A Decision Making System for Selecting Sustainable Technologies for Retail Buildings

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A Decision Making System for Selecting Sustainable Technologies for Retail Buildings

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Abstract

The implementation of sustainable technologies can improve the energy and carbon efficiency of existing retail buildings. However, the selection of an appropriate sustainable technology is a complex task due to the large number of technological alternatives and decision criteria that need to be considered. Also, there exist series of uncertainties that are associated with the use of sustainable technologies, but have to be evaluated to achieve realistic and transparent results. The selection of sustainable technology is therefore most challenging.

An earlier study was conducted with UK experienced practitioners including clients/developers, engineers, contractors and suppliers to identify the drivers and barriers for the use of sustainable technologies in UK retail construction. One major barrier identified from the study was the lack of a decision making tool, highlighted by both construction professionals and stakeholders in the retail industry. The large number of alternatives and potential solutions require a decision support method to be implemented. Information data on the economic variables, energy performance and impact on the environment of these systems is presently affected by vagueness and lack of knowledge. To deal with this high level of complexity and uncertainty an evaluation support approach is needed.

This paper aims to develop a decision making framework to assist both retailers and construction professionals to define and evaluate the selection of sustainable technological options for delivering retail buildings. The research was carried out through a combination of a critical literature review and a survey-based study using expert opinions of retailers and contractors. The developed framework of decision criteria should provide a sustainable technology model to assist both construction professionals and stakeholders in the retail industry to systematically and effectively select the most appropriate technology. This approach should make the decision progression more transparent and facilitate sustainable development of retail buildings in achieving the carbon targets set by the UK and other governments.

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1. Introduction

Sustainability has become an increasing concern for the retail construction industry as construction activities have a significant impact on waste, energy use and greenhouse gas emissions (Ozorhon et al. 2011). Carbon emissions from energy use in non-domestic buildings account for around 18% of total emissions in the UK of which 18% is from retail (Carbon Trust 2009). A large number of new policies and regulations are being introduced to minimize the impact of the built environment and the construction industry on the environment, such as the ambitious targets set by the UK government to reduce carbon emissions by 80% by 2050 compared to 1990 levels (HMG 2010). These pressures are inducing a large amount of product and process innovations across the retail construction industry amongst manufacturers, suppliers, installers, clients, users, and many others. This has led to an increased interest in sustainable retail buildings, which has resulted in pressure to install sustainable technologies in buildings prior to the evaluation of their full life cycle implications.

The study on which this paper reports is part of an on-going research project which aims to optimise the process, energy and carbon efficiency in retail construction by capitalising on sustainable technology. This research project addresses an overarching research question: "How can the use of energy and carbon be reduced for retail construction in a commercially viable way?"

An exploratory study has been conducted with retailers and construction professionals in the retail construction industry (Dangana et al. 2012). The study reviewed the design and construction of sustainable buildings within the context of retail construction; identifying the drivers, barriers and opportunities for sustainable retail buildings and it explored how the UK mainstream retail sector is currently addressing the challenges related to sustainable retail buildings. The study identified the lack of a decision making system for the selection of appropriate sustainable technological innovations to optimize the process, energy and carbon efficiency for retail buildings. Currently, designers, constructors and retailers interested in adopting sustainable technologies in the retail construction industry have no comprehensive evaluation approach to review and select technologies. There is a demand for a systematic and effective evaluation tool for the selection of sustainable technologies (Pan et al. 2012, Devoudpour et al. 2012). The results indicate a big challenge for stakeholders in the retail construction industry to adopt implementation strategies that will support sustainable retail buildings overcoming the barriers for the slow uptake of sustainable technologies.

The results are similar to a study conducted by Odhiambo (2010), which highlights that there is currently no comprehensive standard evaluation process to assist construction professionals to perform a holistic selection of a ST; with most studies addressed from a single issue perspective without taking into account other issues. The current evaluation approaches used by construction professionals for the selection of STs, such as financial models are inadequate as technology selection is a multi-criteria decision problem. Decision makers are unable to make selections due to lack of value-based decision criteria (Pan et al 2012), and also because some benefits of STs are easily measured (water, energy) while some are subjective, intangible or indirect such as improvements to productivity and health (Huang et al. 2011). Thus there is a great need for a methodology to assist decision makers to systematically select STs which addresses multiple criteria rather than from a single criteria approach to obtain an integrated decision making result (Wang et al. 2009). This holistic approach would allow the selection of STs relative to stakeholders' objectives and consider the total influence on all systems (Belton and Stewart 2002).

The aim of this present paper is to address the gap in knowledge of sustainable technology selection by proposing a conceptual decision making system to assist both retailers and construction professionals to define and evaluate the selection of sustainable technological options. The system is based on the concept of MCDA and sustainable development, in which the technologies can be analysed, evaluated and finally compared to select the optimal variant according to a set of criteria (Huang et al. 2011) based on the objectives of the stakeholders.

2. Literature Review

"Sustainable technology" (ST) is defined as technology that provides for our current needs without sacrificing the future ability of populations to sustain themselves (Hmelo et al. 1995). Sustainable technology is not a new concept but is similar to the theory of "appropriate technology" (i.e. technology designed with special consideration for the environment, ethical, cultural, social and economic factors) that evolved in the1970's, but has recently gained importance due to the increasing negative impacts of human activities on the planet and desire to promote sustainable development (Odhiambo et al. 2010). Sustainable building technologies include concepts and products that provide significant improvements in terms of the use of resources, harmful emissions, life-cycle costs and productivity, and building performance (Hakinenene at al. 2011). STs serve to contribute, support or advance sustainable development by reducing risk, enhancing cost effectiveness, improving process efficiency, and creating processes, products or services that are environmentally beneficial or benign, while benefiting humans (DuBose et al. 1995).

Research conducted for the Intergovernmental Panel on Climate Change (IPCC 2007) estimates that around 30% of the baseline CO_2 emissions in buildings projected for 2020 could be mitigated (avoided) in a cost-effective way globally, at no or even negative costs, if various sustainable technological options were introduced. Similarly, Carbon trust (2009) estimates that reducing the carbon emissions from the UK's non-domestic buildings by 35% by 2020 could result in a net cost saving to the UK economy of more than £4.5 billion using simple and cost-effective building technologies that exist today. The use of sustainable technology emerges consistently as "one of the vehicles to enhance sustainability in the built environment" (Odhiambo et al. 2010) and is used as a strategy by construction professionals to design sustainable retail buildings.

The selection of sustainable technologies is a complex and important task due to the rapid development of technologies, lack of skills and knowledge, uncertainties, risks, and a large number of technological alternatives and decision criteria that need to be considered (Pan et al. 2012, Wang 2009, Dangana et al. 2012). It can have significant implications on building performance and stakeholders' satisfaction; creating long-term problems and hindering the adoption of such technologies. It is therefore necessary to base sustainable technology selection decisions on a clear understanding and a proper evaluation of the full range of implications associated with it. However, designers and clients face significant challenges in the selection of appropriate sustainable technologies due to certain characteristics of markets, technologies, and end-users which inhibit rational, energy-saving choices in the purchase and use of appliances as well as during the life-cycle of a building (HMG 2010, Dangana et al. 2012). Also, the risks associated with the reliability and effectiveness of new innovative products dissuades many professionals from specifying green or sustainable building materials (Pearce and Vanegas, 2002, Hakinene et al. 2011). This lack of enthusiasm may be attributable to clients' risk aversity and the risk-averse culture of the construction industry (Pan et al. 2012).

Currently, a Problematic selection approach is used in which many construction professionals choose to intuitively derive such decisions using their own perceptions of established professional experience. In such cases, the criteria evaluation process is very subjective and relies heavily on a manager's experience and knowledge, as well as intuition (Wang et al. 2009). This has led to bias in the decision making process as it is based on limited issues and the influence on other systems of the building are not taken into account (Odhiambo et al. 2010). A systematic approach is needed for the retail construction industry to identify value-based criteria and establish their relative importance to achieve decision making objectives for the selection of sustainable technologies. The use of new efficient processes and knowledge of decision making phases can assist in the selection of STs (Hakinene et al. 2011), and also overcome the hindrances of using STs (Davoudpour et al 2012).

Multi-Criteria Decision Analysis (MCDA) emerged as a formal methodology to support decisions in many fields and has been valuable in environmental decision making (Huang et al. 2011). MCDA is not a tool providing the "right" solution but an aid to decision making to assist stakeholders organize available information, consider the consequences and minimize the possibility of a post-decision disappointment (Belton and Stewart 2002). Wang (2009) describes MCDA as an operational evaluation and decision support approach suitable for addressing complex problems with high uncertainty, conflicting objectives, different forms of data and information, multi interests and perspectives in order to provide an integrated sustainability evaluation. The MCDA approach will be adapted and used to develop the conceptual framework for this study.

2.1 Decision making for selecting sustainable technologies

Decision-making problems involve the process of searching or finding the course of actions from a given set of feasible alternatives which maximizes or satisfies certain criteria associated to the goals intended to be achieved (DCLG 2009). Decisions are made within a decision environment, which consists of the collection of information, alternatives, values and preferences available at the time when the decision must be made. Peldschus et al (2010) describes decision making as “a process involving activities that starts with recognition of a decision making problem and ends with recommendation for a decision”. The process can range from highly structured to highly unstructured decisions (Belton and Stewart, 2002) using either an alternative-focused or value-focused approach (Peldschus et al. 2010).

One of the main goals in decision-making for sustainable retail buildings is to identify and choose the most sustainable technological option from among different alternatives. This complex decision problem usually involves a large number of stakeholders with multiple, often conflicting, objectives (Wang et al. 2009). The selection of sustainable technologies requires a highly structured, alternative-focused approach as the decision problem starts with a choice of options and involves the process of selecting a preferred option from multiple alternatives in a structured way.

Techniques such as multi-criteria decision making methods support decision makers when faced with such a problem with a set of criteria on a set of alternatives. The adoption of multi-criteria methods helps to organise the decision-making process and usually includes four main stages: alternatives’ formulation and criteria selection, criteria weighting, evaluation, and final treatment and aggregation (Belton and Stewart 2002). There has been a significant use of multiple criteria decision analysis (MCDA) tools over the last two decades for environmental decisions (Wang et al. 2009, Huang et. al. 2011). MCDA has been successfully applied to solve evaluation problems in various fields such as sustainable energy, quality of service, engineering systems and new product development (Chen et al 2010, Pan et al 2012, Huang 2011).

The evaluation and selection of building technologies has been widely studied, with most decisions based on knowledge-based techniques which take into account economic sustainability (Wang et al. 2009, Krisciunas et al. 2007). Multiple criteria approaches have been used by various authors for evaluating technical, environmental, social and economic aspects (Pan et al. 2012, Chen et al. 2010, Odhiamba et al. 2011). Sawers (1998) applied decision making matrices as a methodology for designers to compare design alternatives, considering both the objective economic traditional criteria as well as subjective factors such as competitive advantage, improved management information or strategic alignment. This approach does not identify project objectives but it illustrates how attributes can be structured into a value hierarchy where each attribute is weighted according to its importance relative to other attributes from the perspective of the stakeholders. Nassar et al. 2003 used multiple criteria for assessing construction methods but constrained the technical processes from the designers’ perspectives. Similarly, Nelms et al. (2005) presented a synthesis of classification systems that focused on the use of technical attributes of building systems and developed a comprehensive framework that incorporated a set of evaluation criteria that built on the work of other authors. Pan et al. (2012) developed a systematic approach for UK house building organizations to identify value based decision criteria and quantified their relative importance for assessing building technologies systematically.

The proposed framework represents an integration and extension of these works and is developed to evaluate and select sustainable technologies from retailers and contractors perspectives for this study. The MCDA approach has been adapted for the development of the conceptual framework and comprises of three steps; problem identification and structuring; model building and use; and the development of action plans (Figure 1). The framework is intended to be holistic, to include the subjective qualities inherent in sustainable technologies and to reflect the retailers and constructors viewpoints as these have been perceived to be the main decision makers.

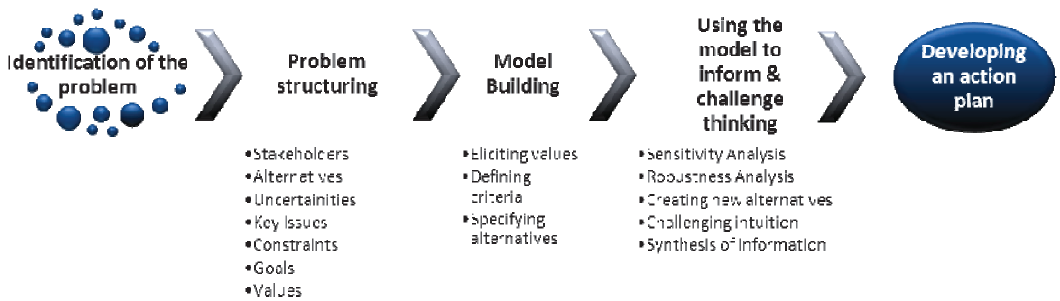

Figure 1: MCDA Approach (Adapted from Belton and Stewart 2002).

3. Methodology

In this study, decision maker(s) or other stakeholders involved in the decision situation are those identifying the nature of the problem and driving the solution procedure towards the preferred direction. Although the two terms are sometimes used interchangeably, for our purposes, decision makers are those assigned with the responsibility to take the final decision, whereas stakeholders is a much broader notion encompassing any single individual or group of people with an interest or concern in the potential problem. When multiple stakeholders are involved in a decision problem, a common understanding of the problem should be achieved through the elicitation of ideas and the sharing of concerns and values. This phase of the study focused on the stakeholders directly involved in the decision problem in order to detect their preferences and values by engaging with those that actually influence the decision (retailers and construction professionals in the retail industry). Hence, the extracted values better reflect concerns and priorities of the people directly affected and were specific, measurable, agreed, realistic and time-dependent (DCLG 2009).

The methodology adopted included a critical literature review and a study using expert opinions of retailers and contractors. Qualitative data was collected using a focus group and semi-structured interviews. The aim was to understand key issues that retail industry stakeholders are concerned with related to the selection of sustainable technologies. Face-to-face semi-structured interviews were carried out with ten senior managers from a leading UK retail contractor company in order to capture the points of view that decision-makers use as a frame for reference in their selection process. The focus group consisted of 12 participants (six retailers and six construction professionals) with experience in retail construction. The CAUSE (Criteria, Alternatives, Stakeholders, Uncertainty, and

Environment) checklist was used to generate and capture ideas to identify the problem of why there was a slow up-take of sustainable technologies (Belton and Stewart 2002).

4. The proposed conceptual decision making system

The conceptual decision making system utilises a set of criteria generated based on the results from the study. It presents a multiple criteria decision analysis problem and the MCDA approach will be adopted and recommended in solving the problem. The key steps of utilising the MCDA process are explained below.

4.1 Identify the problem

This first step of the MCDA process is to identify the issue under consideration, to agree on the focus and the scope of the analysis, and to recognize external constraints such as physical or legislative environments, or time and resources available (DCLG 2009, Belton and Stewart 2002). The identification of the global goal would form the basis for structuring the problem systematically. The issue under consideration was, “The selection of appropriate sustainable technologies to optimize the process, energy and carbon efficiency for existing retail buildings” (Dangana et al. 2012).

4.2 Structure the problem

This is a critical step for the subsequent analysis; it is often said that “a well-structured problem is a problem half solved” (Belton and Stewart 2002).

The triangulation approach was used to ascertain whether the themes identified within the literature review were perceived to be the same by professionals working in the retail industry today; providing a more robust evidence basis for the argument (Bryman 2012).

Based on the study, review and information from industry professionals, a combined list of 22 factors influencing the selection of sustainable technologies for retail buildings was produced. A preliminary coding exercise utilising Nvivo software was used and the 22 factors were grouped under the thematic headings of drivers, barriers and opportunities as illustrated in Figure 2. These factors provide the basis for structuring the problem and represent a fairly complete perspective of the user with regard to the problem. They can be used directly as criteria for evaluating and subsequently selecting the appropriate technology. The next stage involves model building to develop a framework for the evaluation of alternatives.

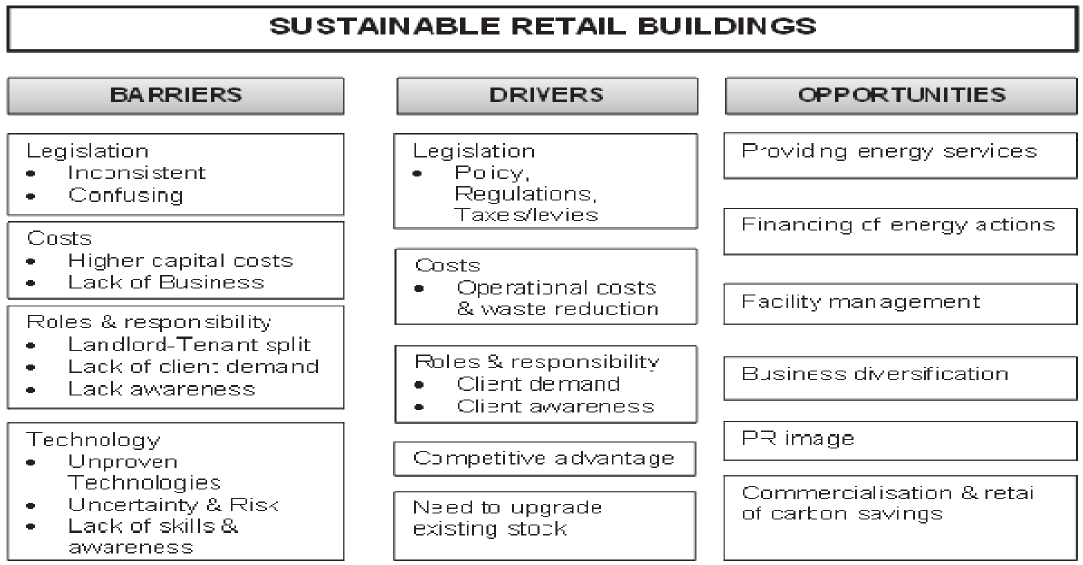

Figure 2: Sustainable retail buildings

4.3 Build the model

This is a dynamic process, both informed by and informing the problem structuring process and interacting with the process of evaluation (DCLG 2009). The type of model used depends on the nature of the investigation and the particular approach to be selected for analysis. The key elements for the model framework are based on the CAUSE framework; the alternatives to be evaluated; the model of values (criteria, objectives, goals) against which they will be evaluated; and how key stakeholders perspectives' on the decision and uncertainties will be taken into account and modelled (Belton and Stewart 2002). A preliminary set of criteria was established by the researcher from the problem structuring phase (Table 1).

Table 1: Preliminary Set of Criteria

Criteria for selection of sustainable technologies.	Reason
Focus on refurbishment & retrofitting of retail buildings (non-domestic buildings)	• It is estimated that by 2050 around 70% of the 2010 building stock will still be in use; it is very clear that low carbon retrofit would have a huge role to play in achieving carbon emission targets (Carbon Trust 2009). • A leading UK contractor which is a good representation of the industry is involved in 95% refurbishment / retrofit projects and only 5% new build. This translates to a ratio of 19:1. • There has been much recent focus on measures to reduce the emissions from new retail buildings; the existing stock remains largely untouched (Dangana et al 2012).
Technologies to focus on optimising process, energy and carbon efficiency for retail buildings.	• Carbon emissions from energy use in non-domestic buildings account for around 18% of total emissions in the UK of which 18% is from retail (Carbon Trust, 2009). Significant cuts in emissions is essential as part of the UK's commitment to reduce carbon emissions by at least 80% by 2050. • Energy costs are typically the second highest operating expense for a retailer, so implementing cost-effective energy saving strategies will have a direct and significant impact on profitability (ASHRAE Website).

	• A 10% decrease in energy costs has an equivalent impact on operating income as a 1.26% increase in sales for the average retail store (Energy Star website 2012)
Early adopter and early majority technologies to be explored	• The technology adoption lifecycle model describes the adoption or acceptance of a new product or innovation. The model indicates that the first group of people to use a new product is called "innovators," followed by "early adopters." Next come the early and late majority, and the last group to eventually adopt a product are called "laggards." • The capacity to innovate – or innovativeness – can lead firms to profitable outcomes, making significant contributions to the performance and efficiency of a business. Innovativeness in organizations can lead to competitive advantage and business performance.

4.4 Identification of alternatives and criteria to be evaluated

This involves the identification of key factors which will form the basis of an evaluation. These are referred to as values, objectives, criteria, points of view (Belton and Stewart 2002). The term "criteria" will be used in this study and these are the measures of performance by which options can be judged. DCLG (2009) suggested two overall approaches for identifying decision criteria: bottom-up and top-down. The bottom-up method is used to identify criteria if options are already given by asking how the options differ from one another in ways that matter. The top-down method is used to identify criteria based on the overall objectives provided by asking about the aim, purpose, mission or overall objectives to be achieved (Pan 2006). In this study the top-down approach was more appropriate for the selection of sustainable technologies using the perspectives of a leading UK contractor and retailers.

The study identified 22 criteria; these were clustered and grouped into several sets that relate to separate and distinguishable components of the overall objective. The main reasons for grouping criteria were: to ensure the set of criteria selected is appropriate to the problem; to ease the process of calculating criteria weights; to help organize the criteria and objectives; to facilitate the emergence of higher level views of the issue; and to highlight conflicts in objectives leading to refinement (DCLG 2009).

The decision criteria at the first level clustered the criteria under the main stakeholders (retailers and contractors) who were perceived to play a key role in decision making for the selection of sustainable technologies. The criteria were then broken down into the second level with 10 broad criteria (Figure 3). The conceptual hierarchy presented will undergo a process of refinement, iteration and modification in the next phases of the study.

The next step involves evaluation and exploration of alternatives to identify the options that contribute to the achievement of the decision objective. The alternatives may be relatively few and explicitly defined or from a large pool of alternatives as is the case in this decision problem.

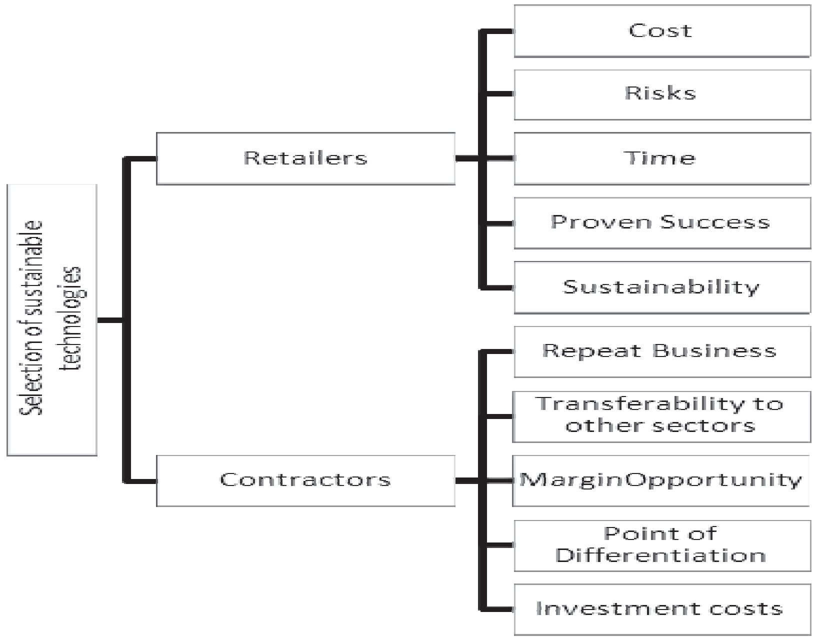

Figure 3: Value Tree of Criteria for Selection of Sustainable Technologies

5. Conclusions and future research

The selection of sustainable technology is an important and complex task due to the rapid development of technologies, lack of skills and knowledge, uncertainties, risks, and a large number of technological alternatives and decision criteria that need to be considered. This can be classified as a complex multi-criteria decision problem due to the high number of alternatives, potential solutions and various stakeholders (clients, professional advisors, end-users) leading to the slow take-up of sustainable technologies.

This paper has developed a decision making system to assist both retailers and construction professionals to define and evaluate the selection of sustainable technological options. This system involved a process of establishing decision criteria, which included clarifying the decision context, establishing decision objectives, identifying, clustering and assessing decision criteria. The study has generated a set of criteria against which sustainable technologies will be evaluated and compared in the next phase of the study. The matrix of criteria would be reviewed and evaluated every year to accommodate the changing needs of the stakeholders.

The decision making system should provide a sustainable technology model to assist both construction professionals and stakeholders in the retail industry to systematically and effectively select the most appropriate technology. From a communication perspective the system will provide a means for all levels of decision-makers to share their concerns and findings. In addition, it will also help to promote dialogue amongst different stakeholders to foster appropriate risk allocation at the outset of the project or before use of the technology. This should make the decision progression more transparent and facilitate sustainable development of retail buildings in achieving the carbon targets set by the UK and other governments.

Nevertheless, it is worth noting that although the aim of this paper is to develop a decision making framework to assist both retailers and construction professionals to define and evaluate sustainable technology selection for retail buildings, the decision making criteria were explored predominantly from the perspective of a main contractor and their clients and supply chains. There are other key stakeholders, such as architects, planning officers, end-users, which also play an important role in the selection of sustainable technologies. The decision criteria which these stakeholders use should also be explored and included in the decision making system, which will be studied in the next stage of the research.

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