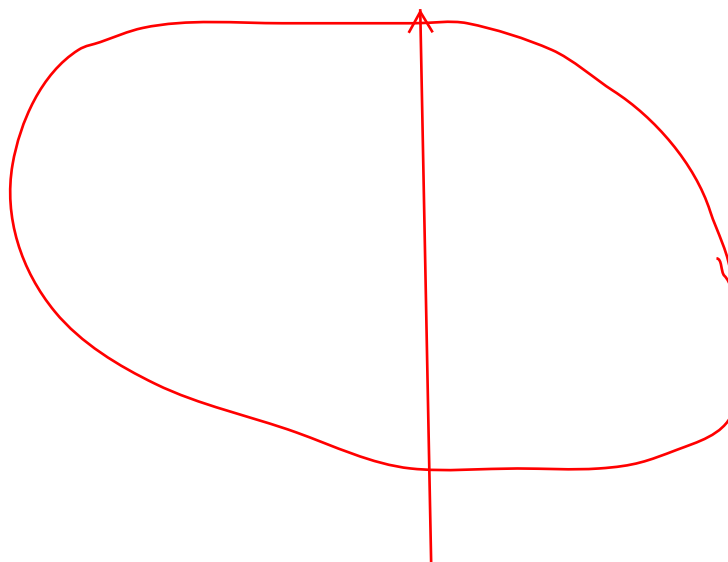
16th February 2005, by 141 countries. It was the follow-up to the U.N. Framework Convention on Climate Change (UNFCCC), which set a non-binding goal of stabilizing emissions at 1990 levels by 2000, and is the first legally binding global agreement to cut greenhouse gases. It is a pact agreed by governments to reduce the amount of greenhouse gases emitted by developed countries by 5.2 percent of 1990 levels during the five-year period 2008-2012. However no discussion on Kyoto is complete without mentioning leapfrogging, which describes the idea that developing economies could find new paths to higher standards of living, bypassing the intermediate steps that have shaped the developed world. Once again Technology and innovation are the cornerstones of change thus “leapfrogging”.

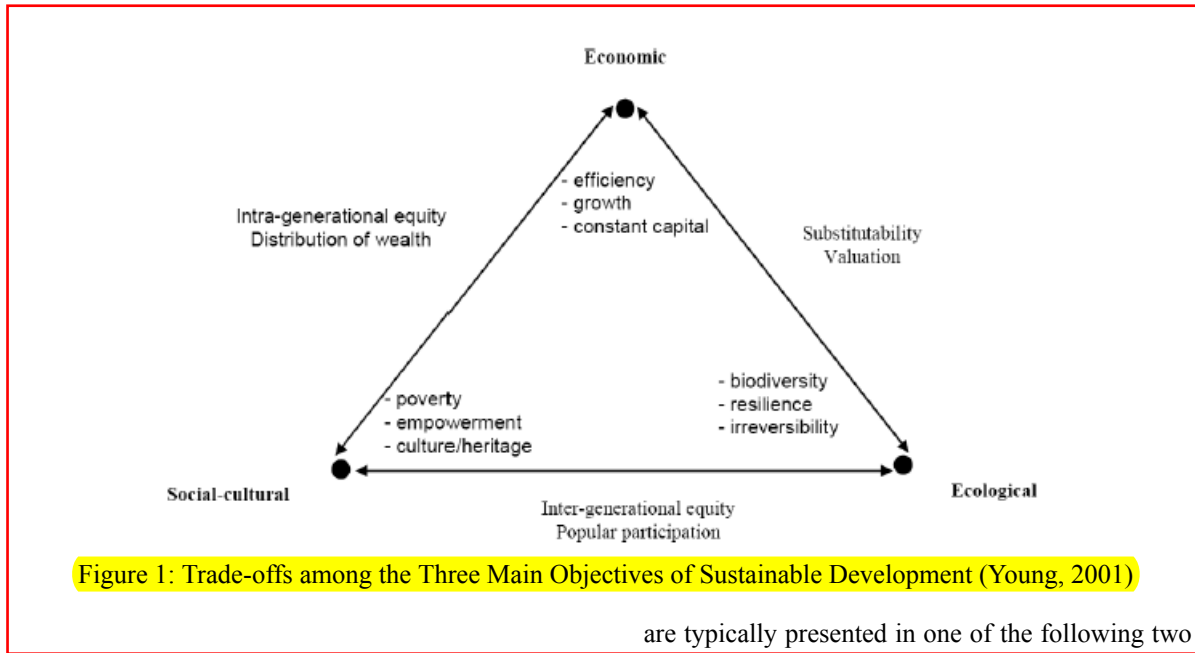
Systems Theory

To reconcile sustainability assessment within system theory, we must decide how sustainability as a system is interrelated. This approach gives the advantage of avoiding problem shifting from dimension to dimension or from time to time. Considering Rapoport (1968) general systems theory's interpretation into sustainability, first we must locate the most general conceptual framework in which a scientific theory or a technological problem can be placed without losing the essential features of the theory or the problem. Sustainability assessment as system may perhaps conform to systems theory provided that it adheres to a process according to Assefa, (2005) systems theory calls for analyzing systems as a whole as a reaction to the Newtonian science of reductionism.

Furthermore Lazlo (2003) defines a system as a group of interacting components that conserves some identifiable set of relations with the sum of their components plus their relationships (i.e., the system itself) conserving some identifiable set of relationships to other entities (including other systems). Hence to manage practical demands of sustainability system, it ought to be viewed within an interdisciplinary framework which develops awareness of the

interconnections between parts of the system, i.e. social, economic, environmental, and technological. The challenge in sustainability is the tradeoff between the three dimensions as per Figure 1. The interaction between the socio-economic systems and the ecological systems has been a subject of many discussions Foxon et al (2002); Labuschagne (2006); Sikdar (2002); Fricker (1998); McKenzie (2004); Assefa and Frostell (2007); Sachs (1999). The interactions between economic and ecological systems is addressed as a core problem in ecological economics by Georgescu-Roegen (1971); Schumacher (1973); Irked, (1997); Daly (1991); Costanza et al (1997); Masood and Garwin (1998); Daly and Farley (2004). According Hediger (2000) sustainability is a normative concept which involves trade-offs among social, ecological and economic objectives, and is required to sustain the integrity of the overall system. Beloff et al (2004) sustainable development is a complex concept that encompasses the “triple bottom line”: the economic, environmental, and social factors that affect the ability of an organization to survive and grow. The “bottom line” is a metaphor is often attributed to John Elkington, a co-founder and chair of SustainAbility LTD, UK, a sustainable business consultancy (Elkington 2004) arising from within the business lexicon that confers the ability to capture in a unique representation (a number) the effect of a multitude of separate actions (transactions) by systematically representing these actions using a common metric and summing the contributions (benefits) and detriments (costs). TBL is a business accounting tool, the quintessential symbol of the bottom line is the net income (earnings) reported on the financial statements of publicly held corporations. As a framework for organizations to translate the concept of Sustainable Development (World Commission on Environment and Development 1987) into the operation of organizations TBL and Corporate Social Responsibility programs are essentially the same. However, the TBL programs are focusing only on accounting and reporting and organizations need to do. (Brown et al, 2006). The next section reviews sustainability assessment tools.





are typically presented in one of the following two classes:

Sustainability Assessment

sustainability assessment (SA) have been developed across different disciplines to serve a multiplicity of purposes, thus it is virtually impossible to give an exact definition of SA, Buselich (2002) defined SA as assessment of proposed initiatives (projects, policies and plans) in terms of sustainability to determine the conditions under which approval would be given. Hence in terms of definitional context sustainability assessment is methodology to gauge sustainable attributes of a project, policy or plan. For the purpose of this review Sustainability Assessment (SA) is defined as an integrated assessment for assessing the social, environmental, technological and economic dimensions of projects, policies and programs (PPP). The range of sustainability assessment methods currently available stretches from highly technocratic tools to far simplistic methods. Results

1. Technical language that seems to require a great deal of time and effort to unpack even the simplest analysis scientific and technical expertise that would allow them to evaluate.
2. oversimplified to a few summary statistics

Many sustainability assessment systems documented in this paper involve the use of qualitative techniques as a foundation used to gather data and quantitative methodologies that employ questionnaires and scaled responses. Hence Table 1 lists the common Sustainability Assessment SA tools readily available; these can be categorized in two types as follows;

1. General laymen: sustainability assessment tools
2. Engineering specific programs: sustainability assessment tools

Table 1: Sustainability Assessment in Literature

General	Engineering
Barometer of Sustainability	Socio-ecological Indicators of Sustainability
Environmental Impact Assessment EIA	Sustainability Assessment by Fuzzy Evaluation (SAFE)
Ecologically Unsustainable Trade	Sustainability Footprint
Ecosystem Resilience	Systems Theory and Basic Orientors
The Natural Step	Waste Assimilation Capacity
Cost Benefit Analysis CBA	Waste Potential Entropy
dynamic hierarchical approach	Energy System Assessment
Contingent ranking	The 7QS Assessment Framework
Pressure state response (PSR)	Material flow accounting MFA
Environmental Pressures (EP)	Sustainability Assessment Model (SAM)

Environmental Space	The Institution of Chemical Engineers Sustainability Metrics
World Bank measuring wealth of nations	Green engineering
Environmental Sustainability Index (ESI)	Cleaner production
Green Net National Product (NNP)	Sustainability Process Index (SPI)
Genuine Progress Indicator	exergy
Genuine Savings	Ecological Footprint
Green Net National Product (NNP)	Life cycle analysis LCA,
Human Appropriation of Net Primary Productivity (HANPP)	The Institution of Engineer, Australia
Triple Bottom Line TBL	Material Unit Per Unit Service (MIPS)
Human Development Index (HDI)	Emergy Analysis
Environmental Sustainability Index and Wellbeing Index	Material and Energy Flow Analysis (MEFA)
I = PAT formula	RM Risk Management
Index of Social and Economic Welfare	Multi-Criteria Decision Making MCDM
Indicators for agro ecosystems	BRIDGES' Sustainability Framework
Level of Living Index	
Sustainable enterprise indices: Dow Jones Sustainability Indexes	
Maximum Sustainable Use (MSU)/ Abuse (MSA)	
Modelling World Resource Dynamics (World3 model)	
Natural Resource Availability	
Real Wages Resource Accounting Input-Output Models	
United nations CSD indicators	

Sustainability Assessment Tools: General

The following section reports on the general sustainability assessment tools:

Pressure state response : In 1993, the OECD Core Set of Indicators for Environmental Performance Reviews reported the first sighting of the Pressure-State-Response frame work for the development of indicators (OECD, 1993). The Pressure-State-Response framework is based on a concept of causality: human activities exert pressures on the environment and change its quality and the quantity of natural resources "state". Society responds to these changes through environmental, general economic and sectoral policies "societal response".

World Bank measuring wealth of nations: In 1995, the World Bank published a report "Measuring the Wealth of Nations", determined the dollar value of natural capital, manmade capital, human capital, for 192 countries. The idea is based on the concept of genuine saving as an indicator to explore the dynam-

ics of creating and maintaining wealth. Genuine saving is "the true rate of saving of a nation after accounting for the depreciation of produced assets, the depletion of natural resources, investments in human capital, and the value of global damages from carbon emissions. Negative rates of genuine saving must lead eventually to declining well-being." (World Bank, 1997)

United nations CSD indicators : In 1996 the first draft of the publication "Indicators of Sustainable Development: Framework and Methodologies" was publicized. It included a list of about 140 indicators as well as detailed methodological aspects. Indicators are organized in four categories: social, economic, environmental and institutional and are related to the chapters of Agenda 21. For example Chapter 40 of Agenda 21 is about information and decision-making and is classified on the institutional category of indicators.

Sustainable enterprise indices : Dow Jones Sustainability World Indexes (DJSI World) is constructed by selecting the leading 10% of sustainability firms (which number more than 300) in the Dow

Jones Global Index, which covers 59 industries over 34 countries Holt et al (2005). The composite DJSI World is available in four specialised subset indexes, which exclude companies that generate revenue from (1) tobacco, (2) gambling, (3) armaments or firearms, and (4) alcohol. Holt et al (2004) reviewed, Dow Jones Sustainability Index (DJSI), Ethibel, FTSE4Good, Domini 400 Social Index and Vanguard Calvert Social Index Fund, and Corporate Governance Quotient (CGQ), to identify similarities and differences across indices and attempt to determine the best approach to measuring sustainability. Holt reports whilst organizations are attempting to measure sustainability, it was discovered that very few actually translated their efforts into a standard metric, across the indices reviewed, found little uniformity. Although the indices evaluated similar areas, such as environmentally and socially sustainable practices, they did not use the same drivers, even terminology varied widely.

The 7QS Assessment Framework: Tahltan (2004) MMSD developed the Seven Questions to Sustainability (7QS) Assessment Framework. 7QS states a theme of sustainability in a practical way on the ground in a way that is meaningful to explorer, mine manager, mill superintendent, community leader or public interest group. The framework begins with seven Questions falls a hierarchy of objectives, indicators and specific metrics. Simultaneously, the starting point for assessing the degree of progress is provided by an "ideal answer" to the initial question. In this way a single, initial motivating question—is the net contribution to sustainability positive or negative over the long term cascades into progressively more detailed elements which can be tailored to the project or operation being assessed

Environmental Sustainability Index and Wellbeing Index: The World Economic Forum's Environmental Sustainability Index is also composite index derived from 68 indicators for 148 countries (WEF, 2002, Esty, 2002). These indicators are aggregated into 5 components and 20 core indicators: environmental systems (air quality, water quantity, water quality, biodiversity, and land); reducing environmental stresses (air pollution, water stresses, ecosystem stresses, waste and consumption pressures, and population growth); reducing human vulnerability (basic human sustenance and environmental health); social and institutional capacity (science and technology, freedom to debate, environmental governance, private sector responsiveness, and ecoefficiency); and global stewardship (participation in international collaborative efforts to reduce greenhouse gas emissions and transboundary environmental pressures). At the extremes the Environmental Sustainability Index agrees well with the Wellbeing Index. However, Hungary is ranked eleventh, Brazil is ranked

twentieth, and the United States is ranked forty fifth out of 148 countries, significantly different results than for the Wellbeing Index.

Victorian Weekly greenhouse indicator: Victorians regularly track their ongoing contributions to climate change via monitoring their carbon emissions, with the launch of a world-first weekly indicator showing the state's key sources of greenhouse gas emissions. The indicator will allow Victorians to see how much their use of coal fired electricity, petroleum and natural gas is adding to the state's growing greenhouse emissions (Minchin, 2007).

Barometer of sustainability: Developed in 1997 by Robert Prescott-Allen, in his book "The Well-being of Nations", offers an aggregate indicator of sustainability. The indicator is visualized in two axes: one for ecosystem well-being and the other for human well-being. The judgment of overall sustainability is based on the axis with the lower score (with the worst performance). Simultaneously covers environmental, social and economic components of sustainability, keeping ecosystem and human system separate to determine their individual sustainability. Graphs the results indicating the range of conditions from good to bad, advantages easy calculations, visual representation of results; Prevent trade-offs between human and ecosystem well-being is reflected from the starting point of the barometer which regards that ecosystem and human well-being are equally important. Each indicator defined is measured on a performance scale. In this way it is possible to compare and aggregate indicators. The Barometers scale is divided into five sectors giving a fully controlled scale. Indicators are then aggregated up to the subsystem level (ecosystem and human well-being) giving the Barometer of sustainability. Limitations recognized by other authors concerning the subjectivity (Hardi and Barg, 1997; Guijt and Moiseev, 2001; Bossel, 1999) have some ground but it is more likely to be the ground of general questioning over what constitutes sustainable development and whether there is a unique set of clearly defined criteria to assess sustainability.

Ecological footprint: The Ecological Footprint is an accounting tool to measure how much nature a given population or country is using it is rather an indirect way for measuring sustainability. The measurement is in land units and is made on the assumption that each human activity uses resources and has waste flows which can be converted to a biologically productive area necessary to provide these functions (Wackernagel and Rees, 1996; Wackernagel et al, 1997) Calculates the appropriated carrying capacity of a population by measuring the total amount of land required to support consumption of food, water, energy and waste generation of a population. Advantages single figure indicator that

is easy for everyone to understand, useful for policy and education (e.g. online personal calculators); limitations large amounts of data required some of which is difficult to obtain; loss of information in aggregation; does not include all resource use (i.e. water, marine resources and waste); does not cover social or equity aspects. Rees and Wackernagel, 1994; Wackernagel et al., 1993). Therefore, it offers a good tool for global and national monitoring of aggregated crude results but when detailed information is needed to proceed to national and sectoral policies, more detailed information would be necessary. Its contribution on the sustainability concept lies on the fact that highlights the issue of equity between nations, between developing and developed societies.

Sustainability Assessment Tools: Engineering Specific Programs

The following is a short account of a small number of engineering specific sustainability assessments. It is intended not to delve into excessively detailed theory; instead a general understanding is provided.

Sustainability Assessment Model SAM : The sustainability assessment model (SAM), measuring operational sustainability is a tool used for modelling and evaluating Sustainable Development performance of projects, organisations and industry sectors. The method builds on full cost accounting techniques (Bebbington *et al.* 2001) which quantify the internal and external costs and benefits related to particular actions, impacts (positive and negative) are dealt with in four categories: economic, resource usage, environmental and social.

The Institution of Chemical Engineers Sustainability Metrics : IChemE the acronym for the Institution of Chemical Engineers; The IChemE's approach to sustainable development is encapsulated in the London Communiqué of 1997; a statement signed by the leaders of 18 chemical engineering societies throughout the world, and later in 2001 the sixth world congress of chemical engineering where the Melbourne communiqué was founded represented by twenty organisations, The content of the 7th World Congress of Chemical Engineering, held in Glasgow in 2005, effectively endorsed this position. IChemE published in May 2002 a set of sustainability indicators to measure the sustainability of operations within the process industry. The IChemE provides standard reporting forms and conversion tables. This framework is intricate and impact oriented (Tallis, 2002). However, the framework strongly favours environmental aspects (Labuschagne, 2003). The metrics are presented in three groups environmental, economic and social indicators.

The Institution of Engineer, Australia : In 1994 the institution adopted its first policy on sustainability and 1997, it published engineering frameworks for sustainability, titled towards sustainable engineering practice, the frame work consisted of 6 chapters ,a green building guide, transport, water, energy efficiency and chemicals management. The basis of the framework referred to LCA, CP, CER, and risk management criteria. It also included the Newcastle declaration on world environment day 5th of June 1997 acknowledging the Rio Earth summit.

Green engineering : Anastas et al (2003) describes the Twelve Principles of Green Engineering as a tool that allow designers to consider fundamental factors at the earliest stages as they are designing a material, product, process, building or a system. The principles should be considered as a collection of parameters in a complex system that needs to be optimized, including taking advantage of synergies and recognizing trade-offs. The application and emphasis of individual principles will be largely contextual dependant on the specific conditions and circumstances of the intended use of the design.

Material flow accounting MFA : Clift (2006) reports on MFA is defined as the “quantitative accounting of material inputs and outputs of process in a chain perspective” (Bringezu and Moriguchi, 2002). MFA is a form of material balance analysis, typically applied to one material or group of materials passing through a geographical area or an industrial sector. MFA was applied to obtain estimates for resource consumption, or of waste arising so that recycling rates can be estimated and activities to improve waste recovery and recycling can be planned (Melo, 1999; van Schaik and Reuter, 2004; Verhoef et al., 2004). Where the material in question is incorporated in products with significant service lives, it is necessary to allow for the distribution of residence times in the economy using what amounts to an application of residence time theory (van Schaik and Reuter, 2004).

Cleaner production : The term Cleaner Production is interchanged with Pollution Prevention, Waste Minimisation, Green Productivity and Eco-Efficiency (UNEP 2001).Cleaner Production is a preventative environmental management strategy emerged in the USA, and promoted on a global scale through the efforts of bodies such as the United Nations Environment Program, the European Union and many national governments, including Australia. The term is often used interchangeably with Eco-Efficiency (Pagan et al. 1999), and although both concepts are complementary (Van Berkel, 2000) and mutually reinforcing (UNEP & WBCSD 1996) there are subtle differences. According to Van Berkel (2000), Eco-Efficiency is focusing on the strategic side of value creation and Cleaner Production on the operational side.

The Sustainability Process Index : The SPI was developed by Krotscheck and Narodoslowsky (2004) as a means to evaluate industrial processes. Based on a life-cycle approach, it uses mass and energy balances of the processes to be evaluated Narodoslowsky and Krotscheck (2000). The references used are the natural concentrations of substances in the compartments atmosphere, groundwater and soil.

Exergy: invented by Rant (1956) exergy combines the first and second laws of thermodynamics in a manner analogous to Gibbs free energy, Helmholtz energy or availability. It is a thermodynamic property that expresses the capacity of a system to perform work under ideal conditions. Because all industrial processes and all material and energetic flows may be modelled in terms of embodied exergy, thermodynamics could theoretically provide a common scientific framework for both LCA and systems analysis, merging the two perspectives into complementary tools. A general relationship can be drawn between exergy and the material life cycle wherein high exergy (low entropy) resources are extracted from the environment, refined by the economy, and returned to the environment as low exergy (high entropy) wastes. Although exergy may be found in four basic forms, kinetic, potential, chemical and physical (i.e. pressure–volume and heat exchange type work), for the present purposes the most important aspect of exergy analysis is chemical, which is analogous to Gibbs free energy.

Emergy : Emergy analysis (spelled with an “m”) is an environmental accounting method that develops

an energy systems language for the thermodynamics of open systems Odum and Odum (1981); Odum (1996). Emergy accounts for, and in effect, measures quality differences between forms of resources and energy. Emergy is an expression of all the energy (and resources) used in the work processes that generate a product or service in units of one type of energy.

Discussion

Many researchers and commentators recognize the absence of a truly integrative sustainability-based assessment and the limitations of current environmental, and other, assessment processes. According to Buselich (2002) there is a worldwide movement to develop a sustainability assessment system. Devuyt (2001) “Sustainability assessment is a tool that can help decision-makers and policy-makers decide what actions they should take and should not take in an attempt to make society more sustainable” furthermore Verheem (2002) reports the aim of sustainability assessment is to ensure that plans and activities make an optimal contribution to sustainable development”. Similarly environmental assessment processes are among the most promising venues for application of sustainability-based criteria. They are anticipatory and forward looking; integrative, often flexible, and generally intended to force attention to otherwise neglected considerations” (Gibson 2001).

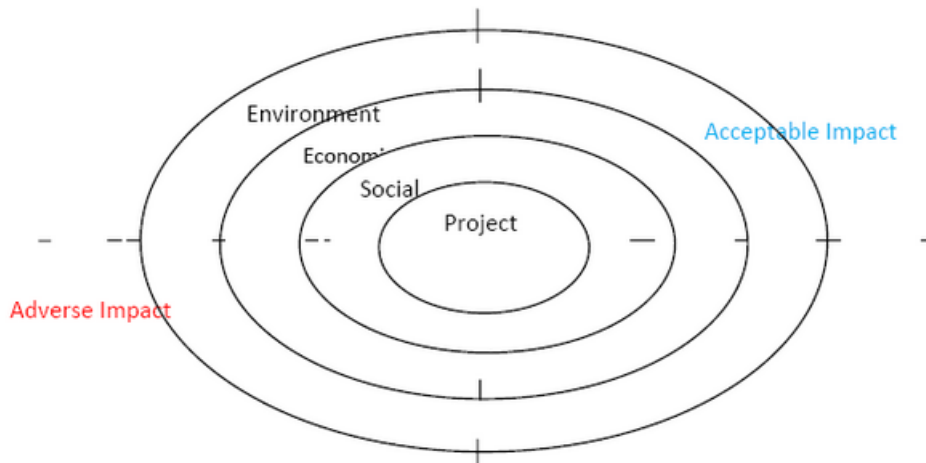


Figure 2: Reactive Assessment

Although the use of both quantitative and qualitative indicators as a device for helping to ‘do’ sustainable development (SD) is logical (Acton, 2000; Gallopin, 1997) as quoted in Bell and Morse (2004), it does present some immediate difficulties. Besides, from the previous section it would be evident that literature is not short on sustainability assessments, however Let us now start this discussion by visiting some of

the available definitions of sustainability assessment, Sustainability assessment is used to describe a range of very different processes, there also dissimilar terminologies used to refer to it, i.e. sustainability appraisal (Sheate et al 2001), integrated sustainability appraisal (Eggenberger and Partidario 2000), integrated impact assessment (Sheate et al 2003), hence thus far in this paper I have reviewed the many

evolving forms of sustainability assessment tools basically the literature of sustainability assessment processes ranges from a variety of ‘assessment’, derived from environmental impact assessment (EIA) and an extended form of strategic and general environmental assessment (SEA) that incorporate social and economic considerations as well as environmental ones reflecting a ‘triple bottom line’ (TBL) approach to sustainability. Finally, the most important remaining question is whether the chosen triple-bottom-line objectives really reflect ‘sustainability’. George (2001) recognises the important role of environmental, social and economic objectives within the decision-making process, but suggests that such objectives, which typically concern issues such as jobs, economic growth, housing, transport, services, etc., relate to development that is not necessarily sustainable and therefore should guide the planning process rather than the sustainability assessment process.

Furthermore we can establish that sustainability assessment tools are classified in four distinct quantities, see Figure 4, the first (EIA) environmental Impact assessments, it compares ecological, economic, and social impacts with baseline conditions. In turn it is available in two preferences a reactive method see Figure 2 which is represented by Environmental impact assessment. Figure 2 highlights the difference in approaches used where it is a choice between the acceptable impact and adverse impact. A proactive method which is represented by (SEA) Strategic environmental assessment, also known as objective driven assessment, which are in contrast with reactive assessment, which aims to ensure that triple bottom line impacts of a proposal are acceptable compared with baseline conditions. Figure 3 illustrates the spectrum where assessment is compared between more sustainable or less sustainable.

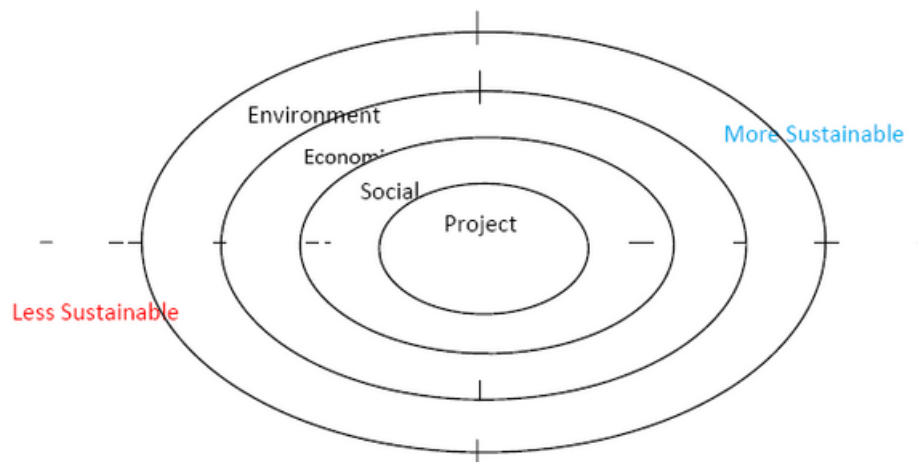


Figure 3: Proactive Assessment

The second is engineering specific which utilises physical sciences to determine numerical outputs, the third is a cliché type, ad hoc approach where more than likely sustainability assessment is bolted or glued on to the final stages of the design or after a proposal has already been conceptualized, basically it is done for show. Finally the fourth assessments is a Dynamic assessments represented by Integrated Sustainability Assessment or Transition Management where Pope et al (2004) assessment for sustainability’ firstly requires that the concept of sustainability is well-defined, in terms of sustainability criteria against which the assessment is conducted. In all but the first three approaches they are based on the notion of minimizing “unsustainability” or achieving TBL objectives.

In this paper I had attempted to present a categorical examination of the various approaches described in the literature, Figure 4 illustrates a summarized outline of the subject. For engineers this presents a confusing position how do we deal with the vast number of assessments that exist, although environmental assessment experts consider sustainability assessment as the next generation of (EA) environmental assessments Sadler and Jacobs (1990), Sadler (1992, 1994, 1996, 1997, 1999, 2000). We can see the sharp contrast in the assessment methods available, the generalist are too general and the engineering specific require a firm degree of expertise to negotiate.

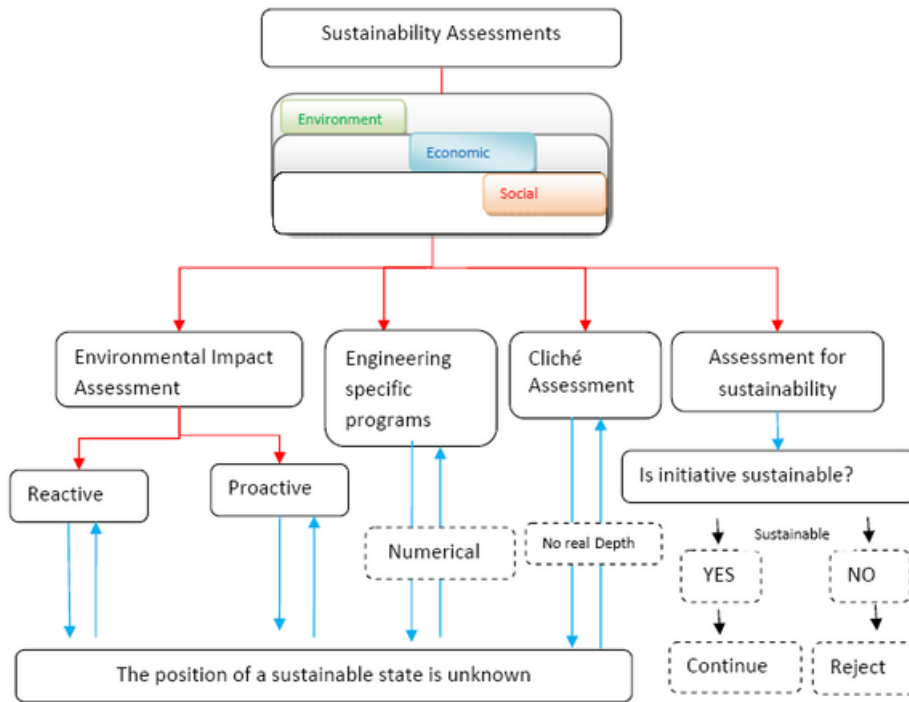


Figure 4: Sustainability Assessment

Parries and Kates (2003) described sustainability indicators to have had broad appeal and little specificity, but some combination of development and environment as well as equity is found in many attempts to describe it. However, proponents of sustainability differ in their emphases on what is to be sustained, what is to be developed, how to link environment and development, and for how long a time. Despite the persistent definitional ambiguities associated with sustainable development, much work (over 500 efforts) has been devoted to developing quantitative indicators of sustainable development. Linking the diverse approaches in sustainability assessment against their conceptual framework, literature abounds with articles that promote the role of triple bottom line concepts applied in the primary indicator or criteria measurement. Upon closer examination of these assessments to evaluate their relative potentials and limitations it was found that dependence is biased towards the TBL social, economic, environmental principals. If these articles fairly represent

our scientific community understanding of assessment and sustainability value system they both appear weak. It is disconcerting to find proponents of TBL assessment provide no scientific justification for their positions.

The surveyed assessment tools exhibited skewed alignment towards the triple bottom line theory i.e. economic, social, environmental objectives with baseline conditions. Also the reviewed literature exhibits a deficiency in combining the generalist characteristics with program specific features. Assessment methods clearly incorporated the three dimensions and discounted technology as a fourth dimension. However viewing sustainability within systems theory these challenges would be viewed as “in complete systems problems”. Realigning sustainability assessments using multiple dimensions, as illustrated in Figure 5. Hence a systemic orientation of the assessment methods is essential to maintain a holistic position that seeks to integrate the needs of society at large and the natural system at larger.

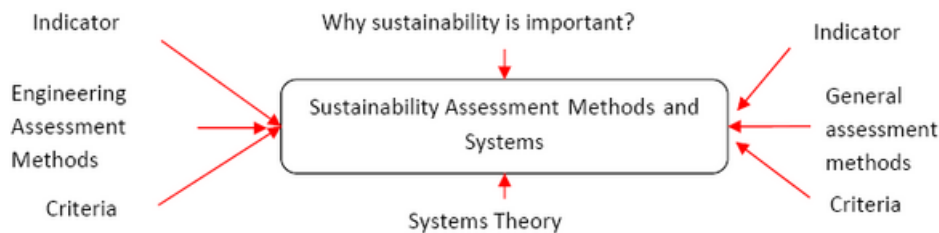


Figure 5: Assessment Layout

Conclusion

This review had attempted to provide a summary of sustainability assessment methods, we have listed some fifty-five sustainability assessment tools, and some were briefly examined. The majority of reviewed research on sustainability assessment (SA), had adopted qualitative rather than quantitative methodology due to the complexity of analysis required to address the vast array of issues surrounding any given proposal/initiative, and the absence of well developed quantitative sustainability assessment tools raises another critical issue of how to integrate qualitative and quantitative information into a single assessment.

Increasingly Sustainability assessment tools are viewed as instruments to aid in the shift towards sustainability. The review basis was; the indicator framework included a set of measurable indicators that addressed dimensions of sustainability, and has a wide focus, i.e. at a national, community or company level. It is noticeably acknowledged that the engineering world is without doubt not in need of another sustainability metric or assessment method

to be added to the list, our experience with this research that a middle ground assessment methodology is required one that mediates the indicators from the generalist and program specific assessment methods, indicator and criteria. Whilst it is recognized that an effective tool for sustainability assessment would require an initiative across all levels of engineering decision-making, across all sectors prevailing across policy and legislation. Since all engineering decisions have the potential to impact on patterns of production and consumption; governance and settlement the conclusion was drawn that the best methods use a holistic, systems approach. This review demonstrates that although the literature contains much sustainability assessment methods, thus, this gap show that there has been no focus of holistic approaches. Finally this work forms a crucial part of generating a discussion on sustainability assessment for engineers and to encourage engineers to use the same language meaning the same benchmarking standard for sustainability assessment; this is the basis of our next proposal for the development of a step by step process for sustainability assessment.

References

- Anastas, P T.(2003) Green engineering and sustainability *Environmental Science & Technology*, 12/1/, Vol. 37 Issue 23, pp423-423, 1p
- Assefa G, Frostell B. . (2007) Social sustainability and social acceptance in technology assessment: A case study of energy technologies *Technology in Society* 29 pp.63–78.
- Assefa G, on sustainability assessment of technical systems, Experience from Systems Analysis with the ORWARE and EcoEffect tools, Stockholm, December 2005
- Bell S, Morse S, (2004), Experiences with sustainability indicators and stakeholder participation: a case study relating to a Blue Plan project in Malta, *Sustainable Development*, Volume 12 Issue 1, pp. 1 - 14
- Beloff B, Tanzil D, Lines M, (2004) Sustainable Development Performance Assessment, *Environmental Progress* (Vol.23, No.4) December, 271
- Bringezu, S., Moriguchi, (2002). Material flow analysis. In: Ayres, R., Ayres, L.W. (Eds.), *A Handbook of Industrial Ecology*. Edward Elgar, Cheltenham.
- Brown D, Dillard J, Marshall R. S, (2006) *Triple Bottom Line: A business metaphor for a social construct*, School of Business Administration, Portland State University, 3 March.
- Buselich K, (2002) An outline of current thinking on sustainability assessment, A background paper prepared for the Western Australian State Sustainability, Murdoch University, Western Australia, August
- Clift R(2003), Metrics for supply chain sustainability, *Clean Technology Environment Policy* 5 240–247.
- Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Naeem, S., Limburg, K., Paruelo, J., O'Neill, R.V., Raskin, R., Sutton, P., and van den Belt, M. (1997), The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.
- Daly, H. (1991), *Steady-State Economics* (2nd Ed.), Washington, D.C.: Island Press.
- Daly, H. Farley, J. (2004), *Ecological Economics: Principles and Applications*. Washington: Island Press.
- Devkota SR. (2005), Is Strong Sustainability Operational? An Example from Nepal, *Sustainable Development*, 13, 297–310
- Devuyst, D. (2001), Introduction to sustainability assessment at the local level. In Devuyst, D. (Ed). *How Green is the City? Sustainability assessment and the management of urban environments*. Columbia University Press. New York.
- Edmundson V. (eds), *Environmental Assessment and Development*, The World Bank, Washington DC
- Eggenberger M, Partida' rio M. (2000)Development of a framework to assist the integration of environmental social and economic issues in spatial planning. *Impact Assess Proj Apprais*;18(1):201– 7.
- Foxon T. J., G. Mcilkeny, D. Gilmour,C. Oltean-Dumbrava, N. Souter, R. Ashley, D. Butler,P. Pearson, P. Jowitt, J. Moir, (2002), *Journal of Environmental Planning and Management*,45(2), pp.285–301.
- Fricke A, Measuring up to sustainability, *Futures*, Vol. 30, No. 4, pp. 367–375, 1998, Pergamon
- George, C. (2001). Sustainability appraisal for sustainable development: integrating everything from jobs to climate change. *Impact Assessment and Project Appraisal*. Vol 19 no 2: 95-106 (2001).
- Georgescu-Roegen, N. (1971), *the Entropy Law and the Economic Process*, Cambridge, Mass.: Harvard University Press.

- Gibson, R. (2001), Specification of sustainability-based environmental assessment decision criteria and implications for determining "significance" in environmental assessment.
- Hasna A M, (2007) Sustainability and Engineering Philosophy: The Paradigm, The International Journal of Environmental, Cultural, Economic and Social Sustainability, Volume 3, Issue 4, pp.107-114.
- Hasna A.M, Thorpe D, (2005) Sustainable Resource Management of engineering technologies - towards an assessment framework", proceedings of the 9th international conference on environmental science and technology, Rhodes Island, 1-3, September
- Hasna A.M. (2007), the engineering design process with sustainability, *Engineering Sustainability SSEE2007*, the international conference of the Society for Sustainability and Environmental Engineering, Engineers Australia, 31 October - 2 November, Perth, Western Australia.
- Keirstead J, Leach M, (2007) Bridging the Gaps between Theory and Practice: a Service Niche Approach to Urban Sustainability Indicators, Sustainable Development, Wiley InterScience.
- Labuschagne C, Brent A C., (2006) Social Indicators for Sustainable Project and Technology Life Cycle Management in the Process Industry, *Intentional Journal LCA* 11 (1) pp.3 – 15
- Laszlo A (2003) Editor, *Systems Thinking Glossary of Terms*, the 47th Meeting of the International Society of the Systems Sciences (ISSS), Crete, Greece, July.
- Linnenluecke MK, Russell S V., Griffiths A, (2007) Subcultures and Sustainability Practices: the Impact on Understanding Corporate Sustainability, *Business Strategy and the Environment*, Wiley InterScience
- Masood, E. Garwin, L. (1998), Costing the Earth: when ecology meets economics. *Science* 395: 426-427.
- McKenzie, S (2004), 'Social sustainability: towards some definitions', Hawke Research Institute Working Paper Series No 27, University of South Australia, Magill, South Australia.
- Melo, M.T., (1999). Statistical analysis of metal scrap generation: the case of aluminium in Germany. *Resources, Conservation and Recycling* 26, 91–113.
- Odum H.T., E.C. Odum, (1981) *Energy Basis for Man and Nature*, McGraw Hill, London, UK.
- Pagan , R , Pullar , S . Lake, M . (1999), Global considerations for cleaner production of the food and beverage industries . Paper presented to the Conference on cleaner production in the food and beverage industries. Hobart, 1-3 September. Organized by Australian Water and Wastewater Association, and The Waste Management Association of Australia.
- Parris TM. , Kates R.W., (2003), Characterizing And Measuring Sustainable Development, *Annual Review of Environment and Resources*, Volume 28: November, 559-586
- Pope J, Annandale D, Morrison-Saunders A, (2004), Conceptualising sustainability assessment, *Environmental Impact Assessment Review* Volume 24, Issue 6, August, pp. 595-616.
- Rant Z. (1956), Exergy, a new word for technical available work. *ForschIng Wis*, 22 (1):36–7 (in German)
- Rapoport A, (1968), *Systems Analysis: General Systems Theory*, *International Encyclopaedia of the Social Sciences* Vol. pp. 452.
- Sachs I. (1999) Social sustainability and whole development: exploring the dimensions of sustainable development. In: Egon B, Thomas J, editors. *Sustainability and the social sciences: a cross-disciplinary approach to integrating environmental considerations into theoretical reorientation*. London: Zed
- Sadler B (1994) Environmental assessment in development policymaking, pp 3-19 in Goodland R. and
- Sadler B (1996) *Environmental Assessment in a Changing World: Evaluating Practice to Improve Performance*, Final Report of the International Study of the Effectiveness of Environmental Assessment, Canadian Environmental Assessment Agency, Ottawa.
- Sadler B (1997), recent progress in strategic environmental assessment, *Environmental Protection Bulletin*, 55: 1-10.
- Sadler B (2002), from environmental assessment to sustainability appraisal?, *Environmental Assessment Yearbook 2002*, Institute of Environmental Management and Assessment, Lincoln and EIA Centre, University of Manchester (pp 145-152).
- Sadler B. (1999), A Framework for Environmental Sustainability Assessment and Assurance. In: J Petts (ed), *Handbook of Environmental Impact Assessment* Volume 1, Blackwell, Oxford.
- Sadler B. A framework for environmental sustainability assessment and assurance. In: Petts J, editor. *Handbook of environmental impact assessment*, vol. 1. Oxford: Blackwell; 1999. pp. 12–32.
- Sadler B. and Jacobs P. (1990) A key to tomorrow: on the relationship of environmental assessment and sustainable development, pp 3-31 in Jacobs P and Sadler B (eds.) *Sustainable Development and environmental Assessment: Perspectives on Planning for a Common Future*, Hull: Canadian Environmental Assessment Research Council .
- Sadler, B (1992), The enterprise of sustainable development, in Sadler B (ed), *The Greening of Business*, Vancouver: GLOBE 92.
- Schumacher, E.F. (1973), *Small is Beautiful: A Study of Economics as if People Mattered*. London: Blond and Briggs.
- Selman P, (2000), a Sideways Look at Local Agenda 21, *Journal of Environmental Policy and Planning* 2: 39-53.
- Sheate W R, The SEA Directive 2001/42/EC: Reinvigorating Environmental Integration, *Environmental Law and Management*, 2004, Vol. 16, Pages: 119 - 124,
- Sikdar S K., (2003), Journey Towards Sustainable Development: A Role for Chemical Engineers, *Environmental Progress* (V01.22, No.4) December
- Spangenberg J H. (2004), Reconciling Sustainability and Growth: Criteria, Indicators, Policies, *Sustainable Development*, 12, 74–86.

- Tahltan First Nation (2004), *Out of Respect, The Tahltan, Mining and the Seven Questions to Sustainability*, The Tahltan Mining Symposium April 4-6, 2003, IISD Publication.
- Tanzil D, Beloff B. R. (2006), *Assessing Impacts: Overview on Sustainability Indicators and Metrics*, Environmental Quality Management, summer, pp. 41-56.
- The World Economic Forum (WEF) (2002) Environmental Sustainability Index. Davos, Switz.: World Econ. Forum. <http://www.ciesin.org/indicators/ESI/downloads.html>
- van Schaik, A., Reuter, M.A., (2004). The time-varying factors influencing the recycling rate of products, *Resources, Conservation and Recycling* 40, 301–328.
- Verheem, R. (2002), *Recommendations for Sustainability Assessment in the Netherlands*. Proceedings of the 22nd Annual Conference of the International Association for Impact Assessment 2002.
- Verhoef, E.V., Dijkema, G.P.J., Reuter, M.A., (2004). Process knowledge, system dynamics and metal ecology. *Journal of Industrial Ecology* 8, 23–43.
- Wackernagel, M. (1997) *Ecological Footprints of Nations. How much nature do they use – How much nature do they have?* Rio +5 Study, Universidad Anahuac de Xalapa, Mexico.
- Wackernagel, M. Rees, W. (1996) *Our Ecological Footprint: Reducing Human Impact on the Earth*, Gabriola Island, BC, New Society Publishers.

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