Embedding Sustainability in Capstone Engineering Design Projects

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Abstract— **The pace of change in education curriculums is growing exponentially due to numerous legislative arrangements and changes. Carbon tax, carbon pollution reduction schemes, emissions trading legislation are paving the way for environmental accountability in engineering industry. Engineering education moves into the twenty first century charged with an environmental agenda due to response to wider changes in society. Educators are regularly modifying curriculum content to embrace sustainability in learning outcomes. However this crosses over between a number of multi-disciplinary, multi-dimensional study areas that include philosophy and ethics. Consequently a major challenge for educators is to encourage engineering students whose primary focus is purely technical to include sustainability viewpoint in their designs. Unlike technical or financial evaluations where measures are either empirical or numerical estimates, sustainability position includes criteria in economic, natural, social, technological and time indicators. For the most part sustainability evaluations are content and competency driven and rely sometimes on rather intangible and proximal criteria. These criteria form the basis of assessment for measuring the sustainability of a design. The purpose of this article is to present various criterion, and indicators available to evaluate sustainability in engineering designs feasibility assessments. The paper presents the application of sustainability design criteria in the context of capstone design projects by way of applying social, economic, ecological, technological and time SEETT framework. These criteria form the basis of sustainability education embedment in engineering capstone design projects. Finally this paper argues the thesis that Sustainability feasibility studies and assessment in capstone engineering design projects are of grave importance for the success of the new frontier.**

Keywords- Engineering eduction model,capstone,new century, indicator, criteria, sustainbility, design, assessment feasibilty.

I. INTRODUCTION

The engineering industry uses vast quantities of natural resources (energy, water, materials and land), and produces products and services. Sustainability is a societal challenge; that also requires the contribution of engineers and technologists. The application of sustainability in engineering is about the implementation of sustainable product and process for the benefit of wider community. Consequently, traditional engineering curriculums were entrenched in the industrial needs of the 19th century; today the new 21st century engineering education model needs to incorporate 21st century principles and ideals including sustainability in the engineering curriculums. However the increasing knowledge needed to practice as a professional engineers and the accelerating rate of change within the discipline suggest that traditional learning models may not address the requirements of learners [1]. Then again the concept of sustainability falls outside the regular numerical subject engineers are classically skilled for. The notion of sustainability education in engineering curriculums is growing at different levels in literature as indicated in TABLE I. Although there are a number of independent efforts to fold environmental issues in existing undergraduate curricula like the Barcelona Declaration Engineering Education in Sustainable Development EESD 2004 which described today's engineers need to acquire new dimensions in ethical, social and cultural issues and systemic vision. No dominant method has emerged as a means of including these concepts. One of the difficulties in adjusting our materials science and engineering (MSE) curricula is the problem of how and what to include in an already full curriculum [2]. Therefore the challenge for the 21st century engineering education model 21EEM is to educate engineers in non-technical issues, which deal with the social subject. This is not to suggest that mere training- equipping engineers with the available analytical tools would be enough to achieve sustainability.

TABLE I. ENGINEERING EDUCATION AND SUSTAINABILITY

Technology to address the challenge.	[3]
Process of change aimed at introducing concepts of sustainable development into activities.	[4]
students' difficulties in differentiating between values and descriptions of phenomena	[5]
sustainable development concepts using cognitive maps	[6]
university engineering courses accreditation requirements	[7]

Sustainability's position in 21EEM would require not just new tools but what's more a new role, being “bilingualism” across disciplines. Therefore, interdisciplinary learning outcomes need to take preference in (21EEM) curriculums to educate the new generation of engineers and technologists. Another vital issue that requires attention in curriculum development is the prima facie of incompatibility between the promotion of an environmental ethic 'sustainability virtues, greener' ideals in education and the political liberal's commitment to 'neutrality' "… the state is not to do anything intended to favor or promote any particular comprehensive doctrine rather than another, or to give greater assistance to those who pursue it…" According to Rawls's political liberalism, which was debated by Derek [8] and Allen [9] arguing that engineering expertise would need to contribute at an early stage in the framing of problems, not just in problem solving; i.e., engineers should have a normative role as well as their more familiar analytical role. The idea of engineering adopting (or returning to) a normative role can be understood by examining the kinds of decisions in which professional engineers as decision makers may be involved with, this presented is as a useful classification of decisions shown in Fig.1.

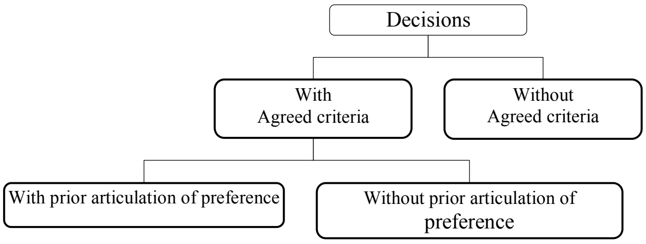

Figure 1: Classification of decisions [10]

The quantitative assessment of engineering design during research, planning and structuring, and implementation and management phases of technological development is important for identifying and prioritizing overall contributions towards sustainability [11]. 14 criteria suggested as vital for the choice of strategies decision makers apply to a given design listed in TABLE II.

TABLE II. DESIGN ALTERNATIVES

Equity	Do those creating the hazard pay for mitigation? Or where inappropriate, is cost equitably distributed among all?
Timing	Will benefits be quickly realized?
Leverage	Will action lead to further risk reduction by others?
Cost	Is there a less expensive way of achieving the same results?
Efficiency	Can the policy be administered efficiently?
Continuity	Will the effects be continuous or short-term?
Compatibility	Is this strategy compatible with others that may be adopted?
Jurisdictional	What authority will have to enact this policy?
Economic	What is the economic impact of this strategy?
Environment	What is the environmental impact of this strategy?
New hazards	Will the strategy itself introduce new risks?
Potential	How much of the risk will the strategy reduce?
Reaction	Are there likely to be adverse political repercussions?
Freedom	Does the strategy deny basic rights?

Adapted from [12, 13]

II. SUSTAINABILITY PHILOSOHOPY

Embedding sustainability education in engineering requires addressing engineers' contribution towards net positive outcome by focusing on minimizing negative impacts on the environment and society. Hasna [14] reported on a taxonomy of sustainability attitude existing within practicing engineers as shown in Fig. 2. In order to respond to these challenges no discussion on sustainability would be complete without mention of the one sustainability philosophy two distinct views, i.e. the pessimism of neo-Malthusians is a sharp contrast with the optimism of cornucopians. Accordingto Malthusians sooner or later population will outgrow natural resources[1]. This is described in the following model;

$$P(t) = P_0 e^{rt} \quad (1)$$

The cornucopian school of thought endorses some degree of intractable natural limits to growth and believes through the advancements of technology the world can provide limitless natural resources. However as engineers we view the cornucopian philosophy with a degree of reservations in context of the second law of thermodynamics governs the conversion of energy from one form to another,

$$\partial U = \partial W + \partial Q = \partial W + T\partial S \quad (2)$$

Where dU, the change in the internal energy of a system is equal to the sum of the reversible work done on it dW and the heat irreversibly exchanged with the environment dQ = TdS (which is associated with a change in the entropy of the system). Simplifying the second Law: Law of increasing entropy or unidirectional flow of thermal energy, hence no system is 100% efficient. According Atkisson [15] who reported that we must accelerate our industrial and technological development, or the forces we have already unleashed will wreak even greater havoc on the world for generations to come. We cannot go on, and we cannot stop. We must transform. The natural conclusion here, would be one of comprise between the two viewpoints, therefore contemporary engineering philosophy regarding sustainability is ought to subsume all known definitional variations and takes responsibly of the world's finite natural resources in a manner which will not compromise the ability of future generations. Building on this basis as engineers discussing sustainability in design projects, we have proposed the use of criteria for assessment, in this way we remain true to the physical laws that govern our universe as it is impractical to totally reject it all. Since all of our current practices support Malthusian theory. Hence our role is to achieve a net positive outcome, by putting forward a premise of balance and moderation through the assessment against known criteria.

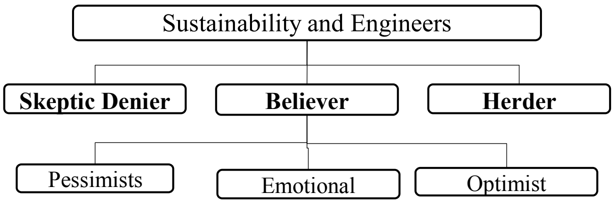

Figure 2: taxonomy of philosophy

Similarly the discussion of how to define sustainability is not new, literature is rich with interpreted meanings and definitions post Bruntland Report [16], whilst these definitions varied linguistically they all share similar nonfigurative, idealistic chic, covering four to six known dimensions[2]. Hence definitional and interpretational meanings directly relate to sustainability assessment. These include converging on protecting the environment and balancing consumption of natural resources.

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[1] Where P_0 = Initial Population, r = growth rate, sometimes also called Malthusian Parameter and t = time.

[2] Note that sustainability principles should remain constant over time, whereas the choice of criteria and indicators may change rapidly as knowledge advances.

III. ASSESSMENT TOOLS AND THE ENGINEERING INDUSTRY

Sustainability assessment tools are typically used to estimate achievements of the transformation. Literature is scoured with non-specific, aggregated and ideal indicator sets, proposed by various organizations with interests in sustainability, for example the report on organizations environmental reporting published by [17]. we have reviewed sustainability assessment tools and metrics available for use in the process industries for example; the United Kingdom Institution of Chemical Engineers; Environmental Sustainability Index [18], Ecological footprint [19-22]; World Business Council for Sustainable Development [23] ;United Kingdom Government Strategy indicators [24]; indicators produced in the academic arena [25]. These indicator sets have been identified as having a general focus on reporting towards sustainability. However the literature proposes a bewildering array of tools and processes in sustainability feasibility assessment for engineers. Some are 'graphical integration' tools, aggregating scores of indicators others are 'numerical integration' tools, aggregating indicators. An detailed literature review that covered theoretical and practical approaches to assess sustainability reviewed some assessment tools which may not be widely known amongst engineers but are nevertheless clearly rooted in engineering science cited 55 tools for sustainability assessment framework with an additional 25 software tools [26], Sigh [27] reported on 38 sustainability composite index that included formulation strategy, scaling, normalization, weighting and aggregation methodology. The mentioned tools do not cover industry specific rating schemes and initiatives, that are non comprehensive and non global. Finally it would not be possible to brand any tool as a total environmental solution. According to Spangenberg and Bonniot [28] sustainability per definition is a composite and thus an ambitious policy target.

IV. PRINCIPLES ,CRITERIA AND INDICATORS

In the literature on sustainability much attention is given describing how sustainability criteria should be but little information on the detail, it was found literature lists the criteria to varying degrees by conventional normative criteria. It is stated in Agenda 21 the need for acknowledging the importance of sustainability indicators by both national governments and the international organizations which should be followed by the identification of relevant indicators [29]. The explicit incorporation of sustainability in the decision support process requires assessment of the social, economic and environmental consequences of potential options. This requires the use of sustainability criteria by which to assess these consequences in terms of whether the option is likely to move the system towards or away from sustainability objectives [30]. Sustainability criteria are defined here as the set of factors that may be used to assess which of a range of options, in this case for the development of engineering sustainability criteria which offers the greatest contribution to achieving sustainability objectives. It is helpful, first, to draw distinction between principles, criteria and indicators of sustainability. Principles are normative definitions or goals for sustainability aspire to a universal validity, which can be agreed upon by all. Criteria are the set of factors that may be used to make a judgment about the relative sustainability of a set of options. Indicators measure the past and current values of specific criteria, and may be used to set standards against which future performance can be assessed [30]. Parsons [31] highlighted the usefulness of conceptual models that can explain complex political processes and issues. Sustainability indicator systems encompass a variety of frameworks, dimensions, criteria, indicators, targets and visualization strategies. The variety of processes and measurements can be analyzed from a systems approach and classified by policy purpose and scale. A key component of the system is the interpretation of the term sustainability and how the concept is applied to the particular issue. Chapter 40 of [32] called for the development of indicators for sustainable development at multiple levels. sustainability indicators development are needed in order to provide decision makers with information on sustainable development that is simpler and more readily understood than raw or even analyzed data [33]. In particular, there is a need for highly aggregated and composite indicators, here defined as indices, in which condensed information is assembled. Comparable (SI) indicators and indices with broad international acceptance remains lacking [34].

V. CHARACTERISTICS OF SUSTAINABILITY INDICATORS

Typically sustainability is measured using indicators; Indicators are an essential component of sustainability measurement, but what are indicators ,the word "indicator" has its roots in Latin "indicare" which means "to direct or to point out" [35], however what is a sustainability indicator? The scientific roots of sustainability Indicators lie in the shore of limnology. Sustainability indicators (SI's) science emerged post the United Nations Conference on Environment and Development Agenda 21, Rio Earth summit[36]. The definition of SI's is an important step, as the selection of sustainable solutions is based on these indicators [37]. Many specific definitions in literature exist, they tend to vary little. However there is a distinction between data and Indicator, hence in a general sense, an indicator is a sign. SI's address the crucial issue of sustainability: how can it be measured [38]. In pursuit of influential factors of (SI) for use in feasibility and assessment, it imperative to settle on characteristics of these indicators, to determine what is to be sustained?

TABLE III. CLASSIFICATION OF SUSTAINABILITY INDICATORS

Definition	Author
measurable variable, that provides information sometimes hypothetically linked to another (latent) variable which cannot be observed directly	[39]
variable describes a characteristic of a phenomenon	[40, 41]
parameter, or a value derived from parameters, which points to, provides information about, describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value, Parameter is a property that is measured or observed	[42]
statistics or measures that relate to a condition, change of quality, or change in state of something valued	[43]
measure that summarizes information relevant to a particular phenomenon, reasonable proxy for a measure	[44, 45]

Hence with respect to indicators for sustainability in engineering, it is therefore crucial to represent a merit-based indicator that provides a snap shot of the design. It is particularly important that the (SI) can be compatible with design criteria hence lending it to be resolved early in the design process. Indicators typically provide key information about a physical, social or economic system [46] provided a comprehensive analysis of various definitions, and demonstrates that an indicator has been defined as "variable", "parameter", "measure", "statistical measure", "a proxy for a measure", and "a subindex", among others. At the concrete level indicators are considered variables. A variable is "an operational representation of attribute (quality, characteristic, property) of a system". Each variable may take different values depending on the specific measurements or observations. Thus, indicators are variables, and data are the actual measurements or observation. TABLE III. presents a summary of the most cited characteristics in literature. Sustainability indicators integrate environmental, social, and economic factors such that the complex cause and- effect relationships between these multiple factors can be more readily investigated [47]. In addition an indicator is a representation of linkages whereby multiple effects can be monitored by a fundamental indicator [48]. Indicators have received increasing attention in the decade, reflecting growing concern by the public and policy makers over environmental trends [49]. However there are two contrast perspectives on indicators:

(I) Indicator-based monitoring tools are frequently applied as effective tools for sustainability assessments [50].

(II) Much of the measurement of indicators has, at the end of the day, largely resulted just in the measurement of indicators [51].

TABLE IV. QUALITY OF SUSTAINABILITY INDICATOR

Scientific quality	Data management
Uncorrelated Independent clear-cut measures what it is supposed to detect measures significant aspect Problem specific Distinguishes between causes and effects Can be reproduced and repeated over time	Easy to quantify Cost effective Data available Comparable across borders and over time Quantifiable Representative Transparent physically relevant Relevant to users User friendly Widely accepted

Spangenberg and Bonniot [28] described proactive indicators cannot focus on symptoms or damages, which only permits an ex-post analysis, but have to concentrate on the underlying trends in order to permit exante measures to be taken on emerging problems therefore, they will usually be response indicators in the (PSR) pressure state response (terminology). Despite the interest in the development and use of indicators the actual operationalisation of indicators to in influence or change, for instance, policy is still in its infancy since there is not enough effort for indicator validation [52]. TABLE IV. lists key attributes for the selection of sustainability indicators, the characteristic are separated into two parts, scientific quality and data management issues, [53]. Therefore, what is the application of these principles, concepts, criteria, factors from engineering design perspective? In this section, we have highlight the central findings in dependent and independent variables, also known as factors, or indicators most prominent sustainability assessment literature to form the empirical foundation in sustainability feasibility assessment in engineering capstone design projects.

A. The Time perspective

Time is the most valued determinant of sustainability; it permits the fuller and more graceful development and deployment of still better techniques to achieve sustainability. Basically the more time is available; the more information will emerge to sustain more robust choices. The time perspectives of most natural resource systems must be at least 250 years, but rather 500-1,000 years is required for any serious sustainability perspective. This can be set against the time perspectives of global climate change/carbon dioxide pollution measures which are planned to fall within the range of 4-500 years. Summarized in TABLE V. a list of four time classifications that can be used to asses an engineering design.

TABLE V. TIME DIMENSION IN SUSTAINABILITY PLANNING

Time Perspective	Years	Description
Instant	2-4	Blink of the eye of the natural system
Short-term	10-30	Fraction of the natural system rotation period
Intermediate	70-120	Is comparable to that of the length of one rotation period
Long-term time	100- 400	Involves more than one to three rotation periods of the natural system

adapted from [54]

B. Sustainability Indicators (SI) Advantages and Pitfalls

Historical research on indicators has been descriptive in nature. This has been useful in the developmental phase of indicator application. Descriptive research in terms of criteria and indicators has been the frameworks [55]. Indicators are different from primary data or statistics in the sense that they provide meaning beyond the attributes directly associated with them and thus providing a bridge between detailed data and interpreted information [56], they have significance beyond the value of the parameter [57]. Thus, indicators provide meaning and concentrated information which otherwise would require an extended detailed amount of information [58]. However, there are limitations of using indicators; one major pitfall is that of subjectivity. Subjectivity enters in two fields: on the selection of the representative indicators and on the evaluation of the indicators results. What Meadows referred to as dependence on a false model and certain scientific and social background and therefore certain degree of subjectivity is inevitable? Other problems include: lack of appropriate data which may result on missing vital information, this further could lead to measuring what is measurable rather what is important [59]; and over aggregation of too many things resulting in an unclear meaning and therefore bad communication and analysis capability. If indicators are not chosen carefully and as systematically as possible they will carry the wrong message resulting in misleading conclusions. Consequently most indicators have not generally been accepted for actual decision-making because of measurement, weighting and indicator selection problems [60].

VI. PRINCIPLES OF RISK MANAGEMENT

Engineering design is subject to multiple, competing tensions. Traditionally, engineering design involves some inherent design risks in the early stages of design that are not always carefully managed, one of main reason is the lack of tools and knowledge to simulate stochastic events (Amir,2004). Four of the main tensions during system or product development have been identified by [61] and are shown Fig.3. According to Australian standard AS/NZS 4360:2004, risk analysis may be undertaken to varying degrees of detail depending upon the risk, the purpose of the analysis, and the information, data and resources available. Analysis may be qualitative, semi-quantitative or quantitative or a combination of these, depending on the circumstances.

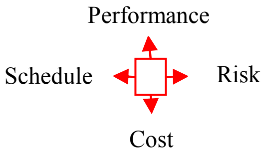

Figure 3: Architecting and design tensions [61]

A comprehensive review of risk management was completed by Pennock and Haimes [62] it was reported that there is a growing body of literature on project risk management composed of a myriad of different approaches and methodologies. In general, there is no one “right” way to conduct project risk management. A comprehensive approach to project risk management can be found in [63], which suggests that project risk management should be a project in of itself. To streamline the subsequent discussion on engineering projects risk and sustainability, this section defines and explains terms and concepts used in this chapter. According to Pennock and Haimes [62] two basic types of risk; technical and programmatic; Technical risk denotes risk in a project will fail to meet its performance criteria. This encompasses the realm of hardware and software failures, requirements shortfalls, and the like. Programmatic risk has two major subcomponents delay in schedule (the project exceeds its projected completion schedule) and cost overrun (the project exceeds its budget or operating costs), this where we propose the interlinks between engineering project technical performance, cost and project’s complete sustainability as shown in Fig.5.

. In all cases risk is defined as the probability and severity of adverse effects [64].

$$Risk = \sum_i N_i \times p_i \quad [3] \qquad (3)$$

Several systemic methods and approaches are available for identifying and tracking risks. While techniques such as Failure Modes and Effects Analysis FMEA [65] fault trees work well for assessment of pure system failure analysis because there are a finite number of pans. Each part can be examined individually to determine its failure modes and how those failures will affect other parts and the overall effectiveness of the device. However, it has limited effects for assessing sociotechnological systems failure which largely include all engineering projects; hence we recognise need for broad-based, interactive, multifaceted approach to track the projects sustainability risk whilst we identify difficult to capture all of them with a single model. Hierarchical Holographic Modelling HHM is based on the premise that no real-life system can be adequately represented by a single model, to do so would be to present only one dimension of the system[66, 67]. Hence we propose investigating the critical and important facets that make up a constitute sustainability system criteria, this is proposed through a comprehensive qualitative assessment to establish topics or set of subtopics for engineers to refer to similar to sustainability assessment criteria.

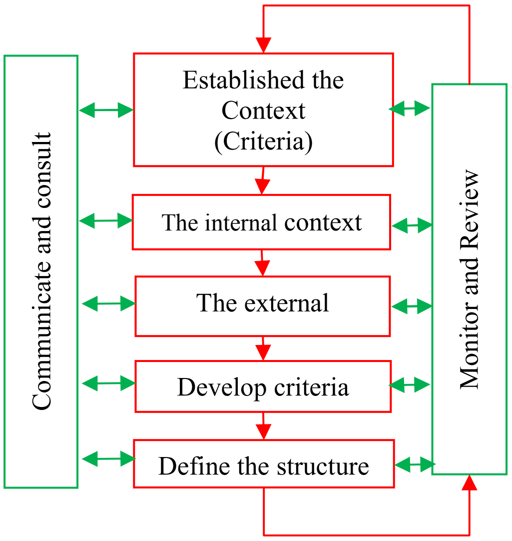

Figure 4: portions of risk management process[68]

VII. SEETT METHODOLOGY

SEETT is a simplified sustainability framework in which it combines social, economic, ecological, technological and time; it addresses complex relationships between these dimensions. The SEETT framework is a conceptual model that integrates sustainability boundaries between goals and indicators. The boundaries of sustainability indicators found are illustrated in Fig.6. It can not only help with the selection of indicators, but show what is not being selected and what might be important in the future [57, 69].Without a framework, indicators can easily proliferate and be little more than a conglomeration of disparate data. There are already numerous evaluation frameworks, however, they are industry specific and do not offer versatility for users to utilize a universal sequence. It is crucial in fact to separate indicators of un-sustainability to gain a common understanding, about what is to be measured. because engineering student need to realize

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[3] Where Ni is the consequence (e.g., persons killed, injured) and pi=the probability of occurrence, the two-dimensional components of risk capture its complex nature, but they also make risk a more difficult entity with which to work.

that sustainability is related to risk assessment of a project since one of the core concepts of sustainability is good environmental stewardship [70] for the engineer, technologists and designer, creating sustainable systems involves making engineering and design decisions based on multiple dimensions: technology, ecology, economics, and socio-cultural, including ethics [71].

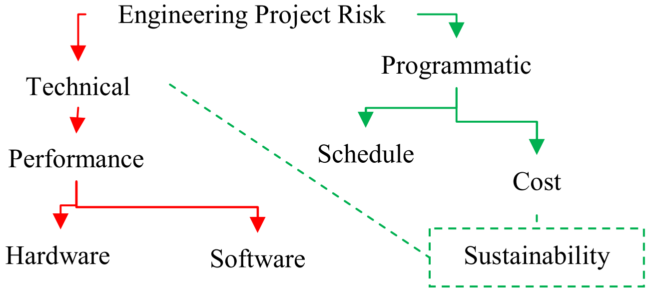

Figure 5: Engineering projects risk identification.

There are already numerous evaluation frameworks in existence, however, they are either industry specific or do not offer versatility for users to utilize a universal sequence. It is crucial in fact to separate indicators of un-sustainability to gain a common understanding, about what is to be measured. because engineering student need to realize that sustainability is related to risk assessment of a project since one of the core concepts of sustainability is good environmental stewardship [70] for the engineer, technologists and designer, creating sustainable systems involves making engineering and design decisions based on multiple dimensions: technology, ecology, economics, and socio-cultural, including ethics [71].

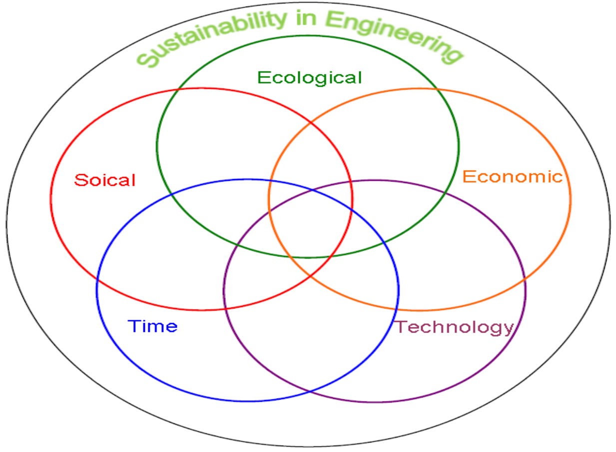

Figure 6: SEETT (social, economic, ecological, technological and time)

The general methodological framework proposed in this paper is an attempt to contribute towards standardization of the indicators of sustainable development for industry. The standardized indicators have many advantages for bench marking. The reviewed indicators suggested a common reoccurring theme, demonstrating a similar array of indicators, with different terminology, goals, scopes and end use, the indicators were streamlined into six distinct categories, social economic, ecological, technology, and time but not implicitly displayed expressed. A summary list of criteria from a large body of literature was selected from the most recurring, is listed in TABLE VI. In addition institutional vastly discussed and recommended as a separate theme, and other times it was integrated within social. Therefore in the assessment we are looking for;

(i) Measures of relative dependence of the economy on non-renewable sources of energy and materials,
(ii) Measures of the productivity of energy and materials consumed by the economic system and
(iii) Measures of dissipative loss, especially of toxic and hazardous substances.

VIII. DISCUSSION

Risky technological projects might affect the well-being of people. Technological risks directly give rise to ethical issues [72]. The criterion provides answer to the students many questions for example when is it justified to impose dangers on others? And how should we judge whether a risk is morally acceptable or not? Engineers define risk as a function of probabilities and unwanted consequences. Examples of unwanted consequences are the number of deaths or injuries, or the degree of pollution. Policy-makers use cost-benefit analysis to weigh the possible advantages of a technology against its possible disadvantages. Many social scientists who work in the field of risk analysis argue that cost-benefit analysis and the definition of risk as a function of probabilities and unwanted consequences are not sufficient to determine whether a risk is acceptable or not. Many social scientists claim that since all risk judgments, also those of experts, include values, all risk judgments are subjective and socially construed. objectivity equates with what is ‘out there’ and with what is quantitative[73], whereas all of the following notions are grouped under the label ‘subjective’: ‘social construction’, ‘values’, ‘assumption-ladenness’, ‘judgment’, ‘intuitions’, ‘subjective assessment’, ‘qualitative’, ‘emotional’, ‘contextual’. Some of these notions are by definition subjective or at least not objective, i.e., subjective assessment and social construction. However, the other notions are not necessarily subjective.

Values, judgments, intuitions, qualitative, emotional and contextual are also not necessarily subjective notions. Judgment, intuition and emotion are ‘subjective’ in the sense that they are bound to persons who have them, but this holds for all our cognitive abilities. The question is whether these abilities can help us assess what is really there? This is a philosophically controversial issue; it is far from philosophically obvious whether emotions, judgments and values are subjective projections or rather, if they are forms of objective discernment. According to most contemporary moral philosophers, moral values are not arbitrary or subjective. Whilst sustainability indicators act as a critical monitoring tool vital to the sustainable management of societal and natural resource and one of the most used tools for communicating information to decision makers indicates that there has been no agreement or consensus on a common set of scientific and management criteria for evaluating indicators from several points of view i.e. reliability of supporting data, scientific rigor of definitions of indicators, validity of underlying assumptions and concepts, relevance of positive or negative trends for sustainability. If decision makers and engineers are to continue basing their decisions on the information thus provided, we must therefore ensure that such indicators be not only scientifically valid but also policy relevant. In order to obtain a scientific validity of the aggregated indicators a scientifically sound methodology is required on the elaboration of indicators, data gathering, data processing, measurability. Integrating, environmental, social, economic, technological and time Indicators of sustainability must be agreed on, transparent, and sufficiently broad criteria, subject to rigorous scientific assessment to be widely accepted. This "wide-angle" is even more critical as it is necessary to discuss the complex interlinkages between the biophysical, social, economic, technological, institutional aspects are appropriately taken into account. Since existing aggregated indicators are often criticized for their shortcomings in this respect. "…everything is an indicator of something but nothing is an indicator of everything…"[74]. This view suggests that a 'sustainability index' is impossible to design. They also suggest that indicators should be selected 'to maximize unique, relevant information and to minimize redundant information'. This presumes that we understand what is relevant and what is not. One thing that scientists have learned over the years is that our knowledge is very limited, otherwise how could we have had an acid rain issue or an ozone depletion issue? But Cairns et al [74] also refer to the consequences of two forms of uncertainty: (1) false negative (FN) signals and (2) false positive (FP) signals. FN signals provide no warning of potential harm when it is bound to occur and FP signals warn of potential harm when none exists. They conclude that multiple lines of evidence (redundancy) are more likely to protect against unpleasant surprises. So rather than minimizing redundancy, the 'sustainability index' should use many indicators (hoping that some of the information obtained will be redundant). Although it is recognized that no single process can describe a universal engineering approach to (SI) however this is a roadmap reflections on the indicator design process that yielded the following key points: Lyytimaki [75] described building a sustainability indicator collection without a concrete, well planned conceptual framework may provide a cheap and quick solution that is sufficient for some situations. The drawback is that the organizing structure and relations between issues and indicators remain obscure and elusive. This kind of ad hoc framework may also easily neglect important issues and highlight wrong issues.

IX. CONCLUSION

This generation is charged with an unprecedented responsibility underpins all human activity; sustainability in engineering education is often referred to as the new frontier due to the numerous legislative changes which are in the pipeline, overlaid with challenges for engineering educators. Therefore the need to prepare engineers to identify and analyse energy usage, areas where reductions can be made through sustainability assessment is paramount. In addition using sustainability criteria in design curriculums can engage engineers to contribute to sustainable development through designing, developing and implementing solutions that are socially acceptable. Given that there is no universal framework or uniform methodology to apply the vision in capstone engineering design projects. In this paper, we propose SEETT a path for integrating environmental and sustainability concepts within the framework of existing curricula conducive towards sustainability in engineering capstone design projects. The presented list of SEETT criteria is a first attempt, intended for achieving a common-metric to address limitations sustainability assessment in class rooms. From this point of view we argue that it would be uncomfortable for students in engineering classes to assess sustainability or work in cohesion if we do not have a similar contextual engagement.

RECOMMENDATION

The global engineering educator's community recognizes the critical need to develop and practice sustainable techniques in design curriculums; one way of achieving this framework is by developing cases study banks to translate experiences of using indicator. The table below collates sustainability criteria SEETT, (social, economic, ecological, technological and time). One way of increasing criteria confidence and value usefulness to potential users is through case studies validation checks which can also assist improving the indicators to meet a satisfactory degree of 'accuracy', and 'credibility'.

TABLE VI. SEETT CRITERIA

Social Assessment Criterion
Aesthetics appearance and nuisance
Social Cohesion Dislocation and Culture
relocation of people
Knowledge or skill enhancement
Education & Training
Recreational value
Provisions for underprivileged
Shelter Impacts upon indigenous, or minority ethnic groups
Heritage perseveration
Improving of living standards
Employment opportunity
Occupational hazards (e.g. falls, fires, explosions, operation of machinery)
Perceived Risk Loss of livelihoods
Increased risk of natural hazards (e.g. floods, slips)
Exposure to physically hazardous wastes (e.g. 'sharps')
Nutritional value provided
Increases Food supply
Mortality reduction-quality of life
Impact upon cultural, historical or religious sites or values
Accessibility increases competition, Ethnic Diversity
Incorporation of women Impacts upon women
Impacts upon the poor
Economic democracy
Avoids Illnesses
Stress at work
Spirituality , Promotes justice , Security
Transparency Participation
Sanitation, Communal violence
Credit and investment
Democracy Transparency
Quality of Life , Equity, Ethics
Institutional , Illness & Disease
Accident & Injury, Health & Wellness
Ecological Assessment Criterion
Virgin source of materials
Recycled materials
Origin of materials
Greenhouse gas
Manufacturing waste

Packaging Existence of rate/ endangered species
Disturbance of existing fauna
Noise pollution Water Run off
Monitoring environmental impact
Smog creation
Ozone Depletion
Climate regulation
Biodiversity reduction
Design objective
Non recyclable waste
Energy efficient Use of fossil fuels for energy needs (i.e. CO 2 emissions)
Energy consumption
Acid rain precursors
Global Warming
Carbon monoxide (CO), nitrogen oxides (NO_X), sulphur dioxide (SO_2)
Heavy metals (e.g. lead, mercury, chromium, zinc)
Water quality
Destruction of carbon sinks (e.g. forests)
Release of other greenhouse gases
Release of CFCs ploychlorinated dibenzo(p)dioxins (PCDD)
polychlorinated dibenzofurans (PCDF) polynuclear aromatic hydrocarbons
(PAH)polychlorinated bipenyls (PCB)
hazardous chemicals dioxins1, furans2, PAH3, PCB4, nitroaromatics,
hazardous chemicals pesticides, herbicides, asbestos

Economic Assessment Criterion
costs
Operation costs (raw material, labour, upgrades)
Closure cost (i.e. site restoration, legal liability costs
Construction costs (i.e. land, equipment, infrastructure)
Maintenance costs (new parts, down time, labour)
Competition effects
Stability
Resource depletion
Ecosystem productivity loss
Employment GDP
Deficit; and capital flow; debt
Stability in prices; debt
Social factor productivity
Raw material
Waste hazards
Solid Wastes or Hazardous Products
Liquid Wastes or Hazardous Products
Gaseous Wastes or Hazardous Products
Capital, Labour, Fixed
Viability CBA ,LCA , NPV
Energy resources , Fossil fuels
Useful product lifetime
Product disposition cost
Clean technologies; adequate waste management
reduction of all forms of pollution
Resource depletion, Recycling revenue
Consumption of goods and services
Institutional
Ethics

Technology Assessment Criterion
Source of the technology Indigenous to the area or Imported
Relatively new/unproven
System performance
Decommissioning of technology
Type of technology Existing
Processing/manufacturing
Based on the use of natural resources
Flexibility and adaptability Business interruption
Customer warranty cost
Ecosystem productivity loss
Loss of goodwill due to customer concerns
Residual consequences
Disruptive to the environment
Resource depletion
Ecosystem productivity loss

Design iterations
Resource Scarce
Renewable /non
Hazardous materials used Product & packaging mass
Power use during operation
Biodiversity reduction
Needs and basic rights
Leisure time and enjoyment of family life
Social assistance and culture
Sate of right and public safety
Identity and self-esteem
Health and social security
Corruption, participation of civil society
cooperation , and agreement; solidarity and altruism
Creativity governance expansion of civil liberties

Time Assessment Criterion
Does the project, product or process have a lifecycle?
What is the deign life of the project, product or process.
Does the proposed project, product or process contribute towards reducing non-sustainable practices to zero over the project time frame?
What is the expected usability for the project, product or process?
If outcomes cannot be accurately foreseen, is your planning based on risk reduction and
the precautionary principle?

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