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Key performance indicators (KPIs) and priority setting in using the multi-attribute approach for assessing sustainable intelligent buildings

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ABSTRACT

The main objectives of this paper are to: firstly, identify key issues related to sustainable intelligent buildings (environmental, social, economic and technological factors); develop a conceptual model for the selection of the appropriate KPIs; secondly, test critically stakeholder's perceptions and values of selected KPIs intelligent buildings; and thirdly develop a new model for measuring the level of sustainability for sustainable intelligent buildings. This paper uses a consensus-based model (*Sustainable Built Environment Tool- SuBETool*), 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 the sustainability assessment of intelligent buildings is introduced. The paper commences by reviewing the literature on sustainable intelligent buildings research and presents a pilot-study investigating the problems of complexity and subjectivity. This study is based upon a survey perceptions held by selected stakeholders and the value they attribute to selected KPIs. It is argued that the benefit of the new proposed model (SuBETool) is a 'tool' for 'comparative' rather than an absolute measurement. It has the potential to provide useful lessons from current sustainability assessment methods for strategic future of sustainable intelligent buildings in order to improve a building's performance and to deliver objective outcomes. Findings of this survey enrich the field of intelligent buildings in two ways. Firstly, it gives a detailed insight into the selection of sustainable building indicators, as well as their degree of importance. Secondly, it tesst critically stakeholder's perceptions and values of selected KPIs intelligent buildings. 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 managers.

1. Introduction

The recent decades have witnessed a maturing of concern and interest in building performance that is increasingly evidenced in building design. Sustainable or green design is not simply about attaining higher environmental performance standards or investing in new values; it is also about rethinking design 'intelligence' and how it is placed in buildings. The distinction between the notions "Green", "Intelligent" and "Sustainable" is critical in what underlies valid sustainable buildings. These concepts have no absolutes- these terms are more useful when thought of as a mindset- a goal to be sought, a process to follow [1]. Indeed, many of the concepts are pertaining to intelligent buildings have inherent relevance in sustainable building. 'Green' is part of being sustainable but tends to emphasise designs that considers the usefulness of applying solar energy, day-lighting and natural ventilation and reducing consumption, as well as treatment of any waste by recycling for example. However, sustainable building could be described as a "subset of sustainable development" which requires a continuous process of balancing all three systems environmental, social and economic sustainability [2] i.e sustain for future generations.

Implementing sustainable practices usually tends to raise the initial design costs, additional design services, commissioning, and certain green features may add as much as 2–7% (based on project nature and size) of total project cost [1], but operating costs can be reduced and healthier workplaces can lead to increased productivity thus whole life cost can be less. Meanwhile, '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. In other words, a sustainable intelligent building can be understood to be

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a complex system of inter-related three basic issues ***People*** (owners; occupants, users, etc.); ***Products*** (materials; fabric; structure; facilities; equipments; automation and controls; services); and ***Processes*** (maintenance; performance evaluation; facilities management) and the inter-relationships between these issues. These goals include all the phases of a building's life span, the environmentally friendly built environment with substantial safety, security, offering well being and convenience, a lower life cycle cost and long term flexibility, controllability and marketability. All this leads to achieving a building that has the best combination of environmental, social and economic values [3–6]. The differing emphasis of these and other definitions balances in various ways technological capacity, design value, and culturally perceived needs in the design of buildings. It is argued that "*intelligent buildings are not intelligent by themselves, but they can furnish the occupants with more intelligence and enable them to work more efficiently*"[7]. Holden [8] points "*... Intelligent buildings represent a key benefit that can reduce the initial capital outlay, as well as enabling a higher potential return on investment (ROI)*". From these definitions, technological innovation was not considered to be the main driver in the system selection. This finding reinforced the argument by Clements-Croome [4] that a true intelligent building is not necessarily a building with purely advanced technologies; instead it should be one with high values.

When aiming to reduce environmental impacts, yardsticks for measuring environmental performance are needed [9]. The term "*Building Performance*" is complex, since different criteria in the building sector have differing interests and requirements [10]. 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*" [11]. These methods are leading to pressure 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 sustainable buildings is measured, in part, by how well they support the management from the inception of the design process, to the recycling of its materials at the end of their useful life [12]. A wide range of existing issues are available in terms of sustainable intelligent buildings, which can be used for the aim of developing a new model called the Sustainable Built Environment Tool (SuBETool) analysed using the analytical hierarchical process (AHP) for multi-criteria decision-making, in which "*multiple methods*" involve quantitative and qualitative approaches [13]. Since the field of key performance indicators is vast, this inspired the authors to develop a conceptual model for the selection of the most appropriate key performance indicators for intelligent buildings. To achieve this a tour study has been conducted to: firstly, Identify key issues related to sustainable intelligent buildings (environmental, social, economic and technological factors); develop a conceptual model for the selection of the appropriate KPIs; secondly, test critically stakeholder's perceptions and values of selected KPIs intelligent buildings; develop a new model for measuring the level of sustainability for intelligent buildings; thirdly, 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 influence and select their own sustainability indicators, priority levels, benchmark comparison and building performance. The new tool explains how to analyse and interpret a broad range of data and 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.

2. Methodology outline

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 cohesive and coherent data management systems to a trusted format in order to ensure that the system performance is monitored properly, that reliability data is collected and that the relevant people are trained to analyse it for use by decision makers, designers and facilities managers [14]. It is advisable to think ahead so that data collected as part of a sustainability assessment can be reported as Key Performance Indicators (KPIs) [15]. 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 a yardstick for measurement of progress along the way*" [16]. The challenge in this case is to find effective indicators, requiring a clear conceptual basis. Hence, the selection of indicators will recognise the available data, resources and time, in addition to the interests and needs of the particular group involved in the selection of indicators [17]. The selected indicators must meet the following criteria [18–21]:

- Assist in informing choice in design decisions (Representative)
- Be usable by anyone- including professional designers and lay users (Reasonably simple)
- Allow participants to compare and contrast different options
- Be flexible, multipurpose and generic in nature, and useable on many different types of buildings (Sensitive to change).
- Comprehensive: Useable at different phases in a buildings life cycle: concept, design, construction and in use.
- Easy to use, with a simple and clear interface.
- Reflect specific issues that could have impacts on sustainable buildings for current and future developments.
- Be quantifiable and scientifically valid (quantitative criteria or qualitative converted to quantitative).
- Be cost effective but give value.
- Data accessibility should be made easy and not constrain the process [20].

The initial step is to choose the most appropriate criteria to formulate an '*indicators set*', which considers the building's performance in relation to the local environment, culture and economy, as well as business goals [22]. To test this approach, the search for appropriate indicators was conducted first by reviewing the literature and second by a survey with a number of professionals by inviting key people from each of the following disciplines to participate: architect, engineers, and facilities managers in order to investigate which KPIs were perceived as most relevant to intelligent buildings. Large samples of professionals are not always available so only a limited number of experts were identified for the surveys described here but the sample included design consultants and facilities managers. 20 stakeholders were presented with the proposed selection criteria, were invited to review the relevance,