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Development of an energy efficiency rating system for existing buildings using Analytic Hierarchy Process – The case of Egypt

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ABSTRACT

This article presents the outcomes of a recent study carried out among engineering professionals and academics in Egypt to propose a criteria-based energy efficiency rating system for existing buildings. It discusses the use of a multiple criteria decision making technique, namely the Analytic Hierarchy Process (AHP), for developing the weights of the proposed rating system criteria, and generally reviews the use of AHP to develop building energy rating systems. While the AHP approach of criteria weighting was applied in other countries, the present study distinctively applied it to developing a proposed rating system for existing buildings in Egypt. In this study, nine energy rating criteria were identified by thoroughly comparing and analyzing internationally established green building / sustainability rating systems for existing buildings such as LEED, BREEAM, Green Globes, Energy Star, IGBC and Pearl rating system for Estidama. A survey was then conducted to collect the opinions of Egyptian engineering professionals regarding the relative priority of the identified criteria, and to determine, according to the opinions of participants, which criteria are mandatory and which are optional for existing buildings seeking to become 'greener'. Using AHP, weights were developed for the optional criteria, representing their relative importance. Based on the performed analysis, the resulting rating criteria are: one mandatory prerequisite, which is the Minimum Energy Performance, and eight optional credits with descending relative weights, which are: Use of Renewable Energy Sources, Building Envelope Efficiency Strategies, Use of Energy Efficient Appliances and Equipment, Building Systems Automation and Controllability, Eco-friendly Refrigerants & Fire Suppression Systems, Operation and Maintenance Practices, Metering and Sub-metering of Building, zones and systems and finally Building-related Transportation Impact.

1. Introduction

The global climate change facing the world today requires quick and cost effective efforts in order to preserve the natural resources of our planet. The enormous increase in the global demand for energy, resulting from industrial development and population growth, is reflected in a similar increase in the usage of fossil fuels (oil, gas and coal). The environmental problems associated with the use of fossil fuels (such as global warming) have grown into a worldwide challenge. Moreover, the continuing dependence on fossil fuels as energy sources results in an energy crisis, as these resources are limited and exhaustible by nature. The call for more sustainable energy usage patterns has grown substantially, and the terms "Sustainability" and "Green Building" have become concepts of widespread interest. The research and development of sustainability standards and rating systems became an international trend.

Policies, standards and research efforts were, in general, more focused on sustainability practices for newly constructed buildings, with less attention towards existing buildings stock. While many rating systems exist on the market, they share two common features: suiting their local environment and targeting four main themes: environmental impact, energy conservation, benchmarking and measurement, and energy use policy and management.

In Egypt, the government is increasingly concerned about the rising energy demand and the corresponding budget burden from energy subsidies. The solution to this problem can be either to increase the energy supply to fulfill the continuously increasing demand, or to improve the efficiency of the energy demand itself. Clearly, improving the efficiency of existing energy demand is more practical than continuously increasing the supply capacity to match the ever rising future energy demand. In this direction, there have been some efforts from the government and from the academic and professional fields in Egypt to develop national regulations for energy conservation, and rating systems for the assessment of building energy efficiency.

The objective of this article is to review the methods used to develop building energy rating systems on the regional level, and to highlight

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the use of the Analytic Hierarchy Process (AHP) method in prioritizing and developing the relative weights of rating system criteria. A recent study which was conducted in Egypt using this methodology is then presented. The outcomes of this study are not only of national importance, but also of high regional significance to other developing countries, especially in the Middle-East North Africa (MENA) region.

2. Importance of "greener" existing buildings

It is estimated that buildings worldwide account for 40% of global energy consumption [1]. Therefore, large and attractive opportunities exist to reduce energy use and consequently natural resources by directing attention towards improving the energy performance of buildings. Most of existing buildings are not energy efficient, with several potential opportunities for upgrading their systems and equipment to be more efficient and thus retrofitting of existing buildings represents an opportunity to achieve some of the most budget-effective energy savings and emission reductions. There is also an associated market opportunity to implement building energy upgrades that serve as an engine for new jobs and capital investments.

2.1. Sustainable versus green buildings

It is important to begin by presenting the definitions of two key terms: Green Building and Sustainability. Although often used interchangeably in the context of environmentally friendly practices, these two concepts have distinct yet related meanings which should be clarified.

The definition given by the United States Environmental Protection Agency (EPA) is that a green building is "*one whose construction and lifetime of operation assure the healthiest possible environment while representing the most efficient and least disruptive use of land, water, energy and resources*" [2]. Another definition given by EPA for green building is "*the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or 'high performance' building*" [3].

The United Nations (UN) defines sustainable development as the "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" [4]. According to the EPA, sustainability is "*to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations*" [5].

Based on the previous definitions, a green building can generally be defined as a building designed, constructed and operated to minimize its adverse environmental impacts. Sustainability is the general philosophy of adopting resource usage practices which are more responsible regarding human and environmental impacts. The main strategies of green building practices include:

- Reducing resource consumption (i.e. energy and water).
- Reducing negative environmental impacts (i.e. by waste recycling, habitat conservation and greenhouse gas reduction).
- Creating a healthier life and work environment for people (i.e. improved air quality, visual and thermal comfort).

The UN World Summit on Sustainable Development defined three "interdependent and mutually reinforcing pillars" of sustainable development: Economic development, Social development and Environmental protection [6] Fig. 1.

As green building is essentially a process of continual improvement, in which the best practices of the present become standard practices of the future, the transformation of conventional practices toward sustainability is "*an ongoing effort that will never be truly complete*" [7].

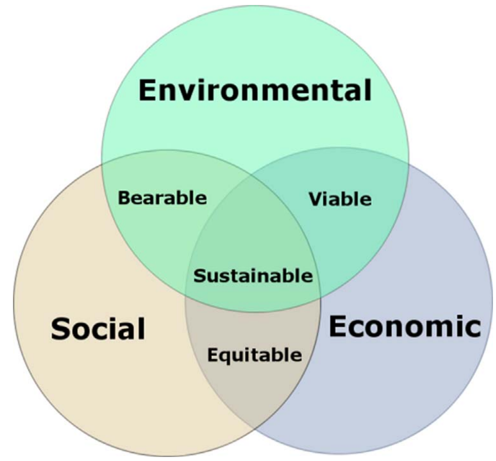

Fig. 1. The three pillars of sustainability.

2.2. Motivation for targeting existing buildings

While much attention from the research community has targeted policies and measures regarding the sustainability of new buildings, significantly less effort has been directed at improving the energy performance of the existing building stock. This is mainly due to the perceived freedom of action in the design and construction of new buildings, as opposed to the inherent constraints in improving the energy performance of existing buildings. Another important reason is the cost barrier of such improvements as perceived by existing buildings owners and/or operators, who see any significant energy performance improvements as cost prohibitive. Owners and operators analyze proposed improvement measures using cost-benefit Analysis (CBA) and/or return-on-investment (ROI) and, with the lack of recognition, regulations or incentives, they often find those improvements impractical.

The energy used in buildings during their operation phase can be around 80% of the total energy [1], with the remaining 20% being the energy consumed in construction, demolition, and the embodied energy in the materials of the building (see Fig. 2). Therefore, it is both logical and practical to identify and pursue energy saving opportunities in existing buildings.

Consequently, much can be achieved by establishing policies and guidelines to promote the adoption of energy efficiency improvements in existing buildings. Recognition of existing buildings improvement efforts through an energy efficiency rating system is a crucial step

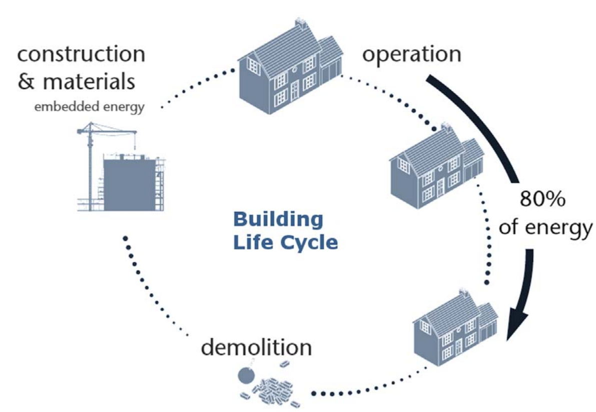

Fig. 2. Building life cycle (source: WBCSD "Energy Efficiency in Buildings – Transforming the Market". 2009).