FACTORS OF SUSTAINABILITY IN BUILDING DESIGN: ESTABLISHING THEIR RELATIVE SIGNIFICANCE

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There has been a growing movement towards sustainable building in the past number of decades and in that time a variety of terms have evolved to describe this design ethos such as green buildings, passive buildings, carbon neutral buildings, low carbon buildings, all of which are different but all of which are striving for similar outcomes. For a building to achieve any of these status the design must take into account a number of different factors. The aim of this research is to establish the factors of sustainability relevant to the evaluation of sustainable buildings and to establish the significance placed on individual factors of sustainability in buildings. This was done by firstly identifying in a holistic manner everything which could be considered a factor of a sustainable buildings. These were then presented as a questionnaire to construction professionals with experience in the design and procurement of sustainable buildings who were asked to indicate the significance they have placed on each of the factors. The results of this exercise showed a) that while for many of the factors there was broad agreement as to their relevant significance, for others opinions varied greatly and b) not all factors are of equal importance with some being scored consistently lower than others. This suggests that amongst the group surveyed there is no overall consensus as to the significance to be placed on the factor contributing towards the design and procurement of a sustainable building.

Keywords: design, green buildings, sustainability.

INTRODUCTION

Since the World Commission on Environment and Development in 1987, a significant number of tools have been developed to assess and rate the sustainability or otherwise of buildings (e.g. BREEAM, Code for Sustainable Homes, LEED, EcoEffect, GBTool, CASBEE, HQE, VERDE, DGNB, SPeAR, EcoStar, SKA). These tools examine a range of issues related to sustainability, grouped into themes and measured in relation to certain criteria. Considerable research has been conducted into these assessment and rating tools and it has been generally found firstly, they do not take into consideration all the issues relevant to sustainability; secondly, they do not

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measure the same criteria; and thirdly, in their calculations the tools do not place the same weighting on the individual criteria or the themes.

The aim of this research therefore is to establish the factors of sustainability relevant to the evaluation of sustainable buildings and to establish the actual significance placed on individual factors of sustainability in buildings in practice.

RATING AND ASSESSMENT TOOLS

Difference in criteria and weighting between the tools:

When comparing issues examined by different building assessment and rating tools the areas of social and economic sustainability are most often overlooked; Essa and Fortune (2008) found this to be the case for EcoHomes (and this appears not to have been rectified in the Code for Sustainable Homes (CSH) which replaced EcoHomes); Bartlett and Guthrie (2005) concluded environmental issues dominated the tools with little consideration given to economic and social issues other than users well-being and local stakeholders issues; Sinou and Kyvelou (2006) found the areas of economic and social issues were frequently overlooked. Table 1 highlights the apparently difference weighting placed on the criteria by the tools as well as the generally relatively small weighting placed on economic and social issues.

It should be noted the SBTool allows the user adjust the weighting given to each theme and therefore the weightings above (taken from an illustrative example on the SBTool website) are subject to change and within BREEAM and LEED there are also optional themes, not included above, which will change the weightings slightly. Notwithstanding this, the different weightings placed by the different tools are apparent.

Other criteria identified as under represented by different tools were supply chain issues, site selection and funding (Essa and Fortune, 2008), design aesthetics, transport and users comfort (Sinou and Kyvelou, 2006) and indoor air quality (Chuck and Jeong, 2011). When comparing BREEAM and LEED Papodapolous and Giama (2009) found although both appear to examine the same issues they are examined by different criteria, for example in pollution BREEAM considers insulants GWP, eco-labelling of goods and energy efficiency of internal and external lighting, none of which are examined by LEED. Even where similarities do exist, some assessment tools allow criteria to be added or omitted (GB Tool and LEED) to reflect local conditions (Sinou and Kyvelou, 2006).

Papadopoulos and Giama (2009) examining the rating of a single building using LEED and BREEAM found the tools gave significantly different results. Wallhagen and Glaumann (2011) conducted similar research looking at the consequence of using three different sustainability assessment tools (LEED, CSH and EcoEffect) in the evaluation of a single building. While LEED and CSH produced similar overall results this was judged a coincident as significant variation was present in *"the content of the tools, issues assessed, issue criteria, issue scores, aggregation and weighting of categories and issues"*. They also explored the adaptation to the design of the building necessary to improve the rating achieved by each assessment tools and found the adaptations differed considerably and its implementation would *"steer the case study building project in different directions."* Ultimately to achieve the highest rating in each tool, different buildings design solutions would be required.

Table 1: Assessment Tool Weightings by Theme.

Themes Grouping the Criteria.	BREEAM	SB Tool	CSH	LEED
Energy	19.00%			
Energy and CO2 emissions			36.40%	
Energy and Atmosphere				35.00%
Energy and Resource Consumption		20.50%		
Materials	12.50%		7.20%	
Materials and Resources				14.00%
Transport	8.00%			
Water	6.00%		9.00%	
Surface Water Runoff			2.20%	
Water Efficiency				10.00%
Waste	7.50%		6.40%	
Land Use and Ecology	10.00%			
Ecology			12.00%	
Pollution	10.00%		2.80%	
Environmental Loading		48.90%		
Site Regeneration and Development		13.60%		
Sustainable Sites				26.00%
Health and Wellbeing	15.00%		14.00%	
Social, Cultural and Perceptual Aspects		3.90%		
Indoor Environmental Quality		6.20%		15.00%
Services Quality		5.80%		
Cost and Economic Aspects		1.20%		
Management	12.00%		10.00%	
Total	100.00%	100.10%	100.00%	100.00%

From: BREEAM SD5073 -2.0, 2011; SBTool, 2012; Code for Sustainable Homes, 2010; LEED 2009

Difference in weighting applied by tools and designers:

Essa and Fortune’s (2008) work on EcoHomes, asked those involved in social housing projects to indicate the importance they placed on each of the seven headings of sustainability identified by EcoHomes when designing. The ranking according to the tool was Energy, Health & Well-being, Land Use & Ecology, Pollution, Materials, Water, Transport; the ranking according to those surveyed was Energy, Materials, Pollution, Water, Health & Well-being, Land Use & Ecology, Transport. The most and least important were consistent, but respondents moved Health & Well-being down from second to fifth and Land Use & Ecology down from third to sixth, whilst Materials moved up from fifth to second. This demonstrates those involved (Architects, Quantity Surveyors and Housing Authorities) did not place the same relative importance on sustainability factors when designing as a building as a given assessment tool suggests they should, despite the UK government policy at the time requiring all such projects to achieve a “very good” rating.

Harmonisation of assessment tools:

Since 2005, CEN/TC 350 has worked on an internationally harmonised approach in the assessment of sustainable buildings. They have produced BS EN 15643, the aim of which is to *"enable comparability on the result of assessment"* and *"do*[es] *not provide valuation methods and do*[es] *not set levels, classes or benchmarks for any measure of performance"* (BSI, 2010). In doing this the results of an assessment are to be expressed in detail and without aggregation, for each of the indicator defined in prEN 15643-2, -3 and -4 (environment, social, and economic). BS EN 15643 gives no practical guidance on evaluation, stating *"valuation systems and related calculation rules for aggregation of indicators may be defined in the national standards or schemes"* (BSI, 2010). Consequently, within calculations carried out by different assessment tools, different weightings can be applied to various indicators. The standards also foresee not all assessment tools will consider all defined indicators, stating if a particular assessment method does not value a particular indicator this is to be shown as *"indicator not assessed"* (BSI, 2010). Therefore despite a move towards harmonisation of assessment tools, this is harmonisation of what should ideally be assessed, but not of what must be, or how it is to be or of what weightings should be applied. This is evidenced by the BRE, in New Construction, Non-Domestic Buildings, they (2011) state BREEAM incorporates *"the majority of environmental"*, *"a significant number of the social"* and *"some [of the] economic"* measures proposed by CEN/TC350.

In research to develop a new sustainability assessment tool for housing, Mateus and Braganca (2011) examined the work conducted by CEN/TC 350. While recognising this work as important progress towards standardization, they did not use it as a basis for their new tool electing instead to use the existing SBTool, which having been developed as an international tool allows users in different countries to reflect different priorities. Mateus and Braganca argue assessment tools, their indicators and their weightings must reflect the region in which the building is placed, identifying inflexible weighting as one of the most common weaknesses of existing tools. Ali and Al Nsairt's (2009) work developing a new tool for sustainable building assessment also emphasised the need for tools to reflect local cultural and environmental conditions. Both these works developing new assessment tools have been conducted since CEN /TC 350 commenced their work and since a great deal of their initial work was published. Yet in both instances those developing new tools concluded both the individual indicators and also the weighting to be placed on those individual indicators will be differ from region to region and therefore tools cannot be fully harmonised internationally. On the basis of this it seems reasonable to assume a variety of assessment tools will continue to be available for some time.

In summary, the literature shows despite moves towards harmonisation of what assessment tools should measure, the existing tools take into consideration different issues, measure them in relation to different criteria and place different weightings on those criteria in their assessment calculation and there is evidence to suggest this will remain so. The literature also shows that even when designers and clients are required to design buildings to achieve certain ratings as measured by a certain tool, it cannot be assumed they will place the same weighting on the individual criteria as is place by the that tool. The aim of this research is to establish the factors of sustainability relevant to the evaluation of sustainable buildings and to establish the actual significance placed on individual factors of sustainability in buildings in practice.

RESEARCH DESIGN

In carrying out this pilot study, a structured questionnaire survey of sustainability factors in building design was administered to building design team members. In order to establish the factors designers take into account when designing a sustainable building a number of areas of pre-existing research were examined, namely a) existing assessment and rating tools and the criteria they consider; b) published critical reviews of these tools; c) research into the constituent elements of sustainable buildings and d) research into sustainable development and sustainability generally. In completing this, the work listed in Table 2 was reviewed and to ensure the list was holistic and comprehensive each criteria identified was treated equally, regardless of whether it appeared in all documents or just one.

Table 2: Identifying factors of sustainable buildings

No	Author(s)	Date	Document Title
1	EcoHomes	2006	Ecohomes 2006 – The environmental rating for homes. The Guidance – 2006 / Issue 1.2
2	Code for Sustainable Homes	2010	Code of Sustainable Homes, Technical Guide November 2010
3	BREEAM (Non Domestic Buildings)	2011	BREEAM New Construction Non-Domestic Buildings. Technical Manual SD5073-2.0:2011
4	LEED	2009	LEED 2009 New Construction and Major Renovations with alternative compliance paths for projects outside the U.S.
5	SKA	2011	Ska rating. Good practice measures for offices, Version 1.1
6	SBTool	2012	SBTool Generic 06 Feb 12
7	SPeAR	2012	www.arup.com/Projects/SPeAR.aspx
8	ISO 15392	2008	Sustainability in building construction – General principles
9	BE EN 15643	2010 & 2011	Sustainability of construction works – Sustainability assessment of buildings. Parts 1 – 4
10	GreenStar	2012	www.gbca.org.au/green-star/technical-clarification-cir-ruling/documentation-guidelines/2086.htm Office v3; Education v1; Retail Centre v1
11	Bartlett & Guthrie	2005	Guides to sustainable built-environment developments
12	DETR	2000	Building a Better Quality of Life. A Strategy for more Sustainable Construction
13	SECBE	2009	An Introductory Guide to Best Practice in Construction
14	Presley & Meade	2010	Benchmarking for sustainability: an application to the sustainable construction industry
15	National Audits Office	2007	Building for the future: Sustainable construction and refurbishment on the government estate
16	Sinou & Kyvelou	2006	Present and future of building performance assessment tools
17	Braganca, Mateus & Koukkari	2010	Building Sustainability Assessment
18	Mateus & Braganca	2011	Sustainable assessment and rating of buildings: Developing the methodology SBTool PT-H
19	HM Government	2008	Strategy for sustainable construction
20	Kates, Parris & Leiserowitz	2005	What is Sustainable Development? Goals, Indicators, Values and Practice.
21	United Nations	2007	Indicators of Sustainable Development: Guidelines and

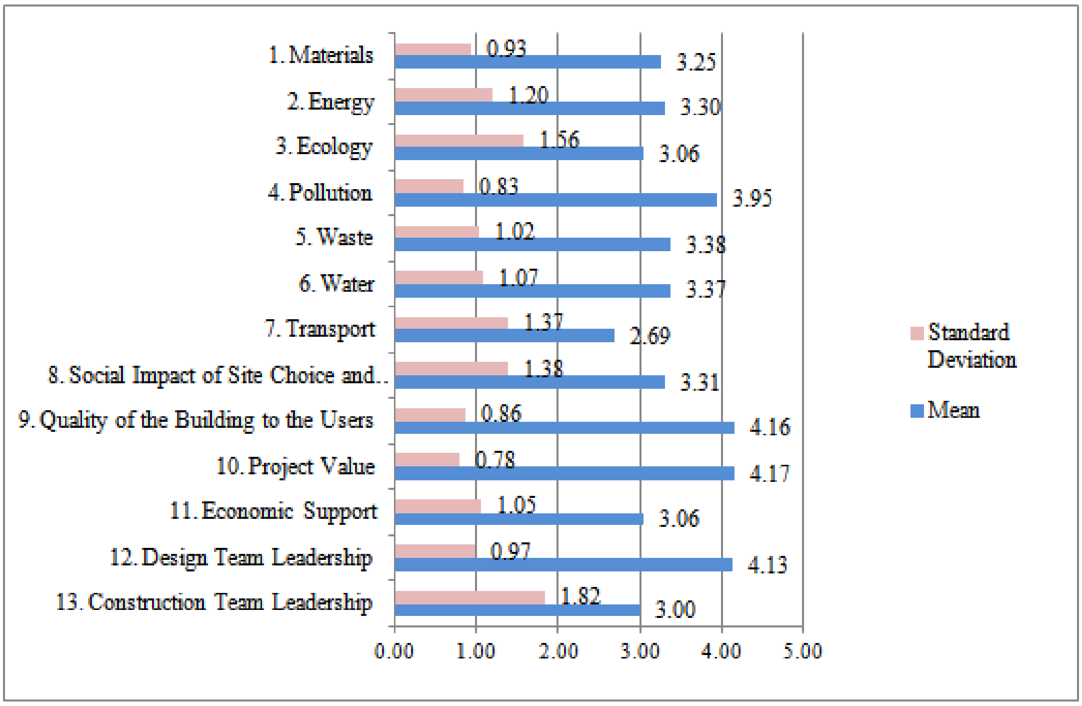
			Methodologies 3rd ed.
22	United Nations	2008	Measuring Sustainable Development
23	DEFRA	2010	Measuring progress. Sustainable development indicators 2010
24	Karl & Brunner	2009	Tools for measuring progress towards sustainable neighbourhood environments

This list of criteria was then organised into common themes, initially using theme headings frequently used by existing tools (see Table 1), then adapted and expanded as necessary to best reflect all factors identified, resulting in thirteen themes (see Fig. 1). Within these themes sixty-four factors were identified reflecting the essence of the individual criteria. Respondents were requested to score on a Likert type scale the level of importance they have placed on the identified sustainability factors in building design. The questionnaires were directed to designers from a range of disciplines with experience and expertise in sustainable buildings.

DATA ANALYSIS

As the research is currently at Pilot Study stage the number of responses was limited to twelve designers (five architects, three project managers, three building services engineers and one sustainability consultant); therefore data analysis is statistically limited at this stage. Each designer was asked to select a sustainable building of their experience and identify the level of emphasis placed on each particular factors making up each theme for their chosen building. In addition, information pertaining to potential independent variables was sought. The Likert scale had six points ranging from *"no emphasis"* to *"very high emphasis"* which were given values of 0 - 5.

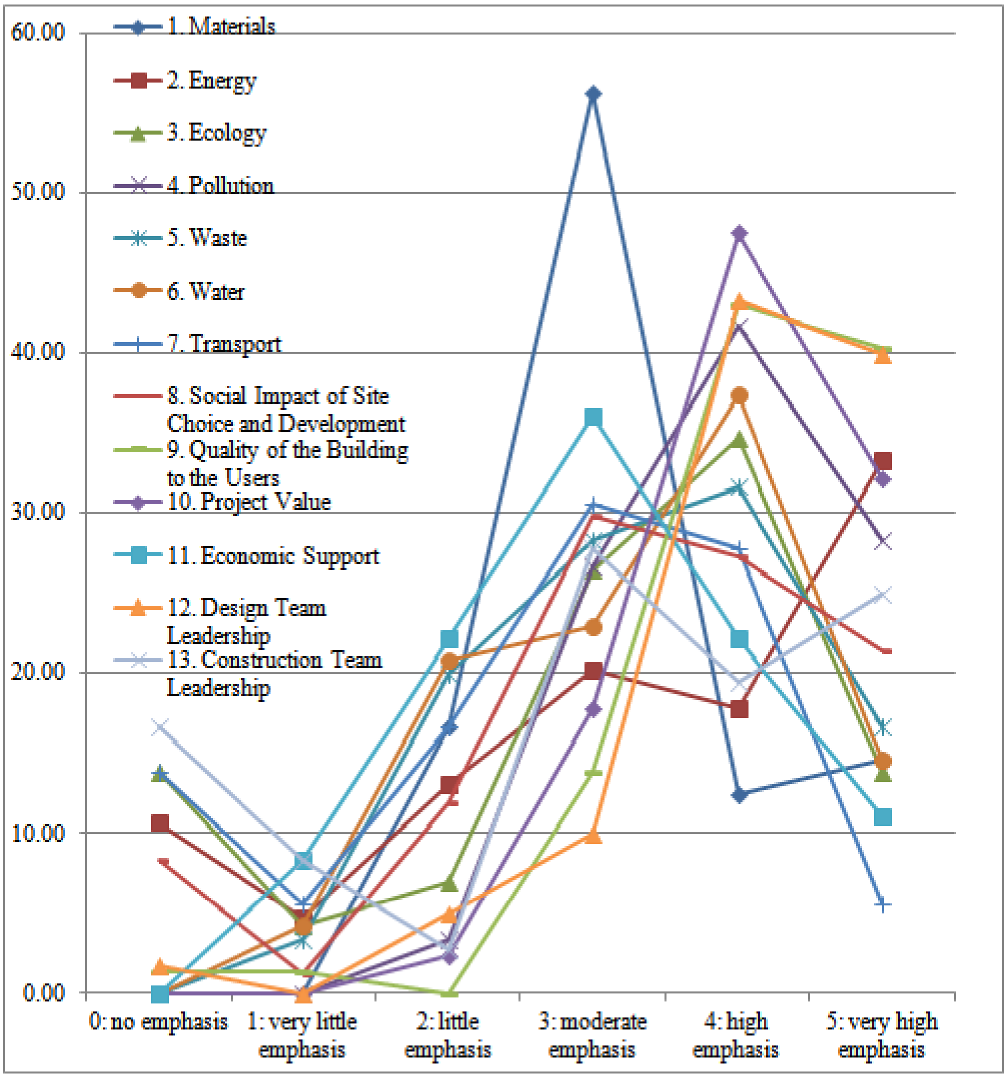
Fig. 1: Emphasis place on each theme by Designers.



When the data was analysed for each of the thirteen themes, the means ranged from a low of 2.69 for *Transport* to a high of 4.17 for both *Project Value* and *Quality of the Building to the Users* (see Fig. 1). The majority (nine) of themes had a mean between 3 and 4, indicating designers placed between moderate and high emphasis on these themes. Having examined the means of the thirteen themes, the means of each of the sixty-four factors making up those themes were addressed. In this instance the range was wider, the lowest mean significance placed on a factor by designers being 1.42 and the highest being 4.83 (both of these factors occur within the theme *Energy*).

The standard deviations of the themes varies significantly suggesting significant variation within these limited responses, also evidenced by the data shown in Fig. 2 and Table 3 (indicating the level of emphasis placed on each theme by the designers , as a percentage of all designers).

Fig. 2: Level of emphasis place on Theme by Designers, as percentage of all Designers



It can be seen from Table 3 that even for themes with high means (e.g. *Quality of the Building to the User*), some respondents placed little or no emphasis on the associated factors and similarly, for themes with low means (e.g. *Transport*), some respondents placed a very high emphasis on criteria within the theme. Of the thirteen themes, seven have responses at both the highest and lowest point in the scale; all thirteen have responses of the highest score. This range in responses is also evident in the data on the sixty-four individual factors making up each theme. On the six points Likert scale 29% of the criteria registered response on all six points, a further 14% registered on five and a further 31% registered on three of the six. 94% of the criteria had at least one respondent who place *"very high emphasis"* on it; 33% had at least one respondent who placed *"no emphasis"* on it.

Table 3: Level of emphasis place on Theme by Designers, as percentage of all Designers

	Level of Emphasis					
	None	Very Little	Little	Moderate	High	Very High
1. Materials	0.00	0.00	16.67	56.25	12.50	14.58
2. Energy	10.71	4.76	13.10	20.24	17.86	33.33
3. Ecology	13.89	4.17	6.94	26.39	34.72	13.89
4. Pollution	0.00	0.00	3.33	26.67	41.67	28.33
5. Waste	0.00	3.33	20.00	28.33	31.67	16.67
6. Water	0.00	4.17	20.83	22.92	37.5	14.58
7. Transport	13.89	5.56	16.67	30.56	27.78	5.56
8. Social Impact of Site Choice and Development	8.33	1.19	11.90	29.76	27.38	21.43
9. Quality of the Building to the Users	1.39	1.39	0.00	13.89	43.06	40.28
10. Project Value	0.00	0.00	2.38	17.86	47.62	32.14
11. Economic Support	0.00	8.33	22.22	36.11	22.22	11.11
12. Design Team Leadership	1.67	0.00	5.00	10.00	43.33	40.00
13. Construction Team Leadership	16.67	8.33	2.78	27.78	19.44	25.00
Total	5.12	3.17	10.91	26.67	31.29	22.84

This range of emphasis is also shown in an analysis of the modes of the factors. While many are strong (50%+ of respondents agree on the level of emphasis placed on a given criteria) some are divided; multiple modes occur fifteen times and of these, non-sequential modes occur five time; e. g. as many indicated "minimising the quantity of potable water used during construction" is given *"little emphasis",* as indicated it is given *"high emphasis"*.

The standard deviation, the range and the visual information presented in Fig. 2 suggest the data pertaining to the themes does not have a normal distribution. This was examined statistically by the calculation of both Skewness and Kurtosis statistics and completing the Shapior-Wilk test (Table 4) although the reliability of these tests is limited due to the small sample size. Five themes have a skewness value of less than +/- 0.5 suggesting for them the distribution is symmetrical to moderately skewed; for the remainder the data is skewness and mostly negatively.

Five themes also have a kurtosis value of less than +/- 0.5 suggesting for them the distribution is normal; for the remainder negative figures indicate a flat curve rather than a bell curve. No theme has a significant value of Shapiro-Wilk greater than 0.05 implying no theme has a normal distribution, including *Project Value*, the only theme with both a skewness value and a kurtosis value of less than + / - 0.5. Similiar results are found when the sixty-four factors are examined in the same way; six (9%) have both a skewness and kurtosis value of less than +/- 0.5 and a Shapiro-Wilk significant value of greater than 0.05. Consequently, if similar results are found in the main study, the majority of the data will be examined using non-parametric; if parametric tests are to be conducted data transformation will be first required.

Table 4: Distribution

Theme	Skewness	Kurtosis	Shapiro-Wilk Sig.
1. Materials	0.71	**-0.14**	0.000
2. Energy	-0.69	-0.62	0.000
3. Ecology	-0.86	**-0.27**	0.000
4. Pollution	**-0.27**	-0.71	0.000
5. Waste	**-0.18**	-0.77	0.000
6. Water	**-0.31**	-0.74	0.001
7. Transport	-0.62	**-0.46**	0.002
8. Social Impact of Site Choice and Development	-0.87	**0.37**	0.000
9. Quality of the Building to the Users	-1.83	5.60	0.000
10. Project Value	**-0.49**	**-0.26**	0.000
11. Economic Support	**0.02**	-0.54	0.013
12. Design Team Leadership	-1.72	4.45	0.000
13. Construction Team Leadership	-0.59	-0.92	0.000

DISCUSSION AND CONCLUSION

Given the factors and themes addressed in the research were identified through an examination of research carried out by experts in this field, and given the respondents were each reflecting actual behaviour in respect of buildings which achieved high sustainability rating, albeit assessed using different methods, it could be anticipated the data would show a) significant levels of emphasis being placed on each criteria and b) relatively homogeneous results.

The calculation of the means for themes showed all to be above 2.5, the mid-point of the range; in all instances an above average emphasis is place on the theme and for some the mean shows a high level of emphasis being placed on the theme. The initial analysis of the individual factors shows a more varied picture, with means for some factors of below 2.5. This will be explored in more detail in further research. Despite the relatively high means, there are a number of instances where "*no*" to "*little*" emphasis is placed on some aspects of sustainability during the design of sustainable buildings. The data shows there are fewer instance of "*very little"* emphasis, than instances of "*no"* emphasis suggesting either aspects are not considered at all or are given at least a certain level of attention. To establish whether or not this is a conscious decision made by the design team will require further investigation.

Whilst the data shows an above average emphasis is placed on all themes there is little consensus beyond this; the data shows considerable variation in the numbers placing "*moderate*", "*high*" and "*very high*" emphasis on the themes, with the exception of *Materials*, where the majority agreed "*moderate*" emphasis should be placed on that theme. The literature suggested rating and assessment tools overlooked economic and social aspects in favour of environmental aspects. While this may be true of the tools, the data indicates the designers place equal if not higher emphasis on economic and social aspects when compared to environmental aspects.

The results were not expected to have a standard distribution; positive skewness and positive kurtosis values indicating most responses at the high end was anticipated. While this was indicated by the means and the ranges, the results of the distribution tests showed significant level of negative skewness and negative kurtosis values indicating sizable amounts of data at the low emphasis end of the scale. This may be due to the poor reliability of these tests when applied to small sample sizes and this will be investigated further when a large sample size is available. Many potential external variable influencing these results exist, such as differences between the respondents and the projects they are reflecting. The effect of these variables could not be analysed in a meaningful way at this stage given the sample size, however they will be looked at in detail in a larger future study.

Upon completion of that future study it is anticipated a greater understanding of the emphasis placed on the individual factors of sustainability in buildings by designers will be achieved. This will be useful to clients in commissioning future buildings. It is also anticipated the factors which influence this emphasis, and the manner by which they do so, will be understood. This could then be used in the control and management of these factors.

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