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Zainab, S

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Contractors' Perspective on the Selection of Innovative Sustainable Technologies for Low Carbon Retail Buildings

Syeda ZAINAB[1], Wei PAN[2], Steve GOODHEW[1]and Alba FUERTES[1]

[1] School of Architecture, Design and Environment, Plymouth University. PL4 8AA, UK; email: rutsdangana@plymouth.ac.uk
[2] Department of Civil Engineering, The University of Hong Kong, Pokfulam, Hong Kong, China; email: wpan@hku.hk

ABSTRACT

The use of innovative sustainable technologies (IST) has been regarded as an effective approach to enhancing energy efficiency and reducing carbon emissions of buildings. However, contractors face significant challenges in the selection of IST. The reported challenges in the literature include: lack of skills and knowledge, uncertainties, risks and the rapid development of a large number of technological alternatives and decision criteria. The selection process emerges as a multi-attribute, value-based task that includes both qualitative and quantitative factors, which are often assessed with imprecise data and human judgments. This paper aims to establish the decision criteria for the selection of IST for achieving low carbon existing retail buildings with a focus on the main contractor's perspective. The arguments are informed by the combination of literature review and an in-depth case study with a UK leading contractor. Five broad decision criteria are identified systematically drawing on the contractor's practice. The established criteria are weighted and ranked using the analytic hierarchy process and expert opinions; with 'margin opportunity' being the most important, followed by 'repeat business', 'investment costs', 'differentiation' and then 'transferability'. The findings should facilitate the integration of various facets of the selection process and stimulate contractors to use IST.

Keywords: Criteria selection, decision-making, contractor, innovative sustainable technology, low carbon retail buildings.

INTRODUCTION

Retail buildings are huge consumers of energy and important contributors to polluting the atmosphere (Carbon Trust 2009). Even in a challenging economy, retail clients are committed to sustainability and are expanding their sustainability platforms due to cost savings and optimized performance as well as taking into account demands for the construction of sustainable retail buildings. Contractors are responsible for transforming clients' requirements into a constructed facility (Fagbenle and Makinde 2011) and play a key role in reducing energy use and the carbon emissions of buildings (Qi et al. 2010). This is achieved by improving the efficiency of the construction process, conserving energy and protecting the environment.

The increasingly demanding pressures from the UK Government and retail clients (Qi et al. 2010) have forced contractors to be innovative in the use of products and construction processes to deliver the specified environmental sustainability performance levels (Ozorhon et al. 2010; Panuwatwanich et al. 2012). This has led to contractors paying increased attention to the use of new sustainable technologies and the application of technologies in new ways (technological innovation) to provide sustainable retail buildings. The use of innovative technologies by contractors can satisfy the demanding needs of both government and clients (Bunduchi et al. 2011) and also generate more business opportunities and competitive advantage (Dodgson et al. 2008).

Contractors are a link between the suppliers of new products and processes and the clients that will adopt them (Winch 1998) and are in a good position as mediators to promote IST to clients. However, contractors face significant challenges when selecting IST due to the rapid development of technologies, their increasing complexity, uncertainty and market dynamics (Davoudpour et al. 2012; Akadiri et al. 2013). The lack of a simple structured decision support tool for the selection of innovative sustainable technologies (IST) has been identified and the need for such a tool for contractors has been recognized.

Preliminary literature review and exploratory studies indicate there is a slow uptake of IST by stakeholders in the retail construction industry in the UK (Dangana et al. 2012). Currently, designers, constructors and retailers interested in adopting IST in the retail construction industry have no comprehensive evaluation approach to review and select technologies (Catalina et al. 2011; Akadiri et al. 2013). An earlier study (Dangana et al. 2013) explored the composition of the main stakeholders involved in the selection process. The study developed a set of criteria predominantly from the perspective of a main contractor and their clients/supply chains. The criteria were clustered in such a way that they contribute to each stakeholder's objectives and were brought together into an overall multi-actor perspective.

This paper focuses on the contractor and aims to examine the selection criteria in the decision making process to select IST for retail buildings in such a way that will satisfy the multiple stakeholders needs and also provide a competitive advantage to the company. Using expert opinions, the study involved clarifying the decision context; establishing decision objectives; identifying, clustering and assessing decision criteria; and finally, quantifying the relative significance of the contractor's criteria using the analytic hierarchy process (AHP) technique.

The study on which this paper reports is part of an on-going research project which aims to optimize the process, energy and carbon efficiency in retail construction by capitalizing on innovative sustainable technologies. This will be achieved by developing a prototype decision tool that will encourage both development and deployment of IST by stakeholders.

INNOVATION

Innovation is one of the five drivers of productivity and is vital in an increasingly competitive UK global economy. It is a major source of competitive advantage for firms (Ozorhon et al. 2010; Panuwatwanich et al. 2012) creating export opportunities that could contribute up to approximately £1.7bn to GDP to 2050 (Carbon Trust 2009). Innovation has been described variously as the successful exploitation of both new and existing ideas, practices and technologies that are new to a firm (DTI 2007); the creation and adoption of new knowledge to improve the value of products, processes, and services (Ozorhon et al 2011); or the profitable exploitation of ideas that can provide competitive advantage (DTI 2007). Dodgson et al. (2008) defined innovation to include the scientific, technological, organizational, financial and business activities leading to the commercial introduction of new (or improved) products or services. Ozorhon et al. (2010) describes innovation as a complex and multidimensional process that has gained attention in all fields due to its contribution to economic growth, competitiveness and quality of life.

Innovation in the construction industry

Innovation scholars have presented a variety of definitions and models of innovation in construction (Qi et al. 2010; Ozorhon et al. 2010). Ling (2003) defined innovation in construction as a new idea that is implemented in a construction project with the intention of deriving additional benefits, although there might also be associated risks and uncertainties. The new idea may refer to new design, technology, material component or construction method deployed in a project (Dodgson et al. 2008). Innovation in the construction industry involves the successful development and/or implementation of new ideas, products, processes or practices to increase organizational efficiency and performance aimed at solving problems, viewing things differently or enhancing standards of living (DTI 2007).

The construction industry can benefit from the diverse benefits offered by innovation (Bunduchi et al. 2011; Panuwatwanich et al. 2012; Ozorhon et al. 2010) particularly by adoption of new methods to improve processes and organizational effectiveness (Ozorhon et al. 2010; Balachandra et al. 2010). Innovation in the construction industry is driven by regulations, client demand and skills supply, and the structure of the industry (Qi et al. 2010). From the perspective of the construction industry, innovation consists of three domains viz. product, process and organization (Ozorhon et al. 2011) and can be broadly classified as either 'organizational innovation' or 'technological innovation' (Bunduchi et al. 2011). Organizational innovation results in the introduction of changes to the organizational structure, the introduction of advanced management techniques, and the implementation of new corporate strategic orientations and technological innovations which are either new products or processes (Ozorhon et al. 2010). This paper focuses on technological innovation.

Use of innovative sustainable technologies in the retail construction industry

There are continuing concerns about the environment, natural resources, security of energy supply and fuel poverty, and the use of innovative sustainable technologies can be used to provide solutions to these problems (Bunduchi et al. 2011). IST can be used to minimize the negative impacts of buildings on the environment (Qi et al. 2010) and due to their high energy saving potential can be used as preventive and curative measures in climate change (Balachandra et al. 2010). These technologies can support and contribute to sustainable retail buildings by reducing risk, enhancing cost-effectiveness, improving process efficiency, and creating processes, products or services which have minimal adverse impact on the environment (Balachandra et al. 2010). Leading UK retailers like M&S, Tesco and Sainsbury are trialing IST to reduce operational energy and carbon emissions. An example is the first M&S 'Sustainable learning store' in Sheffield, UK, that incorporates a host of sustainable and innovative design and construction features. These include:

- All powered lighting from LEDs, using 25% less energy than conventional lighting- one of the first stores in Europe and the first in the UK to do this.

- A sedum roof and green 'living wall' created wildlife habitats, contributing to the insulation of the building and as a pollution filter.
- 100% of the heating in the store is provided by expelled heat from its refrigeration units.
- Glass doors on mobile fridges with predicted energy savings of 45%.
- An overall embodied carbon reduction of 12.3%.

Management of innovative sustainable technologies (IST) in retail construction

Innovative sustainable technologies can provide reductions in energy use and carbon emissions for retail buildings and are of strategic importance to contractors as they can provide distinct and sustainable competitive advantages (Hao et al. 2011; Dodgson et al. 2008). Carbon Trust (2009) estimates that the use of simple and cost effective IST that currently exist could provide a net cost saving to the UK economy of approximately £4.5bn, with reductions in carbon emissions from the UK's non-domestic buildings by 35% by 2020. To realize the economic and environmental benefits of IST, they need to be implemented (Balachandra et al. 2010). However, 90% of the IST that have a potential to reduce the energy use and carbon emissions for buildings are not being selected by construction professionals (Carbon Trust 2009).

Contractors can facilitate the uptake of IST by acting as enablers between the supply side (IST suppliers) and demand side (retail clients) by selecting the right products. However, contractors consider the task of selecting an IST as difficult, time consuming, expensive and demanding, due to the large number of alternatives, high degree of uncertainty, ambiguity and associated risk. Selection often requires changes in the organization and strategies that support it (Davoudpour et al. 2012; Akadiri et al. 2013; Hao et al. 2011; Turskis et al. 2008; Jahan et al. 2013). Selection is frequently made by trial and error or simply on the basis of past experience, leading to compromised and unpredictable outcomes (Jahan et al. 2013; Tan et al. 2007). In many instances contractors choose not to select an IST due to the complex decision making problems involving uncertainty as they are unable to quantify the benefits prior to implementation (Tan et al. 2007). This has led to the slow uptake of IST that have great potential to provide economic, environmental, strategic and competitive benefits for contractors (Carbon Trust 2009).

The difficult nature of managing technological innovation makes it a source of competitive advantage, and if every firm could do it successfully it would not provide a source of relative competitive advantage (Dodgson et al. 2008).The use of multiple criteria decision methods can assist contractors to build up innovative capabilities to analyze, select and successfully manage technological innovations in uncertain and ambiguous circumstances and enhance organizational performance. Decisions are based on establishing criteria values, weighting the criteria and ranking alternatives using stakeholders' opinions (Turskis et al. 2008).

MULTIPLE CRITERIA DECISION-MAKING METHOD (MCDM) TO MANAGE TECHNOLOGICAL INNOVATION

Multiple criteria decision-making methods are an important set of tools that can be used to address challenging business decisions and provide a foundation to select, sort and prioritize technological innovations (Saaty et al.

2006; DCLG 2009; Jahan et al. 2013). They support the decision maker when making a decision, or propose a decision for the user based on the data about the alternatives to be selected (Davoudpour et al. 2012). MCDM can be used to manage technological innovations by assisting contractors to select the right technologies to satisfy the environmental, economic and social requirements of the multiple stakeholders and also provide a source of competitive advantage and differentiation (Dodgson et al. 2008; Jahan et al. 2013). Wang et al. (2009) presented a very detailed literature review on the use of MCDM as an aid in sustainable energy decisions and concluded that the analytic hierarchy process (AHP) is the most popular and comprehensive MCDM technique. They recommended AHP as a powerful tool for decision making when selecting sustainable energy systems.

Due to the complicated and difficult nature of managing technological innovations, MCDM could be adopted by contractors and the analytic hierarchy process (AHP) technique used to rank and weigh the criteria for managing technological innovations. AHP is one of the most popular MCDM tools and has found widespread application in complex decision-making problems (Wang et al. 2009; Pan et al. 2012; Akadiri et al. 2013) for formulating and analyzing environmental decisions.

METHODOLOGY

The research presented in this paper is part of an on-going research study employing an action research approach within a broad case-study based design and builds on the findings from an earlier exploratory study by the researcher (Dangana et al. 2012, 2013). The previous study identified the key stakeholders (clients and contractors) and the selection criteria for IST for retail buildings. This study focuses on the contractor and the selection criteria in the decision-making process.

The study involved an organizational case study of a leading contractor (referred to as company A) in the UK, predominantly involved in retail construction. Company A is committed to protecting the environment by undertaking all operations in an environmentally responsible manner and is keen to explore the use of technological innovations to maximize benefits to clients. It anticipates that an understanding of and planning to manage climate change liabilities will help to strategically direct the business, whilst also providing short-term performance improvements, cost savings and opportunities for new service offerings. The company delivered the first stand-alone M&S ‘store of the future’ (an eco-learning store) in Sheffield, UK which incorporates a range of IST.

The study consisted of two surveys; an initial general survey which consisted of semi-structured interviews with twenty expert construction professionals from Company A. This was followed by an analytic hierarchy process survey (AHP) using a simple questionnaire with ten professionals selected from the general survey group. The data collected was both qualitative (decision criteria were established and verified) and quantitative (the criteria were weighted and ranked).

RESULTS AND DISCUSSION

There are several methods currently available for selecting technological innovations; however these are inadequate as they overemphasize the quantitative and financial criteria, and overlook qualitative factors such as improved human comfort and environmental sustainability (Wong et al. 2008; Pan et al. 2012). Also, they do not provide a process for prioritizing and assigning weights to the relevant selection criteria (Jahan et al. 2013; Akadiri et al. 2013). Although, several sets of criteria have been developed for other building types, specific building components / systems and technologies, there is no set of selection criteria specifically for the selection of ISTs for retail buildings; which reflect the criteria, values and weights of the key stakeholders. Chen et al. (2010) identified 7 criteria and 33 sub-criteria (sustainable performance criteria) for the selection of construction methods for concrete buildings. Similarly, Akadiri at el. (2012) identified 6 criteria and 24 sub-criteria (sustainable assessment criteria) for the selection of sustainable building materials for the UK building industry and Pan et al. (2012) identified 9 criteria and over 50 sub-criteria for assessing building technologies for UK house building organizations. These studies do not focus on the retail sector and the stakeholders' needs, taking into account the context in which they operate and are therefore not appropriate for the selection of ISTs for retail buildings. This study has generated a set of five broad qualitative and quantitative key criteria currently used by Company A that will be used to select IST as explained below.

General survey

The general survey consisted of interactive discussions using semi-structured interviews with twenty senior management personnel from Company A involved in the roles of technical, commercial, retail construction, sustainability, procurement, marketing and customer services. The aim was to understand the current selection process used by Company A and the selection criteria. The company has a well-established supply chain management team and it tends to work mostly with their existing supply chain. However, the team does not explore IST and is missing out on opportunities that could be a source of differentiation and improved competitiveness (Dodgson et al. 2008). The company is keen to explore the use of IST, but due to the already mentioned barriers, is reluctant to adopt IST, and currently does not have any selection process for IST. A simple structured decision support tool would be useful.

A set of decision criteria for the selection of IST was established from literature review and previous research. The established decision criteria was presented and explained to the participants who had an opportunity to add, remove or refine the criteria. Some participants provided more criteria or sub-criteria for consideration, while some suggested minor modifications to the criteria. The general survey resulted in the establishment of five broad criteria (Table 1). These were approved by the participants to reflect current objectives and selection criteria which were most relevant to use in the AHP survey. These five broad criteria represent the company's technological competitiveness criteria. They are under the firm's control and depend on the firm's behavior and decisions (Jolly 2012).

AHP survey

The general survey was followed by a one-day workshop with ten senior managers who were predominantly involved in sustainable retail construction, client facing and job winning roles from Company A. The sample size of ten participants might seem limited; however, AHP is a subjective method and with a large sample size there is a tendency for respondents to provide arbitrary answers which can result in inconsistencies (Wong et al. 2008). The aim of the AHP survey was to evaluate the comparability of the established decision criteria used by Company A for the selection of IST (Table 1) and establish a scoring logic for the criteria (Table 2).

Table 1. Broad criteria established from the study for the selection of IST

Decision criteria	Description
Repeat Business	Technological innovations that could be rolled out in a number of stores for a retail client in line with the company's objective of targeting low value, high volume jobs.
Differentiation	Technologies that could provide a source of differentiation and a competitive edge for the company.
Transferability	The study aims to explore technologies for retail buildings. However Company A is also involved in the construction of other building types such as houses, schools, sports centers, etc. Transferability of the technology to other building types was also considered.
Margin Opportunity (M.O.)	Company A believes that even though the M.O. might be low for a given IST, profit can be generated if it is commercialized on a large scale.
Investment Costs (I.C.)	Some IST would need the assistance of established businesses to support and invest financially.

Table 2. Scoring logic for criteria

Criteria	High (10)	Medium (5)	Low (1)
Repeat Business	Roll Out Opportunity	Only certain building types/sizes	One building type/size only
Differentiation	No contractors offering this & hard to copy	No other contractors offering this	Other contractors offering this
Transferability	All sectors & building types	Some sectors & building types	Retail only
Margin Opportunity	Net Margin of 10%+	Net Margin of 1%- 10%	Net Margin of < 1%
Investment Costs	No investment needed but willing to partner	JV/Strategic alliance with small investment needed	Full investment & resources needed

AHP uses pairwise comparison to allocate weights to the elements of each level, measuring their relative importance with Saaty's 1-to-9 scale, and finally calculates overall weights for evaluation at the bottom level. If A and B are the elements to be compared, then 1 defines that A and B are equal in importance, and 9 defines that A is extremely more important than B. The method also calculates a consistency ratio (CR) to verify the coherence of the judgments, which must be about 0.10 (10%) or less to be acceptable. The value tree of five decision criteria to be used for the AHP questionnaire survey was first explained and participants then performed pairwise comparisons using the scale developed by Saaty (2006).

The first phase of the questionnaire asked for the criteria to be ranked in a given context and the second phase asked for a pairwise ratio/importance response for each of those ranked factors. The comparisons were made using a scale of absolute judgments that represented how much more one element dominated another with respect to a given attribute. The results relied on the judgments of experts to derive priority scales and it is these scales that measure intangibles in relative terms (Saaty 2006; DCLG 2009). The results were first analyzed for each participant to establish the weighting and ranking for the five broad criteria (repeat business, transferability, differentiation, investment costs, and margin opportunity). The results highlight the different view of the participants, however, the CR for each participant was within the acceptable range, and was reliable and consistent to establish the combined weighting and ranking for the stakeholder group. All the results were combined to provide a consensus ranking and weighting for the group using the AHP technique (Table 3).

The margin opportunity criterion was found to be the most important attribute for the group with a score of 38%, followed by repeat business (27%), investment costs (18%), differentiation (11%) and transferability (7%) as the least important. Though the margin opportunity was the most important criteria, this did not imply that IST that provided a high margin opportunity is preferred. IST can have a low margin opportunity but if rolled out on a large number of stores can generate huge savings and profits to the business (Balachandra et al. 2010). This justifies the ranking of repeat business as the second most important criteria by the group; as replicate jobs are easier and more cost effective for a business. Transferability was ranked the lowest, but this was not a surprise as the participants were all from the retail sector of the company. The weighting and ranking can vary due to internal and external changes' within the company, but the results indicate the current objectives of Company A.

Table 3. Combined comparison matrix of selection criteria by group

	A	**B**	**C**	**D**	**E**	**Weights**	**Rank**
Repeat business (A)	1	4 1/2	3 1/3	1 1/3	2/3	27%	2
Transferability (B)	2/9	1	3/8	1/3	1/4	7%	5
Differentiation (C)	2/7	2 3/4	1	3/4	1/4	11%	4
Investment costs (D)	3/4	3	1 1/3	1	1/2	18%	3
Margin opportunity (E)	1 1/2	4 1/4	3 7/9	2 1/6	1	38%	1

CONCLUSIONS

The promotion of innovation and innovative thinking, such as the adoption of new technologies, can offer diverse benefits to the construction industry.

Contractors are using IST as a new way of addressing global challenges to improve the energy efficiency of resource usage and of protecting the environment (Balachandra et al. 2010). They are also generating more business opportunities than their competitors (Qi et al. 2010) by offering new, better, and/or cheaper products and services to their customers. However, they face significant challenges in selecting appropriate ISTs. The need for a decision support has been identified that can assist contractors to define and evaluate the selection of IST and lead to the large scale commercialization of these IST. This study is part of an on-going study to develop a prototype decision tool, based on the concept of MCDM to encourage both development and deployment of IST by stakeholders.

This paper has examined the decision criteria for the selection of IST for achieving low carbon retail buildings. The examination was carried out with a focus on the main contractor's perspective, while drawing on the wide-ranging considerations from the contractor's clients, design and supply chains. The arguments are informed by an in-depth case study with a leading construction company in the UK, and revisited in relation to the existing body of knowledge in the literature. The key results indicate five broad decision criteria, identified systematically, which were integrated into the contractor's practice of selecting IST for retail buildings. The established criteria were weighted and ranked, with margin opportunity being the most important, followed by repeat business, investment costs, differentiation, and then transferability.

The findings should facilitate the integration of IST selection into the contractors' business and reduce the risks associated with the take-up of IST. In turn this will make useful contributions to stimulate innovation in the retail sector. This should improve the quality of the decision by allowing informed decisions that are more explicit, rational and efficient and assist the retail sector in stimulating the use of IST.

The next steps of the research will involve exploring ISTs and scoring them against the established criteria in order to determine the most preferred IST.

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REFERENCES

Akadiri, P.O., Olomolaiye, P.O., and Chinyio, E.A. (2013) "Multi-criteria evaluation model for the selection of sustainable materials for building projects." Automation in Construction, 30:113–125.

Balachandra,P., Nathan, H.S.K., and Reddy, B.S. (2010). "Commercialization of sustainable energy technologies." Renewable Energy (35), 1842–1851.

Bunduchi, R., Weisshaar, C., and Smart, A.U. (2011). "Mapping the benefits and costs associated with process innovation." Technovation (31), 505–521.

Carbon Trust. (2009). "Building the future today." Carbon Trust, London.

Catalina, A.T., Virgone, J., and Blanco, E. (2011). "Multi-source energy systems analysis using a multi-criteria decision aid methodology." Renewable Energy, 36: 2245-2252.

Dangana, Z, Pan, W., and Goodhew, S. (2012). "Delivering sustainable buildings in retail construction" In: Smith, S.D. (Ed) Procs 28th Annual ARCOM Conference, Edinburgh, UK

Dangana, Z, Pan, W., and Goodhew, S. (2013). "A decision making system for selecting sustainable technologies for retail buildings", Australia.

Davoudpour, H., Rezaee, S., and Ashra, M. (2012). “Developing a framework for renewable technology portfolio selection.” Renewable and Sustainable Energy Reviews 16:4291– 4297.

DCLG (2009). “Multi-criteria analysis: a manual”, London

Dodgson, M., Gann, D., and Salter, A. (2008). *The management of technological innovation* .Oxford University press, Oxford, UK.

DTI (2007). *Innovation in Services*, Department of Trade and Industry, London.

Fagbenle, O.I. and Makinde, F.A. (2011). “Factors influencing construction clients’/contractors’ choice of subcontractors in Nig.” J.Sust. Dev. 4(2).

Hao, S. and Yu, B. (2011). “The impact of technology selection on innovation success and organizational performance.” iBusiness, (3), 366-371.

Jahan, A., and Edwards, K. L. (2013). *Multi-criteria decision analysis for supporting the selection of engineering materials in product design*, B-Heinemann. USA.

Jolly, D.R. (2012). “Development of a two-dimensional scale for evaluating technologies in high-tech companies.” J. Eng. Technol. Manage. 307–329.

Ling, F.Y.Y. (2003). “Managing the implementation of construction innovations.” Construction Management and Economics, (21), 635 – 649.

Ozorhon, B., Abbott, C., Aouad, G. and Powell, J. (2010). “Innovation in construction a project life cycle approach.” SCRI Research Report. Salford, UK.

Ozorhon, B., Abbott, C., and Aouad, G. (2011). “Design, process, and service innovations to achieve sustainability.” Management and Innovation for a Sustainable Built Environment", 20 – 23 June 2011, The Netherlands.

Pan, W., Dainty, A.R.J., and Gibb, A.G.F. (2012). “Establishing and weighting decision criteria for building system selection in housing construction.” ASCE Journal of Construction Engineering and Management, 1239-1250.

Panuwatwanich, K., and Stewart, R.A. (2012). “Evaluating innovation diffusion readiness among architectural and engineering design firms.” Automation in construction, 50-59.

Qi, G.Y. et al. (2010). “The drivers for contractors’ green innovation.” Journal of Cleaner Production, 1358-1365.

Saaty, T.L., and Vargas, L.G. (2006). *Decision Making with the Analytic Network Process*, Springer, New York.

Tan, H.K., Noble, J., and Sato, Y. (2007). “Marginal analysis guided technology evaluating and selection.” 19th Int. Conf. on Production Research.

Turskis, Z., Zavadskas, E.K., and Peldschus, F., (2008). “Multi-attribute contractors ranking method.” Technological and Economic Development of Economy, 14(2): 224-239.

Wang, J., Jing, Y., Zhang, C., and Zhao, J. (2009) “Review on multi-criteria decision analysis aid in sustainable energy decision-making.” Renewable and Sust. Energy Reviews, (13), 2263–2278.

Winch, G. (1998). “Zephyrs of creative destruction: Understanding the management of innovation in construction.” Building Research and Information, 268-79.

Wong, J.K.W. and Li, H. (2008). “Application of the analytic hierarchy process (AHP) in multicriteria analysis of the selection of intelligent building systems.” Building and Environment, 43 (1), 108–125.