Journal of Environmental Management 91 (2010) 654–661

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Factors affecting the implementation of green specifications in construction

Patrick T.I. Lam [a,*], Edwin H.W. Chan [a], C.S. Poon [b], C.K. Chau [c], K.P. Chun [a]

[a] Department of Building & Real Estate, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong
[b] Department of Civil & Structural Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong
[c] Department of Building Services Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

ARTICLE INFO

Article history:
Received 29 January 2009
Received in revised form
17 September 2009
Accepted 21 September 2009
Available online 22 October 2009

Keywords:
Specifications
Sustainable development
Contract management

ABSTRACT

Green specifications constitute one of the important elements in green construction. New sustainability requirements and changing priorities in construction management have spurred the emerging green specifications to a faster pace of development. A cross-sectional survey has been conducted in Hong Kong in 2007 to identify principal factors leading to the success of preparing green specifications. Based on extensive construction management literature, 20 variables concerning sustainable construction were summarized. Using the Mann–Whitney U-test, the subtle differences between stakeholders in specifying construction work have been detected even with the high consistency of the responses among the groups. Moreover, five independent factors for successful specification of green construction have been categorized by factor analysis. They are related to (1) green technology and techniques, (2) reliability and quality of specification, (3) leadership and responsibility, (4) stakeholder involvement, and (5) guide and benchmarking systems. Whilst the first and fourth factors are generally more important, different stakeholder groups have different emphases. The results of the survey have been validated against established principles.

1. Introduction

The building industry consumes one-half of the world's physical resources (RCA website). According to data published by the United Nations Environment Programme, the building sector accounts for 30–40% of global energy use (UNEP, 2007). Yet, the lucrative investment returns brought about by property development prompt developers to build in anticipation of demands as a global business. Spurred by the ever-rising needs for infrastructure and leisure, construction activities are changing land forms quickly. Natural resources are being depleted at a rate faster than their replenishment, hence giving rise to an outcry for sustainable development. Many governments are taking a regulatory stance in trying to curb direct environmental pollution, but non-statutory means can be an effective supplement to achieve sustainable construction since most organizations prefer to have room for flexibility in their business operation. Increasingly, designers produce building designs which are environmentally friendly and voluntary assessment schemes (such as BREEAM and LEED) are deployed to verify that their claims are well made. At the contract level, apart from drawn information, client requirements used to be made explicit through specifications, both in the public and private sectors. The prescriptive approach of specifying has enabled the client and his consultants to stipulate materials and workmanship in accordance with environmentally friendly practice. The uprising trend of performance specifying as an alternative (e.g., for curtain walling) has also provided opportunities for contractors to innovate (Lam et al., 2003), but then specifiers should incorporate "green" requirements to achieve sustainability of construction resources. Yet, specifiers adopt different approaches in specifying green elements, with a varying level of competence (Lam et al., 2008). For example, in a survey of UK architects by the Designing for Sustainability Group in 2002, only 46% reported on having experience of specifying recycled materials (Chick and Micklethwaite, 2002).

Apart from the variability in technical competence, the problems with existing specification practice are associated with the unclear delineation of responsibilities amongst stakeholders and the infrequent use of reliable templates (Lam et al., 2007). These problems have caused disputes and inconsistency of work quality in the construction process. When stakeholders wish to achieve sustainable construction through the use of green specifications, these problems must be mitigated and a lucid understanding of the factors involved in successful implementation of green specifications

* Corresponding author. Tel.: +852 27665799; fax: +852 27645131.
E-mail address: bsplam@polyu.edu.hk (P.T.I. Lam).

0301-4797/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jenvman.2009.09.029

is essential. The objectives of this paper are therefore to identify the mentioned factors for better development of green specifications. Following a literature review on sustainable construction principles and green specifications, the results of a survey on green specification implementation factors carried out in Hong Kong are reported. The factors resulting from statistical analysis have been validated against established principles. This approach resembles that of the Grounded Theory, in that the empirical survey findings (i.e., the five factors affecting the implementation of green specifications) help to build up a green specification framework, which is a further step to be taken in the research study.

2. Literature on sustainable construction and green specifications

Through a comprehensive literature review, a list of twenty features (adopting the word of "attributes" as in social science) has been compiled as the possible factors leading to the successful implementation of green specifications. In accordance with the established principles of managing sustainable development (e.g., BS8900, 2006), the twenty attributes in respect of the preparation of green specifications were provisionally classified under four headings for the purpose of a subsequent questionnaire survey: (1) stakeholder involvement, (2) leadership and responsibility, (3) principles and techniques, as well as (4) feedback and building public confidence. The rationale of the classification is discussed below and the twenty attributes under four categories are shown in Appendix A.

2.1. Stakeholder involvement

Following the increasing popularity of quality management systems in the construction industry in the mid-90s, a system-based approach to sustainability was proposed by Holmberg (1998), Robert (2000), Eccleston and Smythe (2002) as well as MacDonald (2005). Protocols published by the British Standards Institution emphasize the importance of identifying the roles and concerns of the stakeholders.

Fenn et al. (1997) pointed out that incompatibility of interests amongst stakeholders caused conflicts and disputes in construction. Notwithstanding, Berke (2002) advocated the holistic inclusion of different interests from stakeholders and involving the public in planning. Incorporating the various interests of stakeholders should be extremely important for the preparation of green specifications.

To enable stakeholder involvement, the preparation of green specifications should be carried out with top management's directives and participation by stakeholders. Examples of such participation include the publication of green product directories (e.g., www.eco.com.au) and web-based sharing of commentaries (e.g., www.greendragonfilm.com).

2.2. Leadership and responsibility

The leadership and responsibility of industry stakeholders should play significant roles in the success of green specifications, in that common objectives (such as reducing energy consumption and pollution arising from construction activities) can be engendered through a decision-making process well managed by business leaders, who act as champions.

Under social principles, Robert et al. (2002) listed standards and legislation as two of the tools for achieving sustainability. However, in a country as big as China, there may be a lack of practical understanding of sustainability, which prohibited the development and enforcement of legislation for sustainable construction (Sha et al., 2000). Using green specifications as a contractual means to address the strict requirements in evolving green standards and requirements appears to make more business sense due to the inherent flexibility of the contract mechanism to cater for individual cases.

Swift (1999) believed that professionalism should hold paramount the welfare of the public, and avoiding conflicts of interest is an important part of professionals' efforts to gain the trust of the public. Prevention of bias towards particular products or processes should be vital for specification preparation.

Liability and uncertainty are two barriers for environmental initiatives in green specifications. Pollution is one of the common exclusions in professional liability insurance as listed by Rubin (1994). Potential liability on the detrimental effects of unconventional products as a result of specifying would affect the premium of professional liability insurance and hence the decision of specifiers on green initiatives.

Uncertainty and risk associated with new green technology is common. Flanagan et al. (1987) admitted that risk is common in life cycle costing. Pearce and Vanegas (2002) identified that risk associated with reliability and effectiveness of a new product prevents many professionals from specifying green or sustainable building materials. Risk adversity is also common among clients. In the Barbour Report 2003, although one-third of the client respondents expected sustainability and life cycle costs to become more important, only 4% of all clients frequently specified innovative products. The low enthusiasm towards green specifying may be attributable to clients' risk adversity (Barbour Index, 2004). Hence, reducing anxiety towards the risk associated with green specifications through a fair allocation of responsibilities should increase their use.

2.3. Principles and techniques

Traditionally, the construction industry mainly focuses on the use of techniques for reducing pollution or increasing efficiency to meet the regulatory requirements or reduce cost. Mora (2007) noticed that sustainable construction can refer either to the building process or to the built object. Green specifications set out the building processes or the requirements of the materials resulting in the final built object serving its occupants' needs in a sustainable manner. In the survey design that follows, seven attributes concerning energy saving, mitigation of environmental impacts and the use of available technologies for the successful preparation of green specifications are summarized under the heading of green technology and techniques.

In accordance with high level directives such as those promulgated in the European Union (e.g., for Integrated Pollution Prevention and Control) or China (e.g., the eleventh Five Year Plan), a willingness to specify available advance green technology for construction purpose should be an important attribute for green specification preparation.

Life cycle assessment with considerations of environmental impacts, energy and material flow is the main principle of most published guides for green specifications, e.g., the BRE Green Guide to specifications (Anderson and Shiers, 2002), the Guideline Specifications by GreenBuilding (2007) and the Federal Green Construction Guide for Specifiers (WBDG, 2007). Customized tools such as the Building for Environmental and Economic Sustainability (BEES) approach as developed by Lippiatt (1999) in the US or the Life Cycle Energy Analysis software as developed by the Electrical and Mechanical Services Department, Government of the Hong Kong Special Administration Region (EMSD, 2008) are available for construction stakeholders. The results of life cycle assessment may be used for costing, benchmarking and option selection.

Considerations and knowledge on life cycle should be important fundamentals for green specifications.

Citherlet and Defaux (2007) highlighted the importance of evaluating a building project on the total emission during construction, and they also stated that material manufacture, transport, replacement and elimination at the end of the building lifetime should be important consideration for energy consumption in its life cycle. The material cycle should be as vital as energy flow in green construction. Therefore, an understanding of the roles of energy, material selection, environmental impacts and green practices in construction should be crucial for the successful preparation of green specifications.

Although green building performance assessment and green specifications are two different tools to promote sustainable construction, green specifications have a strong bonding to green building assessment (e.g., LEED). In the design stage for a new construction, the evaluation of its specifications is usually a significant step for many green building assessment methods, for example, CASBEE (2007) in Japan and the sustainability rating system in the Code for Sustainable Homes in the UK (DCLG, 2006). Following the introduction of various green building assessments in different regions based on local characteristics, many organizations providing specification service already published or are planning to develop green specifications for these green building assessments. For instance, the Building Research Establishment (BRE) in the UK is updating its Green Guide to Specification continuously to align with industry initiatives and building regulation changes (BRE, 2007). BSD SpecLink by Building Systems Design Inc. is an automated program for LEED submittals (Bertram, 2005), whilst the Construction Specifications Institute (CSI) introduced the GreenFormat in the US (McCaffrey, 2006). Therefore, during the preparation of green specifications, the green building assessment in the region and the available model clauses for green specifications should be used as references.

2.4. Feedback and building public confidence

The quality of writing of specifications is directly related to the occurrence of disputes and claims in construction projects (Kululanga and Price, 2005). During preparation of green specifications, issues of quality and reliability of green specifications should not be ignored. Underwood et al. (2000) found that an enhanced building database can help the specification process as a result of closer link between suppliers and the design process. Vrijhoef and Koskela (2000) noted the significance of relationship between suppliers and other stakeholders in the total supply chain. The availability of reliable green product information and feedback from stakeholders should affect the quality of green specifications.

Furthermore, different interpretations of specification among different stakeholders precipitate disagreements, disputes and litigation, and ambiguous words or phrases are often the focal point of disputes (Thomas et al., 1994). Clearly defined green characteristics for prescriptive specifications (e.g., by stating the maximum allowable content of contaminants in recycle aggregates) and verifiable green performance criteria for performance-based specifications (e.g., by stating the energy efficiency requirements of lighting installations) should be important ingredients for the preparation of green specifications. It is only when quality is built in and dispute minimized that public confidence will be placed on the use of green specifications.

3. Survey on factors affecting the implementation of green specifications

Further to the literature review informing the survey content, 652 questionnaires concerning green specifications were sent to various stakeholders in mid-February 2007 to study the attitude of the construction stakeholders in Hong Kong towards sustainable construction and green specifications. The distributed questionnaires were based on the results of a pilot study between December 2006 and January 2007. Relevant sections of the questionnaire are shown in Appendix A. The respondents were asked to indicate basic data (including their work sectors and organization nature) and rate the relative importance of 20 attributes leading to successful implementation of green specifications using the five-point Likert scales. By the end of May 2007, 100 questionnaires were collected, reflecting a response rate of 15%.

3.1. Method of analysis

The Statistical Package for Social Science (SPSS 12.0 for window) was employed to analyze the information from the survey. The Cronbach's alpha coefficient was used to assess the reliability of the Likert scale in the survey by investigating the internal consistency of the responses among 20 attributes (refer to Appendix A for details) concerning the successful implementation of green specifications.

The mean scores were used to establish the relative importance among attributes as perceived by the stakeholders along with the Kendall's coefficient of concordance, which was calculated to assess the extent of agreement of ratings amongst the respondents. The analytical tools employed are similar to those of an empirical study on the safety management of construction workplace in China (Fang et al., 2004), which solicited the views from personnel in construction companies. In addition, the non-parametric Mann–Whitney U-test was used to identify the differences among various stakeholders on the attributes for the successful preparation of green specifications when the sample size for each group of stakeholders is around 20 and hence t-tests may not be applicable.

Further to the analysis on the mean values of individual attributes, factor analysis was preformed to identify common threads linking the 20 attributes for successful implementation of green specifications. Kim and Mueller (1978) demonstrated that factor analysis is a suitable statistical tool for estimating the underlying factor pattern for a number of attributes which have been consolidated into a manageable set for analysis.

Principal component analysis was used as the factor extraction method and Varimax with Kaiser Normalization was used as the rotation method. Before factor analysis, the Kaiser–Meyer–Olkin (KMO) test was used to evaluate the sampling adequacy.

3.2. Analysis of survey results

In the 100 filled questionnaires, more than 75% of the respondents identified themselves with over 10-year working experience. Around 20% of the respondents were consultants, and around 20% of the respondents were electrical and mechanical (E&M) subcontractors. Both clients and contractors made up one-quarter of the respondents, and other stakeholders including building subcontractors and suppliers constituted the remaining 10% of the respondents. Moreover, less than 10% of the respondents claimed that more than 30% of their projects had green considerations, whilst over 50% of the respondents revealed that less than 10% of their projects had "green" elements.

The Cronbach's alpha coefficient is 0.912 (F statistic = 11.781, $p < 0.001$) for the attributes related to the successful implementation of green specifications, showing that the five-point scale measurement should be reliable for the purpose of this study.

Upon Mann–Whitney test, four attributes were identified as having significant differences among stakeholders and they are summarized in Table 1.

Table 1
Mean ranks and Mann–Whitney U-test results.

Rank			Mann–Whitney U-test		
Attribute	Overall mean	Std. deviation	Client *vs* E&M sub-con.	Consultant *vs* main contractor	Main contractor *vs* E&M sub-con.
B1	4.18	0.808			
B2	3.88	0.798			
B3	3.66	0.779	160.00 ($p = 0.028$)		148.10 ($p = 0.01$)
B4	3.43	0.949	146.50 ($p = 0.009$)		
B5	3.46	0.893			
B6	3.66	0.792			
B7	3.63	0.932			
B8	3.79	0.679			
B9	3.92	0.777			
B10	4.10	0.774			170.00 ($p = 0.05$)
B11	3.97	0.787			
B12	3.76	0.843			
B13	3.91	0.755			
B14	3.44	0.916		133.00 ($p = 0.008$)	135.50 ($p = 0.009$)
B15	3.51	0.871			
B16	3.92	0.763			
B17	3.73	0.732			
B18	3.38	0.715			
B19	3.60	0.718			
B20	3.69	0.685			

Note: no. of respondents: client = 24; consultant = 20; main contractor = 25; E&M sub-con. = 20.
Only significant results of Mann–Whitney U-test are shown.
Please refer to Appendix A for the detail wording of B1–B20.

According to the mean score, attribute (B1) concerning top management's directive for environmental protection is deemed to be the most important for the successful implementation of green specifications by the stakeholders in Hong Kong. The second and third crucial attribute are concerning the reduction of energy consumption and environmental impacts. Ball (2002) recognised that there would be limited power to effect the shift towards sustainability from the low hierarchy of organizations if the top management is uncommitted to environmental issues. In Hong Kong, Tam et al. (2006) noticed that the top management can improve the overall performance of companies and the outcomes of their projects. Clear directions by top management together with the adoption of technology to minimize pollution and maximize energy efficiency should be the core attributes for good specifications.

Besides investigating the relative importance of attributes based on the mean scores, the differences in attitude among stakeholders towards the attributes were studied. According to the results of the Mann–Whitney U-tests as shown in Table 1, Clients and E&M subcontractors in Hong Kong attached different importance to surpassing environmental regulations by contractual means and avoiding conflicts of interest in specifications. Being specialists in their fields, E&M subcontractors would like to demonstrate that they are capable of producing works of a higher standard contractually than the statutory minimum as laid down in regulations.

Similarly, main contractors and E&M contractors had different attitudes to some attributes. E&M contractors would put more considerations on environmental regulations, energy consumption and benchmarking of building performance than the main contractors. The difference should be understandable due to the different interests of the two groups of stakeholders and government incentives. In the case of Hong Kong, the Electrical and Mechanical Services Department operates the Energy Efficiency Labelling Scheme (for products such as air-conditioning equipment and light fittings) and the Energy Efficient Building Registration Scheme (EMSD, 2008). Citherlet and Defaux (2007) also stated that those selecting electrical equipment with higher efficiency aim at reducing energy demand, and the Barbour Index (2004) reported that E&M contractors were usually responsible for repairs during the warranty periods of their equipment. Therefore, it should be obvious that the E&M contractors should show higher concern on energy aspects than general contractors owing to the differences as mentioned.

Another significant result of the Mann–Whitney U-test is that consultants attached higher importance on green performance assessment system than contractors. This can be attributed to the design responsibilities of consultants, which normally include environmental compatibility. Despite the differences as mentioned on some particular attributes, the overall responses from different stakeholders were reasonably homogenous.

3.3. Factor analysis

The KMO value of 0.852 means that the degree of common variance among the 20 attributes is "meritorious" according to Kaiser (1974). Five factors accounting for 67% of the variance were extracted by factor analysis with Varimax rotation.

Based on the cross-factor loadings in the rotated component matrix (Table 2), the interpretation of the foremost five factors is summarized as follows.

3.3.1. Factor 1: green technology and techniques

Seven attributes (including mitigating environmental impacts; selecting materials based on low risk to the environment; selecting materials based on their renewability/recyclability; reducing energy consumption; adopting green practices or procedures; life cycle considerations and using available advanced green construction technology) should be grouped into this underlying factor for the successful implementation of green specifications owing to the strong correlations among themselves. This factor should be the most important one in term of the percentage of covariance among the variables.

Table 2
Component matrix with factor loadings.

Attribute	Factor				
	1	2	3	4	5
B11	**0.788**	0.147	0.240	0.113	0.000
B13	**0.731**	0.101	0.169	0.002	0.373
B12	**0.729**	0.043	0.053	0.095	0.417
B10	**0.662**	0.051	0.311	0.243	0.069
B16	**0.562**	0.496	−0.067	0.148	0.108
B9	**0.554**	0.231	0.099	0.340	−0.105
B8	**0.483**	0.398	0.011	0.123	0.193
B18	−0.002	**0.798**	0.244	0.097	0.049
B20	0.273	**0.783**	0.011	0.087	0.110
B19	0.351	**0.759**	0.164	0.144	0.130
B17	−0.028	**0.692**	0.244	0.300	0.225
B5	0.125	0.200	**0.798**	0.119	0.093
B4	−0.013	0.224	**0.744**	0.093	0.107
B7	0.356	−0.012	**0.668**	0.068	0.205
B6	0.204	0.068	**0.639**	0.306	0.036
B2	0.208	0.257	0.215	**0.819**	0.095
B1	0.170	0.161	0.210	**0.809**	0.138
B3	0.192	0.143	0.111	**0.479**	0.428
B14	0.226	0.191	0.217	0.121	**0.820**
B15	0.175	0.497	0.188	0.229	**0.625**

Note: extraction method = principal component analysis; rotation method = Varimax with Kaiser Normalization.
Please refer to Appendix A for the detail wording of B1–B20.

This factor is self-evident since different green principles and tools have been proposed in various green guides and studies including life cycle assessment, mitigations for environmental impacts and various green practices or procedures (Anderson and Shiers, 2002; WBDG, 2007 and GreenBuilding, 2007).

3.3.2. Factor 2: reliability and quality of specification

Based on the inter-correlation, four attributes related to the reliability of the source of information and the clarity of written clauses affecting the quality of green specifications should be consolidated into an underlying factor. The unattainable, vague and disputable clause in specifications undermining the quality of specification would provoke claims for time extension and conflicts among stakeholders (Chan, 1996; Kumaraswamy, 1997). Underwood et al. (2000) observed that a closer link between suppliers and specifiers may eliminate the duplication of specification information by improving accuracy. Indisputably, the attributes affecting the quality and reliability of clauses written by green specifiers are fundamental facets upon which clients and ultimately the public put their confidence.

3.3.3. Factor 3: leadership and responsibility

Managing the legal responsibility, risk, liability and conflict related to green specifications were grouped under the above-named factor based on the analysis. The attributes in common in this factor should be the responsibility and integrity of the specifying organization to the society. Therefore, during preparation of green specifications, the corporate social responsibility for advancing social, business and environmental objectives simultaneously should be observed (Myers, 2005). An example is the stipulation against casual dumping of construction waste, which would become a social hazard if left out in an allegedly "green" specification. The effective management of risk falling on specifiers should be the duty of project leaders who need to remove the implicit hurdles in the promotion of green practice.

3.3.4. Factor 4: stakeholder involvement

Spiegel and Meadows (1999) included the building owner, the contractor and his subcontractors, the design consultants, the product manufacturer, the fabricator, the building official and the building occupants as the stakeholders for any construction project, whether or not green considerations prevail. Through Factor Analysis based on the respondents' ratings, the concerns of stakeholders, the directions from top management and the will to surpass environmental regulations via the contractual framework were grouped together in a factor depicting the stakeholders' roles and their contribution. Similar to environmental management system as defined in ISO 14001 (2004) about effective management, the concerns of stakeholders should be addressed by the management in order to facilitate the successful implementation of green specifications. For example, the testing of green materials (e.g., recycled aggregates) should be carried out by an accredited laboratory to assure clients and design team as to their suitability for the projects, in addition to other mandatory requirements. Through the stakeholders' involvement, green specifications form an essential element of the contractual framework for environmental considerations to be put into real practice.

3.3.5. Factor 5: guide and benchmarking systems

The attributes about model green specification clauses and cross-referencing to environmental performance assessment of buildings should constitute the fifth principal factor. Cole (1999) delineated three functions for environmental assessment of buildings: (1) promoting better green performance of building; (2) providing information to decision markers during design and (3) giving objective measurements of impacts on the environment from buildings. Owing to their high correlation in the factor analysis, the attributes about green performance assessment and model clauses are consolidated as the Guide and Benchmarking factor. When sufficient data has been amassed on the performance of buildings using green specifications, benchmarking can be effected through the publication of specification guides, which would enable specifiers to choose between parameters leading to a range of known performance.

3.3.6. Hierarchy of the five factors

Based on all samples, when the mean rankings of the attributes comprising each factor are added up and divided by its number of attributes, the average ranking of that Factor can be obtained, indicating its relative significance. As shown in Fig. 1, Factor 1 (green technology and techniques) is equally significant as Factor 4 (stakeholder involvement), followed by Factor 2 (Reliability and Quality), Factor 3 (leadership and responsibility) and Factor 5 (Guide and Benchmarking) in descending order of their average ranking values.

When the respondents' ratings were further analyzed by their roles in groups, consultants and E&M subcontractors regarded Factor 1 (green technology and techniques) as the most important, whereas clients and main contractors put Factor 4 (stakeholder involvement) first. Building trade subcontractors and suppliers took a different view by ranking Factor 3 (leadership and

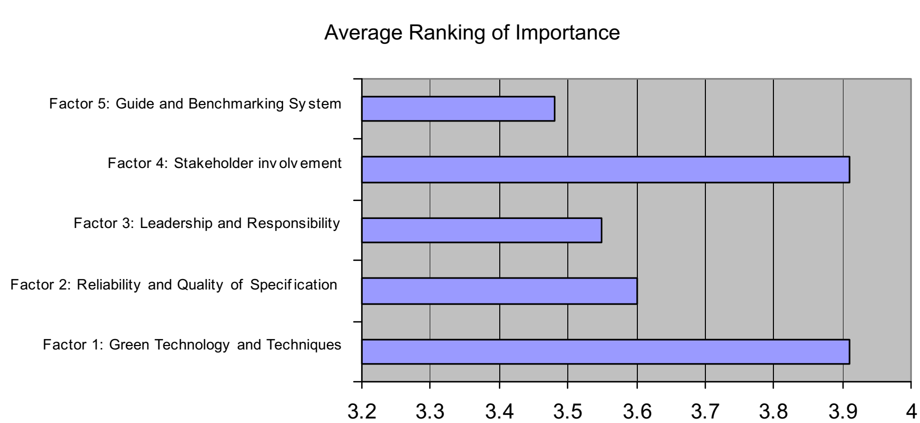

Fig. 1. Mean rankings of the five factors.

Table 3
Mean rankings of different stakeholder groups on the five factors.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1. Client	3.83	3.70	3.54	**4.02**	3.41
2. Consultant	**4.07**	3.67	3.54	3.89	3.67
3. Main contractor	3.82	3.50	3.38	**3.92**	3.21
4. Building sub-contractor	3.39	3.13	**3.40**	3.33	3.25
5. E&M sub-contractor	**4.02**	3.60	3.70	3.98	3.75
6. Supplier	3.82	3.63	**4.13**	3.58	3.75

responsibility) with the greatest importance (Table 3). Knowing these differences, it would assist in "marketing" green specifications to the various stakeholder groups.

3.4. Correlations of the five factors with established sustainability principles

As research on the preparation of green specifications is limited, validation of the identified factors is based on studies concerning environmental management and sustainable construction as well as a set of guidelines for managing sustainable development. Compared with the four principles identified by Hill and Bowen (1997) in respect of sustainability, the five factors for implementation of green specifications should address most of the sustainable construction aspects despite small difference in delineations between the coverage of the principles, as shown in Table 4.

Tam et al. (2006) identified seven critical factors for environment performance assessment (EPA) in the Hong Kong construction industry. Although the EPA is for establishing policies, objectives and targets, the factors identified by Tam et al. (2006) for EPA should provide a good reference for assessing environmental issues pertaining to construction projects in Hong Kong. To reap the potential benefits, green specifications should be written with the scope of EPA in mind, although getting a good assessment result should not be regarded as an end in itself.

The five factors identified in this study are akin to the seven factors by Tam et al. (2006), as shown in Table 4.

Table 4
Comparison of the five factors with established principles.

This study	Hill and Bowen (1997)
Factor 3 (leadership and responsibility) and Factor 4 (stakeholder involvement)	Social sustainability principle
Factor 1 (green technology and techniques), Factor 2 (reliability and quality) and Factor 5 (guide and benchmarking system)	Technical and economic sustainability principles
This study	**Tam et al. (2006)**
Factor 1 (green technology and techniques) and Factor 2 (reliability and quality)	"Air and noise", "waste and water", "cost saving on resources", "energy" and "auditing"
Factor 3 (leadership and responsibility) and Factor 4 (stakeholder Involvement)	"Management and training" and "regulation"
Factor 5: (guide and benchmarking system) – related to green specification	Not mentioned
This study	**BS8900 (2006)**
Factor 1 (green principles and techniques)	Stewardship
Factor 2 (reliability and quality)	Transparency
Factor 3 (leadership and responsibility)	Integrity
Factor 4 (stakeholder involvement)	Inclusivity
Factor 5 (guide and benchmarking system)	Not covered

The convergence with established principles shows that the five factors for implementation of green specifications should help to promote sustainable construction.

Apart from examining the factors for EPA and sustainable construction, the five extracted factors are compared with the principles in BS8900. The results of the factor analysis for preparation of green specifications reflect the principles for sustainable development. In other words, the five identified factors are in line with the four principles (i.e., Inclusivity, Integrity, Stewardship and Transparency) as proposed in BS8900 (2006), which can be used by organizations to set out the main criteria or practice for the assessment of maturity of sustainable development, as shown in Table 4.

From the above evaluation of factor analysis results based on a study concerning EPA and BS8900 (2006), the five factors extracted statistically should reaffirm the principles developed in the front part of this paper from the comprehensive literature review. The factors should therefore provide good reference for assessing the environment issues and managing sustainable development using green specifications.

The five factors which are identified in this study in Hong Kong should be adopted as a matter of general policy on green specifications irrespective of geo-political differences. However, guidelines, standards and material database for green specifications should be further developed in other jurisdictions to facilitate the specification process flow in different regimes and procurement options.

4. Conclusions

The principles for implementing green specifications have been discussed based on literature related to sustainable construction. In parallel with green technology and techniques, the study has identified that involvement by the stakeholders should be the most important factor for the preparation of green specifications. From the factor analysis, four other factors also emerge as important success factors, including "Reliability and Quality", "Leadership and Responsibility", as well as "Guide and Benchmarking System". These factors auger well the problems mentioned in the introduction section in respect of delineation of responsibilities and infrequent use of good specification templates. Knowing the differences in emphasis of the stakeholder groups, the findings should point us in the right directions in the search of a suitable green specification framework which mitigates the associated problems. Further research is being pursued by the authors on such a framework.

Whilst the procurement system being adopted for a construction project affects the contractual relationship between the stakeholders (such as the positions of specialist contractors), the specifications usually form part of the construction contracts (whether they are main contracts, sub-contracts or work packages), thus making it an important management tool to enhance sustainability of construction resources. With contribution from different stakeholders in setting up local material or information database, the success of green specifications relies not only on the specified contents, but the effectiveness of the supply chain and monitoring mechanism for their sustainable adoption on an industry-wide basis.

Acknowledgements

The work described in this paper was fully supported by a grant from the Intra-Faculty Competitive Allocation of the Hong Kong Polytechnic University (Project No. G-YF07). The suggestions made by anonymous reviewers of an earlier manuscript are gratefully acknowledged.

Appendix A. Questionnaire on the sustainable adoption of green specifications.

"Green specifications" mean a full-set of construction specifications with emphasis on environmental friendliness (e.g. The National Building Specifications with green specifying in the UK). This survey is aimed at understanding the current status of green specs in HK and identifying critical issues for their implementation.

It would be appreciated if the filled questionnaire can be returned by facsimile, post or email. If you would like to find out more about this survey or have some questions, you can email to xxxxxxxx

Background Information
(Please tick one appropriate box unless otherwise stated)

Your working experience	Less than 5 years	☐	5-10 years	☐	Over 10 years	☐
Your most familiar project type	Residential	☐	Commercial/Office	☐	Industrial	☐
	Institutional	☐	E&M	☐	Civil works	☐
	Others, pls specify:	______				
Your regular client type	Public sector	☐	Private Sector	☐	Quasi-Public	☐
Nature of your Company	Client	☐	Consultant	☐	Main Contractor	☐
	Builder's work Sub-contractor	☐	E&M sub-contractor	☐	Supplier	☐
	Others, pls specify:	______				
Overall % of works involving green considerations	Less than 10%	☐	10 to 30%	☐	>30%, pls state:_____%	

Please indicate the relative importance of the following factors in the successful implementation of green specifications in Hong Kong

Legend:

1	2	3	4	5
No effect at all	fairly important	important	very important	critically significant (indispensable)

No.	Factors related to the preparation stage of specifications	Degree of Importance Low ⇔ High				
	Stakeholder Involvement	(Pls. circle appropriate box)				
B1	Top management's directive for environmental protection	1	2	3	4	5
B2	Concerns of stakeholders (i.e. related parties)	1	2	3	4	5
	Leadership and Responsibility					
B3	Surpass environmental regulations via the contractual framework	1	2	3	4	5
B4	Avoidance of conflict of interest (e.g. suppliers providing specifications)	1	2	3	4	5
B5	Preventive measures against bias to particular products or processes	1	2	3	4	5
B6	Well-defined liability for detrimental effects of the final product	1	2	3	4	5
B7	Reduce worries associated with risk of using green specifications	1	2	3	4	5
	Principles and Techniques					
B8	Using available advanced green technology for construction purpose	1	2	3	4	5
B9	Life cycle considerations for projects	1	2	3	4	5
B10	Reducing energy consumption	1	2	3	4	5
B11	Mitigating environmental impacts to water, air or soil during construction	1	2	3	4	5
B12	Selecting materials based on their renewability / recycleability	1	2	3	4	5
B13	Selecting materials based on their low risk to the environment	1	2	3	4	5
B14	Facilitating cross references for green performance assessment of bldgs (e.g. HK-BEAM)	1	2	3	4	5
B15	Availability of proven green specification model clauses	1	2	3	4	5
B16	Adopting green practices or procedures (e.g. waste management)	1	2	3	4	5
	Feedback and Building Pubic Confidence	Degree of Importance				
B17	Availability of green product information from reliable database	1	2	3	4	5
B18	Using information from potential suppliers as specifications with care	1	2	3	4	5
B19	Clear requirements of green characteristics for prescriptive specifications	1	2	3	4	5
B20	Verifiable green performance criteria for performance-based specifications	1	2	3	4	5
	Others, please state:					

References

Anderson, J., Shiers, D., 2002. The Green Guide to Specification, third ed. Blackwell Science, Oxford, UK.

Ball, J., 2002. Can ISO 14000 and eco-labelling turn the construction industry green? Building and Environment 37, 421–428.

Barbour Index, 2004. The Barbour Report 2003. United Business Media, Berkshire, Windsor.

Berke, P.R., 2002. Does sustainable development offer a new direction for planning? Challenges for the twenty-first century? Journal of Planning Literature 17, 21–36.

Bertram, P.R.J., 2005. MasterFormat 04 and LCA. Building Design & Construction, 50–51. November.

BRE, 2007. Green Guide to Specifications. Building Research Establishment, UK.

BS8900, 2006. British Standards 8900, Guidance for Managing Sustainable Development. BSI, UK.

CASBEE, 2007. Comprehensive assessment system for building environment efficiency. www.ibec.or.jp (accessed 23.09.07).

Chan, E.H.W., 1996. Conflict between architect and contractor on design information. HKIA Journal 3.

Chick, A., Micklethwaite, P., 2002. Incorporating Recycled Materials into Specifications. Report of the Designing for Sustainability Research Group. Kingston University. December 1–17.

Citherlet, S., Defaux, T., 2007. Energy and environmental comparison of three variants of a family house during its whole life span. Building and Environment 42, 591–598.

Cole, R.J., 1999. Building environmental assessment methods: clarifying intentions. Building Research & Information 27 (4/5), 230–246.

DCLG, 2006. Code for Sustainable Homes. Dept. of Communities and Local Government, , UK.

Eccleston, C.H., Smythe, R.B., 2002. Integrating environmental impact assessment with environmental management systems. Summer. Environmental Quality Management, 1–13.

EMSD, 2008. Website of Electrical and Mechanical Services Dept. Hong Kong SAR Government. www.emsd.gov.hk (accessed 02.04.08).

Fang, D.P., Xie, F., Huang, W.Y., Li, H., 2004. Factor analysis-based studies on construction workplace safety management in China. International Journal of Project Management 22, 43–49.

Fenn, P., Lowe, D., Speck, C., 1997. Conflict and dispute in construction. Construction Management and Economics 15, 513–518.

Flanagan, R., Kendell, A., Norman, G., Robinson, G.D., 1987. Life cycle costing and risk management. Construction Management and Economics 5, S53–S71.

GreenBuilding, 2007. Website: www.greenbuilding.com (accessed 12.01.08).

Hill, R.C., Bowen, P.A., 1997. Sustainable construction: principles and a framework for attainment. Construction Management and Economics 15 (3), 223–239.

Holmberg, J., 1998. Backcasting: A natural step in operationalising sustainable development, The Journal of Corporate Environmental Strategy and Practice, 23, Autumn, 30–51.

ISO 14001, 2004. Environmental Management Systems – Requirements with Guidance for Use. British Standards Institution, UK.

Kaiser, H.F., 1974. Index of factorial simplicity. Psychometrika 39, 31–36.

Kim, J., Mueller, C.W., 1978. Factor Analysis: Statistical Methods and Practical Issues SAGE University Paper 14.

Kululanga, G.K., Price, A.D.F., 2005. Measuring quality of writing of construction specifications. Journal of Construction Engineering & Management, 859–865. August.

Kumaraswamy, M.M., 1997. Common categories and causes of construction claims. Construction Law Journal 13 (1), 21–34.

Lam, P.T.I., Kumaraswamy, M.M., Ng, T.S.T., 2007. An international treatise on construction specification problems from a legal perspective. Journal of Professional Issues in Engineering Education and Practice, ASCE 133 (3), 229–237 July.

Lam, P.T.I., Chan, E.W.H., Chau, C.K., Poon, C.S., Chun, K.P., 2008. An overview of the development of green specifications in the construction industry. In: Proceedings of the International Conference on Urban Sustainability, Hong Kong, 14, 295–301 January.

Lam, P.T.I., Kumaraswamy, M.M., Ng, T.S.T., 2003. A comparative study of user perceptions on prescriptive specifications versus performance-based specifications. In: Proceeding of the 19th Annual ARCOM Conference. Association of Researchers in Construction Management, University of Brighton, pp. 121–130. 3–5 September.

Lippiatt, B.C., 1999. Selecting cost-effective green building products: BEES approach. November/December. Journal of Construction Engineering & Management, 448–455.

MacDonald, J.P., 2005. Strategic sustainable development using the ISO 14001 Standard. Journal of Cleaner Production 13, 631–643.

McCaffrey, J.P., 2006. Supporting sustainability with GreenFormat, the Construction Specifier. Construction Specifications Institute 59 (12) December.

Mora, E.P., 2005. Life cycle, sustainability and the transcendent quality of building materials, building and Environment, 42, 1329–1334.

Myers, D., 2005. A review of construction companies' attitudes to sustainability. Construction Management and Economics 23, 781–785.

Pearce, A.R., Vanegas, J.A., 2002. A parametric review of the built environment sustainability literature. International Journal Environmental Technology and Management 2 (1/2/3), 54–93.

RCA website (Resource Conservation Alliance). http://www.woodconsumption.org/products/bldgcodes.html (accessed 05.08.09).

Robert, K., 2000. Tools and concepts for sustainable development, how do they relate to a general framework for sustainable development, and to each other? Journal of Cleaner Production 8, 243–254.

Robert, K., Bleek, B.S., Larderel, J.A., et al., 2002. Strategic sustainable development – selection, design and synergies of applied tools. Journal of Cleaner Production 10, 197–214.

Rubin, R.A., 1994. Liability insurance for design professionals. Journal of Management in Engineering, 18–23. March/April.

Sha, K., Deng, X., Cui, C., 2000. Sustainable construction in China: status quo and trends. Building Research & Information 28 (1), 59–66.

Spiegel, R., Meadows, D., 1999. Green Building Materials: a Guide to Product Selection and Specification. John Wiley & Sons, Inc.

Swift, J.L., 1999. Integrity: marketing yourself for success. March/April. Journal of Management in Engineering, 24–26.

Tam, V.W.Y., Tam, C.M., Yiu, K.T.W., Cheung, S.O., 2006. Critical factors for environmental performance assessment (EPA) in the Hong Kong construction industry. Construction Management and Economics 24, 1113–1123.

Thomas, H.R., Smithe, G.R., Mellot, R.E., 1994. Interpretation of construction contracts. Journal of Construction Engineering & Management 120 (2), 321–336.

Underwood, J., Alshawi, M.A., Aouad, G., Child, T., Fara, I.Z., 2000. Enhancing building product libraries to enable the dynamic definition of design element specifications. Engineering Construction and Architectural Management 7 (4), 373–388.

UNEP, 2007. Buildings and Climate Change – Status, Challenges and Opportunities. United Nations Environment Programme.

Vrijhoef, R., Koskela, L., 2000. The four roles of supply chain management in construction. European Journal of Purchasing & Supply Management 6, 169–178.

WBDG, 2007. The Federal Green Construction Guide for Specifiers. Whole Building Design Guide. www.wbdg.org (accessed 20.12.07).