BUILDING SUSTAINABILITY ASSESSMENT METHODS: INDICATORS, APPLICATIONS, LIMITATIONS AND DEVELOPMENT TRENDS

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Abstract

The aim of this paper is to analyse different ways of measuring sustainability in architectural projects. Measuring the level of sustainability of a construction project is not easy to achieve particularly when trying to quantify qualitative data and determining the most effective indicators for measuring such projects as defined by various stakeholders can be a complex process. A solid basis for decision making at all levels of building design and planning has been taken into account in terms of identifying key sustainability indicators relating to building development. Indicators of sustainability are necessary in assessing building projects at various levels: regional, national and international, in order to carry out the most balanced evaluation of environmental, economical and social factors.

Over the last ten years it has been increasingly important to understand the sustainability performance of buildings across a broader range of considerations. This has stimulated the development of a number of sustainability assessment tools that aim to encourage designers and planners to improve a building's performance. They aim to deliver objective measurements of a project's impact upon the sustainability, by taking in the three dimensions of environmental, social and economic measures.

This paper attempts to define key indicators for sustainability assessment, and compares three separate methods for the sustainability assessment tools: the Green Building Challenge (GBC) assessment; Building Research Establishment Environmental Assessment Method (BREEAM); and Sustainable Architecture Matrix (SAM). Such comparison is essential in order to evaluate the strengths and weaknesses of the various methods in order to allow for less subjective sustainability measurements.

Keywords : Sustainable assessment methods, Sustainability Indicators, Green Building Challenge (GBC), Sustainable Architecture Matrix (SAM), Building Research Establishment Environmental Assessment Method (BREEAM), Limitations.

1. Introduction

Measuring the level of sustainability of buildings is not easy to achieve. Indicators of sustainability are necessary for determining how well buildings perform against environmental, social, socio-cultural and economic criteria on regional, national and global scales. Sustainable assessment methods have emerged in recent years as a means to evaluate the performance of buildings across a broad range of sustainable considerations. The importance of such methods can be regarded firstly in terms of helping architects and planners in what is defined as the principles of "**selective environmental design**" (Hawkes et al., 2001) in which there is a strong relationship between climate and comfort and where a building is understood as a complex system of interrelated uses, spaces, materials, components and sources of energy. Secondly, the usage of such an assessment provides considerable theoretical and practical experience on their potential contribution in furthering sustainability responsible building practice. This issue was addressed by the WCED in 1987 and the Rio Summit in 1992, referred to as Agenda 21, and has encouraged the integration of 'indicators of sustainable development' in the monitoring of progress by international European governments. In addition to this, an important indirect benefit is that the broad range of issues incorporated in sustainable assessments requires greater communication and interaction between members of the design team and various sectors within the building industry. For example, sustainable assessment methods encourage greater dialogue and teamwork. This paper as a result addresses the differences between the notion of sustainability and green indicators, and what are called effective indicators. It identifies some of the key limitations of existing building sustainable assessment methods and discusses the emerging importance of issues such as indicators, applications and development trends. These are presented as a basis for providing a positive direction for the emergence of less subjective sustainable methods and protocols.

The 'Green' Assessment Agenda? Assessment implies measuring how well or poorly a building is reacting, or is likely to perform, against a set range of criteria and indicators, named over a period of time: "green design", "ecological design" or "sustainable design". The distinction between the notions "Green indicators" and "Sustainable indicators" is critical in what structures sustainable assessment methods. In the early stages of the development of assessment methods 'green' as a concept has referred to design that maximizes the use of solar energy, day lighting and natural ventilation, as well as the harvest of rainwater, treatment of any waste on site and the use of environmentally sound materials. Applying the notion of green has a high market value and green buildings are more expensive than standard buildings. In other words, green buildings are proposed to have additional features to normal buildings and these additional features must carry with them additional costs. Meanwhile, the application of sustainable principles to building design usually lead to more simple solutions (for instance, smaller mass and energy flows), which by contrast with green application are less expensive in investments associated with running costs (Kohler, 1999) .

Sustainable Development. In terms of assessment scale, "green" assessment models place a higher emphasis on comparing performance on a regional and local scale, placing less focus on national and international comparability. Hence, sustainability has emerged to cover the broader concept for the environmental assessment methods. Such a concept is called Sustainable Development (SD) which attempts to address the conflict between protecting the environment and natural resources, and answering the development needs of the human race. However, it is believed that sustainable development would not be possible without certain social and economic changes; SD has environmental, social and economic dimensions including all factors of human activity such as industry, transportation, food production, and so on. *"A development which is respectful of the environment, technically appropriate, economically viable and socially acceptable to meet the needs of present generations without compromising the ability of future generations to meet their own needs"* (UNEP/ MAP/Blue Plan, 2000).

As to the application of sustainable development, unlike that of green architecture, it takes into consideration overlapping sustainability dimensions along with the wider scope of an assessment scale from the building itself to national and global scales. What can be added in terms of the integration of economic and social considerations is that environmental measures must not lead to a socially unacceptable development. Instead, sustainable development requires a continuous process of balancing all three systems to achieve an optimum result and cannot achieve less subjective results by providing sustainable answers for each system independently, as is illustrated by the following figure, where each step taken in the context of the measuring process is considered (Plessis, 1999) .

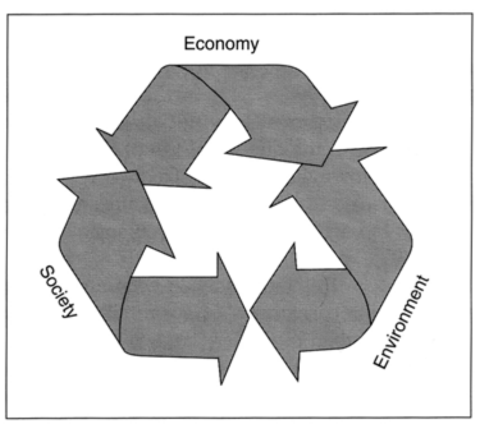

Fig.1 The decision making cycle for sustainable development. Author 2004 adapted from Plessis. C. D

2. The Selection of Sustainability Indicators (SI)

Indicators have become widely acknowledged as tools for measuring the performance of systems, policies, projects and so on. Depending on what is being measured, indicators have been used within different frameworks. The actual framework for indicators recognized by Pressure- State- Response is the mostly widely used. Furthermore, sustainable indicators are aimed at improving the economy, society environment patterns for the benefits of current and future generation's indicators. In other words, sustainable indicators have the overlapping dimensions of sustainable development. *Sustainability indicators are intended to give the level of sustainability in the past, for the current situation and in the future according to certain assumptions about change and evolution (UNEP/MAP/Blue Plan, 2000).* Therefore, sustainable indicators have been met with two main complementary definitions:

(i) A sustainability indicator is a land mark in the spatial scale (SDI Group, 2000). That is to say, using the indicator offers the opportunity to read the level of sustainability of a building design in space dimension, taking into account:

- The geographical location of the building, which is considered to be one of the main boundaries of sustainable assessment.
- The spatial level of intervention: Building, regional, national, international.

(ii) A sustainability indicator is a snapshot on the time scale, which offers the possibility of reading the level of sustainability for any building in the time dimension, taking into consideration two important factors:

- Continuous period, which help to define the trends over a continuous period of time.
- Fixed period, where the measurements are made at a certain time during a fixed period.

2.1 Characteristics of effective sustainability indicators.

An indicator is something that points to an issue or condition, the aim of the indicator being to reflect how a system works. If there is a problem, an indicator can help to determine what direction to take to solve this issue. Effective indicators have in common the following characteristics (Sustainable Measures, 2000)

(i) Effective indicators are **relevant**, which present something about the system that we need to know.
(ii) Effective indicators are **easy to understand**, even by people who are not experts.
(iii) Effective indicators are **reliable**; you can rely on the information that the indicator is providing.
(iv) Lastly, effective indicators are based on **accessible data;** the information is available or can be gathered while there is time to act.

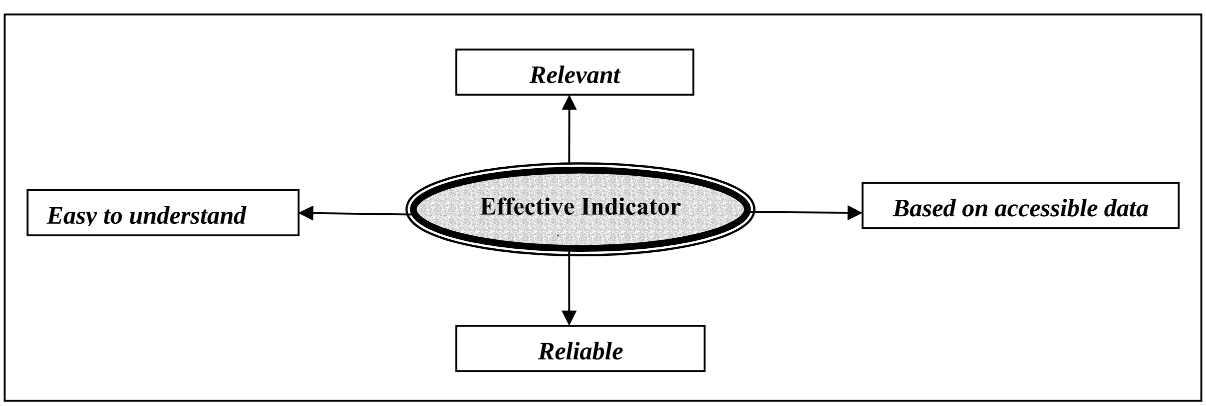

Fig.2 Characteristics of effective sustainability indicators, Author 2004

Items 1 and 2 are straightforward. However in point 3 the problem is ensuring reliability. Verifying and validating the techniques and data in this context is very difficult. In point 4, the problem is that only limited data is readily available and may not be in a form that is useful for the purpose of sustainability measures. Added to that we can not quantify what is an acceptable level of accessibility. Furthermore, achieving effective indicators depends on what dimension or element of sustainability they are trying to measure. Therefore, SIs as an actual framework is categorized into three groups: (Bell and Morse, 2003)

(i) *State SIs:* in this case, SIs describes the state of variable. For instance, human population, income equality, female and male wage ratio.
(ii) *Process (also referred to as pressure, control or driving force) SIs:* these are engaged in the case of measuring a process that in turn will influence a state SI. For example, a control (process) SI may be the rate at which a pollutant is passed into the environment.
(iii) *Response SIs:* these are used to gauge a required process in terms of responding to governments. For example, to achieve adequate values of state and process indicators.

A good indicator however, alerts designer, planner and regulator to a problem before it gets worse, bringing into account qualitative and quantitative factors and helping to recognise what needs to be done to fix the problem.

3. Limitations in Sustainable Indicators Evaluations (Problems of Measurements)

When sustainable evaluation is used as a decision-aid within the public decision process, boundaries of assessment can be difficult to define, forming a critical issue in relation to the sustainable assessment method and revealing what are called ***limitations in sustainable evaluations (Problems of measurements)*** Understanding such limitations can help in providing positive direction towards prompting sustainable assessment methods in terms of delivering as close to objective measurement as possible. Thus some factors have been used to clarify these limitations as in the following paragraphs.

3.1 Boundaries of assessment

The scope and boundaries of the sustainable assessment method are critical; the figure below shows what can be used as a conceptual framework in terms of the wider perspective of sustainable issues in current buildings assessment methods, such a scope consisting of three “dimensions”: **Criteria, Time and Scale** (Cole, 1999). *“The level of sustainability is assessed by the team according to a deep understanding of the relevance and interpretation of the combined messages of the selected sustainability indicators. A view of the sustainability of the system can be built by the systems diagrams. The sustainability of the system can be monitored over time. Periodical re-examination is necessary in order to take into consideration changes occurring over time”* (UNEP/MAP/Blue Plan, 2000).

3.1.1 Criteria (Indicators). The criteria dimension refers to a set of considerations within sustainable assessment, distinguishing between ecological concerns (resource use, ecological loadings etc) human resources (indoor environmental quality, culture heritage integration etc), and economic factors (Maintenance, prosperity, etc). These issues can be divided into further actions as follows.

- The performance criteria, which can be considered as quantifiable factors or numerical, are defined and assessed and can be illustrated as solid lines, such as energy use, water use and so on. Such criteria (indicators) in this case, can be measured and hence can be called direct indicators due to their explicit influence on the way of assessment.

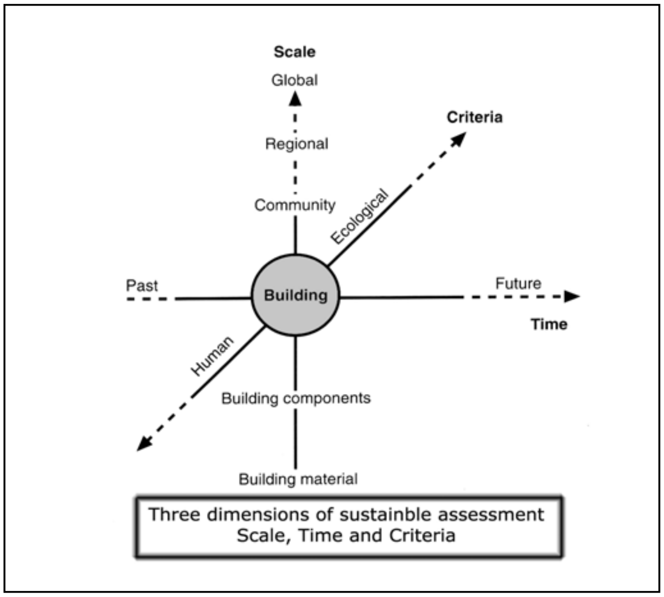

Fig.3. Three dimensions of sustainable assessment, Author 2004, adapted from Cole, R, 1999.

- Some performance criteria (indicators) that can be described qualitatively can be met with a wider interpretation. For instance, the loss of biodiversity etc. Therefore, their assessment is less certain and these are illustrated as broken lines. The application of these criteria in some points can be described as indirect impact because of the difficulties in assessing these or the lesser impact on the environment. Hence, what can be useful in this context is the converting of qualitative issues (feelings, impressions) into a quantitative value (Bell and Morse, 2003).

3.1.2 Time. Time scale is one of the most important factors in assessing sustainable development due to the changing nature of the performance criteria and the appearance of new ones over a period of time. The previous figure indicates two types of lines representing the time scale in the past, present and the future of a building. The distant past and long term future are less clearly known and less certain than the immediate past and future.

3.1.3 Scale. Building location and other contextual issues are important and can help in terms of the discussion regarding their legitimacy for inclusion in either a building assessment or design tool. Consequently, scale is obviously the critical dimension in relation to building environmental performance within the context of sustainability, architecture and urban planning. The individual building, however, is itself useful in the "green" building debate; conversely it is not valid as an appropriate scale to define and discuss optimal performance within a sustainability model. "*The spatial and temporal scale upon which Sustainable Development (SD) is built is considered to continue from the individual to the global" (Dahl, 1997).*

The objectivity and subjectivity of sustainability assessment, however, for building location is not sufficient in itself to obtain good results, despite having been considered for a long time as good enough tools in terms of environment assessment. There are cultural and social variations between regions and countries and measuring sustainability in one region according to several criteria is subject to differences from one area to another even when the same criteria are applied. A flexible assessment system is therefore required to allow the user to consider various spatial boundaries, while retaining an understanding of what is being changed and why it is best (Todd and Geissler, 1999).

4. Problems of Measurement (Combining Qualitative and Quantitative Factors)

Most assessment methods are based on explicit and measurable quality criteria, for instance, air quality and energy use. Meanwhile, some other studies focus on what are called quantitative techniques, striving for objective and comparable measurement, which can be regarded with reference to socio-psychological aspects of quality like privacy and human interaction. There is no doubt that the existing quantitative studies have great value for science and practice, but the problem is that they fail to address the 'softer' and intangible aspects of quality. For example buildings should consider a good indoor environment and functionally support internal activities, but these characteristics only partly define excellence or delight in design because human response is equally important (Dewulf and Meel, 2004).

Another problem has become associated with the scope to find objective or universal quality standards. One of the most interesting issues is that no consensus has yet been validated on what constitutes excellence in building sustainability performance, and hence, one who deals with such an assessment can try to be as objective as possible in developing an assessment system. Achieving this might be possible in terms of basic qualities such air quality, but it seems to be very difficult when the issues are related to privacy and territoriality, not to mention beauty and delight. The question here is why such issues should be judged based on opinion instead of facts and therefore, many methods have accepted that many qualitative performance issues are, and will continue to remain, judgmental. However, it is important that we move towards making such judgments as objective as possible. Moreover, a number of researches have confirmed differences in quality and preferences between architects, other professionals and the public, highlighting major differences in judgments between various stakeholders.

"*The definition of the level of sustainability for any given indicator is a difficult task which assumes an acute knowledge of both the indicator and of its milieu. Developing and evaluating indicators is further complicated because this process as applied in the current context is being undertaken in a subjective and participatory manner"* (UNEP/MAP/Blue Plan, 2000).

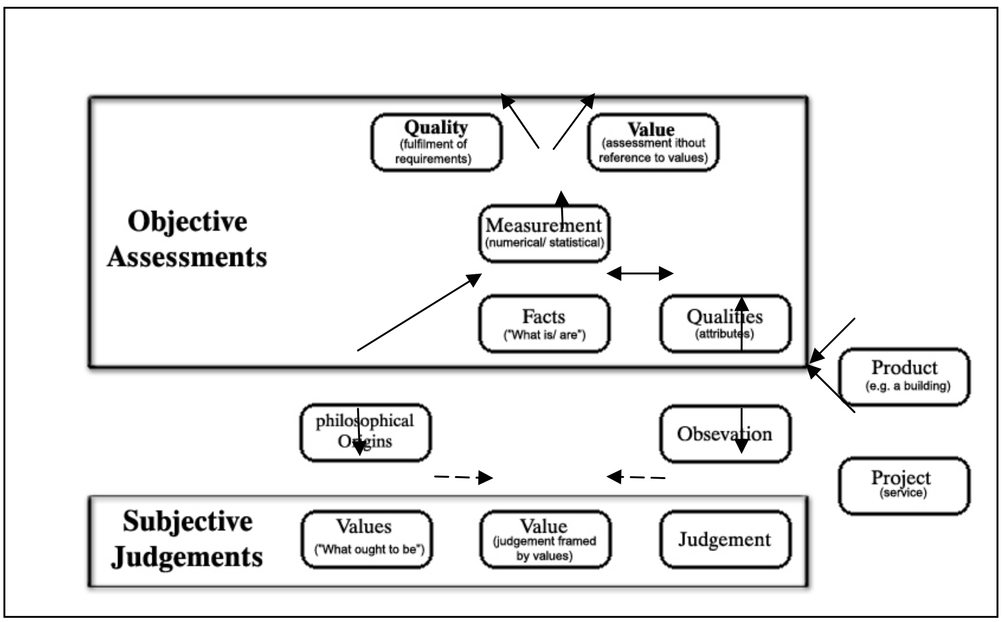

Fig.5. Value translation and assessment framework, Author 2004 adapted from Thomson et al.

5. Example of existing assessment methods

Over the last ten years it has been increasingly important to understand the sustainability performance of building across a range of considerations, stimulating the development of a number of sustainability assessment tools aimed at encouraging designers and planners to improve a building's performance and to deliver an objective measurement of a building's impact upon sustainability within the three dimensions of environmental, social and economic patterns. In order to identify a suitable methodology measurement, this section will present (in chronological order) analyse and compare different methods. This is essential in order to understand the demanded criteria for future proposed models to make the measurement less subjective and to understand the potential advantages and disadvantages of each method in terms of indicators, applications and scoring.

5.1 Sustainable Architecture Matrix (SAM), the original model.

Malcolm Wells in his book *Gentle Architecture* (1981) developed a matrix as a first attempt in terms of a Sustainable Architecture Matrix (SAM), first published in Progressive Architecture, March 1971. SAM is a distinctive matrix subdivided into categories representing a group of sustainability indicators. Each category is further sub-divided into sub-categories, the indicator weighting criteria. The priority level of each sub-category is determined within a range of 1 and 10, with (10) as the highest and (1) as the lowest priority. In this case, designers along with their client's assistance elaborate and decide which priority applies, taking into consideration the developer and the designer's impact criteria. The positive side of this approach is noted from the fact that the matrix itself responds to changing time, place and culture. Salem (1991) adapted this to his own matrix in Egypt with special reference to a tourist development in the Red Sea area. The evaluation mechanism in Salem's measuring matrix works according to both the priority level chosen by the designer and the degree to which the design achieves sustainability standards (25%...100%). Each category can be met either by a positive extreme or by a negative one (+ or -). In this model there is no consideration for a neutral point or Zero. A system of multiplication has been established which helps in obtaining the score level of sustainability of the project through its indicators:

$$\textbf{Level of priority} \times [+ \textbf{(percentage of achieving)}] = \textbf{sustainability score} \qquad \text{Eq. 1}$$

The sum of all the scores represents the level of sustainability of the project, taking into account the whole range of indicators to the developer and/or designer. The limitations of this matrix rest in the consideration of a sole group of indicators (mainly the environmental ones) and reflect an important limitation for SAM in terms of assessing the wider social and economic aspects. In addition, most of the indicators depend on quantitative rather than qualitative factors. The multiplier was identified as the priority level, set on a scale of 1 to 10, making the process of assessment complex and a controversial issue for the assessor to decide. For instance what is the difference between 7, 8 or 6? As a consequence the priority level is dependent on whoever carries out the evaluation, so ending in a subjective result.

Table 1. SAM test of category of water (Salem, 1991)

	-100 always	*-75 usually*	*-50 sometimes*	*-25 seldom*	*Priority Level*	*+25 seldom*	*+50 sometimes*	*+75 usually*	*+100 always*		
Negative Extreme (-)					*Water*					*Positive Extreme (+)*	*Score*
Destroys pure water			■	■	*7.00*					*Creates pure water*	*-350.00*
Wastes precipitation					*4.00*	■	■	■		*Stores pure water*	*+300.00*
Ignores use of grey-water	■	■	■	■	*9.00*					*Uses grey-water*	*-900.00*
Wastes run-offs					*5.00*	■				*Creates percolation*	*+125.00*
Obtains water from hinterland						■	■			*Obtains water locally*	*+400.00*

Score= -425

5.2 BREEAM, Building Research Establishment Environmental Assessment Method: UK experience.

Before the existence of BREEAM as a tool for environmental assessment, some consideration was given to a large share of environmental impacts arising from buildings and constructions in the UK. Such issues have been included as follows:

- People in northern Europe spend on average 90% of their time indoors, likely more than that in an urban environment.

- Buildings have a major impact on the global environment through energy use and the use of chemicals such as CFCs. In the UK and other Western European countries buildings account for about 50% of primary energy use and hence CO2 output, far outweighing the contribution of either transport or industry sectors. Meanwhile, world wide, buildings account for 40% of energy use, 40% of materials use, 25% of timber and about 16% of fresh water.

Therefore, BREEAM, the Building Research Establishment Environmental Assessment Method has been launched as a mechanism for environment assessment, aimed at reducing environmental impacts across a wide range of issues affecting "**Global, Local and Indoor environments**". The facts indicate that clients, designers and building users are convinced by the BREAAM scheme, with 25% of new office developments applying it in the UK. Such a method has covered different building types - new offices, new homes, new superstores, and supermarkets, new industrial buildings and existing offices. In terms of assessment scope however, each issue receives individual credit - a credit represents the design satisfies for the issues concerned. In other words, the assessment has taken into consideration positive aspects, but conversely, the principles of sustainability assessment aim at concerning the importance of diverse impacts for issues, which can be met with negative credit. However, to help the communication of this scheme with the user, a summary of performance has been included, expressing a wide rating of, Fair, Good, Very Good and Excellent where, for instance, a rating of excellent indicates a high standard of performance across the range of impacts.

Since 1990 BREEAM has become the most important organization in the UK dealing mainly with a wider perspective on assessing and improving building environmental performance issues, such as daylight, materials and construction, a wider meaning of energy, and so on. BREEAM has similarities with BEPAC*, Building Environmental Performance Assessment Criteria*, 1993-2000, in Canada and LEED, *Leadership in Energy and Environmental Design*, 1998-2004, in the USA. The similarities in assessment and weighting can be recognised in the use of labelling systems to consider mainly environmental aspects and positive applications. For this reason BREEAM is chosen as the forerunner among these organisations. Furthermore, BREEAM in 2002 developed a new checklist for development, taking into account this integrating process of a wider meaning for sustainable development, covering the aspects of social and economic dimensions for the first time in this method. Despite this attempt to join social and economic factors in this model, still the main purpose is restricted in building and local scales as well as a labelling system of assessment where it is not sufficient to say, good or very good in terms of performance level, because environmental labelling as a concept is not given even an obvious agreement on what it means to build or create a green building or how to define what is called a "good" building. Consequently, what is special about this organisation in recent years is a particular method for sustainability assessment, representing a unique checklist called ***a sustainability checklist for developments 2002,*** depending on the combination of three associations and authorities in the UK, BREEAM, DTLR transport and local government regions, and the DTI (Department of Trade and Industry). Such a process works in terms of integrating all the principles of sustainability development, taking into account the importance of issue and sub issue and their impact on Environment, Social and Economic factors. A set of eight issue headings have defined these principles and are described a follows:

*** Land use, Urban form and design *Transport *Energy * Buildings * Natural resources * Ecology * Community *Business**

Concerning the way of assessment, this method has its own potential in terms of scoring, divided into four main parts of the checklist where in each of these issues; specific questions have been designed to cover the main aspects of sustainability in a schematic process:

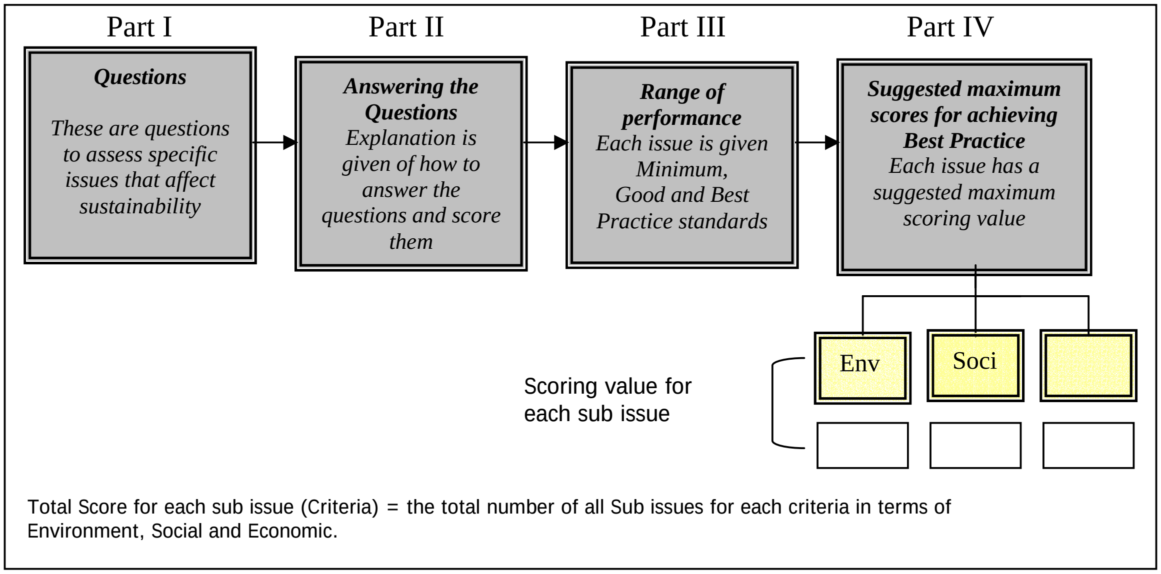

Fig.8 A sustainability checklist for developments 2002: Schematic process (Author, 2004)

In spite of the essential improvements of this method, the use of this mechanism can be met with both positive and negative aspects, where the table below indicates the potential advantages and disadvantages of the checklist process:

Table 3. Potential advantages and disadvantages of the checklist process (Author 2004)

The potential advantages of the checklist process	The potential disadvantages of the checklist process
1- Provides a framework for assessing the sustainability issues relating to buildings and infrastructure. 2- Provides guidance to developers, designers and planners on standards and indicators adaptable to local circumstances. 3- Valid mechanism employing overlapping sustainability indicators in the UK. 4- Assessment result diagrams help the reader understand the output result (Positive considerations), although still not valid in terms of presenting the complex relationship between indicators and sub indicators of sustainable development.	1- Focuses on limited indicators which relate directly to the building potential and its impacts on the sustainability dimensions (to obtain a less subjective assessment). 2- Considers a wide range of issues which can be issued in different countries, but range of performance and scoring in the UK cannot be applicable and sensible in countries like Egypt, where the criteria along with regulations and their impacts are different. (National scale) 3- Method does not use negative scores of sustainability indicators which are important in some organizations as mentioned above. 4- In terms of flexibility and readability, the method structure is not systematic or easy to understand, even worse sometimes an explanation for the process of translating the data to numeric is not clear, whereas it is significant for the reader to understand the process.

5.3 Green Building Challenge GBC and GBTool, the original model.

Green building challenge 98 (GBC 98) was a process developed by international teams from 14 countries which considered 34 cases in 1996. The objective of green building challenge 98 was to develop and demonstrate an improved method for measuring building performance within a range of environmental and energy issues, afterwards informing the international community of scientists, designers, builders and clients of the results. The GBTool as a scheme is aimed at defining explicit reference performance levels for all performance criteria. The purpose of this is to help the national teams establish what is called "reference building" to create benchmark performance levels. Furthermore, the GBTool assesses approximately 120 individual sub criteria and criteria; this can be regarded as an important limitation for GBC where it is necessary to reduce these assessment scores to a manageable number in the output models. Added to that the two critical issues within this debate are the basis for deriving weightings and the manner in which the weighting process affects the interpretation of the aggregated results. As well as this, one of the main issues in this model is that no consensus had yet emerged on what constitutes excellence in building environment performance and what defines good environment building so that most users have found the GBTool difficult to use because of the complexity of the framework. Therefore, the scheme has been developed for use in GBC 2000, GBC 2002 and recently 2005.

Such improvements in the applications of GBC have been considered by international teams throughout the world, trying to find the answer to how one begins to define a 'good' or 'excellent' environmental building, which seems to be less objective than before, along with initial features for integrating environment, social and economic impacts. As a result, this process has been developed to deliver the closet objective measurement possible, using a special GBTool subdivided into categories representing a group of sustainability indicators, using seven main categories. The international team reach a consensus on the importance of each category, where each category has been met with a percentage out of 100% depending on its impact in sustainable dimensions. Each category is further sub divided to represent the indicator weighting criteria. A special range of scoring starting from -2 to +5 is established as a translation of an indicator value into a sustainable measure, as below.

	Highest Level Issues
A	Site Selection, Project Planning and Development
B	Energy and Resource Consumption
C	Environmental Loadings
D	Indoor Environmental Quality
E	Functionality and Controllability of Building Systems
F	Long-Term Performance
G	Social and Economic aspects

Fig.6 Highest level issues (GBTool 2005). Author 2004.

+5 (demanding performance) represent the advance considerations of current practice (Excellent performance)

+1 to +5 represents good practice reflecting stable conditions in terms of sustainability, (+3 Good Performance)

0 represents current standard or typical practice for the particular building type and region or due to the difficulty in obtaining data, these criteria will be given a score of 0. (Usually but not always defined by regulation)

(-1to -2) represents that the performance is not likely to meet the accepted industry norms, or the indicator performance can be met with negative impact.

Fig.7 Translation of an Indicator value into Sustainability Measure, (Author, 2004)

This method is considered to be much less subjective, the GBTool projects a linear ranking scale to identify the value of each criterion's coefficient: in terms of sustainability this is called a *Sustainability Multiplier,* and as it is mentioned in SAM matrix, the designer elaborates and the client decides which priority applies taking into account the developer and the designer impact criteria. Such multipliers are based on the importance of each criterion and weighted according to importance. For instance:

1- **Multiplier 0.9** corresponds to a macro level of importance (90% significance)
2- **Multiplier 0.45** corresponds to a medium level of importance (45% significance)
3- **Multiplier 0.1** corresponds to a micro level of importance (10 % significance)
4- **Multiplier "0"** means that has a nil impact (Insignificant impact now), or if the indicator is excluded from the assessment or if it is not applicable in the area. (0% significance)

Afterwards, each score is then multiplied by the weighting to give a criterion score:

(Level of Performance)× (Multiplier) = Sustainability Score
Vn × W1 = Scn

$V_n = -2$ to $+5$, $W1 \leq 1$

Eq. 2

The addition of all the scores in one category represents the level of sustainability of this category taking into account the whole range of indicators and sub indicators. Afterwards, adding the entire category scores (Seven categories) represents the level of sustainability of the project.
In response to using this model/mechanism, the potential advantages and disadvantages of the GBTool test can be summarised:

Table 2. Potential advantages and disadvantages of the GBTool test

The potential advantages of the GBTool test:	The potential disadvantages of the GBTool test (Limitations):
➢ Application of a "sustainable rating" in terms of scoring and weighting. ➢ Coverage of a wide range of issues and sub issues on a building, national, and international scale. ➢ Integration of overlapping sustainability indicators (Environment economic and social). ➢ In term of objectivity, use of a Multiplier with a clear definition to some extent to create good practice, best practice and negative practice. ➢ Concern for Comprehensive measurement (positive and negative applications) ➢ In the case of feasibility and flexibility for the assessor, provision of defaults for issues whilst allowing teams to change these and to indicate what basis they used for their decision. ➢ Creation of a less subjective mechanism where the evaluator is able to highlight the importance of each individual category, indicator and sub indicator in terms of score and weighting ➢ Use of Excel programme provides cross cultural networks and adoption of international information for use at local level. ➢ Diagrams in the assessment results help the reader to understand either positive or negative outputs.	➢ The range of criteria and sub criteria can not be applicable for all types of building. Applying criteria can not be seen to be at the same level of importance from one region to another. ➢ In accordance with the achieving of less subjective measurements, this should focus on carefully selected indicators (Criteria) which are related directly to the building potential and its impacts on the sustainability dimensions, taking into account (Building, regional, national and global) scales. ➢ Measuring sustainability must express the overlapping sustainability indicators in the concepts of Environmental, Economic and Social aspects, where in GBTool model the variety of three dimensions are not considered despite the initial use of the interaction between these factors. ➢ Using the diagram still is not legible enough for the reader in terms of showing the complex relationship between criteria and sub criteria for each principle of sustainability.

6. Comparative Analysis of SAM, BREEAM, BEPAC, LEED, Checklist 2002 and GBTool

An overall conclusion can be drawn in the table bellow, the potential applications described in the proviso section, where the applications and scope for sustainable assessment in the building sector are used to contrast these six assessment methods: BREEAM 2002, Sustainability Checklist 2002, SAM, BEPAC, LEED, and GBC2005. These are based upon author's experience using the six assessment methods. As can be seen from the table, most methods do not meet all the identified applications needs for building sustainable assessment. Although GBC 2005 comes closest in terms of reliability, comprehensive measurement, considerations of overlapping sustainable indicators and so on.

Table 4. Assessment procedures for each method, Author 2004

Scope and Applications	SAM	BEPAC	LEED	BREEAM 2002	A Sustainability Checklist 2002	GBC 2005
Labelling/ Rating System	Rating	Labelling	Labelling	Labelling	Rating	Rating
National/International Scale	National / International	National (Canada)	National (USA)	National (UK)	National (UK)	International, more than 14 countries
Consideration of overlapping sustainability indicators (Environment, Social, Economic aspects)	Environmental issues (can be more comprehensive)	Environmental issues	Environmental issues	Encompass the underlying Sustainability principles	Encompass the underlying Sustainability principles	Encompass the underlying Sustainability principles
Using a Priority Level (Multiplier)	Yes (1 10)	NO	NO	NO	NO	Yes (-2 +5)
Comprehensive Measurement (Positive and Negative applications)	Yes	Positive Only	Positive Only	Positive Only	Positive Only	Yes
Translated Data into Numeric (Interpreter)	Yes	Yes	Yes	Yes	Yes	Yes
Distribute the scores and weights of Indicators, sub Indicators according to their impacts and importance on SD.	NO	NO	NO	NO	NO	Yes
Using a special equation for Scoring process	YES	NO	NO	NO	NO	YES
Using a Readable and flexible process (Systematic process).	YES	NO	NO	NO	Start using systematic process, not flexible and easy to understand	YES
Using a Diagram in the final result (helping the reader to understand the output result)	NO	NO	NO	Start representing new figures (not comprehensive)	Start representing new figures (not comprehensive)	Start representing new figures (not comprehensive)

“SAM” Sustainable Architecture Matrix
“BEPAC” Building Environmental Performance Assessment Criteria

“LEED” Leadership in Energy and Environmental Design
“BREEAM” Building Research Establishment Environmental Assessment Method

A Sustainability Checklist for Developments 2002
“GBC” Green Building Challenge 2005

Conclusions

Significant advances in sustainable assessment methods have been seen in the last ten years. However, significant work remains to be done on the development of tools to make the measurement less subjective, more reliable, and the process of calculation more flexible and easier to follow. Having carried out a comparative evaluation of various models for the measurement of sustainability it is now possible to define or make recommendations on what a future good model should contain. In order to achieve the higher level of objectivity in the measurement and calculation process the following factors should be carefully considered. The following points summarise carefully the most appropriate and vital principles towards measuring the levels of sustainability of buildings in general:

1- Appropriate (Selective) indicators (SIs): In order to measure sustainability, a SIs based model is the most appropriate format, and hence three overlapping components of sustainability (Environmental (EI, Social SI and Economic EcI), are considered as a basis for sustainable assessment, and form the components of this system. The frontiers of sustainability however, are much larger and cover quite a wide range of issues. Thus, in order to obtain objective measurements a number of sustainability indicators (SIs) are required, directly related to the exiting issues in the region or building, taking into account time and spatial scales.

2- Considering Qualitative and Quantitative data: Apart from finding objective or universal quality standards, one of the most interesting issues in the scope of measuring sustainability is the implementation of qualitative and quantitative data. Until recently most data applied by most stakeholders has been quantitative, such as air quality. However, when it comes to issues of judgment data interpretation this seems to be very difficult and continues to remain subjective. What can be useful in this case is the conversion of qualitative issues into quantitative values (numeric).

3- Using a systematic process (readable and flexible model): The test of any case study should be regarded in a holistic way, where at the same time the tool itself should be flexible and adaptable, as it can be applied to different places, different scales and at different times. Unlike existing models where the structure of how the methods works is not systematic and not easy to understand, or even worse an explanation for the process of translating the data to numeric is sometimes unclear. The proposed model is essential to be readable and flexible in terms of understanding the arrangement of data and the scoring process in the pyramidal or in a systematic structure.

4- Use a comprehensive measurement method (Positive and Negative applications): Measurement of sustainability is regarded as one of the most difficult options for the researcher and the designer, where most stakeholders have implemented positive considerations in their attempt to improve building components or what is regarded as a good building. The problem lies with the notion that no consensus has yet been validated on what constitutes excellence in building sustainability performance, and hence, negative implications which can be applied as unsustainable applications in existing buildings may be ignored. Furthermore, the considerations of positive and negative applications can help the researchers, designers and planners in understanding what make up the various impacts on sustainability applications from both negative and positive dimensions. Negative aspects however, can help in terms of promoting our buildings towards more sustainable dimensions; taking into consideration the lesson we can learn from these applications.

5- Using interpreter, Multiplier and Equations: One of the most important factors in terms of making the sustainability measurement less subjective but readable, adaptable and easy to understand is the use of Interpreters, Multipliers and equations, where existing data for each indicator can be met with a specific numeric (interpreter) in the way of translating the data into a number. Moreover, the importance of this indicator and its difference from another can be translated into a special use of a Multiplier according to the impact of this indicator on the sustainability dimensions. To achieve the sustainability score, an equation is employed to reflect the application of indictor performance in terms of positive and negative applications. The use of interpreters and multipliers will help the reader translate the reference data into numerical values achieving less subjective assessment and avoiding open interpretations.

6- Using a Graphic illustration for the Sustainability measurement, Rader diagrams show different variables simultaneously, allowing the reader to understand the existing data in graphic representation. Such illustrations should also help the reader in understanding both intermediate and final scores of sustainability and allow the comparison of scores across different case studies.

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