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Criteria weighting for green technology selection as part of retrofit decision making process for existing non-domestic buildings

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ABSTRACT

The implementation of green technologies, as part of retrofit, can significantly improve building performance. However, green technology selection is a complex decision making process due to multiple evaluation criteria and often conflicting interests of different stakeholders involved. This paper proposes default criteria weights based for previously-developed criteria tree consisting of in total 39 criteria organised around environmental, economic, social and technical performance of green technologies. Web-based surveys of experts including architects, engineers, planners in the UK and China were conducted to capture expert opinions on sustainability and technical criteria. Analytical Hierarchy Process (AHP) method was used to calculate default criteria weights. Comparisons between expert groups in different countries were also performed. Results show that UK experts more concern about *Economic* performance of green technology, specifically with UK architects and engineers assigning high weights on *Cost*. For the *Environmental* category, *Reduction of energy consumption* and *Reduction of water consumption* are ranked as the most important topics under *In-use environmental performance* by all experts. UK experts have shown a growing concern on *Reduction of water consumption*. Under *The improvement of indoor environmental quality*, *Thermal comfort* is ranked as the most important criterion by UK experts and *Visual comfort* is weighted as the first priority by Chinese experts. Compared with UK experts, Chinese experts have placed a significant importance on *Technical* criteria, represented by engineer group emphasising on *Durability* for this category.

1. Introduction

With increased awareness of environmental pollution, natural resource depletion and social issues, sustainable development has become a growing concern throughout the world (Newton & Bai, 2008). At the same time, buildings have been identified as one of the heaviest consumers of natural resources, accounting for 40% of global energy use, 30% of energy-related GHG emissions, approximately 12% of water use and nearly 40% of waste (UNEP, 2015). For buildings to be more environmental friendly, there is a need to reduce energy and water consumption during operation and take advantage of recycling opportunities at the end of the building life cycle (Wilkinson, 2012). Apart from environment, buildings can affect occupant productivity and business profitability (Clements-Croome, 2006) as well as human wellbeing and community engagement (Akadiri, Chinyio, & Olomolaiye, 2012).

Building performance can incorporate performance in Energy Efficiency, Water Efficiency, Indoor Enviromental Quality and health and wellbeing (BRE, 2016). Whilst improvement in environmental performance of new buildings is primarily driven through legislative efforts, existing buildings often require retrofits to improve their environmental or sustainable performance. Environmental, economic, social and technical implications of building retrofits have been investigated through several studies (Chidiac, Catania, Morofsky, & Foo, 2011; Juan, Gao, & Wang, 2010; Menassa, 2011). Green technologies such as efficient lighting, PV panels and monitoring systems have proved to improve the building performance to a certain level (BRE, 2015a, 2015b).The findings indicate that existing building retrofits can offer significant opportunities for improving overall sustainability performance (Castleton, Stovin, Beck, & Davison, 2010; Langston, Wong, Hui, & Shen, 2008; Ma, Cooper, Daly, & Ledo, 2012; Ruparathna, Hewage, & Sadiq, 2016). Despite the fact that improved performance through building retrofits was demonstrated for non-domestic buildings (Huang, Niu, & Chung, 2013; Rahman, Rasul, & Khan, 2010), research on domestic building stock is still dominant.

There is a wide range of green technologies readily available for retrofit projects. However, the decision as to which green technology

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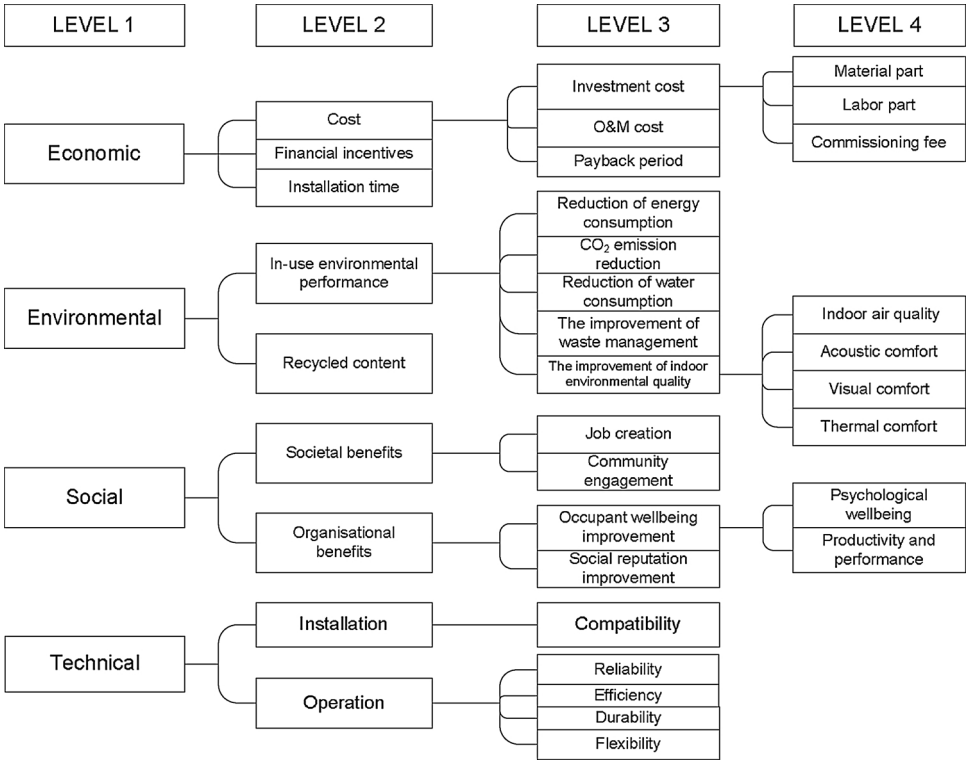

Fig. 1. Integrated AHP hierarchy with multiple criteria (Si et al., 2016).

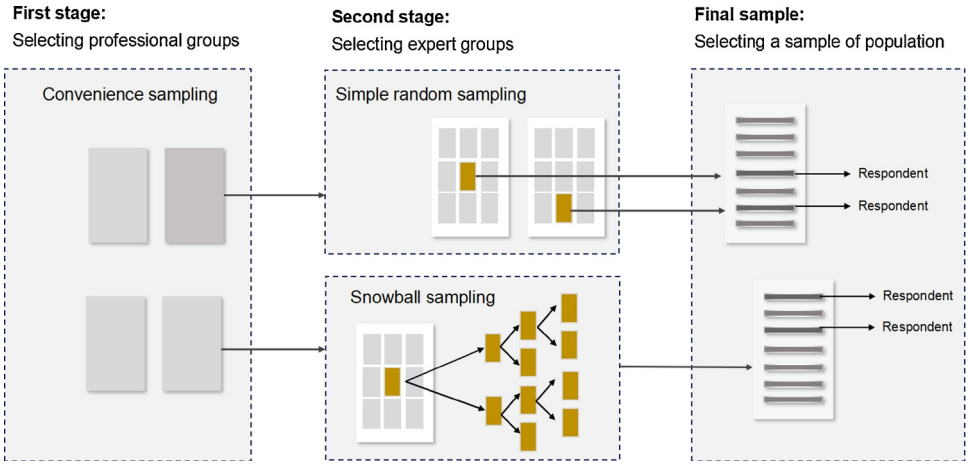

Fig. 2. Multi-stage sampling strategy.
Adapted from Raslan (2010).

Table 1
Targeted professional groups.

Country	Professional groups
UK	MSc Environmental design and Engineering alumni community
	Industry corporation intranet
	LinkedIn Connections
	Total
China	Institutes of Architectural Design personal connection
	Industry corporation intranet
	Higher Education personal connection
	Total

should be selected is a complex decision making process subjective to several technological alternatives, multiple decision criteria and different stakeholder perspectives (Dangana, Pan, & Goodhew, 2013; Pan, Dainty, & Gibb, 2012; Wang, Jing, & Zhang, 2009). Whilst ultimate goals of sustainable development can be considered universal, the sustainable construction has different approaches and different priorities in different countries (Bourdeau, 1999) and the refurbishment part of construction industry is not the exception. In addition to economic and social differences number of other variables and their importance vary from country to country. Agenda 21 on sustainable construction (CIB, 1999) fully recognised that activities within the construction sector driven by sustainable development agenda will be effected by local constructs such as professional practice, nature of building stock, level of industrial development.

Moreover, the stakeholders from different backgrounds may have contrasting opinions which can influence the final decision (Dangana et al., 2013; Zainab, Pan, Goodhew, & Fuertes, 2013). Multi-Criteria Decision Making (MCDM) methods have been successfully used in selecting green technologies for buildings (Collier, Wang, Vogel, Tatham,