Key Performance Indicators (KPIs) and priority setting in using the multi- attribute approach for intelligent buildings (IBs)

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Abstract

The objectives of this paper are to identify key performance indicators (KPIs) for intelligent buildings (IBs) and model the building performance. The authors studied various types of building to develop key performance indicators (KPIs) that could be readily used by architects, clients, producers and end- users to better understand and promote value through design. The tool includes key elements covering Environmental, Socio-cultural and Economic sustainability issues. The value of intelligent buildings is assessed in relation to their design for different uses and their ability to meet a variety of needs including sustainability, whole life value, health and emotional needs of occupants and users. The process raises a lack of consensus on what constitutes a good design indicator for intelligent buildings due to the difficulties in the broad description and application of sustainability indicators.

Sustainability performance of intelligent buildings is not easy to measure particularly when trying to quantify qualitative data. This paper uses a consensus-based model (*Comprehensive Assessment System for Intelligent Buildings*- CASIB) which is analysed using the analytical hierarchical process (AHP) for multi-criteria decision-making. The use of the multi- attribute model for priority setting in sustainability assessment of intelligent buildings is introduced. Issues related to the proper use of the model, such as selection criteria, priority levels, hierarchy structure and allocation of weightings to these criteria are discussed. Other potential applications of the proposed model and methodology are discussed. It is argued that the benefit of the new proposed model (CASIBs) is a 'tool' for 'comparative' rather than an absolute measurement, because it has the potential to provide useful lessons from current sustainability assessment methods for strategic future of intelligent buildings in order to improve a building's performance and to deliver objective outcomes. It is concluded that the priority levels for selected criteria is largely dependent on the integrated design team which includes the client, architects, engineers and facilities manager.

Keywords: Key performance indicators (KPIs), intelligent buildings, sustainability assessment, priority levels, CASIBs.

Introduction

An intelligent building is understood as a complex system of inter-related three basic elements- ***People*** (owners; occupants, users, etc.); ***Products*** (materials; fabric; structure; facilities; equipments; services); and ***Processes*** (automation; control; systems; maintenance; performance evaluation) and the inter-relationships between them. These goals include the entire phases of a buildings life span, the environmentally friendly built environment with substantial safety, security, well-being and convenience, a lower life cycle cost and long term flexibility, controllability and marketability, leading to achieve a building that has the highest environmental, social and economic values (Chen, *et al* 2006, p. 394; Clements-Croome, 2004). The differing emphasis of these and other definitions communicates technological capacity, design value, and culturally perceived needs in the design of buildings. So, *et al*., (2001) suggest, "*intelligent buildings are not intelligent by themselves, but they can furnish the occupants with more intelligence and enable them to work more efficiently*". From the definitions, technological advanced was not considered as the main driver in the system selection. This finding reinforced the argument by Clements-Croome that a true intelligent building is not a building with purely advanced technologies; instead it should be one of high values. Thus, intelligent buildings should be sustainable, healthy, and technologically aware, meeting the needs of the occupants and business, and should be flexible and adaptable to deal with change.

When aiming to reduce environmental impacts, a yardstick for measuring environmental performance was needed (Crawley and Aho, 1999). The term" *Building Performance*" is complex, since different criteria in the building sector have differing interests and requirements (Cole, 1998). A problem has emerged associated with the scope to find objective or universal quality standards. The issue here is the lack of consensus on what constitutes excellence in building assessment performance, covering the overlapping dimensions of social, economic, environment and technological factors. Thus, 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, engineers, planners and decision makers in what is defined as the principles of "*Selective Sustainable Design*" (Hawkes et al., 2001) in which there is a strong relationship between *climate*, *comfort* and *Technology*. These issues are leading to pressures on industry to demonstrate how well (or how poorly) they are currently performing vis-à-vis "sustainability." In addition, the construction industry, are being confronted with a new set of regulatory practices and priorities, largely generated by the push for sustainability. However, the success of intelligent building is measured, in part, by how well it supports the management at these issues at all stages of its existence, from the inception of the design process to the recycling of its materials at the end of its useful life (Kroner, 1997, p. 387). Thus, a wide range of existing issues are available in terms of intelligent buildings, and can be used for the aim of developing a new model called Comprehensive Assessment System for Intelligent Buildings analysed using analytical hierarchical process (AHP) for multi-criteria decision-making, in which "*multiple methods*" that involve quantitative and qualitative approaches are employed (Lee, et al, 2006, p.1832). The main objective of the new model in this paper is to make it accessible to the developers, designers, occupiers and decision makers by providing practical benefits on how they can insight their own sustainability indicators selection, priority levels, benchmarking and building performance. The new tool explains how to analyse and interpret various range of data ad feedback, and how to share results so that any lessons learnt can be put into practice. The paper will end with a discussion of the difficulties the proposed analytical framework would face in practice.

Objective of the study

Since the field of key performance indicators is vast, the aim of this study is to clarify that field by undertaken the following specific objectives, to:

1- Evaluate the trends in the development of intelligent buildings

2- Identify key issues related to intelligent buildings (Environmental, social, economic and technological factors).

3- Develop a new model for measuring the level of sustainability for intelligent buildings.

4- Evaluate stakeholder’s perceptions and values of selected SIs intelligent buildings

Methodology

In order to achieve the goal of this paper, the methodology is broken into 3 phases:

Phase 1; *To develop general conceptual models that highlight the* ***critical selection factors and indicators****;*

Before choosing a methodology, however, it is essential to decide how the data will be used. It is essential to design data management systems to the correct format in order to ensure the system performance is monitored properly, that reliability data is collected and that the relevant people are trained to analyze it for use by decision makers, architects and facilities management (Clements-Croome, et al, 2007). It is advisable to think ahead so that data collected as part of a sustainability assessment can be reported as Key Performance Indicators (KPIs) (British Council for Offices, 2007, p. 19). The use of (KPIs) and benchmarking is fundamental to any improvement strategy. “*An indicator system should provide a measure of current performance, a clear statement of what might be achieved in terms of future performance targets and yardstick for measurement of progress along the way*” (Jefferson, et al., 2007, p. 58). The challenge in this case is to find effective indicators, requiring a clear conceptual basis. Hence, the selection of indicators will recognize the available data, resources and time, in addition to the interests and needs of the particular group involved in the selection of indicators (Becker, 2004). Hence, it is important for the selected indicators to meet the following criteria (adapted from Brandon & Lombardi, 2005, p. 39; Gann, Salter, & Whyte, 2003, P. 323; Bell and Morse, 2003, p. 31) and be:

1- Specific and must directly relate to outcomes.

2- Easily understood by the general public.

3- Measurable. Implying that indicators must be either quantitative, or, if qualitative, must be interpreted into quantitative values.

4- Useable at different phases in a building's life cycle: conception, design, construction and operation. This is essential, as the criteria and indicators are not applicable at all times or for the same stage during the life cycle of a building.

5- Able to reflect changes over a period of time. Time scale is one of the most important factors in selecting sustainability indicators due to the changing nature of the performance criteria and the appearance of new ones over a period of time. Also, some indicators are ideally looked at over even longer time frames presenting valuable information about tendencies of overall development (i.e. energy and water consumption in buildings). Additionally, considering a time scale offers the possibility of reading the level of sustainability for any building in the time dimension (Alwaer & Sibley 2005; Alwaer, 2006; Dalman, 2002, p. 1).

6- Sensitive, i.e they must readily change as circumstances change.

7- Able to reflect the multi-faceted nature of indicators (Composite indicators), which combine two or more individual indicators, can also be useful as integrative indicators. For instance, the cost of recycling per ton of waste recycled is a simple composite indicator that integrates economic and environment considerations (Maclaren 1996 in Wheeler and Beatley, 2004, p. 206). Also, natural lighting for example in shopping centres can have a functional quality, such as providing a safe, pleasing environment for customers, but it can also have an impact on energy saving. Unfortunately, the problem we could be face in constructing more complex composite indicators, including such issues as deciding how to weight the individual indicators and how to standardised different measurement unites (Maclaren 1996 in Wheeler and Beatley, 2004, p. 206).

8- Available, i.e. it must be relatively straightforward to collect the necessary data for the indicator.

9- Cost effective. It should not be a very expensive task to access the necessary data, *"a clear concern that data availability should not be a constraint in selecting relevant indicators"* (Meter, 1999, in Bell and Morse, 2003, p.32).

10- Able to reflect the multi-spatial scale of sustainability indicators: Consideration of the individual building is itself useful in the "green" building debate; however, it is not always valid as an appropriate scale to define and discuss optimal performance within broad sustainability models. Therefore, a special scale is essential in order to read the level of sustainability of a building design in different contexts. The objective behind this is to show the scale in which indicator is applied.

The initial step is to choose the most appropriate criteria to formulate an '*indicators set*', for a project which relates to the building's performance in relation to the local environment, culture and economy, in addition to business goals (Roaf, 2005, p. 100). However, since the intelligent building industry is new and developing, large samples of professionals are not always available.

Only a very limited number of experts could be identified for the surveys described here but does include design consultants and facilities managers. 20 stakeholders were presented with the proposed selection criteria, and a survey was carried out with stakeholders from different fields in practice and academia. The selected stakeholders were invited to review the relevance, coherence and clarity of approximately 115 individual indicators identified as having a major influence on the overall perceived and operational quality of a building. They were also invited to add and refine new attributes to the indicators. The selected indicators were derived from reformulated sustainability assessment methods used within the UK (*Building Research Environmental Assessment Method* 'BREEAM' , *Design Quality Indicator* 'DQI'…), supplemented with additional ideas taken from sustainability indicators used in other countries, such as, (*Leadership in Environmental and Energy Design* 'LEED', *Comprehensive Assessment System for Building Environmental Efficiency* 'CASBEE', *Asian Institute of Intelligent Buildings* 'AIIB', *Green Star, Sustainable Building Challenge* 'SBC' and *Hong Kong Building Environmental Assessment Method* 'HK-BEAM'... The additional indicators related to health and well being and their effects on productivity and well being of users... Automation, intelligence and user control of the indoor environmental quality, temperature, daylighting and sound in buildings were considered. The CASIBs system is designed is designed to include consideration of regional conditions and values, but the calibration to local conditions does not destroy the value of a common structure and terminology. The system is therefore a very useful international benchmarking tool, one that provides signals to local industry on the state of performance in the region, while also providing absolute data for international comparisons (Larsson, 2007).

Although most of the indicators are directly transferable from UK to elsewhere, it should be noted that depending on the context some indicators may require reformulation or new indicators may be needed to take into consideration the specificity of the context in which they are applied. However, there should be a limited number of indicators, which can be compared to targets, benchmarks or other standards as appropriate. "*There is no limit on the number of indicators that can be used, although a greater number can limit comprehension and the relative importance of each indicator*" (Becker, 2004, p. 204). The selected stakeholders were invited to attach new attributes to the indicators and select related ones based on their *relative importance* and potential *value* of each indicator on various projects size and functions (shopping centres, offices, schools, etc…).. In order to facilitate the selection process and make it transparent and easy to follow, four hierarchical categories of indicators were introduced as follows (adapted from Design Quality Indicator framework- see http://www.dqi.org.uk):

1- **Required (prerequisite) Indicators or Mandatory** (*as a*rticulated by demand side): Compliance with standards, regulations and quantified minimum targets.
2- **Desired Indicators**: Setting ideal targets for building performance beyond the minimum required by guides and codes of practice to include the *users vision*.
3- **Inspired Indicators**: Inspiring goals and vision set by client: refers to long term mission and values.
4- **Non- applicable indicators** or *non- active indicators*: The scope of the project does not require these, or they cannot be achieved.

The table 1 (See Table 1) reveals the stakeholder's (in this case an architect) response to this survey, with reference to energy and natural resources sustainability indicators. The stakeholder’s contribution in this study therefore is a response to the question “*Which sustainability issues are required (mandatory) or desired more than other issues (non applicable or non active indicators)*?” based on their intensive knowledge, experience and preferences. For instance, it may not possible to answer this question with absolute certainty by creating a credible and robust process to arrive at a consensus as to what are currently the most important issues for sustainable buildings (Aizlewood, Edwards, Hamilton, Shiers & Steele, 2007, p. 1). It is notable that the stakeholder selected 6 out of 9 main indicators in terms of required and desired categories. Thus, the inspired and non applicable criteria could be marginalised at this stage. This may be the case if the indicator needs to be addressed, but is not relevant in the region or case study. Or it requires client vision and statement or the relevant raw data has not been provided, or the importance of the indicator or sub indicator is not applicable at this stage but might be over a period of time (i.e. five years). This might be considered as a wide approach, but conversely highlights one significant issue in customising a general assessment scale to regional application.

Table 1: An example of a stakeholder (one of the architects) perceptions selection process for proposed energy indicators based on relative impact and importance on the buildings.

Proposed Sustainability Indicators			**Minimum Request and the Compliance Requirements**	**Indicators Classification**				**Life Cycle Stage (Spatial Scale)**			
Category	**Credit No.**	**Indicator (SI)**		**Required** Mandatory	**Desired**	**Inspired**	**Non Applicable**	**D & P**	**M & OP**	**POE**	**R**
Energy and natural resources	E1	Total life cycle primary non-renewable energy	To predict non-renewable primary energy used for building operations and greenhouse gas emissions	●	○	○	○	✓	✓	✓	
	E2	Lot orientation to maximise passive solar energy	To ensure that the project site plans provide for the location and orientation of building that will maximise passive solar potential	○	◉	○	○	✓	✓		
	E3	Total life cycle primary from renewable energy (renewable energy implications)	To encourage the use of sources that generates power by renewable energy means, e.g. 'green power'.	○	○	◍	○	✓	✓		
	E4	Use of Daylight in the primary areas (Daylight absorbability)	To ensure an adequate level of daylighting in all primary occupied spaces.	●	○	○	○	✓	✓		
	E5	Peak Energy Demand Reduction for building operations	To encourage and recognise projects that implement systems to reduce peak demand on energy supply infra-structure	○	◉	○	○	✓	✓		
	E6	Passive solar gain and cooling	To encourage using the natural movement of heat and air to maintain comfortable temperatures, operating with little or mechanical assistance	○	○	◍	○	✓			
	E7	Annual electrical energy conservation	To minimize the peak monthly electrical demand for building operations, especially where the grid is near peak capacity	○	○	◍	○	✓	✓		
	E8	Design features to maximise effectiveness of ventilation in naturally ventilated occupancies	To encourage and recognise the provision of natural ventilation system from the early design stage considering building orientation and wind directions	●	○	○	○	✓	✓	✓	
	E9 … … En	Maximize the effectiveness of operable windows (Glass structure encourage effectively natural air flow)	To ensure that the number, placement and type of windows or other openings in a naturally-ventilated building are capable of providing a high level of air quality and ventilation	○	◉	○	○	✓	✓		

Key: (the degree of importance)	**Key: (Life Cycle Stages)**
Highly Important and Required ■	Design and Post Construction (**D&P**)
Desired and Important issue ◉	Management and Operation (**M&OP**)
Inspired issue with less important than other issues ◍	Post Occupancy Evaluation (**POE**)
Non applicable or they can not be achieved ○	Recycle, Reassemble and Reuse (**R**)

At the end of the survey, 11 complete answered questionnaires were received from (4 architects, 4 engineers, 3 sustainability assessors). The stakeholders identified 18 main key categories relevant to intelligent buildings based on their influence on the whole life cycle of intelligent buildings, and categories under the four headings of *Environmental* (e.g. energy, CO_2 emissions, transport, land use, waste reduction….), *Socio-cultural* (user satisfaction, quality of space, safety at work, quality of services…), *Economic factors* (predictability, maintenances, life cycle costs…) and *Technological Factors* (Intelligence, communications, Controllability….). Within these categories, 57 indicators and sub indicators were identified within the scope of required and desired indicators.

1- Environmental Indicators group (En-SIs):

- Energy and Natural Resources (E)
- Water and Water Conservation (W)
- Materials used, Durability and Waste (M)
- Land use and Site selection (L)
- Transport and Accessibility (T)
- Greenhouse Gas Emissions (Pollution) (GHG)

2- Socio- Cultural Indicators group, (So-SIs):

- Functionality, Form, and Aesthetic aspects (F)
- Indoor Environmental Quality (IEQ) - Health and Wellbeing 1-
- Daylighting and Illumination (D) - Health and Wellbeing 2-
- Architectural considerations – cultural heritage integration and the compatibility with local heritage value (A)
- Users trends and aspirations (Us)
- Innovation and design process (ID)

3- Economic Indicators group (Ec- SIs):

- Flexibility & Adaptability(FA)
- Economic performance and affordability (EP)
- Building Manageability (BM)
- Whole Life Value (V)

4- Technological Indicators group (Tc- SIs):

- Intelligence and controllability (IC)
- Communications and mobility (C)

The importance of the selected indicators can be considered in relation to the implementation of various aspects, from building issues at the “***micro scale***” (water, energy, maintenance, and so on), to urban and regional planning on the “***meso scale***” (such as land use and site selection, planning considerations,…), to national issues on the “***macro scale***” (such as greenhouse gas emissions from all energy used for building operations, transport, and infrastructure) and cross country issues on the ***global scale*** (climate change). The selection of sustainability indicators are based on a through life model focusing on ***People***, ***Products*** and ***Processes*** based on design, construction, commissioning, operation, maintenance, post-occupancy evaluation, recycling and disposal (see Clements-Croome, *et al* 2004; Clements-Croome, *et al* 2007). However, due to the time constraints of this research dealing with a large set of sustainability indicators- and in order to make the selected indicators relevant to intelligent buildings, only those indicators located within building scale are chosen in this paper as follows:

Environmental SI (Ecological and Natural resource) group (En-SIs):

- Energy and natural resources (E)
- Material used, Durability and Waste (M)

SOCIO- Cultural Indicators group, (So-SIs):

- Functionality, Form, and aesthetic aspects (F)
- Indoor Environmental Quality (IEQ) - Health and Wellbeing 1-
- Daylighting and Illumination (D) - Health and Wellbeing 2-
- Innovation and design process (ID)

Economic Sustainability Indicators group (Ec- SIs):

- Flexibility & Adaptability(FA)
- Economic performance and affordability (EP)

Technological Indicators group (Tc- SIs):

- Intelligence and controllability (IC)

Phase 2; To **test and refine the general conceptual models developed in phase 1** by testing the level of importance of the selection criteria and indicators;

There are no hard and fast rules about which techniques embodied in sustainability assessment should be used, because each study will be unique to the building location or prevailing situation. However, it is clear that adopting well-known and widely used techniques ensures that results are meaningful; that they can be repeated and therefore compared; and that the information can be benchmarked against other tools that have used the same methodology. With the possibility of not having scientifically derived weights, it is possible to use ‘consensus-based’ weighting for the different categories of indicators. In the CASIBs, the 11 selected stakeholders (from sample of 20) ranked various factors, such as environmental issues, in terms of their relative importance or assigned weights to the process of design, construction and operation of offices. Since people have different views and different levels of understanding about sustainability issues, a standardised production for assigning relative importance to different sustainability impacts is required if there is to be a consistent basis for decision-making. The relative importance has been derived using the analytical tool called the *Analytical Hierarchy Process* (AHP) (Saaty, 2001), which uses a 9 point scale. In brief, the AHP approach can help to improve the decision-making process, and has been applied to numerous multi-criteria problems in the last few decades (Chang, et al, 2007; Wong, 2007; Clements-Croome and Li, 2001; Saaty, 2001).

The AHP approach consists of several levels of hierarchies, but in this case five have been selected beginning with goals followed by dimensions, categories, indicators, interrelationship between indicators, and inter-relationship between categories. AHP enables the users to make *effective decisions* on complex issues by helping to order their natural decision-making processes. In addition, AHP helps to establish decision models through a process that contains both qualitative and quantitative components. *Qualitatively*, it helps to *decompose a decision problem* from the overall goal to a set of manageable categories, indicators and sub-indicators. *Quantitatively*, it uses *pair-wise comparison* to assign weights to the elements at the indicator and sub indicator levels, and finally calculates “score” weights for assessment taking place at the bottom level (Wong, 2007; Chung and Li, 2007, p. 279).

Intelligent buildings can be treated as a complex system and can best be understood by breaking the system down into their constituent elements and then structuring the elements hierarchically (See Figure 1); composing judgments on the relative importance of the elements at each level of the hierarchy into a set of overall priorities (Saaty, 2001). Each level in the hierarchy corresponds to the common characteristic of the elements in that level. For example, the aim of the stakeholder's contribution in this study therefore is to ask the question "*Which sustainability issues are of greatest importance*? That is, is transportation and accessibility more important than say, energy and natural resources or water consumption and if it is, then *how much more important*?" The nominal-ratio scale of the priority levels among the categories was represented as the score from a 1 to 10 point scale, with participants asked to judge the relative importance of one issue compared with another (pair-wise comparisons).

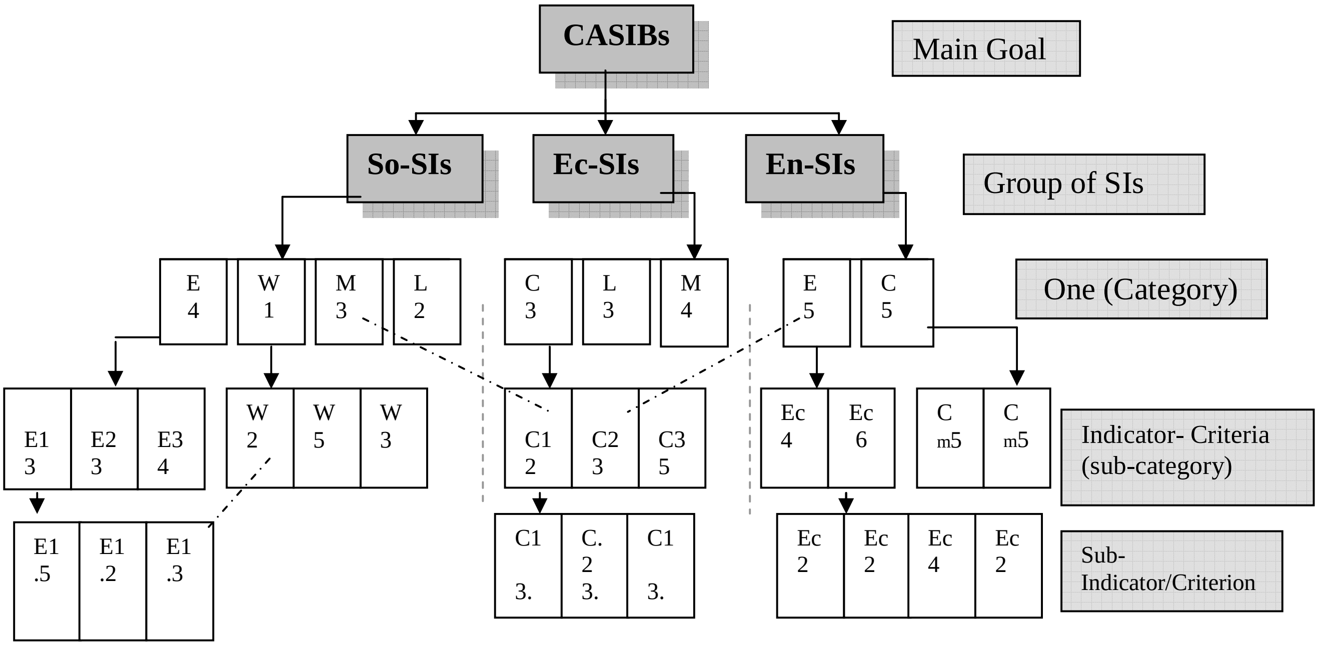

Figure 1: The principles and the priority values used in CASIBs: Hierarchy order (interactive hierarchies).

For instance, taking Environmental sustainability indicators (En, SIs) as one group illustrates two main categories. In this case, the evaluators, sustainability assessor, the architect and the building engineer, determine the priority level attributed to each one taking into account that each value for a category in one group will be granted a value out of 10 (See Figures 2 and 3).

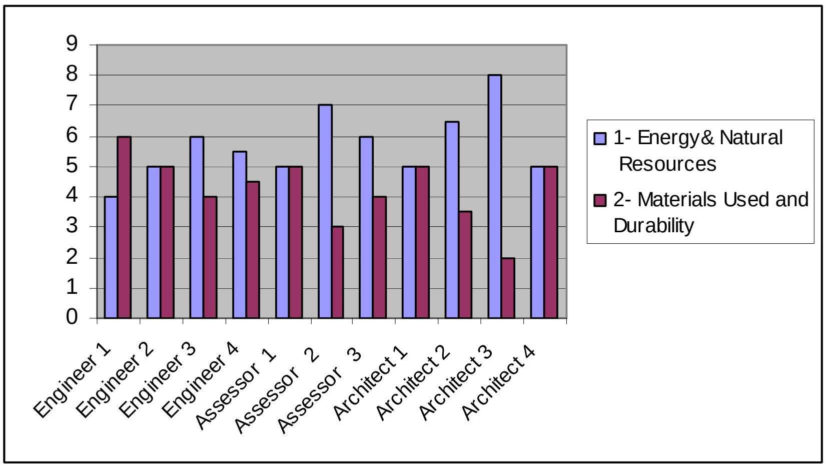

Figure 2: The priority levels attributed for selected Environmental categories by different stakeholders.

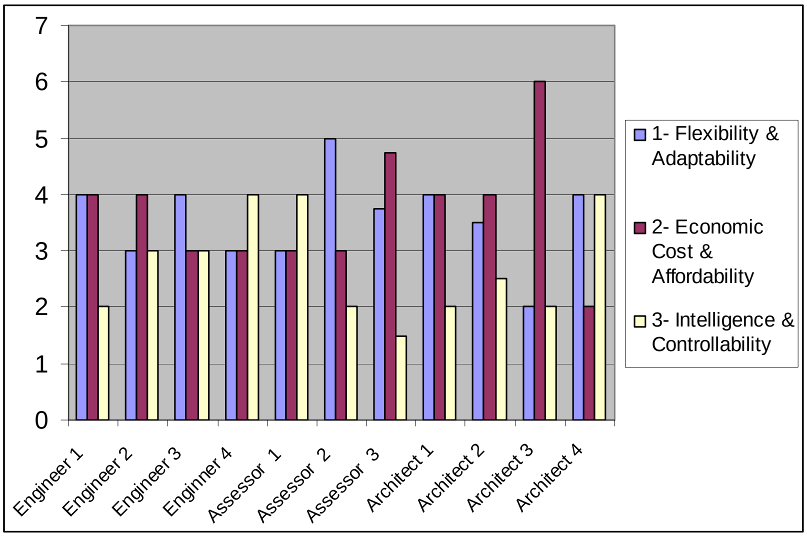

Figure 4: The priority levels attributed for selected Economic categories by different stakeholders.

It is noted from the previous tables that, although each multiplier (Priority level) is identified on a scale of 1 to 10, the process of assessment is complex. The differing views of the assessor, the building architect and the building engineer on multiplier level lead to subjective results. When this method is applied in different regions, the reference building types, climatic conditions and geographical locations are different. Additionally, the differences in priority levels between stakeholders could result in major differences in sustainability assessment results. Also, according to the survey, the aggregated results illustrate that the different individuals of the same skill group (i.e. architects) have given different weightings scores based on their preferences and experiences of buildings. Even by making the average between the architects, the building managers and the assessors, the aggregated results have given different weightings which could skew the final assessment results. Also, it is clear from the aggregated results that, the priority levels expressed qualitatively and quantitatively are open to wide interpretation by the 11 assessors and therefore the assigning of scores can vary considerably depending on those making the assessment- even within the same system. These can also be very subjective leading to a distorted evaluation, as there has been no consensus in various sustainability indicators.

Phase 3; To **develop practical model** of intelligent building systems assessment and performance;

A sustainability assessment methodology and tool has been developed called- the *Comprehensive Assessment System for Intelligent Buildings* (CASIBs). The aim of developing the system is to deliver the most objective measurement possible, by considering a range of vital issues. The CASIBs have been developed to deliver the best objective measurement possible. Such improvements rely on the accurate translation of an indicator value into a sustainability measure. The CASIBs was designed to comply with the following principles:

- The system is a rating framework or toolbox and only becomes a rating tool after a third party (a range of stakeholders) calibrate it for their region and meet local area considerations by defining selective criteria, priority levels and setting weights, context and performance benchmarks.

- Negative implications are as valuable as positive ones, particularly for assessing existing buildings. Furthermore, a survey carried out by Lee & Burnett (2006) revealed that 70% of the stakeholders agreed with the use of 'negative scoring'. The supporters of negative scoring considered that this would give more incentive to building owners, developers and decision makers for achieving higher sustainability scores. Hence, in the CASIBs, a negative scoring system should be adopted to downgrade non-performing buildings.

- In this model a linear ranking scale for the level of each criterion has been used. '*Priority level*' and the value for each indicator can be translated into a numerical score. Moreover, the importance of this indicator is further modified by a weighting to represent its priority within the criteria group. To summarise, the value of the multipliers are based on the importance of each criterion which is weighted according its importance in each case;

- Apart from weighting issues, the arrangement of data has been categorized using the following equation to reflect the application of indicator performance in terms of positive and negative applications. Adapting the approach of SBC (Larsson, 2007) as follows:

$$\textbf{Sustainability Score} = \textbf{(Level of Performance (L)} \times \textbf{(Priority Level) relative importance (PL)}$$
$$\textbf{Scn} = \textbf{L} \times \textbf{PL (by Stakeholders)}$$

$L = -2$ to $+5$, $PL \leq 10$

Each category is further sub-divided into individual indicators and these are weighted according to their relative importance (Becker, 2004). The actual value of each indicator is translated into a sustainability measure value in the range: from +5 to -2 (Level of performance) as below:

- +5 (demanding performance) represent best practice (Excellent performance)

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

- 0 represents current standard (Minimum acceptable performance) or typical practice for the particular building type and region, or also due to the difficulty in obtaining data.

- -1 to -2 represents unsatisfactory performance (Deficient) which is not likely to meet the accepted regulations, design criteria and industry norms, or the indicator performance gives a negative impact on the environment in social, economic and environmental terms.

One could ask why the level of performance of each indicator is allocated a value between -2 to +5 instead of -5 to +5? The main justification for this by the evaluators is to provide a scale where the focus in sustainability assessment is based on more positive than negative attributes. This is why the researchers did not use “0” as a middle terms in their assessment tool. This scale is designed to encourage those involved in sustainability projects to achieve better design results.

Each criterion is allocated a score after the data analysis. The score for a criterion is multiplied by the priority level for that area. The score for an indicator is, therefore, the total of the criteria’s scores under each category. Afterwards this value is multiplied by the multiplier (priority level) provided beside each indicator or sub-indicator, and the resulting number from such a multiplication represents the weighted score for the indicator or sub indicator.

The authors found it may be easy to achieve a consensus between stakeholders in most building performance on the CASIBs scale (-2 to +5). For instance, if there is no evidence for renewable energy applications in buildings the performance level could be given the score -2. However, it seems more difficult to obtain this consensus when it is related to the relative important and priority level of each indicator. For instance, the four selected architects (from sample of 11 selected stakeholders in this study) have revealed different priority levels with reference to Renewable energy implication (1, 2, 3, and 2 respectively). The difference in priority level between stakeholders could have a much bigger impact on the final “Score” or outcome than all performance inputs into the system from “measured data” (See Table 2). Thus, weighting and expert weightings can skew results dependent on who is carrying out the evaluation, and thus results in a subjective assessment even when the same indicators are applied.

Table 2: Weighting process for renewable energy for four individuals (Architects) of the same skill group

Energy and Natural Resources (E)	**Weighting L1 × PL 1 = Scn**	**Weighting L2 × PL 2 = Scn**	**Weighting L3 × PL 3 = Scn**	**Weighting L4 × PL4 = Scn**
E1: Use Renewable Energy Systems	**-2** ×1 = -2	**-2** ×2 = -4	**-2** ×3 = -6	**-2** ×2= -4

L= -2 to +5 (Performance Level for applied indicators)

Priority Level attributed by Architect 1	PL1
Priority Level attributed by Architect 2	PL2
Priority Level attributed by Architect 3	PL3
Priority Level attributed by Architect 4	PL4

The overall results show remarkable differences in the level of sustainability despite the similarities in the performance value for the applied indicators between stakeholders

(Architects). For instance, in the three figures, the non implication of renewable energy systems have greatly different levels of sustainability, equalling respectively -2 for Architect 1, -4 for Architect 2, -6 for Architect 3 and -4 for Architect 4. In other words, the aggregated results can vary from expert to expert and sometimes can be skewed which are not reliable in terms of the accuracy of the tool itself and make the results open to interpretation .The problem in fact, understanding requirements and transforming them into high quality indicators is a universal one that many stakeholders have struggled with (Gann, et al, 2003, p. 321; Alwaer, et al, 2008). It raises questions about the nature of good sustainable indicators in terms of priority levels and benchmarking. It is typically the case that different individuals or groups are responsible for different levels within building sectors, and they will have their own take on the narrative and its implications. For example, some architects might be concerned that the functionality and quality of internal spaces are relegated to a secondary issue in comparison with the external shape of their buildings. Meanwhile for the managers their main concerns may be for the indoor environmental quality and energy consumption of their buildings rather than with the external aesthetics. Their stories are their experiences of these interactions, and others may (or may not) have quite different perspectives (Bell and Mores, 2007). However, given different weightings and scores by each stakeholder, it would be really meaningful to take their averages in real practice. For instance by making the average between the four selected architects, it is possible to read the overall trends for each selected indicators from their judgments. Thus, by recognizing KPIs as a tool to reach consensus among stakeholders, it seems useful to discuss a procedure to do so as a future topic.

Discussions

Although the research has generally achieved the specific objectives stated in the introduction, this research was limited to the following points:

- Determine the relative significance of different sustainability impacts is a problematic and complex process but one that is necessary if we are to identify sustainability priorities and make an informed decision toward better building performance and assessment;

- The AHP (pair-wise) comparisons of indicators can only be subjectively performed, and thus their accuracies always depend on the knowledge and experience of the raters on the issues and its field (Yurdakul, 2003). In fact, preference modeling of the human decision makers is often uncertain in many cases, and it is also relatively difficult for the decision maker to provide exact numerical values for the comparison ratios;

- New sustainability indicators might be added when new innovative features and properties developed. Complexity increases exponentially with the number of indicators or criteria and their interdependence (Wolfslehner et al., 2005). This requires more calculations and the formation of additional comparison matrices, and eventually requires significant time resources and efforts for completion from an application perspective (Wong, 2007);

- The research methodology adopted in this paper also imposed its own limitation. First, the size of the sample of this research was limited. Since the intelligent building industry is new and developing, a large sample of professionals was not available. Only a very limited number of experts could be identified for the surveys. The major group of experts were the design consultants together with engineers and facility managers;

- The key point is that we believe that the developed framework and key criteria identified in this study will improve the understanding of industry practitioners, but in a way that allows comparison, discussion and learning. Also, the developed framework is able to consider different levels of information and structure all relevant issues in an ordered manner, helping decision makers to handle the multiplicity of the issues embodied in the concept of sustainability.

Conclusions

The paper revealed that although the participation of all decision makers and stakeholders in the establishment of proper levels and weighting could facilitate the process of recognition and incorporation of regional diversities. The problem in this regard is in understanding the different stakeholder perspectives on what constitutes good performance in buildings in order to reach consensus about shared indicators and priorities and relationships. Also, weighting and expert weightings can skew results dependent on who is carrying out the evaluation, and thus results in a subjective assessment. The main difficulties associated with benchmarks include the definition of typical, good and advanced (outstanding) practice in intelligent buildings. In addition, subjectivity in sustainability is unavoidable and consensus needs to be reached by a wide variety of stakeholders. This should be facilitated by whoever is carrying out a sustainability assessment. Additionally, participation of stakeholders and decision makers in the establishment of benchmarks and weightings could significantly facilitate the process of recognition and incorporation of regional diversities (Alwaer, Sibley and Lewis, 2008).

The AHP approach was chosen since it was essential to collect data from experts who were highly experienced in the whole life span of intelligent building and thereby make a positive contribution to the identification of optimum design solutions and facility operation. Also, the AHP provides a means of structuring the decision maker’s mind by providing a systematic prioritisation of sustainability indicators. However, a large sample size seemed inappropriate in this paper as the intelligent building is a new form of building development which is yet to mature (Wong, 2007). The AHP is an analytical method which permits a small group of survey population. Thus, the AHP is helpful in collecting and analysing data from a small group of experienced experts. It is generally believed that feeding more information to the model (or experts) would lead to better decisions. It is meaningful to discuss accuracy of assessment of each weight. In this problem, however, it seems that further discussion about the consistency of each rater’s assessment and reliability of overall assessment should be carried out. In addition, reliable sustainability assessment is a difficult task; the CASIBs system was particularly intended to give guidance on which categories (indicators) are likely to have greatest sustainability impact in order to prioritize effort. This approach has led to a very large and complex system, which requires large quantities of detailed information to be assembled and input, causing further difficulties and frustration. However, it is essential to emphasise that the new proposed framework for selecting sustainability indicators is a starting point for discussion rather than any pretence at a finished, tried and tested, end product (Bell and Morse, 2003, p. 108).

Finally, based on continually changing and evolving character of information technology and due to appearance of new features intelligent buildings, new innovative features and criteria mean that new key performance indicators might be added (Wong, 2007). This implies that the models developed in this paper can be validated at least to a yearly time span, but it is subjected to the nature of changes in the environment including technological advancement and changes of user's values. Also, the models effectiveness in other countries will be ascertained when they have been claimed as broadly received. Thus, significant work remains to be carried out in order to make the measurement less complex, less subjective, more reliable and the process of calculation more flexible and easier to follow. Also, greater integration across various stakeholders, urban policy makers, planners and architects needs to generate a consensus in various sustainable buildings issues. The researchers contend that the CASIBs in its current form is most useful as a starting point for discussion. It cannot provide an absolute measure of the design quality of an intelligent building but can be used to articulate the subjective qualities felt by different stakeholders in the design process and thereafter in the use of a building.

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